Michigan State University
AgBioResearch

In Cooperation With
Michigan Potato Industry Commission

Michigan Potato Research Report
Volume 51
2019

Michigan Potato Industry Commission

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January 03, 2020

To all Michigan Potato Growers and Shippers,

The Michigan Potato Industry Commission continues to provide over $180,000 in direct funding on an annual basis for potato research. This research is the one of the core components that continue to move the Michigan potato industry forward. Expanding research has provided increased insights into varieties, disease, soil fertility, and storage management. Research outcomes continue to provide a competitive advantage for the industry in Michigan and to provide Michigan with a highly respected reputation among the national industry professionals.

The following research report was compiled with the help of the Michigan State University AgBioResearch and Michigan State University Extension. On behalf of all parties, we are proud to present you with the results of the 2019 potato research projects.

We hope that each of you see value in the investment made in these projects and can apply some of the results directly to strengthen your own operation.

We would like to thank our many suppliers, researchers, and industry partners who are involved in making this year's research season a success. As the industry faces new challenges and strives to improve upon best practices, we are inspired by the level of cooperation within the industry and look forward to future success together.

Sincerely,

Kelly Turner

Kelly Turner, CAE

Executive Director

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2019 MICHIGAN POTATO RESEARCH REPORT

C. M. Long, Coordinator

INTRODUCTION AND ACKNOWLEDGMENTS

The 2019 Potato Research Report contains reports of the many potato research projects conducted by Michigan State University (MSU) potato researchers at several locations. The 2019 report is the 51st 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), Project GREEEN and numerous other sources. The principle source of funding for each project has been noted in 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 goes to Mathew Klein for his management of the MSU Montcalm Research Center (MRC) and the many details which are a part of its operation. We also want to recognize Trina Zavislan, MSU for organizing and compiling this final draft.

WEATHER

The overall 6-month average maximum and minimum temperatures during the 2019 growing season were consistent with the 15 year averages at 72°F and 52°F respectively (Table 1). April, May, and June were slightly cooler than the 15 year average. The average minimum temperature in July, 69°F was much warmer than the 15 year average temperature of 59°F. Daytime extreme heat events were slightly less than average in 2019 (Table 3) with five hours over two days in which temperatures exceeded 90°F during the entire summer. Extreme high nighttime temperatures were slightly higher than average in 2019, with 177 hours of nighttime temperatures above 70°F over 31 days, compared to the seven-year average of 154 hours over 33 days.

Rainfall for April through September was 22.07 inches, which was 4.47 inches above the 15-year average (Table 2). A total of 7.5 inches of irrigation water over 15 application timings was applied to Comden 3 between early June and mid-August. In general, May and September had more precipitation than average while April and July were drier months.

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

	April		May		June		July		August		September		Average	
Year	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
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	33	67	40	77	56	80	58	80	54	73	50	73	49
2009	56	33	67	45	76	54	75	53	76	56	74	49	71	48
2010	64	33	70	49	77	57	83	62	82	61	69	50	74	52
2011	53	33	68	48	77	56	85	62	79	58	70	48	72	51
2012	58	33	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
2014	55	33	68	45	78	57	77	54	79	56	72	47	72	49
2015	58	33	71	48	76	54	80	56	77	57	77	54	73	51
2016	53	32	70	45	78	53	82	60	85	60	78	54	74	51
2017	61	39	67	44	78	55	81	58	77	54	77	50	74	50
2018	55	33	81	46	84	58	88	64	84	63	76	52	78	53
2019	**55**	**35**	**65**	**45**	**75**	**54**	**84**	**69**	**80**	**55**	**73**	**54**	**72**	**52**
15-Year Average	57	34	69	46	79	55	82	59	80	57	74	50	74	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
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
2014	4.24	5.51	3.25	3.71	1.78	2.35	20.84
2015	3.71	2.96	4.79	1.72	2.42	3.90	19.50
2016	2.25	2.77	1.33	3.42	5.35	3.05	18.17
2017	4.45	1.98	6.37	0.92	1.36	0.70	15.78
2018	2.04	5.51	3.64	1.19	7.73	2.65	22.76
2019	**2.64**	**5.46**	**2.9**	**2.04**	**3.31**	**5.72**	**22.07**
15-Year Average	3.08	3.18	2.92	2.57	3.25	2.60	17.60

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Table 3. Seven-year heat stress summary (from May 1st – Sept. 30th)*

Year	Temperatures > 90°F		Night (10pm-8am) Temperatures > 70°F	
	Hours	Days	Hours	Days
2013	14	3	140	28
2014	0	0	58	15
2015	0	0	114	31
2016	26	7	248	50
2017	12	3	124	29
2018	26	8	215	46
2019	**5**	**2**	**177**	**31**
Average	12	3	154	33

GROWING DEGREE DAYS

Table 4 summarizes the cumulative growing degree days (GDD) for 2019 while providing historical data from 2007-2019. GDD are presented from May 1st – September 30th using the Baskerville-Emin method with a base temperature of 40 °F. The total GDD base 40 by the end of September in 2019 was 4073 (Table 4), which is 285 GDD higher than the 13-year average of 3788.

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

Year	May	June	July	August	September
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	522	1340	2120	2977	3552
2015	604	1353	2230	3051	3789
2016	547	1318	2263	3274	4053
2017	480	1279	2202	2990	3695
2018	689	1487	2423	3373	4073
2019	**457**	**1189**	**2179**	**3024**	**3731**
Average	567	1334	2259	3134	3789

*2007-2019 data from the weather station at MSU Montcalm Research Center "Enviro-weather", Michigan Weather Station Network, Entrican, MI.

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PREVIOUS CROPS, TILLAGE AND FERTILIZERS

The general potato research area utilized in 2019 was Montcalm Research Center property in the field referred to as 'Comden 3.' This acreage was planted to wheat in the spring of 2018 with crop residue disked into the soil in fall and sprayed off in the spring of 2019. In the spring of 2019, the recommended rate of potash was broadcast applied following deep-chisel plowing. The ground was vertical tilled and direct planted to potatoes. The area was not fumigated with Vapam prior to potato planting, but Admire Pro® was applied in-furrow at planting.

The soil test analysis for the general crop area (taken in November 2018) was as follows:

	lbs/A			
pH	P	K	Ca	Mg
7.2	356 (178 ppm)	222 (111 ppm)	1612 (806 ppm)	184 (92 ppm)

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

Application	Analysis	Rate	Nutrients ($N\text{-}P_2O_5\text{-}K_2O$-Ca/Mg/S/Zn)
Broadcast at plow down	0-0-22-11Mg-22S 0-0-0-21Ca-16S 0-0-0-21Ca-12Mg 10%B 0-0-62 0-0-0-9Zn	200 lbs/A 150 lbs/A 300 lbs/A 6 lbs/A 350 lbs/A 1 qt/A	0-0-44-22Mg-44S 0-0-0-32Ca-24S 0-0-0-63Ca-36Mg 0.6 lb. B 0-0-217 0.3 lb. Zn
At-planting	28-0-0 10-34-0	24 gpa 12 gpa	72-0-0 14-49-0
At-cultivation	28-0-0 10-34-0	24 gpa 12 gpa	72-0-0 14-49-0
At-hilling	46-0-0	120 lbs/A	55-0-0
Late side dress (late varieties)	46-0-0	100 lbs/A	46-0-0

HERBICIDES AND PEST CONTROL

A pre-emergence application of Linex at 1.25 qts/A and Brawl II at 1.0 pts/A was made in late May.

Admire Pro® was applied in-furrow at planting at a rate of 8.7 fl oz/A.

Echo 720 (24 oz/A), Equus 720 (24 oz/A), Koverall (2.0 lbs/A), Oranil 6L (24 oz/A), Coragen (6 oz/A), and Mustang Maxx (4 oz/A) fungicides were applied alone or in combination on eleven dates between June and mid-August.

Potato vines were desiccated with Reglone in early September at a rate of 32 oz/A.

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2019 MSU POTATO BREEDING AND GENETICS RESEARCH REPORT
January 2020

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Cooperators: Robin Buell, Ray Hammerschmidt, Noah Rosenzweig, Jaime Willbur and Chris Long

INTRODUCTION

At Michigan State University, we have been dedicated to developing improved potato varieties for the chip-processing and tablestock markets since 1988. The program is one of four integrated breeding programs in the North Central region supported through the USDA/NIFA Potato Special Grant. At MSU, we conduct a comprehensive multi-disciplinary program for potato breeding and variety development to meet Michigan's needs. Our program integrates traditional and biotechnological approaches to breed for disease and insect resistance that is positioned to respond to scientific and technology opportunities that emerge. We are also developing more efficient methods to breed improved potato varieties.

In Michigan, variety development 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 Agronomy Farm), we ship seed to other states and Canadian provinces for variety trials, and we cooperate with Chris Long on grower trials throughout Michigan. This testing is crucial in determining the commercial potential of the lines. 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, PVY resistance, late blight resistance and higher specific gravity). We continue to see the increase in scab, late blight and PVY resistance in the breeding material and selections. We need to continue to combine these traits in long-term storage chip-processing lines. It has been 10 years since we started the SolCAP project and we are benefiting from the SolCAP SNP array DNA marker technology as we can now query 35,000 SNPs (compared to 8,303 SNPs in the past). This SolCAP translational genomics project has 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. The SNPs also allow us to accurately fingerprint the varieties (DNA ID database). 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. In 2020, we plan to test potatoes with late blight resistance, drought tolerance, invertase silencing and gene editing for PPO and self-compatibility. Furthermore, PotatoesUSA is supporting national early generation trials called the National Chip Processing Trial (NCPT) which will feed lines into the SNAC (SFA) trials and also Fast Track lines into commercial testing (NexGen testing). This national cooperative testing is the key! We are leveraging the NCPT fast track to have seed increased for promising chip-processing lines. This has led to the release of Saginaw Chipper (MSR061-1), Manistee (MSL292-A), Huron Chipper (MSW485-2), Mackinaw (MSX540-4), and Petoskey (MSV030-4). We also have funding to develop genome editing technologies that may not be classified as genetic engineering through a USDA/BRAG grant. This technology can be used to introduce lower sugars, bruising and asparagine as well a number of other traits in the future. We also have a USDA/AFRI diploid breeding grant to develop some foundational diploid breeding germplasm. In 2015 we were awarded the USAID grant to generate late blight resistance potatoes for Bangladesh and Indonesia. This project brings us into cutting edge GM work with Simplot and the International Potato Center (CIP). Lastly we have NSF-funded grants to better understand the potato genome and study wound-healing in potato. 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 advanced technologies with the breeding of improved chip-processing and tablestock potatoes.

The breeding goals at MSU are based on 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, keep potato production profitable as well as reduce the reliance on chemical inputs such as insecticides, fungicides and sprout inhibitors, and improve overall agronomic performance through 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. In 2016 year we constructed a greenhouse to expand our breeding and certified minituber seed production. This greenhouse is at the MSU Crops facility on south campus. In 2016 we began to upgrade the grading line and this was completed with funding from MPIC and AgBioResearch. Variable speed drives control: a new lift; custom built barrel washer; grading table; and Kerian speed sizer are all part of the set up as of 2019. Incorporation of bar-coded labels, and scales synchronized to computer hot keys, have improved the speed, accuracy and efficiency of the grading process. All entities of the potato group: Potato Breeding and Genetics; Potato Outreach Program; pathologists and soil fertility researchers have access to this new equipment. Thank you!

Varietal Development
Breeding

The MSU potato breeding and genetics program is actively producing new germplasm and advanced seedlings that are improved for long-term storage chipping, and resistance to scab, late blight, and Colorado potato beetle. For the 2019 field season, progeny from about 400 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 2019 harvest, about 1,000 selections were made from the 45,000 seedlings produced. All of these first-year selections are segregating for PVY resistance. All second, third or fourth-year potential chip-processing selections will be tested in January and April 2020 directly out of 45°F (7.2°C) and 50°F (10°C) storages. Atlantic, Lamoka and Snowden 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 100 selections were made, respectively; based on 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 scab and late blight evaluations of the early generation material. *Unfortunately, in 2019 we were unable to get effective late blight infection to collect useful data.* 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 as well as the traditional methods that was developed in our lab to remove viruses. 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, but PVS can still be difficult to remove in certain lines. We tested the removal of PLRV and succeeded. Over 1700 lines are maintained in tissue culture for the breeding and genetics program.

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 Mackinaw (MSX540-4) (scab, late blight and PVY resistant), Petoskey (MSV030-4) (scab resistant), Huron Chipper (MSW485-2) (late blight resistant), MSW075-2 (scab resistant), MSZ242-13 (scab resistant) and MSZ219-1, MSZ219-13 and MSZ219-14 (all three sibs are 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. Manistee was licensed to Canada and Chile. Saginaw Chipper and Mackinaw are being tested in Australia and Korea.

Tablestock

Efforts have been made to identify lines with good appearance with an attractive skin finish, 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, red-skinned, and yellow-fleshed lines. We have also been selecting some pigmented skin and tuber flesh lines that fit some specialty markets. There is also interest in some additional specialty mini-potatoes 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 round white, red-skin, and improved Yukon Gold-type yellow-fleshed potatoes. Some of the tablestock lines were tested in on-farm trials in 2019, while others were tested under replicated conditions at the Montcalm Research Center. Promising tablestock lines include MSV093-1Y (yellow, scab resistant), MST252-1Y (scab resistant), MSV179-1 (scab resistant), Isle Royale (MSX569-1R) (scab resistant) and MSX324-1P (scab resistant). MSZ109-8PP and MSZ109-10PP (Blackberry) are purple-fleshed chippers with deep purple flesh, round shape and attractive skin as well as scab resistance. Jacqueline Lee (late blight resistant) was licensed to Australia and is being grown in Central America for its late blight resistance. Spartan Splash, Raspberry, Blackberry, MSQ558-2RR and our PVY resistant Red Marker #2 potato are being marketed in the specialty markets. Blackberry is also being chip-processed by the Great Lakes Chip Co. in Traverse City, MI and receiving local and national press.

Disease and Insect Resistance Breeding

Scab: In 2019 we had two locations to evaluate scab resistance: a commercial field with a history of severe scab infection (we thankfully acknowledge the support of Sackett Potatoes for this important trial) and a highly infected site at the Montcalm Research Center. In 2019 the commercial site and the Montcalm Research Center both gave us very high scab infection levels. The susceptible checks of Snowden and Atlantic were highly infected with pitted scab. Promising resistant selections were MST252-1Y, MSV179-1, MSX324-1P, MSW474-01, MSZ219-1, MSZ219-13, MSZ219-14, as well as the Z-series selections from the commercial scab site. If you examine the Advanced Chip trial you will notice that almost all the lines are scab resistant. We need to continue in this direction of many selections with scab resistance so we can find the great scab resistant chipper. 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 (Figure 1). All susceptible check plots (Snowden and Atlantic) were scored as susceptible.

Fig. 1. Scab Disease Nursery Ratings from MRC trials

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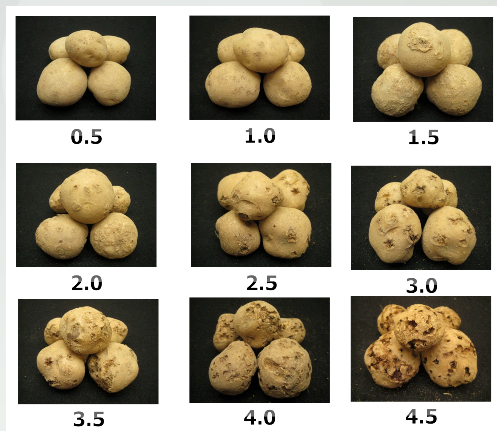
Breeding for Scab Resistance

	Scab Disease Rating (0-5)									
Trial	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**Total**
Variety Trial	1	15	43	54	30	18	9	1	0	171
Early Generation	1	9	36	37	49	26	10	5	1	174
Diploid	3	18	26	15	17	10	7	2	2	100

Reference Variety	Scab Rating
Pike	1.3
Lamoka	1.7
Snowden	2.5
Atlantic	2.5



Based upon this data, scab resistance is strong in the breeding program. We lead the nation in scab resistant lines. This is evident in the NCPT. 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. The ability to select under commercial settings at Sackett Potatoes is accelerating our ability to select for highly scab resistant varieties. MSZ052-14, MSZ219-1, MSZ219-13, MSZ219-14, MSZ022-07, MSZ242-09 and MSZ242-13 are some of the first scab resistant chippers to advance through this effort.

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. In 2019 we conducted late blight trials at the MSU campus. We inoculated with the US23 genotype but the infection levels were not successfully established for data collection. We are not reporting late blight trial results this year. We will continue with late blight trials in 2020 on the MSU campus.

PVY: We are using PCR-based DNA markers to select potatoes resistant to PVY. The gene is located on Chromosome 11. In our first round we made crosses in 2013 to generate over 7,000 progeny segregating for PVY resistance. Each year since 2013 we are making new crosses, making selections and expanding the germplasm base that has PVY resistance (Fig. 2). We are also using DNA markers to also screen for PVX resistance, PLRV resistance, late blight resistance and Golden nematode resistance. As a result of this work, Mackinaw has PVY resistance as well as MSZ219-1,13 and 14. More PVY resistant advanced selections are in the queue. We have identified an advanced breeding line, MSCC725-232 that combines three virus resistance genes (PVY, PVX and PLRV).

Fig. 2 PVY resistant selections in the breeding program

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Marker Tests on FF Families Selected from Single-Hills *

Resistance Marker	M6 (PVY)	RGASC850 (PLRV)	R8 (LB)
# of Samples Tested	629	89	87
# of Samples with the Marker	203	17	37

****MSCC725-232 – resistance to PVY, PVX and PLRV**

*Samples selected in field Fall 2018 and marker tests completed in lab early 2019

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MSU Lines with Commercial Tracking

Manistee (MSL292-A)

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

Saginaw Chipper (MSR061-1)

Parentage: Pike x NY121
Developers: Michigan State University and the Michigan Agricultural Experiment Station
Plant Variety Protection: Trademark

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.

MSV093-1Y

Parentage: McBride x MSP408-14Y
Developers: Michigan State University and the MSU AgBioResearch.
Plant Variety Protection: To Be Applied For

Strengths: MSV093-1Y is a high yield potential yellow-flesh breeding line with an attractive, round tuber shape. This line has demonstrated excellent high yield potential in replicated trials at the MSU Montcalm Research Center and on grower field trials throughout Michigan. This yellow flesh line has excellent internal quality (few defects) and a low incidence of blackspot bruise. MSV093-1Y also has moderate scab tolerance. MSV093-1Y has a strong vine and a mid-early season maturity.

Incentives for production: High yield potential with an attractive tuber shape with good yellow flesh with excellent internal quality.

Mackinaw (MSX540-4)

Parentage: Saginaw Chipper x Lamoka
Developers: Michigan State University and the MSU AgBioResearch.
Plant Variety Protection: To Be Applied For.

Strengths: MSX540-4 is a chip-processing potato with resistance to potato virus Y (PVY), late blight (*Phytophthora infestans*), tolerance to common scab (*Streptomyces scabies*), and demonstrated tolerance to *Verticillium* wilt. This variety has average yield with a high specific gravity, and a high percentage of A-size tubers with an attractive, uniform shape. MSX540-4 has a strong vine and a mid- to late-season maturity, and has demonstrated excellent long-term storage chip-processing quality. MSX540-4 has performed well in multiple locations in the PotatoesUSA National Chip Processing Trials (NCPT).

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Incentives for production: Long-term chip-processing quality with resistance to PVY and late blight, and tolerance to common scab.

Morphological Characteristics:
Plant: Medium height vine, semi-erect with a balance between stems and foliage visible, and flowers.
Tubers: Round tubers with lightly netted, tan colored skin. Tubers have a creamy-white flesh with a low incidence of internal defects.

Agronomic Characteristics:
Vine Maturity: Mid- to late-season maturity.
Tubers: Smooth shaped tubers with lightly netted, tan colored skin and a creamy-white flesh.
Yield: Average yield under irrigated conditions, with uniform A-size tubers.
Specific Gravity: Averages similar to above Snowden in Michigan.
Culinary Quality: Chip-processes from short to long-term storage.
Diseases: Resistant to PVY and late blight (*Phytophthora infestans*), tolerant to common scab (*Streptomyces scabies*).

Petoskey
(MSV030-4)

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

Strengths: Petoskey is a chip-processing potato with resistance to common scab (*Streptomyces scabies*). This variety has high specific gravity and yield potential, with attractive, uniformly round tubers. Petoskey has a medium vine and a mid-season maturity, and has demonstrated excellent long-term storage chip-processing quality. MSV030-4 has performed well in Michigan and multiple locations in the PotatoesUSA National Chip Processing Trials (NCPT) and national SFA (SNaC) trials.

Incentives for production: Excellent chip-processing quality out of the field and long-term chip quality with high specific gravity and resistance to common scab, and a good size profile of uniform, round tubers.

Morphological Characteristics:

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Plant: Medium height vine, semi-erect with a balance between stems and foliage visible, and flowers.
Tubers: Uniform, smooth, round tubers with lightly netted, tan colored skin. Tubers have a white flesh with a low incidence of internal defects.

Agronomic Characteristics:
Vine Maturity: Mid-full season maturity.
Tubers: Smooth, round tubers with lightly netted, tan colored skin and white flesh.
Yield: Above average yield under irrigated conditions, with uniform tubers.
Specific Gravity: Averages higher than Atlantic and Snowden.
Culinary Quality: Chip-processes from short and long-term storage.
Diseases: Resistant to common scab (*Streptomyces scabies*).

Huron Chipper (MSW485-2)

Parentage: MSQ070-1 x MSR156-7
Developers: Michigan State University and the MSU AgBioResearch.
Plant Variety Protection: To Be Applied For.

Strengths: MSW485 is a chip-processing potato with resistance to and late blight (*Phytophthora infestans*), and stronger tolerance to common scab (*Streptomyces scabies*) than Atlantic. This variety has high yield and good specific gravity, with attractive, uniformly round tubers. MSW485-2 has a strong vine and a mid-season maturity, and has demonstrated excellent long-term storage chip-processing quality. MSW485-2 has performed well in multiple locations in the PotatoesUSA National Chip Processing Trials (NCPT) and national SFA (SNaC) trials.

Incentives for production: Excellent chip-processing quality out of the field and long-term chip quality with resistance to late blight and a good size profile.

Morphological Characteristics:
Plant: Medium height vine, semi-erect with a balance between stems and foliage visible, and flowers.
Tubers: Uniform, smooth, round tubers with lightly netted, tan colored skin. Tubers have a white flesh with a low incidence of internal defects.

Agronomic Characteristics:

Vine Maturity: Mid-season maturity.
Tubers: Smooth, round tubers with lightly netted, tan colored skin and a white flesh.
Yield: Above average yield under irrigated conditions, with uniform tubers.
Specific Gravity: Averages similar to above Atlantic and Snowden.
Culinary Quality: Chip-processes from short to long-term storage.
Diseases: Resistant to late blight (*Phytophthora infestans*) and tolerant to common scab (*Streptomyces scabies*).

Blackberry
(MSZ109-10PP)

Parentage: COMN07-W112BG1 x MSU200-5PP
Developers: Michigan State University and the MSU AgBioResearch
Plant Variety Protection: To Be Applied For.

Strengths: Blackberry is a tablestock variety with unique purple skin and a deep purple flesh. The tubers have an attractive, uniform, round shape and a purple flesh with common scab resistance and low incidence of internal defects. Yield can be high under irrigated conditions. Blackberry will also chip-process out of the field.

Incentives for production: The unique purple skin and purple flesh of the tubers of Blackberry offer a unique potato that could lend itself to the specialty variety market, such as gourmet restaurants and food stores, as well as farm and road-side markets. The primary market for this clone will be farm market and direct retail sale growers, and home gardeners. This variety is also used as a gourmet chip processing variety.

Morphological Characteristics:
Plant: Full-sized vine, semi-erect with a balance between stems and foliage visible, and flowers.
Tubers: Round tubers with a smooth skin and unique purple skin and purple flesh color. Tubers have a deep purple flesh with a low incidence of internal defects.

Agronomic Characteristics:
Maturity: Mid-season.
Tubers: Round tubers with unique purple skin and deep purple flesh.
Yield: Above average yield.

Specific Gravity: Averages 1.065 in Michigan.
Culinary Quality: Gourmet specialty with deep purple flesh and also chip-processes.
Diseases: Good common scab resistance.

MSX569-1R (Ilse Royale)

Parentage: MSS002-2R x MSS544-1R
Developers: Michigan State University and the MSU AgBioResearch.
Plant Variety Protection: To Be Applied For.

Strengths: MSX569-1R is a fresh market variety with an attractive red skin, bright white flesh, excellent round tuber shape, and tolerance to common scab (*Streptomyces scabies*). This variety has average yield with a high percentage of A-size tubers with an attractive, uniform shape. The bright red skin is highly desirable in the fresh market, and also maintains good red color in storage. This line has demonstrated good marketable yield potential in replicated trials at the MSU Montcalm Research Center, on grower field trials throughout Michigan, as well as in North Central Regional Trials, and trials in Florida and North Carolina. MSX569-1R has excellent internal quality (few defects) and a low incidence of blackspot bruise.

Incentives for production: Fresh market variety with a bright red skin, attractive tuber size and shape, excellent internal quality, and tolerance to common scab.

Morphological Characteristics:
Plant: Medium height vine, semi-erect with a balance between stems and foliage visible, and flowers.
Tubers: Round tubers with a smooth, bright red colored skin. Tubers have an attractive white flesh with a low incidence of internal defects.

Agronomic Characteristics:
Maturity: Mid-season maturity.
Tubers: Round tubers with a red skin and an attractive white flesh.
Yield: Average yield under irrigated conditions, similar or better than Red Norland.
Specific Gravity: Good fresh market specific gravity (1.055 in Michigan).
Culinary Quality: Excellent culinary quality.
Diseases: Tolerance to common scab (*Streptomyces scabies*).

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Application of Molecular Markers in MSU Potato Breeding

With the development of molecular markers for potato breeding, marker-assist selection has been incorporated into our routine breeding practice and greatly facilitate the selection process. Some of the main markers that are used at MSU include: *RYSC3* and M6, *Potato virus Y* (PVY) resistance markers; *RxSP*, a *Potato virus X* (PVX) resistance marker; *TG689*, a Golden Nematode resistance marker; RB and R8, Late Blight resistance marker. PVY markers have been the most frequently used tools to assist selection in our program due to the importance of PVY resistance. According to the pedigrees, selections from our single-hill trial (1st year of field selection) are screened for PVY markers every year. This allowed for a prioritization of the space in the field, and for earlier, more informed decisions in variety selection.

The trait mapping populations have been a major research focus for us over the previous four 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. Our first SNP marker is linked to a gene for late blight resistance on Chr. 9 and the second is located on Chr. 10 with new ones recently identified on Chr. 4 and Chr. 5. The ability to use the DNA markers to stack a set of late blight resistance genes will lead to durable late blight resistance. We are now bringing in late blight resistance genes from germplasm from Europe and China.

Decoding *S. chacoense*-derived Colorado potato beetle resistance

Introgression of Colorado potato beetle resistance from *S. chacoense*-derived diploid recombinant inbred lines into cultivated backgrounds is being conducted through GREEEN funding. Subsequent marker assisted selection will yield diploid breeding lines with beetle resistance and desirable tuber traits. The spatio-temporal durability of this glycoalkaloid-based host plant resistance will be assessed using Colorado potato beetle populations from potato growing regions across the nation and examining 10 successive generations of beetles grown on host plant resistant material. Furthermore, the development of cross-resistance by beetles grown on host plant resistant material to commercial insecticides will be examined to inform the most sustainable deployment of this germplasm. We have made crosses to introgress the beetle resistance. We will be able to use DNA markers to track the resistance genes as we continue to breed.

Overcoming self-incompatibility in diploid potato using CRISPR-Cas9

The aim of this project was to generate a targeted knock-out (KO) of the *S-RNase* gene, involved in gametophytic self-incompatibility in diploid potatoes, using CRISPR/Cas9 technology in an effort to avoid self-pollen degradation. We identified *S-RNase* alleles with flower-specific expression in two diploid self-incompatible lines using genome resequencing data. *S-RNase* gene mapped to chromosome 1 within a low recombination region. *S-RNase* KO lines were obtained causing premature stop codons. Fruits were set in selected KO and produced viable T1 seeds, and a Cas9-free KO line. Our results suggest that creating *S-RNase* KO can contribute to generation of self-compatible lines as a first step for the generation of commercial diploid cultivars.

Gene editing in diploid potato

MSU's breeding program has developed diploid germplasm with important agronomic qualities. These lines can be further characterized on traits for the use of gene editing. Thus, the first objective of this project is to characterize the MSU diploid germplasm for important molecular and morphological traits such as regeneration capability. The second major objective is to use gene editing, namely, CRISPR-Cas9 to knockout vacuolar invertase (*VInv*) and PPO in select diploid lines. The overall goal is to further advance the diploid breeding program by introducing economically important traits and proving the utility of gene editing in potato.

Dihaploid Potato Production at Michigan State University

The benefits of developing a richer germplasm of dihaploid potatoes brings the industry ever closer to the expansive changes that would come with diploid potatoes. Many of the difficulties associated with tetraploid potatoes, such as problems with seed storage, would be greatly reduced if the potato had a lower, and therefore less complicated, ploidy. Our goal is to develop a broad-based dihaploid germplasm that can be used in diploid potato breeding. We started by crossing currently established MSU tetraploid germplasm with a known haploid inducer, *S. phureja* IVP 101. Parent lines were selected based on traits such as high yield, disease resistance, and good chip quality, among others. Resulting seeds were inspected for a purple embryo spot and grown in tissue culture before transplanting in the greenhouse. Chloroplast numbers in guard cells were counted to determine ploidy level. Plants that we determined to be diploid were also SNP genotyped with the Infinium 22K Potato SNP array for ploidy determination. These dihaploids were then tested for disease resistance markers: RYSC3+ (Potato Virus Y extreme resistance), GN (Golden Nematode) resistance, and PVX resistance. Those with a Jacqueline Lee lineage were also tested for presence of late blight resistance via a SNP KASP assay. Confirmed dihaploids were crossed with a diploid self-compatible inbred line of *S. chacoense*, M6 to introgress self-compatibility. Of the hundreds of seeds produced in the past 6 years from these dihaploid crosses with 24 breeding lines or varieties, about 200 progeny have been confirmed as diploid. These dihaploids (diploids derived from tetraploid varieties) are the foundation of our diploid breeding program for round white potatoes for the chip and table markets. We have also now selected some russet dihaploids and will be selecting some red dihaploids in 2020.

Introgressing Self-compatibility to *Solanum tuberosum* Dihaploids for Diploid Variety Development

Dihaploids of cultivated potato (*Solanum tuberosum* L.) have been produced for over 50 years to reduce the breeding and genetic challenges of autopolyploidy. Most dihaploids are male sterile (MS) that reduces the benefit of lower ploidy level of cultivated tetraploid potato. In this study, we used three self-compatibility (SC) donors to introgress SC into a wide range of dihaploid germplasm through a series of crosses to dihaploids which we refer to as *S. tuberosum* backcrossing. The SC increased from 11% in the F_1 generation to 33% in the BC_2 generations. Over 6,000 genome-wide SNPs were used to characterize the germplasm diversity, heterozygosity, and structure in two backcrossing generations. The BC_3 generation was significantly improved regarding maturity, scab resistance, average tuber number, however, the yield in BC_3 was not greater than the F_1 and BC_2 generations.

Certified NFT Minituber production at Michigan State University

For 3 years, the MSU Potato Breeding program has operated its own certified NFT minituber production greenhouse. The ability to produce certified seed allows faster introduction of early generation material to the potato industry. It also helps position the program for participation in international trials.

MICHIGAN STATE UNIVERSITY

2019 Certified Seed Production

Line	Tubers	Remarks
Blackberry (MSZ109-10PP)	3644	
Colonial Purple	430	
Huron Chipper (MSW485-2)	741	
Mackinaw (MSX540-4)	2156	NexGen
MSCC447-1WR	853	
MSCC720-1WP	564	
Petoskey (MSV030-4)	991	NexGen
MSX324-1P	317	
MSZ109-05RR	1092	
MSZ109-07PP	635	
Raspberry	1002	
Red Marker #2	1382	

Line	Tubers	Remarks
Atlantic	998	USAID
Ranger Russet	1249	USAID
Diamant	1447	USAID
UB 10 Events	~800 ea.	USAID
Granola	449	USAID
UG 10 Events	~200 ea.	USAID

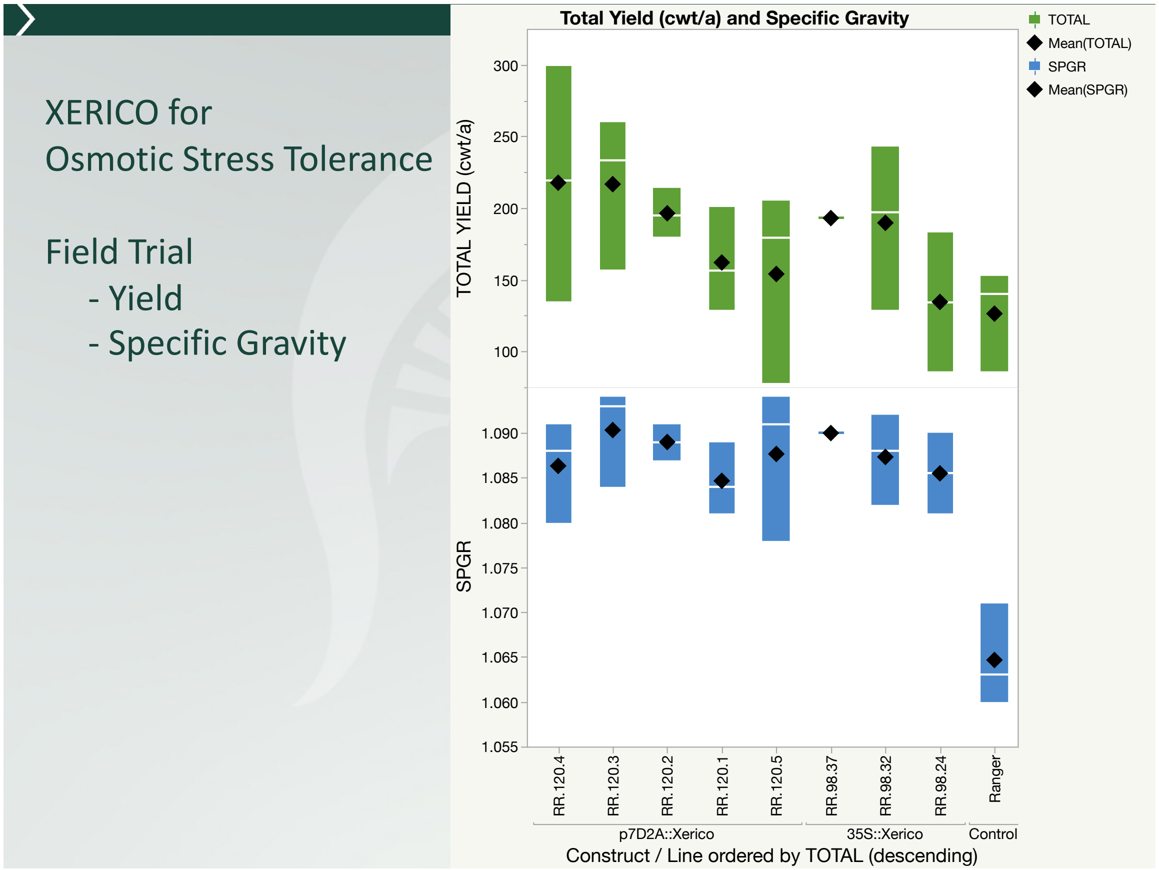
Germplasm Enhancement

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 are now placing more emphasis on the diploid breeding effort because of the advantages the breeding system brings when we introduce the ability to self-pollinate a line. Features of diploid breeding include 1) a simpler genetic system than current breeding methods, 2) tremendous genetic diversity for economic traits, 3) minimal crossing barriers to cultivated potato, 4) the ability to reduce genetic load (or poor combinations) through selfing and 5) the ability to create true breeding lines like wheat, soybeans and dry beans. We are also using some inbred lines of *S. chacoense* that have fertility and vigor (also a source of *Verticillium* wilt resistance to initiate our efforts to develop inbred lines with our own diploid germplasm. We have over 40 populations that we have cycled 5 generations to improve for self-compatibility and tuber traits. We have also been crossing self-compatible donors to the dihaploids of Atlantic, Superior, Manistee, MSZ219-14, Kalkaska, MSR127-2, MSS576-5SPL and others so we can develop inbred chip-processing diploid lines. This new diploid potato breeding project is expanding to develop promising lines to use as parents in the future as well as to think about F1 hybrid varieties.

Integration of Genetic Engineering with Potato Breeding

MSU conducts genetic engineering research to introgress and test economically important traits into potato. We have a USAID-funded project to create and commercialize 3-R-gene potato varieties in Bangladesh and Indonesia. This a partnership with Simplot Plant Sciences. Simplot has been creating the plants for the target countries. 2019 greenhouse and field trials show that a high level of resistance to late blight has been achieved in events that have no backbone and are single inserts. Trials are further planned for the fall of 2020.

We have also generated lines with the genes for water use efficiency. The XERICO gene is showing the most promise. In 2018 and 2019 we conducted preliminary trials at MRC with Ranger Russet events. These results are indicating that we are not seeing a yield reduction from the XERICO gene and the XERICO events also had a higher specific gravity than Ranger Russet. Meanwhile the greenhouse experiments are showing an ability to refrain from wilting under sub-optimal soil water levels. In 2020 we will continue field trials at MRC. Lastly, we have generated and selected a Kalkaska invertase silencing line (Kal91.03) that has resistance to accumulating reducing sugars in cold (40°F) storage. We tested the agronomic characteristics of Kal91.03 from 2016-2019. The initial results are suggesting that the invertase silencing line has good tuber type, size and similar specific gravity. This suggests that we can correct sugar issues in a chip processing lines with this genetic engineering strategy. In 2020 we will be producing XERICO events and Kal91.03 in the NFT greenhouse to run larger trials in 2021.



Chipped directly after 3 months at 40F

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Funding: Fed. Grant/MPIC/Potatoes USA

2019 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 2019, we tested over 150 varieties and breeding lines in the replicated variety trials, plus over 150 lines in the National Chip Processing Trial (NCPT). The variety evaluation also includes disease testing in the scab nursery (Montcalm Research Center) and foliar late blight evaluation (MSU Campus Plant Pathology Farm). The objectives of the evaluations are to identify superior varieties for fresh or chip-processing markets (chip, round white/yellow table, specialty/red and russet). 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 as well as from 45°F (7.2°C) and 50°F (10°C) storage at 3 and 6 months), along with susceptibilities to common scab, late blight (foliar and tuber), and blackspot bruising are determined.

We would like to acknowledge the collaborative effort of the Michigan Potato Industry and research colleagues Matthew Klein and the MSU Potato Breeding Team (especially M. Alsahlany, N. Kirkwyland, Mathilde Iop and Will Behling) for helping to get the field 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 in Montcalm County. The field experiments were conducted on a sandy loam soil that has been out of potato production for 5 years. Oats were grown in 2018 on this ground.

The most advanced selections were tested in the Advanced chip and tablestock trials, representing selections at a stage after the preliminary trials. The other field trials were the Russet, Preliminary (chip-processors and tablestock), Preliminary Pigmented, the NCPT and the early observational trials.

2019 was the eighth 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 9 trial locations (Northern sites: NY, MI, WI, ND, OR and Southern: NC, FL, CA, TX) in addition to a scab trial Wisconsin.

In each of these trials, the yield was graded into four size classes (pick outs, Bs, As, oversize) using the new Kerian sizer on the grading line, incidence of external and internal defects in >3.25 in. (8.25 cm) diameter potatoes were recorded. Samples were taken for specific gravity, chip-processing, 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 345°F (174°C) for 2 minutes 15 seconds or until fully cooked. 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 April. Select 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 Center. There has been very strong scab disease pressure at the new Montcalm Scab Disease Nursery for seven years now. The 2019 late blight trial was conducted at the MSU campus Plant Pathology Farm. The simulated blackspot bruise (from 50°F tuber temperature) results for average spots per tuber have also been incorporated into the summary sheets.

RESULTS

A. Advanced Chip-Processing Trials (Table 1)

A summary of the 30 entries evaluated in the trial results is given in **Table 1**. Overall, the yields for the Advanced trial (140 days) were above average. The check varieties for this trial were Lamoka, Snowden and Atlantic. The highest yielding and most promising lines were MSZ120-4, MSZ219-14, MSZ219-13, Lady Liberty and MSAA076-6. Internal defects were minimal for 2019. Specific gravity was good with a trial average of 1.086. Snowden and Atlantic had a specific gravity of 1.087 and 1.089, respectively. All chip-processing entries in the trial had excellent chip-processing quality out of the field, with an SFA score of 1.0. Almost all of the MSU breeding lines have good scab resistance. Nineteen MSU chipping lines were classified as having scab resistance scores equal or better than Lamoka. Mackinaw (MSX540-4) has PVY and late blight resistance while MSZ219-13 and MSZ219-14 (all three are scab, PVY and late blight resistant). MSZ120-4 is also noted to have strong *Verticillium* wilt resistance.

B. Russet Trial (Table 2)

In 2019, 11 lines were evaluated after 125 days. The results are summarized in **Table 2**. Russet Norkotah, GoldRush and Silverton Russet were the reference varieties used in the trial. In general, the yields were below average for many russet lines while Silverton Russet, Reveille Russet and A071012-4BFRUS were the top tier for yield. In most cases specific gravity was average with 1.080 average for the trial. Hollow heart was only observed in A071012-4BFRUS and AO02183-2. Bruise incidence was average, but a couple of Aberdeen lines stood out as blackspot susceptible. Scab resistance was variable with susceptibility was observed in a number of the russet lines.

D. Adaptation Trial (Table 3)

The Adaptation Trial of the tablestock lines was harvested after 125 days and the results of 24 lines are summarized in **Table 3**. The many of the lines evaluated in the Adaptation Trial were tested in the Preliminary Trials the previous year. Three reference cultivars (Red Norland, Yukon Gold and Superior) are reported in the tablestock trial. In general, the yields were below average and internal defects were low. The highest yielding lines were MSX156-1Y, MSV093-1Y, MSAA196-06 and MSZ551-1. Scab tolerance is becoming more prevalent among the advanced selections but the challenge remains to combine scab and late blight resistance together. Promising lines in the trial are MSZ416-8RY, MSV179-1, MST252-1Y and Blackberry. Blackspot bruising was low for most lines.

E. Preliminary Trials (Tables 4, 5 and 6)

The Preliminary trials (chip, table, pigmented) are the first replicated trials 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. In 2019, there were 90 entries trialed in the three Preliminary trials.

The chip-processing Preliminary Trial (**Table 4**) had 30 entries and was harvested after 141 days. Many of the lines chip-processed well from the field but specific gravity values were below average with Snowden at 1.081. Internal quality weakness was predominantly vascular discoloration. Promising MSU lines are MSZ269-01Y, MSBB610-24Y, MSBB613-07, MSB079-2, MSBB635-14 and MSBB058-04 combining yield, specific gravity, scab resistance and chip quality. Some of these lines also contain PVY resistance. We continue to make progress selecting for chip-processing with scab resistance with 18 lines in the trial with scab ratings equal or lower than 1.7, whereas Snowden had a scab rating of 3.0. We are also combing chip-processing quality and late blight resistance, but we did not collect late blight results in 2019 to validate the 2017 results.

Table 5 summarizes 30 tablestock entries evaluated in the Preliminary Tablestock Trial. Onaway, Reba and Yukon Gold were the check varieties. This tablestock trial was harvested and evaluated after 132 days. MSY022-02, MSZ407-7 and MSZ169-1 all have high yield potential, low internal defects and scab resistance, as well as low blackspot bruising. In general, the level of scab resistance and internal quality are improving in this pool of lines. We are working towards better skin finish also. This trial also included

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some European varieties. None of the lines were promising due to poor shape or scab susceptibility.

The interest in the specialty market continues to increase. In 2019, 30 entries were evaluated in a targeted Preliminary Pigmented Trial (**Table 6**), which was harvested at 132 days. This trial evaluated breeding lines with unique skin and flesh colors. Many of these lines have commercial agronomic performance and specialty characteristics, as well as some scab resistance. Eighteen lines were scored as scab resistance. Blackspot bruising is low and internal defects were almost non-existent. MSBB213-1Spl and MSBB305-2Spl combine high yield and scab resistance. MSAA161-04RY is a promising red skin with yellow flesh line. MSX443-3P is an attractive "mini" potato while MSCC282-01WR is a potato with a white skin and an attractive red pigmented flesh. Some of the purple flesh lines have an attractive purple flesh with random patterns of white flesh that looks like a "tie dye" pattern.

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

Each year, a replicated field trial is conducted to assess resistance to common scab. The scab trial is now located at the Montcalm Research Center where high common scab disease pressure was observed in the previous seven years. This location is being used for the early generation observational scab trial (177 lines) and the scab variety trial (171 lines) and diploid scab trial (385). In 2019, the scab infection was aggressive with the susceptible controls having a high coverage of pitted scab.

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 2017-2019 scab ratings are based upon the Montcalm Research Center site. **Table 7** categorizes many of the varieties and advanced selections tested in 2019 over a three-year period. The varieties and breeding lines are placed into nine 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% surface infection and severe pitted lesions.

The check varieties Russet Norkotah, GoldRush, Red Norland, Yukon Gold, Onaway, Pike, Atlantic, and Snowden can be used as references (bolded in **Table 7**). The table is sorted in ascending order by 2019 scab rating. This year's results continue to indicate that we have been able to breed numerous lines with resistance to scab. Scab ratings ranged from 0.3 - 4.0 for the variety trial. A total of 76 lines, of the 171 tested, had a scab rating of 1.5 or lower in 2019. Most notable scab resistant MSU lines are found in the trial summaries **(Tables 1-6)**.

There are also an increasing number of scab resistant lines that also have late blight resistance and PVY resistance such as Saginaw Chipper, Mackinaw, MSZ219-1, MSZ219-13,MSZ219-14, MSBB613-07, MSBB610-24Y and MSBB635-14. Blackberry also has a consistent level of scab resistance over the three years of testing. We also continue to conduct early generation scab screening on selections in the breeding program beginning after two years of selection. Of the 171 early generation selections that were evaluated, 85 had scab resistance (scab rating of ≤ 1.5) (**Table 8**).

H. Late Blight Trial

In 2019, the late blight trial was planted at the East Lansing campus Plant Pathology farm. 206 entries were planted in early June for late blight evaluation. These include lines tested in a replicated manner from the agronomic variety trial (144 lines) and 62 entries in the early generation observation plots. The trials were inoculated four times in August and September with the US-23 genotype of *P. infestans*. Late blight infection was identified in the plots in late September which was too late to assess foliar symptoms for resistance. As a result, we did not collect data that could discriminate resistant from susceptible lines.

I. Blackspot Bruise Susceptibility (Table 9)

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 9**. 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 2019, the bruise levels were average compared to previous years. There are many lines with lower blackspot bruise potential across the trials. Some of our advanced selections are similar to or less than Atlantic and Snowden in their level of bruising. A few lines will high susceptibility to bruise were identified and will be discontinued from testing. All the bruise ratings are also found in the variety trial tables (**Tables 1-6**).

J. National Chip Processing Trial (NCPT) data available on-line

The Potatoes USA-funded National Chip Processing Trial (NCPT) is an effort to synergize the strengths of the public breeding programs in the U.S. to identify improved chip-processing varieties for the industry. Cooperating breeding programs include the USDA (Idaho and Maryland) and land grant universities (Colorado, Maine, Michigan, Minnesota, North Carolina, North Dakota, New York, Oregon, Wisconsin and Texas). The coordinated breeding effort includes early stage evaluation of key traits (yield, specific gravity, chip color, chip defects and shape) from coordinated trials in 10 locations. Since the inception of the trial in 2010, over 1,000 different potato entries, including reference varieties, have been evaluated. The data for all the lines tested are summarized on a searchable, centralized database housed at Medius Ag (https://potatoesusa.mediusag.com/trials/ncpt). More than 40 promising new breeding lines from the trials have been fast-tracked for larger-scale commercial trials and processor evaluation. The NCPT is also a feeder for the national SNAC International trials and PotatoesUSA Fast Track and NexGen programs. We are using the NCPT trials to more effectively identify promising new selections. These are MSW485-2, MSX540-4, MSV030-4, MSZ219-13, MSZ219-14 and MSW075-1, MSW474-1, MSZ063-2 and MSZ242-13 have been added to the mini-fast track. Minituber production and/or commercial seed have been produced of these lines and will be tested in Michigan in 2020.

Table 1

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

ADVANCED CHIP-PROCESSING TRIAL
MONTCALM RESEARCH CENTER
May 7 to September 24, 2019 (140 days)
DD Base 40°F 3211[8]

LINE	N	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]	3-YR AVG US#1 CWT/A
MSZ120-4	4	416	477	87	13	87	0	0	1.088	1.0	1.0	0	0	0	0	1.7	4.5	1.2	-
MSZ219-14	4	345	395	87	12	87	0	0	1.080	1.0	1.0	0	3	3	0	1.8	3.6	1.8	378
MSZ219-13	4	344	373	92	8	91	0	0	1.087	1.0	1.0	0	3	0	0	1.7	3.8	4.0	359
Lady Liberty (NY152)	4	317	407	78	21	77	0	1	1.082	1.0	1.0	0	0	0	0	1.8	3.3	1.2	394*
MSAA076-6	4	299	385	78	22	78	0	0	1.095	1.0	1.0	0	0	0	0	2.0	2.8	4.0	-
MSZ222-19	4	290	383	76	24	76	0	1	1.093	1.0	1.0	3	3	0	0	0.8	2.8	2.4	475
MSZ200-6	3	281	365	77	22	77	0	1	1.081	1.0	1.0	0	7	0	0	1.5	3.3	2.2	-
MSV498-1	4	280	345	81	18	81	0	0	1.082	1.0	1.0	0	23	0	0	1.2	3.0	2.0	341
MSZ242-09	4	273	347	78	22	78	0	0	1.100	1.0	1.0	0	3	0	0	1.5	3.3	1.7	315
MSZ101-7	4	272	316	86	14	86	0	0	1.087	1.0	1.0	0	0	0	0	1.3	3.9	2.5	-
MSX225-2	4	271	355	76	24	76	0	0	1.082	1.0	1.0	0	30	0	0	1.3	2.8	2.0	306*
MSZ200-3	4	254	298	85	14	85	0	1	1.076	1.0	1.0	3	0	0	0	2.0	3.9	1.3	-
MSZ052-13	4	254	304	83	17	83	0	0	1.087	1.0	1.0	0	0	0	0	0.8	2.8	2.9	-
MSZ020-10	4	245	299	82	18	82	0	0	1.094	1.0	1.0	0	3	0	0	1.8	3.8	4.6	-
MSZ219-01	4	238	274	86	10	86	0	4	1.085	1.0	1.0	0	0	0	0	0.5	2.4	1.2	369
Huron Chipper (MSW485-2)	4	230	315	73	27	73	0	0	1.087	1.5	2.0	3	3	0	3	2.0	3.3	1.6	389
Lamoka	**4**	**230**	**296**	**77**	**23**	**77**	**0**	**1**	**1.084**	**1.0**	**1.0**	**0**	**0**	**0**	**0**	**1.5**	**2.0**	**1.7**	**320**
Atlantic	**3**	**221**	**273**	**81**	**18**	**81**	**0**	**1**	**1.089**	**1.0**	**1.0**	**0**	**3**	**0**	**0**	**2.5**	**2.5**	**2.0**	**339**
MSZ242-13	3	218	265	82	16	81	1	1	1.105	1.0	1.0	0	3	0	0	1.3	3.2	3.2	271
Petoskey (MSV030-4)	4	198	284	69	30	69	0	1	1.090	1.0	1.0	0	3	3	0	1.8	2.6	1.6	-
BNC182-5	2	191	258	74	26	74	0	0	1.085	-	-	0	0	0	0	0.0	2.3	-	-
MSW044-1	4	189	298	64	36	64	0	0	1.089	1.0	1.0	0	3	0	0	1.5	3.4	1.7	272
MSX193-1Y	4	187	260	70	30	70	0	0	1.069	-	-	0	0	0	0	2.0	2.6	-	-
Snowden	**4**	**186**	**315**	**59**	**41**	**59**	**0**	**0**	**1.087**	**-**	**-**	**0**	**0**	**0**	**0**	**3**	**2**	**2.6**	**316**
Manistee	4	180	254	70	30	70	0	0	1.078	1.0	1.0	0	0	0	0	3.0	1.4	0.5	317
Mackinaw	4	177	278	63	35	63	0	2	1.096	1.0	1.0	0	10	3	0	1.5	3.3	3.2	272
MSZ052-14	3	166	252	63	36	63	0	1	1.083	1.0	1.0	0	0	0	0	1.3	2.5	2.3	280*
MSZ022-07	4	153	226	67	33	67	0	0	1.081	1.0	1.0	0	0	0	0	0.8	2.1	1.2	225*
B2869-29	2	109	201	54	46	54	0	0	1.085	-	-	0	0	0	0	3.3	1.8	1.8	-
MEAN		242	314						1.086							1.6	2.9	2.2	338
$HSD_{0.05}$		131	129						0.007										

* Two-Year Average

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.
[2]CHIP SCORE: SNAC 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 20, 2019; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).

Plant Date:	5/7/19
Vine Kill:	9/11/19
Days from planting to vine kill:	127

[8]Enviroweather: Entrican Station. Planting to vine kill

Table 2

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

RUSSET TRIAL
MONTCALM RESEARCH CENTER
May 07 to September 9, 2019 (125 days)
DD Base 40°F 3056[6]

		CWT/A		PERCENT OF TOTAL[1]						PERCENT (%) TUBER QUALITY[2]							3-YR AVG US#1
LINE	N	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	SCAB[3]	MAT[4]	BRUISE[5]	CWT/A
ATX91137-1Rus (Reveille Russet)	4	274	322	85	10	85	0	5	1.075	0	23	0	0	2.0	2.6	0.9	-
Silverton Russet	**4**	**263**	**334**	**79**	**20**	**79**	**0**	**2**	**1.076**	**0**	**10**	**0**	**0**	**0.5**	**3.1**	**1.3**	405
A071012-4BFRUS	4	262	349	75	20	75	0	5	1.097	25	13	0	0	3.2	3.5	2.2	289*
AO02183-2	4	235	303	77	17	77	0	6	1.090	20	15	0	0	2.7	3.6	2.0	-
Payette Russet	4	234	309	74	18	74	0	7	1.091	0	10	0	0	1.2	3.5	2.3	-
A07061-6RUS	4	217	312	70	26	70	0	4	1.075	0	8	0	0	2.8	3.0	1.6	329
AOR07781-5	4	162	228	71	22	71	0	7	1.083	8	15	0	0	0.5	2.1	1.2	-
POR06V12-3 (Castle Russet)	4	147	219	67	32	67	0	2	1.088	8	5	0	0	1.5	2.6	0.9	-
TX08352-5Rus (Vanguard)	4	146	229	64	34	64	0	2	1.066	0	3	0	0	1.3	1.0	1.6	172
Goldrush Russet	**4**	**137**	**269**	**51**	**45**	**51**	**0**	**4**	**1.068**	**0**	**18**	**0**	**0**	**0.8**	**1.1**	**0.9**	264
Russet Norkotah / Texas 112	**4**	**102**	**218**	**47**	**50**	**47**	**0**	**3**	**1.070**	**3**	**18**	**0**	**0**	**2.2**	**1.0**	**0.8**	**280**
MEAN		198	281						1.080					1.7	2.5	1.4	290
$HSD_{0.05}$		90	79						0.007								

* 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 20, 2019; 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]Enviroweather: Entrican Station. Planting to vine kill

Plant Date:	5/7/19
Vine Kill:	9/4/19
Days from planting to vine kill:	120

Table 3

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

ADAPTATION TRIAL, TABLESTOCK LINES
MONTCALM RESEARCH CENTER
May 07 to September 9, 2019 (125 days)
DD Base 40°F 3056[6]

		CWT/A		PERCENT OF TOTAL[1]						PERCENT (%) TUBER QUALITY[2]						
LINE	N	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	SCAB[3]	MAT[4]	BRUISE[5]
MSX156-1Y	4	397	410	97	3	96	1	0	1.070	0	3	0	0	2.7	3.0	1.9
MSV093-1Y	3	366	395	92	7	92	0	1	1.074	0	10	0	0	1.2	3.7	0.2
MSAA196-06	4	350	463	75	22	75	0	3	1.068	0	5	0	0	2.3	3.1	1.4
MSZ551-1	4	348	379	92	7	90	2	1	1.080	0	23	0	0	1.8	3.0	1.7
MSX245-2Y (Chip)	4	303	347	87	13	87	0	0	1.084	0	20	0	0	2.0	3.4	2.5
MSV443-1PP	4	287	371	78	22	78	0	0	1.063	0	0	0	0	1.3	2.3	0.4
MSZ416-08RY	4	286	329	87	13	87	0	0	1.065	0	18	0	0	1.0	2.0	0.8
MSV179-1	4	272	293	93	6	93	0	1	1.071	0	3	0	0	1.5	2.9	0.7
MSAA174-1	4	260	311	84	15	84	0	1	1.062	0	60	3	0	1.5	2.9	1.3
Yukon Gold	**4**	**247**	**278**	**89**	**11**	**89**	**0**	**0**	**1.076**	**0**	**35**	**0**	**3**	**3.0**	**1.1**	**0.5**
MSZ107-01PP	4	234	404	58	42	58	0	0	1.080	0	0	0	0	1.3	5.0	-
Blackberry (MSZ109-10PP	4	222	363	61	39	61	0	0	1.066	0	0	0	0	1.2	3.1	0.4
MSAA157-2PY	4	218	311	70	30	70	0	0	1.071	0	8	0	0	3.2	3.5	0.8
MST252-1Y	4	175	256	68	30	68	0	2	1.067	0	15	0	0	1.7	1.3	1.2
MSX497-6	4	169	186	91	9	91	0	0	1.067	0	0	0	0	2.2	1.8	1.4
Dark Red Norland	**4**	**169**	**248**	**68**	**32**	**68**	**0**	**0**	**1.060**	**0**	**15**	**0**	**0**	**1.2**	**1.0**	**0.7**
Superior	**4**	**163**	**227**	**72**	**27**	**72**	**0**	**1**	**1.069**	**0**	**35**	**3**	**5**	**1.7**	**1.0**	**0.8**
Pike (Chip)	4	156	223	70	30	70	0	1	1.085	0	8	0	0	1.5	2.3	0.8
MSX324-2R	4	148	215	69	29	69	0	2	1.069	0	8	0	3	1.5	1.4	0.7
MSX324-1P	4	141	240	59	40	59	0	1	1.082	0	0	0	0	1.0	1.0	**0.7**
MSZ598-2	4	135	190	69	31	69	0	0	1.068	0	33	0	0	1.5	1.5	0.6
MSAA182-3R	4	121	250	48	52	48	0	0	1.078	0	10	0	0	1.7	3.5	0.4
Isle Royale (MSX569-1R)	4	109	184	61	38	61	0	1	1.048	0	15	0	0	2.0	1.0	0.2
Queen Anne	4	66	241	26	74	26	0	0	1.060	0	5	0	0	1.8	1.1	0.8
MEAN		223	296						1.070					1.7	2.3	0.9
$HSD_{0.05}$		128	131						0.005							

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.
[2]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.
[3]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.
[4]MATURITY RATING: August 20, 2019; 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]Enviroweather: Entrican Station. Planting to vine kill

Plant Date: 5/7/19
Vine Kill: 9/4/19
Days from planting to vine kill: 120

Table 4

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

PRELIMINARY TRIAL, CHIP-PROCESSING LINES
MONTCALM RESEARCH CENTER
May 7 to September 25, 2019 (141 days)
DD Base 40°F 3211[8]

		CWT/A		PERCENT OF TOTAL[1]						CHIP	OTF	PERCENT (%) TUBER QUALITY[4]						
LINE	N	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]
MSBB621-03	2	383	424	90	9	90	0	1	1.076	1.5	1.0	0	35	10	0	1.8	4.3	3.5
MSBB610-24Y	2	375	394	95	5	92	3	0	1.087	1.0	1.0	25	0	0	0	1.2	4.8	2.5
MSBB075-1Y	2	373	402	93	6	90	3	1	1.079	1.5	1.0	0	10	0	0	2.2	3.5	2.6
MSBB107-1	2	347	375	92	7	92	0	0	1.076	1.0	1.0	0	0	0	0	2.2	3.8	0.3
MSBB613-07	2	309	343	90	9	90	0	1	1.079	1.5	2.0	5	15	0	0	1.0	4.8	1.0
MSBB079-2	2	305	377	81	19	81	0	0	1.081	1.0	1.0	0	5	0	0	1.3	3.8	1.6
MSBB190-03	2	295	340	87	13	87	0	0	1.087	1.0	1.0	0	0	0	0	2.0	2.8	3.6
MSAA342-02	2	295	312	94	6	91	3	0	1.072	1.0	1.0	0	10	0	0	2.0	3.8	1.9
MSBB018-1	2	289	346	84	16	84	0	1	1.078	1.0	1.0	0	10	0	0	1.2	3.8	2.1
MSAA240-05	2	285	325	87	13	87	0	0	1.086	1.0	1.0	5	5	0	0	2.5	3.5	3.8
MSBB230-02	2	280	379	74	26	74	0	0	1.077	1.0	1.0	0	0	0	0	1.7	5.0	2.3
MSBB058-04	2	274	315	87	11	86	1	3	1.085	1.0	1.0	5	0	0	0	1.5	4.8	1.5
MSBB635-14	2	267	353	75	24	75	0	0	1.079	1.0	1.0	0	5	0	0	1.2	3.8	-
MSBB210-A	2	261	296	88	12	88	0	0	1.076	1.0	1.0	0	45	0	0	1.5	2.8	2.3
MSAA036-01	2	251	294	86	14	86	0	0	1.080	1.0	1.0	0	15	20	0	1.2	3.0	2.3
MSAA228-1Y	2	228	268	85	14	85	0	1	1.080	1.5	1.0	0	5	0	0	1.5	4.3	1.8
MSBB190-01	2	226	261	87	13	87	0	0	1.069	-	-	0	10	0	0	2.0	2.5	-
MSBB038-01	2	224	257	87	13	87	0	0	1.071	1.0	1.0	0	65	0	0	1.0	2.8	0.8
MSAA056-03Y	2	214	246	87	13	87	0	0	1.070	1.5	1.0	5	0	0	0	2.2	2.3	1.3
MSAA498-07	2	211	241	87	13	87	0	0	1.081	1.0	1.0	0	30	0	0	2.0	2.0	2.3
MSAA218-03	2	210	326	64	36	64	0	0	1.079	1.5	2.0	0	0	0	0	2.8	3.0	2.2
MSAA072-05	2	208	244	85	12	85	0	3	1.084	-	-	0	10	0	0	1.5	2.0	2.4
MSBB020-8	2	187	222	85	15	85	0	0	1.072	1.0	1.0	0	15	0	5	0.8	2.8	-
MSBB165-1	2	186	245	76	19	76	0	5	1.075	1.5	1.0	0	10	0	0	1.5	1.8	0.7
MSBB032-1	2	186	273	68	32	68	0	0	1.082	1.0	1.0	5	0	0	0	2.8	3.0	1.0
Snowden	**2**	**180**	**310**	**58**	**42**	**58**	**0**	**0**	**1.081**	**1.0**	**1.0**	**0**	**50**	**0**	**0**	**3.0**	**2.0**	**2.6**
MSAA392-03	2	158	201	79	21	79	0	0	1.064	-	-	0	15	0	0	1.0	2.5	-
MSBB634-8	2	129	172	75	25	75	0	0	1.079	1.5	2.0	0	30	0	0	1.5	2.3	3.0
MSAA392-05	2	115	146	79	21	79	0	0	1.073	-	-	0	10	0	0	2.0	1.0	-
MSAA061-7	2	112	200	56	43	56	0	1	1.084	1.0	1.0	0	0	0	0	1.5	2.3	1.1
MEAN		245	296						1.078							1.7		2.0
$HSD_{0.05}$		156	152						0.012									

Table 4

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

PRELIMINARY TRIAL, CHIP-PROCESSING LINES
MONTCALM RESEARCH CENTER
May 7 to September 25, 2019 (141 days)
DD Base 40°F 3211[8]

		CWT/A		PERCENT OF TOTAL[1]						CHIP	OTF	PERCENT (%) TUBER QUALITY[4]						
LINE	N	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]

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.
[2]CHIP SCORE: SNAC 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 20, 2019; 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.

Plant Date:	5/7/19
Vine Kill:	9/11/19
Days from planting to vine kill:	127

[8]Enviroweather: Entrican Station. Planting to vine kill

Table 5

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

PRELIMINARY TRIAL, TABLESTOCK LINES
MONTCALM RESEARCH CENTER
May 7 to September 16, 2019 (132 days)
DD Base 40°F 3056[6]

		CWT/A		PERCENT OF TOTAL[1]						PERCENT (%) TUBER QUALITY[2]						
LINE	N	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	SCAB[3]	MAT[4]	BRUISE[5]
MSY022-02	2	423	441	96	4	89	7	0	1.079	5	5	5	0.0	1.2	4.0	1.0
White Beauty	2	365	439	83	16	83	0	1	1.077	0	20	0	0.0	2.0	4.0	0.6
MSZ407-7	2	363	438	83	16	83	0	1	1.081	0	5	0	0.0	1.5	4.0	1.5
MSZ169-1	2	338	378	89	9	89	0	1	1.080	0	0	0	0.0	0.8	4.3	2.0
Onaway	**2**	**311**	**346**	**90**	**8**	**90**	**0**	**2**	**1.062**	**0**	**10**	**0**	**0.0**	**2.5**	**1.0**	**1.0**
MSBB375-1	2	307	355	86	13	86	0	1	1.084	0	30	0	0.0	1.8	3.0	0.6
MSAA085-1	2	302	351	86	13	86	0	1	1.080	0	45	0	0.0	1.8	3.0	0.6
MSZ242-07	2	269	315	85	15	85	0	0	1.101	0	0	0	0.0	1.3	3.8	2.5
Harmony	2	257	356	72	24	72	0	4	1.062	0	0	0	0.0	2.2	3.0	0.1
Reba	**2**	**256**	**287**	**89**	**11**	**89**	**0**	**0**	**1.076**	**0**	**0**	**0**	**0.0**	**2.5**	**2.5**	**1.3**
MSX526-1	2	235	291	81	19	81	0	0	1.080	0	10	0	0.0	1.2	2.8	0.4
MSBB364-1	2	235	254	92	5	91	1	3	1.059	0	0	0	0.0	1.3	3.3	0.2
Obama	2	232	325	72	28	72	0	0	1.064	0	35	0	0.0	1.8	1.3	0.9
NY162	2	228	275	83	16	83	0	1	1.083	0	0	0	0.0	2.2	3.0	2.1
Nadine	2	214	367	58	41	58	0	0	1.060	0	0	10	0.0	2.7	1.8	0.6
MSZ615-2	2	210	253	83	17	83	0	0	1.069	0	10	0	0.0	1.2	1.3	1.0
MSZ513-2	2	191	219	87	13	87	0	0	1.067	0	15	0	0.0	1.7	1.8	0.7
Yukon Gold	**2**	**188**	**216**	**87**	**12**	**87**	**0**	**1**	**1.072**	**0**	**10**	**0**	**0.0**	**3.0**	**1.3**	**0.5**
NY149	2	186	278	67	33	67	0	0	1.075	0	75	0	0.0	1.8	3.3	0.4
Fioretta	2	169	336	51	44	51	0	4	1.067	0	25	0	0.0	2.5	3.0	1.5
MSBB719-1	2	167	301	55	45	55	0	0	1.068	0	0	0	0.0	2.2	1.5	1.0
MSDD085-13	2	153	230	67	33	67	0	0	1.085	0	20	0	0.0	1.3	2.3	1.6
MSZ101-6	2	119	224	53	47	53	0	0	1.082	0	0	0	0.0	1.3	4.0	0.9
W8893-1R	2	59	186	32	68	32	0	0	1.059	0	10	0	0.0	1.0	1.0	0.6
MEAN		241	311						1.074					1.8	2.7	1.0
$HSD_{0.05}$		120	152						0.008							

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

Table 5

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

PRELIMINARY TRIAL, TABLESTOCK LINES
MONTCALM RESEARCH CENTER
May 7 to September 16, 2019 (132 days)
DD Base 40°F 3056[6]

		CWT/A		PERCENT OF TOTAL[1]						PERCENT (%) TUBER QUALITY[2]						
LINE	N	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	SCAB[3]	MAT[4]	BRUISE[5]

[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 20, 2019; 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]Enviroweather: Entrican Station. Planting to vine kill

Plant Date:	5/7/19
Vine Kill:	9/4/19
Days from planting to vine kill:	120

Table 6

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

PRELIMINARY TRIAL, PIGMENTED LINES
MONTCALM RESEARCH CENTER
May 7 to September 16, 2019 (132 days)
DD Base 40°F 3056[6]

		CWT/A		PERCENT OF TOTAL[1]						PERCENT (%) TUBER QUALITY[2]						
LINE	N	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	SCAB[3]	MAT[4]	Bruise[5]
MSBB213-1Spl	2	389	440	88	12	88	0	0	1.077	0	30	0	0	1.3	3.5	1.0
MSBB305-2SPL	2	362	429	84	16	84	0	0	1.062	0	10	0	0	1.5	3.0	0.5
MSZ443-01PP	2	319	409	78	22	78	0	0	1.065	0	0	0	0	1.5	2.3	0.3
MSBB308-2PP	2	251	305	82	18	82	0	0	1.061	0	5	0	0	1.2	1.5	0.2
MSCC553-1R	2	243	277	88	11	88	0	1	1.076	5	5	0	0	2.0	3.3	0.6
MSAA161-04RY	2	242	307	78	20	78	0	2	1.079	0	0	0	0	1.3	3.5	0.6
MSZ107-06PP	2	234	413	57	42	57	0	1	1.076	0	0	0	5	2.3	3.0	0.5
Dark Red Norland	2	222	314	71	29	71	0	0	1.058	0	0	0	0	1.2	1.0	0.2
MSBB371-1SPL	2	218	309	70	30	70	0	0	1.071	0	0	0	0	1.8	1.8	0.6
MSAA127-1PP	2	212	273	78	22	78	0	0	1.054	0	0	0	0	2.5	1.8	1.1
MSAA706-7PP	2	202	243	83	17	83	0	0	1.063	0	0	0	0	1.3	2.5	1.1
NDAF113484B-1	2	182	249	73	27	73	0	0	1.058	0	0	0	0	2.2	1.0	0.4
MSBB262-1YSpl	2	182	300	61	38	61	0	1	1.067	0	0	0	0	2.5	1.3	0.1
MSZ427-03R	2	181	270	67	33	67	0	0	1.049	0	0	0	0	1.3	1.0	0.5
MSAA161-01RY	2	176	294	60	29	60	0	11	1.068	0	0	0	0	0.7	1.8	1.5
MSZ413-6P	2	159	274	58	39	58	0	3	1.070	0	0	0	0	1.8	1.8	0.7
MSAA127-7PP	2	154	257	59	41	59	0	0	1.054	0	0	0	0	1.8	1.8	0.0
MSBB238-01RY	2	148	268	55	44	55	0	0	1.059	0	10	0	0	0.8	1.0	0.5
MSAA101-1RR	2	145	275	53	47	53	0	0	1.078	0	0	0	0	0.8	2.0	0.3
Red Sunset	2	138	276	50	50	50	0	0	1.060	0	0	0	0	2.2	1.0	0.6
MSX443-3P (mini)	2	137	307	45	55	45	0	0	1.081	0	0	0	0	2.0	4.0	0.7
MSZ109-07PP	2	103	214	48	51	48	0	2	1.060	0	0	0	0	1.5	3.3	0.5
MSZ427-01R	2	90	237	38	62	38	0	0	1.062	0	0	0	0	0.7	1.0	0.5
MSZ413-7PP	2	80	169	47	53	47	0	0	1.063	0	0	0	0	1.5	1.5	0.3
MSCC282-01WR	2	72	183	39	61	39	0	0	1.073	0	0	0	0	3.2	2.0	0.7
MSZ107-02PP	2	58	186	31	68	31	0	1	1.075	0	0	0	0	1.8	3.3	0.9
MSBB270-1Spl	2	43	204	21	79	21	0	0	1.070	0	10	0	0	2.0	1.0	0.6
MEAN		183	284						1.066					1.7		0.6

Table 6

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

PRELIMINARY TRIAL, PIGMENTED LINES
MONTCALM RESEARCH CENTER
May 7 to September 16, 2019 (132 days)
DD Base 40°F 3056[6]

		CWT/A		PERCENT OF TOTAL[1]						PERCENT (%) TUBER QUALITY[2]						
LINE	N	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	SCAB[3]	MAT[4]	Bruise[5]
$HSD_{0.05}$		131	146						0.014							

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.
[2]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.
[3]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.
[4]MATURITY RATING: August 20, 2019; 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]Enviroweather: Entrican Station. Planting to vine kill

Plant Date:	5/7/19
Vine Kill:	9/4/19
Days from planting to vine kill:	120

Table 7

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

2017-2019 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	3-YR* AVG.	2019 RATING	2019 WORST	2019 N	2018 RATING	2018 WORST	2018 N	2017 RATING	2017 WORST	2017 N
Sorted by ascending 2019 Average Rating;										
AOR07781-5	-	0.3	0.5	3						
MSZ219-01 PVYR	0.7	0.5	0.5	3	0.5	0.5	3	1.0	1.5	3
Silverton Russet	**0.8***	**0.5**	**0.5**	**3**	**1.2**	**1.5**	**3**			
Goldrush Russet	**0.8**	**0.7**	**1.0**	**3**	**0.3**	**0.5**	**3**	**1.5**	**2.0**	**3**
MSAA161-1PY	1.2*	0.7	1.0	3	1.7	2.0	3			
MSZ052-13	-	0.7	1.0	3						
MSZ219-13 PVYR	0.7	0.7	1.0	3	0.8	1.0	3	0.5	0.5	3
MSZ427-1R	0.9*	0.7	1.5	3	1.2	1.5	3			
MSBB020-8	-	0.8	1.0	2						
MSZ022-07	1.0	0.8	1.0	2	1.2	2.0	3	1.0	2.0	3
MSAA101-1RR	0.7*	0.8	1.5	3	0.5	0.5	3			
MSBB238-01RY	-	0.8	1.0	3						
MSZ169-1	-	0.8	1.5	3						
MSZ219-14 PVYR	0.8	0.8	1.5	3	0.8	1.0	3	0.7	1.0	3
MSZ222-19	0.9	0.8	1.0	3	1.2	1.5	3	0.8	1.0	3
MSAA392-03	-	1.0	1.5	3						
MSBB038-01	-	1.0	1.5	3						
MSBB613-07	-	1.0	1.0	2						
MSZ416-08RY	-	1.0	1.5	3						
W8893-1R	-	1.0	2.0	3						
Blackberry (MSZ109-10PP)	1.3	1.2	1.5	3	1.2	1.5	3	1.7	3.0	3
Dark Red Norland	**1.3**	**1.2**	**2.0**	**6**	**1.3**	**1.5**	**6**	**1.4**	**2.0**	**6**
MSAA036-01	-	1.2	1.5	6						
MSBB018-1	-	1.2	1.5	3						
MSBB308-2P	-	1.2	1.5	3						
MSBB610-24Y	-	1.2	1.5	3						
MSBB635-14	-	1.2	1.5	3						
MSV093-1Y	1.4*	1.2	1.5	3	1.7	2.0	3			
MSV498-1	1.4	1.2	2.0	3	1.8	2.0	3	1.2	1.5	3
MSX194-3	1.2*	1.2	1.5	3	1.2	1.5	3			
MSX324-2R	1.6*	1.2	2.0	3	2.0	2.0	3			
MSX526-1	-	1.2	1.5	3						
MSY022-02	-	1.2	1.5	3						
MSZ242-13	1.3	1.2	1.5	3	1.3	1.5	3	1.5	2.0	3
MSZ615-2	1.3	1.2	1.5	3	1.7	2.0	3	1.2	1.5	3
MSZ709-14	-	1.2	2.0	3						
Payette Russet	-	1.2	1.5	3						
MSBB213-1Spl	-	1.3	1.5	2						
MSX225-2	1.3	1.3	1.5	2	1.5	2.0	3	1.2	1.5	3
MSX472-2	1.3*	1.3	1.5	2	1.3	2.0	3			
MSZ101-6	-	1.3	1.5	2						
MSAA061-7	1.3*	1.3	1.5	3	1.2	1.5	3			
MSAA161-4RY	1.1*	1.3	1.5	3	0.8	1.0	3			
MSAA706-7PP	1.6*	1.3	1.5	3	1.8	3.0	3			
MSBB079-2	-	1.3	1.5	3						
MSBB364-1	-	1.3	1.5	3						
MSDD085-13	-	1.3	2.0	3						
MSV030-4	-	1.3	2.0	3						
MSV443-1PP	1.4*	1.3	1.5	3	1.5	2.0	3			
MSW119-2	1.3*	1.3	1.5	3	1.3	1.5	3			

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Table 7

2017-2019 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	3-YR* AVG.	2019 RATING	2019 WORST	2019 N	2018 RATING	2018 WORST	2018 N	2017 RATING	2017 WORST	2017 N
MSX324-1P	1.0	1.3	1.5	3	0.8	1.0	3	0.8	1.5	6
MSZ052-14	1.4*	1.3	1.5	3	1.5	2.0	3			
MSZ101-7	-	1.3	1.5	1						
MSZ107-01PP	1.1	1.3	1.5	3	1.0	1.0	3	1.0	1.5	3
MSZ242-07	1.4	1.3	1.5	3	1.5	2.0	3	**1.3**	2.0	3
MSZ407-7Y	-	1.3	1.0	3						
MSZ427-3R	1.7*	1.3	2.0	3	2.0	2.5	3			
MSZ590-1	1.2	1.3	1.5	3	1.0	1.0	3	1.3	1.5	3
Vanguard (TX08352-5Rus)	1.5	1.3	1.5	3	1.8	2.5	3	1.3	1.5	3
Castle Russet	-	1.5	2.0	3						
Lamoka	**1.7**	**1.5**	**2.0**	**3**	**2.0**	**2.5**	**3**	**1.7**	**2.0**	**3**
Mackinaw (MSX540-4)$^{PVYR, LBR}$	1.8	1.5	2.0	3	1.8	2.0	3	2.2	2.5	3
MSAA174-1	1.5*	1.5	1.5	3	1.5	2.0	3			
MSAA228-1Y	1.8*	1.5	2.0	3	2.0	2.5	3			
MSBB058-04	-	1.5	1.5	3						
MSBB165-1	-	1.5	2.0	3						
MSBB210-A	-	1.5	1.5	3						
MSBB305-2SPL	-	1.5	1.5	2						
MSBB634-8	-	1.5	2.0	3						
MSV179-1	1.6	1.5	2.0	2	1.5	1.5	1	1.8	2.0	3
MSW044-1	1.6*	1.5	1.5	3	1.7	2.0	3			
MSX398-2	1.7*	1.5	2.5	3	1.8	2.0	3			
MSZ109-07PP	1.7*	1.5	2.0	3	1.8	2.0	3			
MSZ200-6	1.6*	1.5	2.0	3	1.7	2.0	3			
MSZ242-09	1.3	1.5	1.5	2	0.7	1.0	3	1.7	2.0	3
MSZ413-07PP	-	1.5	1.5	3						
MSZ443-1PP	1.5	1.5	2.0	3	2.2	2.5	3	0.8	1.5	3
MSZ598-2	1.5*	1.5	2.0	3	1.5	2.0	3			
Pike	**1.3**	**1.5**	**2.0**	**3**	**1.8**	**2.0**	**6**	**0.7**	**1.0**	**3**
MSAA072-05	-	1.7	2.0	3						
MSAA182-3R	1.6*	1.7	2.0	3	1.5	2.0	3			
MSAA578-7	-	1.7	2.5	3						
MSBB230-02	-	1.7	2.0	3						
MSBB343-2Y	-	1.7	2.0	3						
MSBB621-03	-	1.7	2.0	3						
MST252-1Y	1.6*	1.7	2.0	3	1.5	1.5	3			
MSZ120-4	1.7*	1.7	2.0	3	1.7	2.0	3			
MSZ513-2	1.5	1.7	2.0	3	1.3	2.0	3	1.5	1.5	3
Reveille Russet (ATX91137-1Rus)	1.8	1.7	2.5	3	2.0	2.5	3	1.7	2.5	3
Superior	-	1.7	2.0	3						
MSZ107-02PP	-	1.8	2.0	2						
Lady Liberty (NY152)	2*	1.8	2.0	3	2.2	2.5	3			
MSAA076-6	1.6*	1.8	2.5	3	1.3	1.5	3			
MSAA085-1Y	1.8*	1.8	2.0	3	1.8	2.0	3			
MSAA127-7PP	2*	1.8	2.0	3	2.2	2.5	3			
MSAA342-02	-	1.8	2.5	3						
MSAA498-07	-	1.8	2.5	3						
MSBB270-1SplY	-	1.8	2.5	3						
MSBB371-1SPL	-	1.8	2.0	3						
MSBB375-1	-	1.8	2.0	3						
MSZ020-10	-	1.8	2.0	3						

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Table 7

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

2017-2019 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	3-YR* AVG.	2019 RATING	2019 WORST	2019 N	2018 RATING	2018 WORST	2018 N	2017 RATING	2017 WORST	2017 N
MSZ413-6P	1.6*	1.8	2.0	3	1.3	2.0	3			
MSZ436-2SPL	1.8*	1.8	2.0	3	1.8	2.0	3			
MSZ551-01	-	1.8	2.0	3						
NY149	1.8	1.8	2.5	3	1.8	2.0	3	1.8	2.0	3
Obama	-	1.8	2.5	3						
Queen Anne	1.5	1.8	2.0	3	1.7	2.0	3	1.0	1.5	3
Huron Chipper (MSW485-2)	1.8	2.0	2.5	3	1.7	2.0	3	1.8	2.5	3
MSBB190-01	-	2.0	2.0	3						
MSBB190-03	-	2.0	2.5	3						
MSCC553-1R	-	2.0	2.5	3						
MSX193-1Y	-	2.0	2.5	2						
MSX245-2Y	1.8	2.0	2.0	3	2.0	2.0	3	1.5	1.5	3
MSX443-3P	2.3*	2.0	2.5	3	2.5	4.0	3			
MSY733-1	-	2.0	2.5	3						
MSZ200-3	-	2.0	2.5	2						
White Beauty	-	2.0	2.5	3						
Harmony	-	2.2	2.5	3						
MSAA056-03Y	-	2.2	2.5	3						
MSAA392-05Y	-	2.2	2.5	3						
MSBB075-1Y	-	2.2	2.5	3						
MSBB107-1	-	2.2	2.5	3						
MSBB719-1	-	2.2	2.5	3						
MSX497-6[LBR]	2.6	2.2	3.0	3	3.0	3.5	3	2.5	3.0	3
MSZ578-1Y	-	2.2	2.5	3						
NDAF113484B-1	-	2.2	2.5	3						
NY162	-	2.2	2.5	3						
Red Sunset	-	2.2	2.5	3						
Russet Norkotah	**2.3**	**2.2**	**3.0**	**3**	**2.8**	**4.0**	**3**	**1.9**	**2.5**	**6**
MSZ107-6PP	2.3	2.3	2.5	2	2.0	2.5	3	2.7	3.0	3
BNC182-5	2.5*	2.3	2.5	3	2.7	3.0	3			
Isle Royale (MSX569-1R)	1.7	2.3	3.5	3	1.3	2.0	3	1.5	2.5	6
MSAA196-6	2.2*	2.3	2.5	3	2.0	2.5	3			
MSBB232-3	-	2.3	2.5	3						
MSL211-3	2.2*	2.3	2.5	3	2.0	2.0	3			
Mystery Splash	1.6*	2.3	3.0	3	0.8	1.5	3			
Atlantic	**2.7**	**2.5**	**2.5**	**3**	**3.0**	**3.5**	**3**	**2.5**	**3.0**	**4**
Fioretta	-	2.5	3.0	3						
MSAA127-1PP	2.4*	2.5	3.0	3	2.3	3.0	3			
MSAA183-2PY	2.1*	2.5	3.0	3	1.7	2.0	3			
MSAA240-05	-	2.5	3.0	3						
MSBB262-1YSpl	-	2.5	3.0	3						
MSZ552-2P	-	2.5	2.5	2						
Onaway	**2.3**	**2.5**	**2.5**	**2**	**2.5**	**3.0**	**3**	**2.0**	**2.0**	**3**
Reba	**2.4**	**2.5**	**2.5**	**2**	**2.5**	**2.5**	**3**	**2.2**	**3.0**	**6**
AO02183-2	-	2.7	3.0	3						
MSAA218-03	-	2.7	3.0	3						
MSBB281-1PY	-	2.7	3.0	3						
MSX156-1Y	2.4*	2.7	3.0	3	2.1	2.5	5			
Nadine	-	2.7	3.0	3						
A07061-6RUS	2.6	2.8	3.0	2	2.5	3.0	3	2.7	3.0	3
Snowden	**2.8**	2.8	3.5	6	**3.0**	**3.5**	**3**	**2.5**	**3.0**	**6**

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Table 7

MICHIGAN STATE UNIVERSITY

POTATO BREEDING and GENETICS

2017-2019 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	3-YR* AVG.	2019 RATING	2019 WORST	2019 N	2018 RATING	2018 WORST	2018 N	2017 RATING	2017 WORST	2017 N
MSBB032-1	-	2.8	3.5	3						
Manistee	2.5	3.0	3.5	3	2.2	2.5	3	2.3	2.5	3
MSZ705-03	-	3.0	3.5	3						
Yukon Gold	2.6	**3.0**	**3.5**	**6**	**2.6**	**3.5**	**6**	**2.2**	**2.5**	**6**
A071012-4BFRUS	3*	3.2	3.5	3	2.8	3.0	3			
MSCC282-01WR	-	3.2	4.0	3						
MSY719-01	-	3.2	3.5	3						
B2869-29	3.3*	3.3	3.5	3	3.3	4.0	3			
MSAA157-2PY	2.8*	3.3	3.5	3	2.3	2.5	3			
$HSD_{0.05}$ =		**1.7**			**2.8**			**2.2**		

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.

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2019 SCAB DISEASE EARLY GENERATION TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER, MI

LINE	2019 RATING	2019 N	LINE	2019 RATING	2019 N
Sorted by ascending 2019 Rating:			*HSD $_{0.05}$ =*	1.7	
MSDD039-01	*0.0*	*1*	MSEE158-01	*1.0*	*1*
MSBB613-04	*0.5*	*1*	MSEE182-03	*1.0*	*1*
MSCC374-1Y	*0.5*	*1*	MSEE207-02	*1.0*	*1*
MSDD138-02	*0.5*	*1*	MSBB078-1	*1.5*	*1*
MSDD457-01	*0.5*	*1*	MSBB213-1Spl	*1.5*	*1*
MSEE063-06	*0.5*	*1*	MSBB351-1	*1.5*	*1*
MSEE107-01	*0.5*	*1*	MSBB614-10	*1.5*	*1*
MSEE141-01	*0.5*	*1*	MSBB623-12	*1.5*	*1*
MSEE159-01	*0.5*	*1*	MSCC168-1	*1.5*	*1*
MSEE164-01	*0.5*	*1*	MSCC266-1	*1.5*	*1*
MSBB024-1	*1.0*	*1*	MSDD040-01	*1.5*	*1*
MSBB038-03	*1.0*	*1*	MSDD146-01	*1.5*	*1*
MSCC009-01	*1.0*	*1*	MSDD372-07	*1.5*	*1*
MSCC376-1	*1.0*	*1*	MSDD372-15	*1.5*	*1*
MSDD034-01	*1.0*	*1*	MSDD505-01	*1.5*	*1*
MSDD074-02RR	*1.0*	*1*	MSDD516-01	*1.5*	*1*
MSDD114-03	*1.0*	*1*	MSDD565-01	*1.5*	*1*
MSDD244-15	*1.0*	*1*	MSEE010-03	*1.5*	*1*
MSDD247-07	*1.0*	*1*	MSEE022-12	*1.5*	*1*
MSDD247-11	*1.0*	*1*	MSEE031-03	*1.5*	*1*
MSDD254-01	*1.0*	*1*	MSEE033-02	*1.5*	*1*
MSDD267-03	*1.0*	*1*	MSEE063-10	*1.5*	*1*
MSDD271-10	*1.0*	*1*	MSEE101-02	*1.5*	*1*
MSDD403-01	*1.0*	*1*	MSEE105-01	*1.5*	*1*
MSDD491-01	*1.0*	*1*	MSEE127-01	*1.5*	*1*
MSDD543-01	*1.0*	*1*	MSEE127-02	*1.5*	*1*
MSEE017-04	*1.0*	*1*	MSEE130-02	*1.5*	*1*
MSEE025-01	*1.0*	*1*	MSEE137-02	*1.5*	*1*
MSEE085-01	*1.0*	*1*	MSEE151-04	*1.5*	*1*
MSEE090-01	*1.0*	*1*	MSEE155-01	*1.5*	*1*
MSEE094-01	*1.0*	*1*	MSEE157-01	*1.5*	*1*
MSEE101-01	*1.0*	*1*	MSEE163-01	*1.5*	*1*
MSEE113-01	*1.0*	*1*	MSEE169-01	*1.5*	*1*
MSEE113-02	*1.0*	*1*	MSEE171-02	*1.5*	*1*
MSEE116-01	*1.0*	*1*	MSEE175-01	*1.5*	*1*
MSEE130-01	*1.0*	*1*	MSEE180-2P	*1.5*	*1*
MSEE137-01	*1.0*	*1*	MSEE185-04	*1.5*	*1*
MSEE137-03	*1.0*	*1*	MSEE247-06WP	*1.5*	*1*
MSEE138-02	*1.0*	*1*	MSEE312-01	*1.5*	*1*
MSEE141-03	*1.0*	*1*	MSEE313-01	*1.5*	*1*
MSEE149-01	*1.0*	*1*	MSBB222-01	*2.0*	*1*
MSEE151-02	*1.0*	*1*	MSBB238-01RY	*2.0*	*1*
MSEE152-01	*1.0*	*1*	MSBB618-09	*2.0*	*1*

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2019 SCAB DISEASE EARLY GENERATION TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER, MI

LINE	2019 RATING	2019 N	LINE	2019 RATING	2019 N
Sorted by ascending 2019 Rating:			*HSD $_{0.05}$ =*	1.7	
MSCC302-1	*2.0*	*1*	MSEE247-2WR	*2.0*	*1*
MSCC314-1	*2.0*	*1*	MSEE308-01	*2.0*	*1*
MSCC515-2Y	*2.0*	*1*	MSEE314-01	*2.0*	*1*
MSCC570-1	*2.0*	*1*	MSCC081-01	*2.5*	*1*
MSDD088-01	*2.0*	*1*	MSCC300-1	*2.5*	*1*
MSDD089-01	*2.0*	*1*	MSCC614-1RYSPL	*2.5*	*1*
MSDD107-01Y	*2.0*	*1*	MSDD005-01	*2.5*	*1*
MSDD114-06	*2.0*	*1*	MSDD039-02	*2.5*	*1*
MSDD219-02	*2.0*	*1*	MSDD251-01Y	*2.5*	*1*
MSDD483-1	*2.0*	*1*	MSDD370-02	*2.5*	*1*
MSDD553-01	*2.0*	*1*	MSDD495-01	*2.5*	*1*
MSDD847-1	*2.0*	*1*	MSEE018-02	*2.5*	*1*
MSEE031-01	*2.0*	*1*	MSEE022-08	*2.5*	*1*
MSEE038-01	*2.0*	*1*	MSEE076-01	*2.5*	*1*
MSEE052-05	*2.0*	*1*	MSEE092-02	*2.5*	*1*
MSEE079-01	*2.0*	*1*	MSEE102-01	*2.5*	*1*
MSEE088-01	*2.0*	*1*	MSEE142-01	*2.5*	*1*
MSEE092-01	*2.0*	*1*	MSEE149-02	*2.5*	*1*
MSEE096-01	*2.0*	*1*	MSEE153-02	*2.5*	*1*
MSEE099-01	*2.0*	*1*	MSEE154-01	*2.5*	*1*
MSEE103-02	*2.0*	*1*	MSEE162-01	*2.5*	*1*
MSEE115-01	*2.0*	*1*	MSEE171-01	*2.5*	*1*
MSEE123-01	*2.0*	*1*	MSEE174-01	*2.5*	*1*
MSEE131-01	*2.0*	*1*	MSEE190-01	*2.5*	*1*
MSEE134-01	*2.0*	*1*	MSEE206-04	*2.5*	*1*
MSEE135-01	*2.0*	*1*	MSEE222-01R	*2.5*	*1*
MSEE138-01	*2.0*	*1*	MSEE246-01WP	*2.5*	*1*
MSEE142-02	*2.0*	*1*	MSEE319-03	*2.5*	*1*
MSEE151-01	*2.0*	*1*	MSCC282-02PP	*3.0*	*1*
MSEE151-03	*2.0*	*1*	MSDD045-01	*3.0*	*1*
MSEE158-02	*2.0*	*1*	MSDD350-01	*3.0*	*1*
MSEE158-03	*2.0*	*1*	MSEE120-01	*3.0*	*1*
MSEE163-02	*2.0*	*1*	MSEE173-01	*3.0*	*1*
MSEE163-03	*2.0*	*1*	MSEE202-04	*3.0*	*1*
MSEE168-01Y	*2.0*	*1*	MSEE213-01	*3.0*	*1*
MSEE180-3P	*2.0*	*1*	MSEE216-01	*3.0*	*1*
MSEE183-02	*2.0*	*1*	MSEE217-01Y	*3.0*	*1*
MSEE185-03	*2.0*	*1*	MSEE240-01Y	*3.0*	*1*
MSEE185-05	*2.0*	*1*	MSCC720-1WR	*3.5*	*1*
MSEE187-01	*2.0*	*1*	MSDD244-05	*3.5*	*1*
MSEE216-02	*2.0*	*1*	MSDD251-02Y	*3.5*	*1*
MSEE224-01	*2.0*	*1*	MSDD311-01	*3.5*	*1*
MSEE241-01P	*2.0*	*1*	MSEE307-1Y	*3.5*	*1*

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Table 9

2019 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
RUSSET TRIAL									
Russet Norkotah / Texas 112	**1.070**	**11**	**8**	**6**	0	0	0	**44**	**0.8**
ATX91137-1Rus (Reveille Russet)	1.075	8	12	4	1	0	0	32	0.9
Goldrush Russet	**1.068**	**7**	**13**	**5**	0	0	0	**28**	**0.9**
POR06V12-3 (Castle Russet)	1.088	11	9	4	1	1	0	42	0.9
AOR07781-5	1.083	5	11	8	1	0	0	20	1.2
Silverton Russet	**1.076**	**4**	**8**	**5**	**2**	0	0	**21**	**1.3**
TX08352-5Rus (Vanguard)	1.066	3	8	10	4	0	0	12	1.6
A07061-6RUS	1.075	0	11	12	2	0	0	0	1.6
AO02183-2	1.090	4	8	3	5	2	2	17	2.0
A071012-4BFRUS	1.097	0	7	8	9	2	0	0	2.2
Payette Russet	1.091	2	3	8	6	1	2	9	2.3
ADAPTATION TRIAL, CHIP-PROCESSING LINES									
Manistee	1.078	14	9	2	0	0	0	56	0.5
MSZ219-01	1.085	6	13	3	2	1	0	24	1.2
Niagara (NY152)	1.082	8	9	6	0	2	0	32	1.2
MSZ120-4	1.088	8	7	7	3	0	0	32	1.2
MSZ022-07	1.081	10	4	8	2	0	1	40	1.2
MSZ200-3	1.076	7	9	5	3	0	1	28	1.3
FL2137	1.090	7	6	5	5	0	1	29	1.5
Huron Chipper (MSW485-2)	1.087	2	10	9	4	0	0	8	1.6
MSAA578-7	1.085	7	6	6	3	2	1	28	1.6
MSV030-4	1.090	7	5	7	4	0	2	28	1.6
MSW044-1	1.089	3	9	8	3	2	0	12	1.7
Lamoka	**1.084**	**3**	**4**	**8**	**4**	0	0	**16**	**1.7**
MSZ242-09	1.100	0	11	7	0	1	1	0	1.7
MSZ219-14	1.080	6	4	9	4	3	0	23	1.8
B2869-29 (2 reps)	1.085	1	0	3	1	0	0	20	1.8
MSX225-2	1.082	3	5	9	7	0	1	12	2.0
Atlantic	**1.089**	**2**	**7**	**8**	**4**	**2**	**1**	**8**	**2.0**
MSV498-1	1.082	1	6	11	6	1	0	4	2.0
MSZ200-6	1.081	1	6	3	5	3	0	6	2.2
MSZ052-14	1.083	3	4	8	6	4	1	12	2.3
MSZ222-19	1.093	1	5	7	7	2	2	4	2.4
MSZ101-7	1.087	4	3	7	4	2	5	16	2.5
Snowden	**1.081**	**0**	**3**	**10**	**8**	**2**	**2**	**0**	**2.6**
MSZ052-13	1.087	2	3	3	9	3	5	8	2.9
Mackinaw (MSX540-4)	1.096	1	1	6	6	6	5	4	3.2
MSZ242-13	1.105	0	1	3	3	4	2	0	3.2
MSZ219-13	1.087	0	1	2	4	8	10	0	4.0
MSAA076-6	1.095	0	2	0	5	7	11	0	4.0
MSZ020-10	1.094	0	1	1	1	2	20	0	4.6
ADAPTATION TRIAL, TABLESTOCK LINES									
Isle Royale (MSX569-1R)	1.048	20	5	0	0	0	0	80	0.2
MSV093-1Y	1.074	19	5	0	0	0	0	79	0.2
MSV443-1PP	1.063	16	9	0	0	0	0	64	0.4
Blackberry (MSZ109-10PP)	1.066	14	10	0	0	0	0	58	0.4

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SIMULATED BRUISE SAMPLES*

ENTRY	SP GR	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
MSAA182-3R	1.078	16	7	2	0	0	0	64	0.4
Yukon Gold	**1.076**	**15**	**8**	**2**	**0**	**0**	**0**	**60**	**0.5**
MSZ598-2	1.068	11	13	0	1	0	0	44	0.6
Dark Red Norland	**1.060**	**17**	**9**	**3**	**2**	0	0	**55**	**0.7**
MSX324-01P	1.082	10	9	3	0	0	0	45	0.7
MSX398-2	1.084	3	3	1	0	0	0	43	0.7
MSV179-1	1.071	10	12	3	0	0	0	40	0.7
MSX324-02R	1.069	12	9	3	1	0	0	48	0.7
Queen Anne	1.060	10	12	2	1	0	0	40	0.8
Superior	**1.069**	**13**	**6**	**5**	**1**	**0**	**0**	**52**	**0.8**
Pike (Chip)	**1.085**	**12**	**7**	**5**	**1**	**0**	**0**	**48**	**0.8**
MSAA157-2PY	1.071	7	7	4	0	0	0	39	0.8
MSZ416-08RY	1.065	9	11	5	0	0	0	36	0.8
MST252-1Y	1.067	8	9	5	4	0	0	31	1.2
MSAA174-1	1.062	10	4	9	1	2	0	38	1.3
MSX497-6	1.067	8	6	6	4	1	0	32	1.4
MSAA196-06	1.068	7	7	7	3	0	1	28	1.4
MSX194-3 (Chip)	1.077	0	3	4	0	0	0	0	1.6
MSZ551-01	1.080	4	7	8	2	3	0	17	1.7
MSX156-1Y	1.070	1	7	11	6	0	0	4	1.9
MSX245-2Y (Chip)	1.084	3	1	8	8	4	1	12	2.5
PRELIMINARY TRIAL, CHIP-PROCESSING LINES									
MSBB107-1	1.076	18	6	1	0	0	0	72	0.3
MSBB165-1	1.075	13	8	3	1	0	0	52	0.7
MSBB038-01	1.071	10	11	3	1	0	0	40	0.8
MSBB032-1	1.082	8	11	3	2	0	0	33	1.0
MSBB613-07	1.079	8	12	3	2	0	0	32	1.0
MSAA061-7	1.084	8	8	6	2	0	0	33	1.1
MSAA056-03Y	1.070	8	8	4	4	1	0	32	1.3
MSBB058-04	1.085	3	5	4	2	1	0	20	1.5
MSBB079-2	1.081	5	7	7	5	1	0	20	1.6
MSAA228-1Y	1.080	4	7	6	6	1	1	16	1.8
MSAA342-02	1.072	5	5	6	6	2	1	20	1.9
MSBB018-1	1.078	4	9	5	2	3	4	15	2.1
MSAA218-03	1.079	2	5	8	8	1	1	8	2.2
MSBB230-02	1.077	3	6	3	7	3	2	13	2.3
MSAA036-01	1.080	2	6	6	5	5	1	8	2.3
MSAA498-07	1.081	2	4	9	5	4	1	8	2.3
MSBB210-A	1.076	1	7	5	8	3	1	4	2.3
MSAA072-05	1.084	1	6	5	9	2	2	4	2.4
MSBB610-24Y	1.087	2	4	5	3	4	2	10	2.5
MSBB075-1Y	1.079	1	3	6	10	5	0	4	2.6
MSBB634-8	1.079	4	3	3	4	2	9	16	3.0
MSBB621-03	1.076	1	1	4	6	5	9	4	3.5
MSBB190-03	1.087	0	2	4	5	3	10	0	3.6
MSAA240-05	1.086	1	3	0	4	4	13	4	3.8
PRELIMINARY TRIAL, TABLESTOCK LINES									
Harmony	1.062	22	3	0	0	0	0	88	0.1
MSBB364-1	1.059	21	4	0	0	0	0	84	0.2
NY149	1.075	16	8	1	0	0	0	64	0.4
MSZ590-1	1.060	9	1	2	0	0	0	75	0.4
MSX526-1	1.080	14	11	0	0	0	0	56	0.4

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SIMULATED BRUISE SAMPLES*

ENTRY	SP GR	0	NUMBER OF SPOTS PER TUBER 1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
Yukon Gold	**1.072**	**16**	**7**	**3**	**0**	**0**	**0**	**62**	**0.5**
Nadine	1.060	15	6	4	0	0	0	60	0.6
White Beauty	1.077	15	7	2	1	0	0	60	0.6
W8893-1R	1.059	12	11	2	0	0	0	48	0.6
MSAA085-1	1.080	11	12	2	0	0	0	44	0.6
MSBB375-1	1.084	13	9	2	1	0	0	52	0.6
MSZ513-2	1.067	14	7	1	1	1	0	58	0.7
Obama	1.064	8	10	4	1	0	0	35	0.9
MSZ101-6	1.082	10	10	3	1	1	0	40	0.9
MSBB719-1	1.068	7	11	6	0	0	0	29	1.0
MSZ615-2	1.069	9	10	3	3	0	0	36	1.0
Onaway	**1.062**	**7**	**13**	**4**	**0**	**1**	**0**	**28**	**1.0**
MSY022-02	1.079	8	9	7	1	0	0	32	1.0
Reba	1.076	6	9	4	5	0	0	25	1.3
Fioretta	1.067	7	5	8	4	0	1	28	1.5
MSZ407-7	1.081	7	4	9	2	1	1	29	1.5
MSDD085-13	1.085	4	8	7	3	2	0	17	1.6
MSZ169-1	1.080	2	7	10	2	2	2	8	2.0
NY162	1.083	2	8	5	7	1	2	8	2.1
MSZ242-07	1.101	0	4	7	8	1	2	0	2.5
PRELIMINARY TRIAL, PIGMENTED LINES									
MSAA127-7PP	1.054	25	0	0	0	0	0	100	0.0
MSBB262-1YSpl	1.067	21	3	0	0	0	0	88	0.1
Dark Red Norland	**1.058**	**21**	**4**	**0**	**0**	**0**	**0**	**84**	**0.2**
MSBB308-2PP	1.061	19	6	0	0	0	0	76	0.2
MSAA101-1RR	1.078	18	7	0	0	0	0	72	0.3
MSZ413-07PP	1.063	19	5	1	0	0	0	76	0.3
MSZ443-01PP	1.065	14	4	1	0	0	0	74	0.3
NDAF113484B-1	1.058	16	4	2	0	0	0	73	0.4
MSBB305-2SPL	1.062	8	4	1	0	0	0	62	0.5
MSZ107-06PP	1.076	11	7	1	0	0	0	58	0.5
MSZ109-07PP	1.060	9	9	0	0	0	0	50	0.5
MSZ427-03R	1.049	6	6	0	0	0	0	50	0.5
MSZ427-01R	1.062	15	7	3	0	0	0	60	0.5
MSBB238-01RY	1.059	13	8	2	0	0	0	57	0.5
MSCC553-1R	1.076	14	8	3	0	0	0	56	0.6
Red Sunset	1.060	12	12	1	0	0	0	48	0.6
MSAA161-04RY	1.079	13	9	3	0	0	0	52	0.6
MSBB371-1SPL	1.071	11	13	1	0	0	0	44	0.6
MSBB270-1Spl	1.070	10	14	1	0	0	0	40	0.6
MSCC282-01WR	1.073	10	12	2	0	0	0	42	0.7
MSZ413-6P	1.070	10	13	2	0	0	0	40	0.7
MSX443-3P (mini)	1.081	4	9	0	0	0	0	31	0.7
MSZ107-02PP	1.075	5	4	4	0	0	0	38	0.9
MSBB213-1Spl	1.077	9	7	6	2	0	0	38	1.0
MSAA127-1PP	1.054	2	7	3	0	0	0	17	1.1
MSAA706-7PP	1.063	5	6	7	0	0	0	28	1.1
MSAA161-01RY	1.068	1	7	3	2	0	0	8	1.5
USPB/SFA TRIAL CHECK SAMPLES (Not bruised)									
ND7519-1	1.086	19	6	0	0	0	0	76	0.2
AOR09034-3	1.086	19	4	1	0	0	0	79	0.3

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SIMULATED BRUISE SAMPLES*

ENTRY	SP GR	0	NUMBER OF SPOTS PER TUBER 1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
Mackinaw	1.090	15	6	3	1	0	0	60	0.6
MSW075-2	1.082	14	8	2	1	0	0	56	0.6
MSV030-4	1.092	14	8	2	0	1	0	56	0.6
Lamoka	**1.088**	**11**	**10**	**4**	**0**	**0**	**0**	**44**	**0.7**
MSZ219-14	1.084	14	5	5	1	0	0	56	0.7
Snowden	**1.086**	**10**	**10**	**5**	**0**	**0**	**0**	**40**	**0.8**
USPB/SFA TRIAL BRUISE SAMPLES									
ND7519-1	1.086	12	7	4	1	1	0	48	0.9
AOR09034-3	1.086	6	12	5	2	0	0	24	1.1
MSW075-2	1.082	4	10	7	3	1	0	16	1.5
MSV030-4	1.092	7	3	5	6	3	1	28	1.9
MSZ219-14	1.084	5	4	7	4	5	0	20	2.0
Lamoka	**1.088**	**5**	**4**	**7**	**3**	**6**	**0**	**20**	**2.0**
Snowden	**1.086**	**1**	**2**	**3**	**13**	**3**	**2**	**4**	**2.9**
Mackinaw	1.090	1	2	4	11	6	1	4	2.9

* Thirteen to twenty-five (dependent on the number of replications used) 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 12/3/2019.
The table is presented in ascending order of average number of spots per tuber.

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2019 On-Farm Potato Variety Trials

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Cooperators: James DeDecker, (Presque Isle Co.), Monica Jean (Delta Co.)

INTRODUCTION

Our main objectives for on-farm potato variety trials are to: 1) identify promising lines for further testing and evaluation, 2) conduct larger scale commercial agronomic and processing trials through multi-acre block plantings, and 3) use trial data to encourage the commercialization of new varieties in the state of Michigan. We share our results with growers, breeders, and processors across the country to aid in the development of new varieties. In 2019, we conducted 40 on-farm potato variety trials with 16 growers in 13 counties.

Processing trial cooperators were: 4-L Farms, Inc. (Allegan), Black Gold Farms (Branch), County Line Farms (Allegan), Hampton Potato Growers (Bay), Lennard Ag. Co. (Cass, St. Joseph), Main Farms (Montcalm), Sandyland Farms (Montcalm), Verbrigghme Farms (Delta), and Walther Farms, Inc. (St. Joseph). We also conducted processing trials at the Michigan State University (MSU) Montcalm Research Center (Montcalm). The Potatoes USA/Snacking Nutrition and Convenience International (SNAC Int.) chip trial was conducted at Sandyland Farms (Montcalm).

Fresh market trial cooperators were: 4-L Farms (Allegan), Crawford Farms, Inc. (Montcalm), Elmaple Farm LLC (Kalkaska), Hampton Potato Growers (Bay), Horkey Bros. (Monroe), Jenkins Farms (Kalkaska), Kitchen Farms, Inc. (Antrim), Lennard Ag. Co. (St. Clair), Styma Potato Farms (Presque Isle), Verbrigghe Farms (Delta), Walther Farms, Inc. (St. Joseph, Tuscola), and Wilk Farms (Presque Isle).

PROCEDURE

A. Processing Variety Trials

We evaluated 50 chip processing varieties in 2019. To evaluate selected processing lines, we used the following check varieties: Altantic, Lamoka, Pike, and Snowden. For all trials, we used 10” in-row seed spacing and 34” rows.

The majority of our processing trials were strip trials. These trials consisted of a single 75-100’ strip for each variety of which we harvested and graded a single 23-ft section. For each variety in the Walther Farms, Inc. trials, we planted three, 15-ft long rows and harvested the center row. We also conducted multi-acre block plantings of promising, non-commercialized trials at Sackett Potatoes, Sandyland Farms, and Walther Farms. Agronomic production practices for these block plantings varied based on each grower’s production system.

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B. Processing Variety Trials

We conducted the Potatoes USA/SNAC Int. Trial for Michigan at Sandyland Farms, LCC (Montcalm County). We planted 12 varieties in 300’ strips and harvested three, 23-ft sections of row for each variety. Our check varieties were ‘Lamoka’ and ‘Snowden’. For more details on this trial, please reference the 2019 annual report published by Potatoes USA.

C. Fresh Market Trials

Within the fresh market trials, we evaluated 74 primary entries (this does not include entries from Potatoes USA/NFPT trial) which included: 21 russet, 15 red, 19 yellow, 9 novelty, and 19 round white types. To evaluate selected table-stock lines, we used the following check varieties:
<u>Red</u>: Dark Red Norland
<u>Round White</u>: Onaway, Reba, Superior
<u>Russet</u>: GoldRush, Russet Norkotah, Silverton Russet
<u>Yellow</u>: Yukon Gold
We planted all trials with 34” wide rows and 10” in-row seed spacing.

We evaluated the majority of our fresh market trials as strip trials. These trials consisted of a single 60-100’ for each variety of which we harvested and graded a single 23-ft section. We planted the NFPT trial at Walther Farms, Inc. as single 15’ long strips and harvested the entire strip. 2019 was the first year conducting an early generation tablestock variety trial with red skin white flesh potato varieties. This trail was planted and harvested like the NFPT trial, and also took place at Walther Farms, Inc. For each variety in the Elmaple Farm LCC trial, we planted three, 30-ft long rows and harvested the entire center row. We planted Walther Farms, Inc. trials similarly to the Elmaple trial but with 15-ft rows. We also conducted multi-acre block plantings of promising, non-commercialized trials at Crawford Farms, Lennard Ag. Co., Sackett Potato Growers, Sandyland Farms, Thorlund Farms, Walther Farms, and Yoder Farms. Agronomic production practices for these block plantings varied based on each grower’s production system.

RESULTS

A. Processing Variety Trial Results

We recorded general descriptions, pedigrees, and scab ratings for all varieties tested in 2019 (Table 1) and evaluated these varieties based on yield, specific gravity, internal quality, common scab ratings, and maturity (Table 2). Below are six superior processing varieties from 2019.

> **MSZ096-3**: This Michigan State University selection was evaluated in five locations in 2019 and had the fourth highest overall and US #1 yields of 477 cwt/A US#1 potatoes. It produced mainly A-sized tubers with 83% A size potatoes and 13% B-sized potatoes, approximately average for the trial. It had an attractive, round type, and a full-season maturity. It will be further evaluated across multiple locations in 2019. This variety had an average common scab rating of 0.6, lower than the trial average of 2.0. It had a stem end defect rating of 0.6, lower than the trial average of 1.0. Compared to the trial average of

1.084, MSZ096-3 had a slightly lower specific gravity of 1.080. It requires full season maturity and has smaller vines.

NY165: This Cornell variety was evaluated across the state in ten locations. It had an above average US#1 yield of 448 cwt/A and 82% A-sized tubers. NY165 had excellent internal quality, with only four percent vascular discoloration and one percent internal brown spot observed in 2019. With a stem end defect rating of 0.6 and a fresh chip score of 1.3, it had good off-the-farm chip quality. This variety is in the box bin storage trial at the Montcalm Research Center for the 2019-2020 storage season. Some variability in type was observed at harvest, which will be further evaluated in 2020.

NY166: This variety had thin, bright skin and attractive appearance in 2019. With 78% A-sized tubers, this variety had a slightly smaller size profile than the trial average, but a high yield of 440 cwt/A US#1 tubers. The common scab rating of 1.0 is the trial average. NY166 displayed good fresh chip color and a lower than average incidence of stem end defect. It displayed mid- to full-season maturity in 2019 when evaluated in seven locations. This variety is being evaluated for storage potential at the Montcalm Research Center.

Lady Liberty (NY152): This recently named Cornell variety was evaluated at nine locations in 2019. It had 86% US #1 tubers and a US#1 yield of 485 cwt/A, the third highest in the trial. This variety had an average specific gravity of 1.082 and an off the farm chip score of 1.4. It had an average amount of internal defects. Lady Liberty had almost no stem end defects with a score of 0.2. The tubers were uniformly shaped and round. 2019 was likely the final year of evaluation for this variety, as it has been evaluated since 2014 in on-farm trials and since 2016 in demonstration storage. This variety had demonstrated commercialization potential in Michigan

BNC182-5: This Maryland variety was planted at nine locations, and had an average yield of 421 cwt/A US #1 tubers with 83% A-sized tubers. It had an average specific gravity of 1.083, and an off the farm chip score of 1.6. It had a low incidence of internal defects except for 17% vascular discoloration, approximately the trial average. This variety had average scores for both common scab and stem end defects. BNC182-5 had a moderately vigorous vine and medium maturity. It will be further evaluated in 2020 as a fresh chip variety only, as it has poor chip quality after storage.

NY163: This Cornell variety had an above average yield of 441 cwt/A at nine Michigan locations in 2019. The specific gravity of 1.085 was slightly above average. NY163 displayed excellent internal quality, with all tuber defects below the trial average. With a fresh chip score of 1.1 and stem end defect rating of 0.3, it displayed good fresh chip quality. Some anthocyanin pigmentation in the apical end of the tuber was observed in 2019, but did not affect chip quality. This will be further evaluated during the current storage season and in on-farm trials in 2020.

B. Potatoes USA/SNAC Int. Chip Trial

In 2019, we conducted the Potatoes USA / SNAC Int. Michigan chip trial at Sandyland Farms, LLC in Montcalm County. We compared yield, size distribution, and specific gravity of eight test varieties to Lamoka and Snowden (Table 3). We also evaluated at-harvest raw tuber quality (Table 4) and sent samples to Herr Foods, Inc. (Nottingham, PA) where potatoes were processed and scored for out of the field chip quality (Table 5). We assessed blackspot bruise susceptibility (Table 6) and pre-harvest panels for each variety (Tables 7A and B).

The varieties with the highest US#1 yields were AOR09034-3, Petoskey, and Lamoka, with yields ranging from 461 cwt/A to 440 cwt/A. AOR09034 also had the highest percent of US #1 tubers at 86%, while MSW075-2 had the lowest at 62%. The average specific gravity of the trial was 1.087 (Table 3). Almost no brown spot, hollow heart, and brown center were observed in 2019. However all varieties displayed at least 3% vascular discoloration, with 17% incidence in Lamoka (Table 4). Samples collected on October 16th were processed by Herr's Foods, Inc. on October 22nd. ND7519-1 had the lowest SFA chip color, and was ranked first by Herr's for overall chip quality. MSW075-2 and MSV030-4 were also ranked highly, while MSZ219-14 and AOR09034-3 were ranked last in the trial (Table 5). Black spot bruise assessments demonstrated that ND7519-1, AOR09034-3, and MSW075-2 were most resistant to black spot bruising, while Mackinaw and Snowden were most susceptible (Table 6).

C. Fresh Market and Variety Trial Results

We recorded general descriptions, pedigrees, and scab ratings for all fresh market varieties evaluated in 2019 (Table 8) and assessed these varieties based on yield, specific gravity, internal quality, common scab ratings, and maturity (Tables 9 and 10). The NFPT and Early Generation Tablestock trials screen potato selections under initial evaluation. In 2019, 33 NFPT-designated russet varieties and an additional 28 russet selections were evaluated (Table 11). Continued evaluation of these varieties are determined based on national performance. In total, 128 red skin potato varieties from Michigan, Colorado State University, and North Dakota State University potato breeding programs were grown in Michigan. Of these, 42 varieties were chosen for continued evaluation in Michigan, and 35 of these remain under evaluation by their respective breeding programs (Table 12). They were be grown in 15-foot plots in 2020. Below are top performing russet, yellow, red, white, and novelty fresh pack varieties.

Russets

Reveille Russet: This variety was evaluated at eleven locations in 2019, and will be planted across multiple locations in both strip trials and bulk plantings in 2020. It had the highest US#1 and total yield of all trial varieties, 524 and 596 cwt/A, respectively. It had excellent internal quality, with all defects occurring less than the trial average. This variety had an attractive appearance and a common scab rating of 0.4. Reveille had a larger size profile, with an average of 27% oversize tubers observed. A wider seed spacing is recommended to decrease tuber size.

AOR07781-5: This variety had an above average US#1 yield of 391 cwt/A at eleven locations. It had a medium russeted skin type and 75% US#1 tubers. This medium maturing variety has a vigorous vine type and is resistant to common scab, with an average rating of 0.0. It had a high specific gravity of 1.087, above the trial average. AOR07781-5 had good internal quality, excluding 20% hollow heart.

A08433-4sto: This Aberdeen, Idaho variety also had a high yield of 466 cwt/A with 81% US #1 tubers. It had an average specific gravity of 1.079 and a common scab rating of 0.3.

This full season variety had a moderately vigorous vine, and internal defects below the trial average, excluding hollow heart, which was at the trial average. A08433-4stoRUS has multiple disease resistances including PVY, *Verticillium* Wilt, Early Blight, and tuber Late Blight.

Vanguard: This variety was evaluated at twelve locations in 2019. It had a slightly above average US#1 yield of 365 cwt/A, and 78% US #1 tubers. This variety had a specific gravity of 1.067 and excellent internal quality, with 9% vascular discoloration. It had a lower than average common scab rating of 0.3 and an earlier vine maturity. Vanguard has a blocky appearance and attractive type.

Yellow Flesh

Fioretta: This yellow-fleshed variety had a high total and US#1 trial yield of 380 and 636 cwt/A, respectively. It produced 56% A-sized tubers and had a lower specific gravity of 1.068. Internal quality was good except for 12% vascular discoloration, the trial average. This variety had a common scab rating of 0.8, and medium yellow flesh. It had smooth, waxy skin, but did not have a consistently uniform tuber type.

Queen Anne: This variety has a consistent attractive appearance with a smooth skin finish and medium yellow flesh. With a US#1 yield of 287 and total yield of 515 cwt/A, this variety had a smaller size profile with 44% B-sized tubers. It had high ratings for both skin waxiness and yellow flesh color. Queen Anne produces uniform, oval shaped tubers with a bright appearance.

Paroli: This selection has an average yield of 383 cwt/A in 2019 with 84% US#1 potatoes. It had a specific gravity of 1.064, lower than the trial average of 1.071. Paroli has a larger vine type and an earlier vine maturity. It had good internal quality, with internal defects below the trial average, and a common scab rating of 0.5.

Nixie: This variety was only grown at one location in 2019, and had the second lowest US #1 yield of 138 cwt/A with 47% US #1 tubers. It had a waxy skin and bright appearance, as well as a smaller tuber size profile, making it attractive as a B-sized tablestock variety. At 1.079, it had a higher than average specific gravity, and a common scab rating of 0.2. Nixie had no internal defects in 2019. This full season variety had oval to oblong tubers.

Red Skin

NDAF113484B-1: This North Dakota selection was the highest yielding variety in the 2019 red skin potato trial with a US #1 yield of 399 cwt/A. It was evaluated at eight locations in 2019, and had 85% US #1 tubers. NDAF113484B-1 had a specific gravity of 1.063, slightly lower than the trial average of 1.069. It had good internal quality with defects at or below the trial average, excluding 20% vascular discoloration. This mid-season variety had a common scab rating of 0.6 and slight skin flaking.

Roko: This variety had a high US #1 yield of 367 cwt/A and a specific gravity of 1.074. Its internal quality was generally good, but Roko had 22% internal brown spot, higher than the

5% trial average. This variety had an oval tuber type with uniform skin color. It had a mid-season maturity and moderately vigorous vine.

CO99076-6R: This early maturing Colorado variety produced attractive, uniform tubers with deep red skin. It had a US #1 yield of 359 cwt/A, slightly above the trial average of 293 cwt/A. CO99076-6R had a larger size profile with only 5% B size tubers. It had good internal quality with only 10% vascular discoloration.

W8893-1R: This Wisconsin selection has an attractive tuber type and skin finish, but had a higher than average silver scurf rating. It had a below average yield of 232 cwt/A and good internal quality. The common scab score was average for the trial. W8893-1R had very early vine maturity and an average vine vigor.

Round White

AF5280-5: This variety had an average yield of 372 cwt/A US #1 potatoes across seven locations in 2019. It had approximately 70% A size tubers and 20% B size tubers. This variety had good internal quality, but slightly more vascular discoloration than the trial average. It had slightly early to mid-season vine maturity, and a specific gravity of 1.066. This variety had an attractive round shape.

NDAF102629C-4: This North Dakota selection had an average yield of 267 cwt/A of US#1 tubers and 348 cwt/A total yield, both slightly below the trial average. This variety produced 72% A-sized tubers, which were round with a bright appearance. It had good internal quality with only 5% vascular discoloration. This early maturing variety had a common scab rating of 0.3 at seven locations.

AF5819-2: This variety was evaluated at two locations in north central Michigan in 2019. It produced larger tubers, with 83% A-sized tubers and a high yield of 495 cwt/A US #1 tubers. It had good internal quality, a common scab score of 1.0, and earlier maturity. While this variety had a poor skin finish, it had an attractive, consistent shape.

Novelty

Blackberry: This Michigan State University selection had purple skin and flesh, and a slightly below average yield of 308 cwt/A US #1 tubers. It produced 36% A sized tubers and 62% B sized tubers. Blackberry had no internal defects, but was only evaluated at two locations in 2019. The purple skin was a uniform dark color, but moderate silver scurf was observed.

MSV443-1PP: This variety had purple skin and purple flesh, and was evaluated at four locations in 2019. It had the second highest total yield of 348 cwt/A and 67% US#1 tubers. It had excellent internal quality and slight silver scurf with a rating of 1.5, below the trial average of 2.9. This variety tended to have deep stem ends and growth crack in the pickouts.

Table 1. 2019 Chip Processing Variety Descriptions

Entry	Pedigree	2019 Scab Rating*	Characteristics
Atlantic	Wauseon x B5141-6 (Lenape)	0.7	High yield, early maturing, high specific gravity, good internal quality.
Hodag (W5955-1)	Pike x Dakota Pearl	0.7	Average to above average yield, high specific gravity, size profile similar to Atlantic, management should be adjusted because this variety tends to produce large tubers, long storage potential with common scab tolerance.
Lady Liberty (NY152)	B38-14 x Marcy	1.3	High yield potential, average specific gravity, excellent long-term storage chip quality, attractive round shape.
Lamoka (NY139)	NY120 x NY115	1.2	Average yield, mid-late season maturity, medium specific gravity, oval to oblong tuber type, low internal defects, long-term chip quality.
Mackinaw (MSX540-4)	Saginaw Chipper x Lamoka	0.9	Average yield with high specific gravity and high percentage of A-sized tubers, mid to late-season maturity, long-term chip-processing quality with resistance to PVY and late blight and tolerance to common scab, flattened oval type, netted skin
Manistee (MSL292-A)	Snowden x MSH098-2	1.7	Average yield with early to mid-season maturity, excellent chip-processing quality and long storage potential, scab tolerance and specific gravity similar to Snowden, uniform round tubers with shallow eyes and heavy netted skin, some compressed tubers apical to stem

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(2019 Processing Varieties cont.)

Entry	Pedigree	2019 Scab Rating*	Characteristics
Petoskey (MSV030-4)	Beacon Chipper x MSG227-2	0.9	High yield and specific gravity, uniform round tuber type with heavy netting, good OTF chip and internal quality.
Pike (NYE55-35)	Allegany x Atlantic	0.5	Average yield, early to mid-season maturity, early storage, some internal defects, medium specific gravity, tuber bottlenecking and points.
Snowden (W855)	B5141-6 x Wischip	1.4	High yield, medium season maturity, mid-season storage, reconditions well in storage, medium to high specific gravity.
Winterset (CO02321-4W)	NY115 x BC0894-2W	2.8	Below average yield, good OTF chip quality, common scab susceptibility, smaller tuber size profile.
AF5563-5		0.0	Thin bright skin, lower specific gravity, common scab tolerant, good OTF chip quality.
AOR09034-3		3.0	Common scab susceptible, poor fresh chip quality, full season maturity.
B2869-29	B0564-8 x B1316-5	1.0	Average yield potential, higher specific gravity, light skin, smaller size profile
B2904-2	B1873-6 x Coastal Chip	1.1	Average yield potential, susceptible to vascular discoloration and hollow heart
BNC182-5	Tacna x B0766-3	0.9	Uniform type, skin flaking, slight growth crack.

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(2019 Processing Varieties cont.)

Entry	Pedigree	2019 Scab Rating*	Characteristics
CO10076-4W	CO03243-3W x CO02024-9W	1.3	Above average yield, susceptible to vascular discoloration, full season maturity
MSAA275-3	Snowden x MSS297-3	2.0	Oblong, compressed tuber type, sticky stolons, earlier maturity.
MSAA311-1	Elkton x Atlantic	0.5	Thinner skin, full season maturity, good internal quality.
MSAA498-18	MSV092-2 x Elkton	0.5	Below average yield potential, earlier maturity, good fresh chip quality.
MSAFB609-12	NY148 x MSQ086-3	0.0	Bright and uniform appearance, good internal quality, no common scab, average yield potential.
MSAFB636-1	NYH15-5 x MST096-2Y	1.0	Uniform, attractive type, below average specific gravity, high percentage A-sized tubers.
MSBB008-3	Atlantic x MSR127-2	1.0	Moderate vascular discoloration, smaller tuber size profile, average specific gravity.
MSBB058-1	NY148 x MSR127-2	0.8	Bright, round, uniform tubers, very high specific gravity, good internal quality.
MSBB058-4	NY148 x MSR127-2	1.1	Blocky shape, poor appearance, above average yield.
MSBB060-1	NY148 x MSS297-3	1.3	Earlier maturity, moderate vascular discoloration, larger oversize tubers.

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(2019 Processing Varieties cont.)

Entry	Pedigree	2019 Scab Rating*	Characteristics
MSBB131-1	MSK409-1 x MSR127-2	1.0	Bright skin, cream flesh, very early maturity, poor fresh chip quality, average yield.
MSBB625-2	MSW242-1 x MSS297-3	0.9	Full-season maturity, high specific gravity, moderate internal brown spot, above average yield.
MSBB626-11	Saginaw Chipper x Kalkaska	0.9	Slight sticky stolons, deep apical ends, poor fresh chip quality.
MSW044-1	Kalkaska x Lamoka	0.5	High specific gravity, above average yield, good internal quality, bright skin, uniform round tuber type, thin skin.
MSW075-2	MSK061-4 x Nicolet	0.7	Higher proportion of B-sized tuber than trial average, uniform round tubers.
MSX472-2	MSQ070-1 x MSP292-7	0.7	Earlier vine maturity, below average specific gravity, average yield.
MSZ020-10	Kalkaska x MSM246-B	1.3	Poor appearance, blocky and flattened tubers, smaller vine type, good internal quality.
MSZ052-14	Pike x MSR127-2	0.9	Blocky tubers, lower specific gravity, slight sheep nose.
MSZ096-3	Boulder x MSR127-2	0.6	Round shape, netted skin, full season maturity, above average yield.
MSZ120-4	Kalkaska x MSQ086-3	0.9	Sticky stolons, average yield, specific gravity, and chip quality.

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(2019 Processing Varieties cont.)

Entry	Pedigree	2019 Scab Rating*	Characteristics
MSZ200-3	MSQ070-1 x Lamoka	1.3	Large tubers, marginal appearance, lower specific gravity.
MSZ219-13	Saginaw Chipper x MSR127-2	0.5	Darker netted skin, moderate growth crack, good internal quality, high percentage A sized tubers, smaller vine type.
MSZ219-14	Saginaw Chipper x MSR127-2	0.5	High yield potential with a high percentage of A-sized tubers, mid to late season maturity, long-term chip-processing quality with resistance to common scab, late blight, and PVY.
MSZ222-19	MSR127-2 x Tundra	0.9	Deep apical ends, high specific gravity, good internal quality, above average yield.
MSZ242-13	MSR169-8Y x MSU383-A	0.5	Average yield potential, excellent internal quality, mid-season maturity, darker netted skin.
MSZ248-10	Snowden x MSV229-2	1.0	Good OTF chip quality, some internal brown spot, above average yield, heavy netted skin.
ND7519-1	ND3828-15 x W1353	0.9	Average yield potential, rhizoctonia and silver scurf observed in 2019, average size profile.
NY162	NYE106-2 x NYE48-2	1.1	Excellent internal quality, light skin, oval tuber shape, average yield potential.
NY163	NYE50-8 x NYE48-2	0.7	Apical anthocyanin pigmentation, good internal quality, mid-season maturity, above average yield.

(2019 Processing Varieties cont.)

Entry	Pedigree	2019 Scab Rating*	Characteristics
NY165	NY148 x NYF48-4	0.6	Variable type and appearance, excellent internal quality, average yield, specific gravity, and size profile.
NY166 (N16-11)	NY140 x E48-2	1.0	Thin bright skin, some pear shaped tubers, most characteristics at trial average.
NYP111-9	NY148 x F48-4	0.5	Smaller size profile, buff skin, very high specific gravity, more B sized tubers than average.
NYP14-1	Snowden x E48-2	0.8	Deep stem ends, slight skin flaking, good fresh chip quality, average yield potential.
WAF10664-3	Superior x W6609-3	0.2	Round tubers, thin and bright skin, minimal stem end defect, high percentage A sized tubers.

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. Common scab data provided by Potato Outreach Program. Line descriptions provided by various potato breeding programs and updated by Potato Outreach Program following evaluations at various trial locations throughout Michigan.

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Table 2. 2019 Michigan Statewide Chip Processing Potato Variety Trials Overall Averages - Fourteen Locations

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR[2]	OTF CHIP SCORE[3]	RAW TUBER QUALITY[4] (%) HH	VD	IBS	BC	COMMON SCAB RATING[5]	SED SCORE[6]	VINE VIGOR[7]	VINE MATURITY[8]	COMMENTS
WAF10664-3[n]	584	635	92	6	91	1	2	1.078	1.5	0	13	3	0	0.2	0.2	4.7	3.0	round, bright thin skin
MSAFB636-1[n]	515	567	91	8	91	0	1	1.072	1.5	0	0	0	7	1.0	0.3	3.2	3.5	uniform, attractive type
Lady Liberty[aceghijln]	485	559	86	12	86	1	1	1.082	1.4	9	10	0	0	1.3	0.2	3.4	3.0	round, misshapen pos
MSZ096-3[bcdfm]	477	515	86	13	83	2	2	1.080	2.0	4	20	10	0	0.6	1.0	2.6	4.3	round, netted skin
Snowden[abcdefghiklmn]	**471**	**536**	**83**	**14**	**80**	**3**	**3**	**1.088**	**1.4**	**7**	**15**	**0**	**0**	**1.4**	**0.5**	**3.2**	**3.0**	**sl gc, pitted scab lesions**
MSBB626-11[in]	468	554	84	8	84	1	7	1.088	2.0	10	20	4	0	0.9	0.9	3.5	3.0	sl sticky stolons, deep ends
MSZ248-10[n]	467	546	86	10	85	1	4	1.081	1.0	3	3	27	7	1.0	0.6	3.0	3.7	heavy, dark, netted skin
AOR09034-3[k]	461	536	86	12	86	0	2	1.086	2.0	0	13	0	7	3.0	0.4	4.5	4.0	pointed tubers, moderate rhizoctonia
MSZ219-14[abcdefghikmn]	460	512	88	11	87	0	2	1.083	1.5	6	15	0	3	0.5	0.6	3.5	3.1	bright, uniform, attractive
Atlantic[bdfm]	**458**	**494**	**90**	**7**	**89**	**1**	**3**	**1.093**	**1.5**	**3**	**3**	**0**	**5**	**0.7**	**0.7**	**3.7**	**3.3**	**pointed tubers, gc**
Manistee[abcdefghimn]	456	530	84	12	84	1	3	1.085	1.5	3	8	5	1	1.7	0.4	3.3	2.5	flattened type, deep apical ends, mod skinning
NY165[abcdefghin]	448	543	82	15	82	0	3	1.084	1.3	0	4	1	0	0.6	0.5	2.7	3.4	variable type
MSZ222-19[bdfghm]	447	533	83	13	83	0	4	1.091	1.4	7	7	12	2	0.9	0.6	3.4	2.3	deep apical ends, sl gc
NY163[abcefghin]	441	502	83	12	83	0	5	1.085	1.2	1	9	0	0	0.7	0.3	2.8	3.0	apical anthocyanin pigmentation
NY166[abcegin]	440	561	78	16	78	0	6	1.081	1.4	2	9	2	10	1.0	0.4	2.8	3.5	thin bright skin, pear shapes
Hodag[abcdefghimn]	439	495	87	8	85	2	5	1.085	1.5	14	13	9	5	0.7	0.4	3.1	3.1	pointed tubers, bottlenecking, tr knobs
AF5563-5[n]	438	482	91	1	87	4	8	1.073	1.0	7	17	0	0	0.0	1.8	2.8	2.5	misshapen pos, thin bright skin
MSBB058-4[dgin]	431	505	85	12	85	0	3	1.085	1.4	1	10	2	1	1.1	0.5	2.7	3.5	blocky, poor appearance in box bin
BNC182-5[abcdefghn]	421	475	84	14	83	1	2	1.083	1.6	7	17	0	1	0.9	0.8	3.5	3.1	uniform, skin flaking, sl gc
MSW044-1[abcdefghimn]	421	509	81	17	81	0	2	1.090	1.5	3	8	0	0	0.5	0.5	3.4	3.2	thin skin, bright, round to oval
MSBB625-2[gin]	419	499	83	13	83	1	3	1.091	1.7	0	21	27	2	0.9	0.6	3.2	4.1	round, heavy netted skin
MSAA275-3[hin]	418	463	90	7	89	1	3	1.077	1.7	0	29	0	0	2.0	1.2	2.5	2.5	oblong, compressed, sticky stolons
Mackinaw[abcdefghijklmn]	413	498	82	14	80	2	4	1.091	1.5	0	15	2	1	0.9	0.5	2.9	3.0	flattened oval type, heavier skin netting
Petoskey (MSV030-4)[abcdefghijklmn]	412	474	86	12	85	0	3	1.092	1.2	1	8	0	1	0.9	0.5	2.5	3.0	heavy netting, nice shape, mod ah
MSBB131-1[ci]	405	484	83	7	79	5	9	1.075	2.0	20	25	0	0	1.0	0.5	3.5	1.5	bright skin, cream flesh
MSBB058-1[hin]	403	473	84	12	84	0	4	1.096	1.3	0	11	0	0	0.8	0.3	3.0	2.4	bright, uniform, round, sl gc
NY162[abcdefghin]	398	454	84	10	84	1	5	1.088	1.5	1	5	0	1	1.1	0.7	2.4	2.7	light skin, oval type
ND7519-1[abcdeghijklm]	397	478	82	15	81	1	3	1.087	1.5	4	11	11	4	0.9	0.4	3.7	2.6	tr rhizoc, sl silver scurf
NYP14-1[cign]	396	487	78	19	77	1	3	1.088	1.0	14	8	0	5	0.8	0.2	3.5	2.0	deep stem ends, sl skin flaking
MSX472-2[cegi]	392	482	79	18	79	0	3	1.073	1.3	10	13	3	5	0.7	0.2	2.8	2.2	small, round, attractive type
CO10076-4W[icghn]	390	487	80	14	80	0	6	1.073	1.7	3	12	2	0	1.3	0.4	1.6	3.0	light skin, deep stem ends
Pike[abcdgh]	**381**	**429**	**89**	**8**	**88**	**1**	**3**	**1.086**	**1.6**	**10**	**12**	**13**	**10**	**0.5**	**0.4**	**2.7**	**3.0**	**tuber bottlenecking, pointed ends**
MSAA311-1[fm]	375	429	88	10	88	0	2	1.078	1.8	0	10	5	0	0.5	0.5	3.5	4.8	thinner skin, gc
Lamoka[abceghik]	**373**	**445**	**82**	**14**	**82**	**0**	**4**	**1.084**	**1.5**	**0**	**15**	**1**	**1**	**1.2**	**0.6**	**3.4**	**2.5**	
MSZ219-13[abcdefghijmn]	364	392	92	4	89	3	4	1.083	1.5	13	8	1	1	0.5	0.4	1.7	3.7	darker netted skin, mod gc
MSZ052-14[cfhi]	363	424	76	19	76	0	5	1.077	1.6	3	18	0	3	0.9	0.7	2.3	3.3	blocky, sheep nose
MSZ200-3[in]	362	416	87	10	86	1	3	1.073	1.8	5	30	0	10	1.3	0.7	2.8	3.4	large, marginal appearance
MSZ120-4[ci]	358	435	83	11	86	0	3	1.083	1.8	5	20	0	0	0.9	0.6	2.3	3.5	sticky stolons
MSAFB609-12[m]	354	442	80	20	80	0	0	1.085	1.0	0	0	0	0	0.0	0.5	3.5	3.5	bright and uniform
MSW075-2[abcdefghikmn]	350	435	78	20	78	0	2	1.079	1.4	0	16	0	0	0.7	0.5	2.5	3.3	uniform, round, bright, attractive type
MSZ242-13[h]	345	383	90	9	90	0	1	1.101	1.0	0	0	0	0	0.5	0.1	2.5	3.0	darker netted skin
MSZ020-10[gin]	343	418	81	12	79	2	7	1.086	1.5	0	12	2	1	1.3	0.3	0.9	3.4	poor appearance, blocky, flattened
Winterset[ai]	326	431	72	25	72	0	3	1.086	1.5	5	20	10	0	2.8	0.4	3.0	2.5	
B2869-26[abcdefghmn]	323	417	72	25	72	0	3	1.090	1.6	8	14	0	2	1.0	0.6	3.9	2.7	light skin, smaller, sl scurf
B2904-2[abcdefghmn]	321	375	82	11	82	1	6	1.080	1.5	22	27	1	2	1.1	0.8	2.9	3.3	sl gc, bright, non uniform
MSBB060-1[i]	317	387	82	7	78	4	11	1.080	1.5	0	40	0	0	1.3	0.5	2.0	2.5	nice shape
NYP111-9[i]	282	439	64	27	64	0	9	1.100	1.5	0	30	10	0	0.5	0.2	3.0	3.0	smaller size profile, buff skin
MSAA498-18[i]	250	306	82	14	82	0	4	1.080	1.5	0	20	0	0	0.5	0.1	2.0	2.0	
MSBB008-3[i]	218	301	73	24	73	0	3	1.081	2.0	0	40	0	0	1.0	0.3	3.0	1.0	
Manistee SEL[i]	190	370	51	37	51	0	12	1.078	2.0	0	30	0	0	3.5	0.3	3.0	1.0	lots of pitted scab lesions
MEAN	**397**	**471**	**82**	**13**	**82**	**1**	**4**	**1.084**	**1.5**	**4**	**15**	**3**	**2**	**1.0**	**1**	**3**	**3.0**	

2019 CHIP VARIETY TRIAL SITES

a 4-L Farms
b Black Gold Farms
c County Line Farms
d Hampton Farms, Fresh Trial
e Hampton Farms, Storage Trial
f Lennard Ag. Co., Fresh Trial
g Lennard Ag. Co., Storage Trial
h Main Farms
i MRC Box Bin
j Sandyland Farms, Set 1
k Sandyland Farms, SNAC
l Verbrigge Farms
m Walther Farms, Fresh Trial
n Walther Farms, Storage Trial

[1]SIZE

Bs: < 1 7/8"
As: 1 7/8" - 3 1/4"
OV: > 3 1/4"
PO: Pickouts

[2]SPECIFIC GRAVITY

Data not replicated

[3]OUT OF THE FIELD CHIP COLOR SCORE

(SNAC Scale)
Ratings: 1 - 5
1: Excellent
5: Poor

[4]RAW TUBER QUALITY

(percent of tubers out of 10)
HH: Hollow Heart
VD: Vascular Discoloration
IBS: Internal Brown Spot
BC: Brown Center

[5]COMMON SCAB RATING

0.0: Complete absence of surface or pitted lesions
1.0: Presence of surface lesions
2.0: Pitted lesions on tubers, though coverage is low
3.0: Pitted lesions common on tubers
4.0: Pitted lesions severe on tubers
5.0: More than 50% of tuber surface area covered in pitted lesions

[6] SED (STEM END DEFECT) SCORE

0: No stem end defect
1: Trace stem end defect
2: Slight stem end defect
3: Moderate stem end defect
4: Severe stem end defect
5: Extreme stem end defect

[7]VINE VIGOR RATING

Date: Variable
Rating 1-5
1: Slow emergence
5: Early

[8]VINE MATURITY RATING

Date: Variable
Rating 1-5
1: Early (vines completely dead)
5: Late

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**
AOR09034-3	461[a]	536	86	12	86	0	2	1.086
MSV030-4	443[ab]	552	80	19	80	0	1	1.092
Lamoka	**440[ab]**	**541**	**81**	**18**	**81**	**0**	**1**	**1.088**
Mackinaw	433[ab]	600	72	27	72	0	1	1.090
MSZ219-14	426[ab]	503	85	15	85	0	0	1.084
Snowden	**374[b]**	**488**	**77**	**23**	**77**	**0**	**0**	**1.086**
ND7519-1	294[c]	445	66	32	66	0	2	1.086
MSW075-2	256[c]	414	62	38	62	0	0	1.082
MEAN	**391**	**510**	**76**	**23**	**76**	**0**	**1**	**1.087**
ANOVA p-value	**<.0001**	**0.0023**	**<.0001**	**<.0001**	**<.0001**	**-**	**0.0593**	**0.0442**
LSD	**75.0**	**77.2**	**5.3**	**5.6**	**5.3**	**-**	**-**	**0.006**

*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.				
	Raw Tuber Quality[1] (%)			
Entry	**HH**	**VD**	**IBS**	**BC**
AOR09034-3	0	13	0	7
MSV030-4	0	3	0	0
Lamoka	0	17	0	0
Mackinaw	**0**	**3**	**0**	**0**
MSZ219-14	0	7	0	0
Snowden	0	13	0	0
ND7519-1	**0**	**7**	**0**	**0**
MSW075-2	0	7	0	0
MEAN	**0**	**9**	**0**	**1**
ANOVA P-value	-	0.5251	-	**0.0103**
LSD	-	-	-	**3.5**

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

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Table 5. Post-Harvest Chip Quality[1] for the 2019 SNAC Trial at Sandyland Farms						
Merit Score	Entry	SNAC[2] Color	Specific Gravity	Percent Chip Defects[3] Internal	External	Total
2.0	ND7519-1	2.0	1.079	0.4	9.5	9.9
2.0	MSV030-4	2.0	1.085	13.4	6.3	19.7
2.5	**Lamoka**	**3.0**	**1.080**	**22.0**	**5.0**	**27.0**
3.0	MSW075-2	2.0	1.073	1.7	8.2	9.9
3.5	**Snowden**	**4.0**	**1.085**	**16.1**	**15.6**	**31.7**
4.0	Mackinaw	4.0	1.084	23.7	5.4	29.1
4.0	MSZ219-14	4.0	1.079	43.2	4.3	47.5
4.0	AOR09034-3	4.0	1.085	40.1	14.6	54.7

[1] Samples collected October 16th and processed by Herr Foods, Inc., Nottingham, PA on October 22nd, 2019.

[2] SNAC 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

Lines are sorted by Herr's merit score: excellent (1.0), good (2.0), marginal (3.0), drop (4.0).

Table 6. Black Spot Bruise Test for the 2019 SNAC Trial at Sandyland Farms																			
	A. Check Samples[1]									B. Simulated Bruise Samples[2]									
	# of Bruises Per Tuber						Total	Percent	Average	# of Bruises Per Tuber						Total	Percent	Average
Entry	0	1	2	3	4	5	Tubers	Bruise Free	Bruises Per Tuber	0	1	2	3	4	5	Tubers	Bruise Free	Bruises Per Tuber
ND7519-1	19	6	0	0	0	0	25	76	0.2	12	7	4	1	1	0	25	48	0.9
AOR09034-3	20	4	1	0	0	0	25	80	0.2	6	12	5	2	0	0	25	24	1.1
MSW075-2	14	8	2	1	0	0	25	56	0.6	4	10	7	3	1	0	25	16	1.5
MSV030-4	14	8	2	0	1	0	25	56	0.6	7	3	5	6	3	1	25	28	1.9
MSZ219-14	14	5	5	1	0	0	25	56	0.7	5	4	7	4	5	0	25	20	2.0
Lamoka	**11**	**10**	**4**	**0**	**0**	**0**	**25**	**44**	**0.7**	**5**	**4**	**7**	**3**	**6**	**0**	**25**	**20**	**2.0**
Mackinaw	15	6	3	1	0	0	25	60	0.6	1	2	4	11	6	1	25	4	2.9
Snowden	**10**	**10**	**5**	**0**	**0**	**0**	**25**	**40**	**0.8**	**1**	**2**	**3**	**14**	**3**	**2**	**25**	**4**	**2.9**

[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 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 for the 2019 SNAC Trial at Sandyland Farms, Taken on 8/20/2019								
Entry	Specific Gravity	Glucose[1] %	Sucrose[2] Rating	Canopy Rating[3]	Canopy Uniform.[4]	Number of Hills	Number of Stems	Average[5] Tuber Weight
AOR09034-3	1.087	0.003	0.920	40	95	4	18	3.81
MSV030-4	1.093	0.003	0.611	45	95	6	20	3.81
Lamoka	**1.086**	**0.002**	**0.643**	**50**	**90**	**5**	**11**	**3.44**
Mackinaw	1.092	0.007	0.462	80	95	3	8	3.20
MSZ219-14	1.082	0.003	0.361	80	95	4	12	3.00
Snowden	**1.088**	**0.004**	**0.630**	**75**	**95**	**4**	**17**	**3.39**
ND7519-1	1.083	0.002	0.737	5	95	3	16	3.91
MSW075-2	1.083	0.003	0.439	45	75	5	17	2.90

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.

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Table 8. 2019 Russet and Tablestock Variety Descriptions

Russet Variety Descriptions

Entry	Pedigree	2019 Scab Rating*	Characteristics
Alta Cloud Russet	Real Potatoes	0.0	Heavier russet skin, above average yield potential.
Castle Russet (POR06V12-3)	PA00V6-4 x PA01N22-1	0.1	Long, full season russet with dual-purpose potential, resistant to PVY, Pecto. and corky ring spot, moderate dormancy, susceptible to foliar late blight. Above average specific gravity in 2019.
Clearwater Russet (AOA95154-1)	Bannock Russet x A89152-4	0.5	Very high incidence of vascular discoloration in 2019, earlier vine maturity, below average yield potential.
Dakota Russet	Marcy x AH66-4	0.5	Silverton Russet type and appearance, good internal quality, mid-season maturity.
GoldRush Russet (ND1538-1Rus)	ND450-3Rus x Lemhi Russet	0.0	Medium maturity, oblong-blocky to long tubers, bright white flesh, common scab resistance, average yield potential
Pacific Russet (VO168-3)	NDA8694-3 x Century Russet	0.6	Inconsistent type, lower specific gravity, average yield potential.
Payette Russet	EGAO9702-2 x GemStar Russet	0.5	Moderate skinning, blocky tuber shape, some vascular discoloration observed in 2019, higher specific gravity.
Ranger Russet (A7411-2)	Butte x A6595-3	1.2	Tubular type, darker skin, common scab susceptible, very high specific gravity, higher proportion B-sized tubers, moderate vascular discoloration observed in 2019.

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(2019 Russet Varieties cont.)

Entry	Pedigree	2019 Scab Rating*	Characteristics
Reveille Russet (ATX91137-1Rus)	Bannock Russet x A83343-12	0.4	Excellent yield potential, common scab tolerant, early bulking, nice uniform dark russeted skin with good general tuber appearance, occasional misshapen tubers observed, long dormancy. Highest yielding russet variety in 2019
River Russet	Solanum	0.2	Poor appearance in 2019, moderate incidence of hollow heart, lower specific gravity, higher incidence of pickouts.
Russet Burbank	Unknown	0.7	Oblong type, lower yield, many misshapen pickouts.
Russet Norkotah	ND9526-4Rus x ND9687-5Rus	0.7	Above average yield, mid-season maturity, long to oblong tubers, heavy russet skin, low specific gravity, highest incidence of hollow heart in 2019.
Silverton Russet (AC83064-6)	A76147-2 x A7875-5	0.2	High yield, oblong to long blocky tuber type, medium netted russet skin, masks PVY, medium to low specific gravity, PVY, Sencor & Linuron susceptibility. High yield and good internal quality in 2019.
Umatilla Russet (AO82611-7)	Butte x A77268-4	1.5	Small tuber profile, 60% B-sized tubers in 2019, high specific gravity, earlier maturity.
Vanguard (TX08352-5RUS)	TXA549-1Ru x AOTX98137-1Ru	0.3	Nice slightly blocky shape, medium size profile, medium vine vigor and maturity, semi-erect vines, above average yield potential

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(2019 Russet Varieties cont.)

Entry	Pedigree	2019 Scab Rating*	Characteristics
A07061-6RUS	Clearwater Russet x Targhee Russet	1.0	Above average yield potential, good internal quality, full season maturity, light russet skin.
A071012-4BFRUS	A85331-7 x A01054-4	1.0	Light russet skin, low tuber set with larger tuber size profile, susceptible to blackspot bruise and hollow heart, high specific gravity, longer tuber shape.
A08433-4STO	A02611-1 x AOND95249-1	0.3	Oblong tuber shape with medium russet skin, resistant to shatter bruise, tuber late blight, and common scab, high yield potential, full season maturity.
AO02183-2	A97236-3 x Premier Russet	0.3	Tubular shape, moderate vascular discoloration, mid-season maturity, bottlenecking.
AOR07781-5	PA92A08-17 x PALB03035-6	0.0	Attractive type and appearance, moderate hollow heart, above average yield potential.
CO10091-1RUS	CO03371-4RU x CO98067-7RU	0.1	Resistant to blackspot bruise, rounded, smaller tubers, smaller vine, below average yield potential.

* Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. Common scab data provided by Potato Outreach Program. Line descriptions provided by potato breeding programs and updated by Potato Outreach Program following evaluations at trial locations throughout Michigan.

2019 Yellow Flesh Variety Descriptions

Entry	Pedigree	2019 Scab Rating*	Characteristics
Actrice	Meijer Potato	0.6	High tuber set, resistant to leaf roll and several nematode species, deep apical eyes, oval shape, netted skin
Arizona	Agrico	1.8	Highest yielding yellow flesh variety in 2019, oval to long tuber shape, light yellow flesh color, good internal quality.
Captain	Germicopa	0.0	Poor tuber shape, blocky, early vine maturity, below average yield potential
Electra	C1992/42 x Picasso	0.8	Flat oval type, netted skin, above average yield, mid-season maturity.
Fioretta	Solanum	0.8	Smooth skin, non-uniform tuber type, good internal quality, average specific gravity.
Nixie	Real Potatoes	0.2	Small tuber size, bright skin, excellent internal quality, above average specific gravity.
Noah	-	0.7	Pointed tubers, pitted scab present in 2019, average specific gravity, above average yield potential.
Obama	Agriana	0.8	Oval to oblong type, buff skin, moderate alligator hide, above average yield potential.
Paroli	Norika	0.5	Attractive waxy skin, larger vine type, good internal quality, above average yield potential.

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(2019 Yellow Flesh Varieties Cont.)

Entry	Pedigree	2019 Scab Score*	Characteristics
Picobello	Real Potatoes	1.7	Common Scab susceptible, many misshapen tubers, lower yield, average specific gravity, mid-season vine maturity.
Queen Anne	Solanum International	0.5	Oval to oblong shape, yellow flesh, yellow skin, shallow eyes, medium to high scab resistance, PVY resistance and resistance to Ro1 and Ro4 nematodes, attractive appearance, waxy skin.
SF Vario	Norika	1.3	Buff skin, higher percentage of pickouts, lower yield potential.
Yukon Gold	Norgleam x W5279-4	1.2	Moderate yields, medium maturity, oval shaped with yellow-white skin and light yellow flesh, common scab susceptible
CO10064-1W/Y	CO00412-5W/Y x CO04099-4W/Y	1.5	B sized tuber profile, above average specific gravity, full season maturity, moderate incidence of internal brown spot, some pointed tubers
MSBB343-2Y	MSQ341-BY x MSL211-3	1.6	Uniform type, moderate incidence of vascular discoloration, higher specific gravity, high incidence of A-sized tubers.
MST252-1Y	MSL024-AY x MSL211-3	0.7	Above average yield potential, good internal quality, light yellow skin color, flattened oval type.
MSV093-1Y	McBride x MSP408-14Y	0.5	Above average yield, good internal quality, rough netted skin, deep apical ends

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(2019 Yellow Flesh Varieties Cont.)

Entry	Pedigree	2019 Scab Score*	Characteristics
MSX156-1Y	MSI005-20Y x Boulder	1.4	High yield potential, moderate internal brown spot, medium yellow flesh color, larger tuber size, buff skin.
NY149	Yukon Gold x Keuka Gold	0.7	Mid to late season, slightly-textured skin and pink eyes, oval shape, medium yellow flesh, resistance to Ro1 cyst nematode, moderate common scab resistance, netted skin.

* Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. Common scab data provided by Potato Outreach Program. Line descriptions provided by potato breeding programs and updated by Potato Outreach Program following evaluations at trial locations throughout Michigan.

2019 Red Skin Variety Descriptions

Entry	Pedigree	2019 Scab Rating*	Characteristics
Autumn Rose	Solanum	0.7	Uniform red skin, good internal quality, above average specific gravity, size profile split between A and B sized tubers.
Cerata	Stet Holland	0.2	Medium maturity, oval shaped tubers, white flesh and light red skin, adapted to all soil types, suitable for storage, resistant to potato cyst nematodes Ro1, moderate resistance to common scab, good internal quality.
Dark Red Norland	Redkote x ND626	0.5	Broadly adapted, moderate to above average yields, early season maturity, smooth, oblong, slightly flattened tubers, common scab tolerant.
Isle Royale (MSX569-1R)	MSS002-2R x MSS544-1R	0.3	High percentage B size tubes, early maturity and small vine type, red pigmentation in vascular ring, Uniform dark waxy skin.
Red Prairie (W8405-1R)	Kankan x W2303-9R	0.9	High yield potential, oval to oblong tuber type, mid-season maturity, lighter skin color
Red Sunset	NDO3503-5 x Mazama	1.2	Variable skin color and skin finish, some vascular discoloration, average yield potential
Roko	Alwara x MA81-0536	0.7	Uniform dark red skin, oval tuber shape, moderate internal brown spot, above average specific gravity, above average yield potential.
CO98012-5R	A79543-4R x AC91844-2	1.9	Attractive tuber size profile, dark red skin, susceptible to common scab

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(2019 Red Skin Varieties Cont.)

Entry	Pedigree	2019 Scab Rating*	Characteristics
CO99076-6R	AC91848-1 x NDC5281-2R	0.0	Above average specific gravity, good internal quality, medium red skin color and highly uniform, sticky stolons, above average yield.
CO99256-2R	NDC5281-2R x CO89097-2R	0.0	Mid-season maturity, good internal quality, high percentage A-sized tubers, attractive type, round shape, waxy skin.
MSAA182-3R	MSU200-5PP x MSS544-1R	0.3	High specific gravity, round type, sticky stolons, smaller tuber size profile, mid-season maturity,
NDAF113484B-1	ND060570B-1R x ND8555-8R	0.6	Moderate silver scurf, skinning, moderate vascular discoloration, highest yield of red varieties in 2019, A-sized tuber profile.
NY164	D32-4 x C100-2	1.0	Moderate skinning, uniform type and skin, good internal quality, average yield potential and specific gravity.
W8893-1R	W1101R X Dakota Rose	0.5	Average yield potential, lower specific gravity, early vine maturity, attractive appearance and skin type.

* Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. Common scab data provided by Potato Outreach Program. Line descriptions provided by various potato breeding programs and updated by Potato Outreach Program following evaluations at various trial locations throughout Michigan.

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2019 Round White Variety Descriptions

Entry	Pedigree	2019 Scab Rating*	Characteristics
AAC Hamer	AC87340-2 x ND2008-2 (Parkland)	1.6	Small round tuber type, good internal quality, very vigorous vine, below average to average yield potential.
Bridget	Sinora x Agnes (Parkland)	1.1	Flaky, netted skin, long oval tuber shape, high specific gravity.
Harmony	Nadine x Stamina (Caithness)	0.8	Long dormancy, resistance to black dot and bruising, susceptible to dry rot, powdery scab, and silver scurf, attractive skin type
Laperla	Solanum	0.0	Smooth, bright skin, average yield, below average specific gravity.
Libertie	Harmony x Diva (Caithness)	0.8	Moderately resistant to bruising, dry rot, common and powdery scab, susceptible to PVY, variable appearance, oblong tuber shape.
Nadine	Caithness	0.9	Resistance to potato cyst nematode, bright skin color and appearance, light skin netting
Onaway	USDAX96-56 x Katahdin	0.5	Early maturity, average specific gravity, used primarily out-of-the field for fresh market, minimal internal defects, not recommended for storage, deep eyes, very high yield.
Reba (NY 87)	Monona x Allegany	1.0	High yield, bright tuber appearance, low incidence of internal defects, medium specific gravity, resistance to golden nematode Ro1, common scab, verticillium wilt, and early blight, susceptible to late blight and PVY

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(2019 Round White Varieties cont.)

Entry	Pedigree	2019 Scab Rating*	Characteristics
Superior	USDA96-56 x M59.44	0.8	Early maturity, round to oblong tubers, deep eyes, resistant to net necrosis and common scab, susceptible to verticillium wilt, pressure bruise issues in long-term storage, dark netted skin.
White Beauty	New Zealand	0.9	Resistant to PVY and common scab, susceptible to late blight, high yield, anthocyanin pigmentation at apical ends.
AF5280-5	ND7799C-1 x ND860-2	0.9	Average yield potential, susceptible to vascular discoloration, early maturity, attractive round shape.
AF5819-2		1.0	Poor skin finish, attractive tuber shape, good internal quality, high yield and specific gravity
MSV179-1	LBR8 x MSL211-3	1.3	Large round tubers, uniform type, early season maturity, good internal quality, high yield potential.
MSW407-7	E69.6 x MSL766-1	1.3	Attractive tuber shape, netted skin, very early maturity, very high specific gravity, high percentage A-sized tubers.
MSX194-3	Missaukee x CO95051-7W	0.9	Rough netted skin, flattened tuber shape, good internal quality, average yield potential
MSX398-2	Lamoka x Stirling	1.9	Round tuber shape, below average yield, poor internal quality including hollow heart and brown center, high specific gravity.

(2019 Round White Varieties cont.)

Entry	Pedigree	2019 Scab Rating*	Characteristics
MSZ551-1	MSM182-1 x MSL268-D	1.3	Round tuber type, sticky stolons, high specific gravity, above average yield, high percentage A-sized tubers.
MSZ598-2	MSS576-5SPL x Superior	1.0	Below average yield and specific gravity, moderate alligator hide.
NDAF102629C-4		0.3	Bright skin, round tubers, slight skinning, good internal quality, below average yield potential.
WAF13058-1		1.0	Smaller tuber sized profile, mainly B-sized tubers, good internal quality, below average specific gravity.

* Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. Common scab data provided by Potato Outreach Program. Line descriptions provided by various potato breeding programs and updated by Potato Outreach Program following evaluations at various trial locations throughout Michigan.

2019 Novelty Variety Descriptions

Entry	Pedigree	2019 Scab Rating*	Characteristics
Blackberry (MSV109-10PP)	COMN07-W112BGA x MSU200-5PP	0.5	Moderate silver scurf, very dark red/purple skin color, good internal quality, average yield potential
Michigan Purple	W870 x Maris Piper	1.3	Lighter purple skin, moderate skinning, severe silver scurf
MSV443-1PP	MSU200-5PP x NDTX4271-5R	0.6	Mid to full season maturity, moderate silver scurf, dark purple skin color, recessed stem ends, good internal quality
MSZ252-2P	MSS156-2Y x W6609-3	0.0	Variable skin color, high specific gravity, size profile split between A and B-sized tubers
MSZ413-6P	Colonial Purple x MSU200-5PP	0.6	Pointed ends, moderate skinning, smooth and waxy skin type
MSZ413-7PP	Colonial Purple x MSU200-5PP	0.5	Dark and uniform skin color, small tuber size profile, average specific gravity.
MSZ416-8R/Y	MSN2301RY x NDTX4271-5R	0.0	Rougher, netted skin texture, medium yellow flesh, moderate vascular discoloration.
MSZ436-2SPL	MSS576-5SPL x MSQ440-2	0.9	Pinto type variety with purple and white skin, but mainly white skin observed in 2019, inconsistent type and appearance.
MSZ552-5P	MSM182-1 x Colonial Purple	0.0	Highest novelty yield in 2019, high incidence of hollow heart, slight skinning

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* Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. Common scab data provided by Potato Outreach Program. Line descriptions provided by potato breeding programs and updated by Potato Outreach Program following evaluations at trial locations throughout Michigan.

Table 9. 2019 Michigan Statewide Russet Potato Variety Trials Overall Averages- Fourteen Locations

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR[2]	RAW TUBER QUALITY[4] (%) HH	VD	IBS	BC	COMMON SCAB RATING[5]	VINE VIGOR[7]	VINE MATURITY[8]	COMMENTS
Reveille Russet[abcdeghklmn]	524	596	87	7	60	27	6	1.071	2	6	3	0	0.4	2.6	3.1	mod skinning, uniform type
A08433-4sto[abcdeghiklmn]	466	571	81	11	64	17	8	1.079	16	5	0	0	0.3	2.9	3.8	misshapen pos, points, sl gc
Silverton Russet[abcdefhklmn]	437	539	82	11	64	18	7	1.073	4	6	6	1	0.2	3.4	3.5	mod gc, points, bottlenecking
Alta Cloud Russet[l]	435	561	78	10	72	6	12	1.078	20	10	3	10	0.0	2.0	3.5	heavy russetting, bottlenecking
Russet Norkotah[abcdefhiklmn]	425	535	77	15	61	16	8	1.074	43	15	0	4	0.7	2.9	2.7	severe pinkete, mod ah
A071012-4BFRUS[abcdefklmn]	406	514	79	12	57	22	9	1.084	35	4	0	1	1.0	3.4	3.8	tubular, knobs, misshapen, long shape
A07061-6RUS[abcdefhklmn]	392	502	78	15	55	23	7	1.078	6	6	1	0	1.0	3.5	3.5	light russet skin, variable skin finish
AOR07781-5[abcdefhklmn]	391	512	75	13	61	14	12	1.087	20	6	1	0	0.0	3.6	3.7	attractive appearance, sl skinning
River Russet[bcefhklmn]	388	518	76	8	51	25	16	1.074	30	3	6	1	0.2	3.0	3.2	poor shape and size, misshapen
Vanguard[abcdeghiklmn]	365	450	78	16	66	12	6	1.067	0	9	1	0	0.3	2.6	2.1	blocky, attractive type, tr ah
Pacific Russet[bcdeghklmn]	361	470	71	25	63	8	4	1.068	0	12	0	0	0.6	3.3	2.4	variable type, points, deep apical ends
Castle Russet[abcdefhiklmn]	351	428	79	17	69	10	4	1.086	36	11	0	4	0.1	2.4	3.5	dark skin, nice appearance
Payette Russet[ci]	314	427	72	16	67	5	12	1.091	10	20	0	0	0.5	1.5	2.8	skinning, blocky shape
AO02183-2[abcdefhijklmn]	313	450	64	28	62	2	8	1.086	14	23	1	2	0.3	2.8	3.4	tubular, bottlenecking, mod ah
Dakota Russet[ik]	308	404	76	19	63	13	5	1.083	0	5	0	0	0.5	2.5	3.3	silverton type, mod ah
CO10091-1RUS[cefhklmn]	292	418	68	28	66	2	4	1.083	19	13	8	1	0.1	1.7	3.3	smaller tubers, sl skinning, rounder
Goldrush Russet[cef]	244	354	66	27	61	5	7	1.076	17	3	9	9	0.0	2.7	1.8	attractive dark russet skin
Ranger Russet[ci]	243	484	48	39	47	1	13	1.095	7	30	0	0	1.2	3.0	3.0	tubular, dark skin, mod ah
Clearwater Russet[i]	216	346	62	34	59	3	4	1.087	0	70	0	0	0.5	2.0	2.5	
Russet Burbank[eij]	142	434	30	43	29	1	27	1.080	15	15	0	0	0.7	3.5	3.2	oblong type, misshapen pos
Umatilla Russet[i]	111	378	29	62	29	0	9	1.087	0	30	0	0	1.5	2.5	2.0	smaller tubers, inconsistent shape
MEAN	**339**	**471**	**69**	**22**	**58**	**11**	**9**	**1.080**	**14**	**14**	**2**	**2**	**0.5**	**2.8**	**3.1**	

2019 RUSSET VARIETY TRIAL SITES

a 4-L Farms, Allegan County
b Crawford Farms, Montcalm County
c Elmaple Farms, Kalkaska County
d Horkey Brothers, Monroe County
e Jenkins Farms, Kalkaska County
f Kitchen Farms, Antrim County
g Kitchen Farms Mini Bulk Trial, Antrim County
h Lennard Ag. Co., St. Clair County
i Montcalm Research Center, Montcalm County
j NFPT Trial Selected Varieties, St. Joseph County
k Styma Potato Farm, Presque Isle County
l Verbirgghe Farms, Delta County
m Walther Farms Norkotah Fertility Trial, St. Joseph County
n Walther Farms Silverton Fertility Trial, St. Joseph County

[1]SIZE
Russets
Bs: < 4 oz
As: 4 - 10 oz
OV: > 10 oz
PO: Pickouts

[2]SPECIFIC GRAVITY
Data not replicated

[3]RAW TUBER QUALITY
(percent
HH: Hollow Heart
VD: Vascular Discoloration
IBS: Internal Brown Spot
BC: Brown Center

[4]COMMON SCAB RATING
0.0: Complete absence of surface or pitted lesions
1.0: Presence of surface lesions
2.0: Pitted lesions on tubers, though coverage is low
3.0: Pitted lesions common on tubers
4.0: Pitted lesions severe on tubers
5.0: More than 50% of tuber surface area covered in pitted lesions

[5]VINE VIGOR RATING
Date: Variable
Rating 1-5
1: Slow emergence
5: Early emergence (vigorous vine, some flowering)

[6]VINE MATURITY RATING
Date: Variable
Rating 1-5
1: Early (vines completely dead)
5: Late (vigorous vines, some flowering)

Table 10. 2019 Michigan Statewide Tablestock Potato Variety Trials Overall Averages- Thirteen Locations

		CWT/A		PERCENT OF TOTAL[1]						RAW TUBER QUALITY[4] (%)							YELLOW FLESH		RED SKIN				
	LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR[2]	HH	VD	IBS	BC	COMMON SCAB RATING[5]	VINE VIGOR[7]	VINE MATURITY[8]	WAXINESS[7]	FLESH COLOR[8]	WAXINESS[7]	SKIN COLOR[9]	UNIFORMITY[10]	SILVER SCURF[11]	COMMENTS
YELLOW SKIN TYPE	Arizona[abcdefhik]	539	639	84	13	76	8	3	1.062	5	8	0	2	1.8	3.1	2.2	2.3	1.5					oval to long, sl scurf
	MSBB343-2Y[dfk]	519	569	91	7	91	0	2	1.085	10	38	0	0	1.6	3.8	3.0	1.8	2.1					uniform type, gc in pos
	MSX156-1Y[abcdegk]	517	554	89	9	85	4	2	1.071	6	4	19	4	1.4	3.2	3.3	2.2	2.0					larger type, buff skin
	Electra[abcdeghik]	451	582	73	15	70	3	12	1.065	0	10	0	0	0.8	2.8	3.3	2.5	2.7					flat oval type, netted skin
	MSV093-1Y[acdefhil]	423	477	86	13	78	7	2	1.074	1	1	4	3	0.3	3.6	3.1	2.1	2.2					rough netted skin, deep apical ends
	MST252-01Y[def]	407	523	78	14	78	0	8	1.078	7	17	0	0	0.7	3.2	2.7	2.2	2.2					flattened oval type, sl silver scurf
	Noah[k]	396	495	80	12	79	1	8	1.071	0	13	0	0	0.7	3.5	3.0	2.7	1.3					pointed pos, pitted scab
	Obama[abcdeghik]	392	489	75	19	74	2	5	1.066	0	26	0	0	0.8	3.8	2.7	2.5	2.7					oval to oblong, buff skin, mod ah
	Actrice[abcdeghik]	384	480	71	24	70	1	5	1.059	2	13	2	1	0.6	2.7	2.5	2.8	2.5					deep apical eyes, oval, netting
	Paroli[k]	383	454	84	10	84	0	6	1.064	0	10	0	0	0.5	4.0	1.5	3.3	2.3					gc in pos, attractive waxy skin
	Fioretta[abcdeghik]	380	636	56	36	55	1	8	1.068	0	12	0	0	0.8	3.9	3.2	2.6	3.3					smooth skin, non uniform type
	Yukon Gold[abdefhikl]	**354**	**408**	**85**	**10**	**80**	**5**	**5**	**1.082**	**15**	**9**	**1**	**4**	**1.2**	**3.2**	**2.6**	**2.7**	**2.7**					**netted skin, pitted scab**
	NY149[abcdefhik]	326	423	72	22	69	3	6	1.081	3	15	1	2	0.7	3.3	2.9	2.5	2.4					netted skin
	Captain[k]	319	397	80	12	80	0	8	1.065	0	40	0	0	0.0	3.5	1.5	2.8	1.3					poor shape, blocky
	Picobello[fhk]	290	483	59	34	59	0	7	1.070	0	11	0	0	1.7	3.2	2.5	2.8	2.2					many misshapen tubers
	Queen Anne[abcdeghijk]	287	515	54	44	54	0	2	1.060	0	8	0	0	0.5	3.1	2.6	3.9	3.1					oval, bright skin, smooth
	SF Vario[abefhk]	269	451	55	23	55	0	22	1.065	2	7	4	2	1.3	3.5	2.5	2.4	2.0					buff skin
	Nixie[k]	138	292	47	52	47	0	1	1.079	0	0	0	0	0.2	3.5	2.3	2.7	2.2					smapp, bright, points in pos
	CO10064-1W/Y[a]	0	92	0	74	0	0	26	1.075	0	0	40	0	0.0	1.5	3.5	1.5	3.5					pointed pos, netted skin
	MEAN	357	472	69	23	68	2	7	1.071	3	13	4	1	0.8	3.3	2.7	2.5	2.3					
RED SKIN TYPE	NDAF113484B-1[abcdefhi]	399	451	85	12	81	4	3	1.063	0	20	6	0	0.6	2.7	2.8			3.3	2.6	3.1	2.8	mod scurf and skinning, sl greening
	Red Prairie (W8405-1R)[abdefhik]	398	517	73	22	71	3	4	1.066	0	13	18	0	0.9	3.0	3.2			3.3	2.7	3.4	2.0	lighter skin color, points, flattened
	Dark Red Norland[abcdefhikl]	**378**	**449**	**83**	**13**	**81**	**2**	**4**	**1.064**	**2**	**18**	**7**	**0**	**0.5**	**3.5**	**2.1**			**2.8**	**3.3**	**3.0**	**2.3**	**mod silver scurf, variable skin color**
	Roko[acdefhik]	367	516	67	27	67	0	6	1.074	0	5	22	0	0.7	3.4	3.6			2.8	2.5	3.5	2.2	mod silver scurf, dark skin, oval
	CO99076-6R[k]	359	385	93	5	93	0	2	1.076	0	10	0	0	0.0	3.5	2.3			3.2	3.2	4.0	1.8	sticky stolons, dark skin
	Red Marker #2[jl]	347	388	90	6	87	3	4	1.080	0	20	0	0	0.3	4.0	3.3			2.5	3.0	3.5	2.0	
	Cerata[k]	332	383	87	11	87	0	2	1.068	0	7	0	0	0.2	4.2	3.2			3.3	2.3	4.2	0.0	lighter skin color
	Red Sunset[abcdeghik]	325	418	74	24	72	2	2	1.063	0	20	1	0	1.2	3.3	2.3			3.1	2.0	3.1	1.9	variable skin color and finish, silver scurf
	NY164[abdefhik]	314	376	77	19	77	0	4	1.067	0	3	0	0	1.0	3.2	2.9			3.2	2.3	3.4	2.1	mod skinning, uniform type and skin
	CO98012-5R[bcek]	297	393	55	24	73	0	3	1.073	8	8	5	0	1.9	2.0	2.5			3.5	3.8	3.4	2.5	
	W8893-1R[abcdeghik]	232	337	62	34	60	2	4	1.061	6	14	0	1	0.5	3.2	1.7			3.3	2.9	3.3	2.5	nice appearance, silver scurf, attractive skin
	Autumn Rose[abcdefhik]	216	389	51	41	51	1	7	1.077	0	12	0	0	0.7	3.8	2.8			2.7	2.5	3.8	2.1	
	MSAA182-3R[ehl]	215	350	62	35	62	0	3	1.081	7	13	0	3	0.3	3.0	3.5			2.7	3.0	3.3	2.3	round, sticky stolons
	CO99256-2R[l]	145	182	79	21	79	0	0	1.072	0	0	0	0	0.0	1.5	3.0			3.5	3.0	3.0	3.5	round type, attractive skin color
	Isle Royale (MSX569-1R)[akj]	77	117	64	32	64	0	4	1.054	0	19	10	17	0.3	2.3	2.0			3.2	3.4	3.4	1.7	nice skin, sl gc
	MEAN	293	377	73	22	74	1	3	1.069	2	12	5	1	0.6	3.1	2.7			3.1	2.8	3.4	2.1	
ROUND WHITE TYPE	**Onaway[dh]**	**590**	**745**	**82**	**12**	**81**	**1**	**6**	**1.068**	**0**	**30**	**0**	**0**	**0.5**	**3.5**	**3.0**	**2.8**						**deep eyes, non uniform**
	AF5819-2[ef]	495	596	83	16	83	0	1	1.082	0	10	0	0	1.0	3.8	2.3	3.0						poor skin finish, nice shape
	MSV179-1[adefghi]	490	530	89	5	80	9	6	1.076	6	6	3	0	1.3	3.3	3.8	2.0						large, round, uniform, sl ah
	Superior[ef]	**457**	**590**	**77**	**16**	**77**	**0**	**7**	**1.083**	**0**	**25**	**0**	**0**	**0.8**	**4.3**	**2.0**	**3.5**						**dark netted skin**
	MSZ551-1[de]	446	499	90	7	90	0	3	1.083	10	10	15	5	1.3	3.0	2.0	2.5						round type, sticky stolons
	White Beauty[abcdeghi]	436	534	80	16	77	2	5	1.079	0	4	6	0	0.9	2.8	3.9	2.8						anthocyanins at apical ends, bottlenecking
	Reba[bdefi]	**433**	**506**	**89**	**6**	**81**	**9**	**4**	**1.074**	**30**	**4**	**0**	**0**	**1.0**	**3.2**	**3.0**	**2.2**						**deep eyes, variable appearance**
	MSW407-7[de]	427	533	80	15	80	0	5	1.085	15	10	0	0	1.3	3.3	3.5	1.5						netted skin, nice shape
	Harmony[abcdeghil]	405	557	68	20	65	3	12	1.061	8	7	10	9	0.8	2.5	3.0	2.5						severe gc, nice skin
	AF5280-5[abdefhi]	372	448	76	20	69	7	4	1.066	3	20	1	0	0.9	3.9	2.5	2.6						attractive round shape, sl greening
	Nadine[abdefhi]	366	533	70	23	69	1	7	1.061	0	6	14	0	0.9	3.4	2.8	2.4						sl netting, misshapen pos
	Laperla[k]	328	473	69	29	69	0	2	1.061	0	23	0	0	0.0	4.3	1.7	3.2	1.2					smooth, bright skin
	Bridget[abcdefhik]	305	463	60	35	58	2	5	1.081	0	12	1	1	1.1	3.4	3.1	1.8						flaky, rough skin, netted, long oval
	MSX194-3[bdefhi]	297	395	76	22	74	2	2	1.079	0	5	0	0	0.9	3.3	3.4	2.0						rough netted skin, flattened shape
	AAC Hamer[abcdfhik]	283	385	69	27	66	3	4	1.077	4	8	9	3	1.6	4.0	2.3	2.2						small round, surface scab
	NDAF102629C-4[abdefhi]	267	348	72	20	68	4	8	1.073	0	5	0	0	0.3	3.3	2.4	3.0						bright, sl skinning, round
	Libertie[adeghik]	217	416	47	37	44	3	16	1.066	0	13	0	0	0.8	2.9	2.8	3.3						variable appearance, oblong
	MSZ598-2[af]	212	292	54	32	53	2	13	1.068	0	10	25	0	1.0	3.5	3.3	2.0						internal defects, mod ah
	MSX398-2[defh]	171	240	72	25	72	0	3	1.080	25	10	5	15	1.9	2.3	3.0	2.3						round
	WAF13058-1[a]	49	144	34	51	34	0	15	1.059	0	10	0	0	1.0	3.5	2.5	2.0						
	MEAN	352	461	72	22	70	2	6	1.073	5	11	4	2	1.0	3.4	2.8	2.5						

NOVELTY TYPE	MSZ552-5P[b]	416	512	81	16	81	0	3	1.092	60	0	0	0	0.0	3.0	4.0			2.0	4.0	2.5	1.5	sl skinning
	MSV443-1PP[abef]	348	459	67	34	64	0	2	1.072	0	0	0	0	0.6	2.3	3.6			2.4	4.5	3.5	3.0	deep stem ends, gc
	MSZ436-2SPL[aefhl]	310	371	79	18	79	0	3	1.065	0	8	0	0	0.9	3.0	2.9			2.4	0.5	1.5	1.5	minimal splashing, mainly white skin
	Michigan Purple[adefhi]	308	384	77	17	74	3	6	1.077	2	10	3	0	1.3	3.6	2.4			2.7	2.7	2.7	3.6	light skin, mod skinning
	MSZ413-6P[aef]	260	424	70	26	59	11	4	1.078	0	13	0	0	0.6	2.7	3.0			3.2	4.2	3.5	3.8	pointed ends, skinning
	Blackberry (MSV109-10PP)[af]	225	399	36	62	36	0	2	1.076	0	0	0	0	0.5	2.5	3.5			2.3	5.0	3.3	3.3	mod silver scurf
	MSZ252-2P[aef]	178	350	46	46	46	0	8	1.081	0	15	0	0	0.0	2.8	3.7			2.5	4.5	3.8	3.3	misshapen pos, variable color
	MSZ416-8R/Y[ae]	154	242	55	39	54	1	6	1.069	0	30	5	0	0.0	3.3	3.8		2.5	2.5	3.3	3.8	2.8	rough skin texture
	MSZ413-7PP[ae]	90	197	42	54	42	0	4	1.072	0	0	0	0	0.5	2.8	3.5			3.0	5.0	4.3	3.3	darker skin color, silver scurf
	MEAN	254	371	61	35	59	2	4	1.076	7	8	1	0	0.5	2.9	3.4			2.5	3.7	3.2	2.9	
	TRIAL MEAN	**326**	**431**	**70**	**24**	**68**	**2**	**6**	**1.072**	**4**	**12**	**4**	**1**	**0.8**	**3.2**	**2.8**	**2.5**	**2.3**	**2.9**	**3.2**	**3.3**	**2.4**	

2019 TABLESTOCK VARIETY TRIAL SITES

a 4-L Farms, Allegan County
b Crawford Farms, Montcalm County
c Hampton Potato Growers, Bay County
d Horkey Brothers, Monroe County
e Jenkins Farms, Kalkaska County
f Kitchen Farms, Antrim County
g Kitchen Farms Mini Bulk, Antrim County
h Styma Potato Farms, Presque Isle County
i Verbrigghe Potato Farms, Delta County
j Walther Farms Early Generation, Tuscola County
k Walther Farms Replicated, Tuscola County

[1]**SIZE**
Non-russet tablestock
Bs: < 1 7/8"
As: 1 7/8" - 3 1/4"
OV: > 3 1/4"
PO: Pickouts

[2]**SPECIFIC GRAVITY**
Data not replicated

[3]**RAW TUBER QUALITY**
(percent of tubers out of 10)
HH: Hollow Heart
VD: Vascular Discoloration
IBS: Internal Brown Spot
BC: Brown Center

[4]**COMMON SCAB RATING**
0.0: Complete absence of surface or pitted lesions
1.0: Presence of surface lesions
2.0: Pitted lesions on tubers, though coverage is low
3.0: Pitted lesions common on tubers
4.0: Pitted lesions severe on tubers
5.0: More than 50% of tuber surface area covered in pitted lesions

[5]**VINE VIGOR RATING**
Date: Variable
Rating 1-5
1: Slow emergence
5: Early emergence

[6]**VINE MATURITY RATING**
Date: Variable
Rating 1-5
1: Early (vines completely dead)
5: Late (vigorous vines, some flowering)

[7]**WAXINESS RATING**
1: Heavy netting, buff
5: Waxy, smooth

[8]**FLESH COLOR**
1: White
5: Dark yellow

[9]**SKIN COLOR**
1: Light pink
5: Dark red

[10]**UNIFORMITY OF SKIN COLOR**
1: Highly variable, non-uniform
5: Highly uniform, color throughout

[11]**SILVER SCURF**
0: No incidence of silver scurf
5: High incidence of silver scurf

Walther NFPT and Added Lines

Planting: 4/16/19 Vine Kill: 8/19/19 Harvest: 9/18/19

GDD_{40}: 3243

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR[2]	RAW TUBER QUALITY[4] (%) HH	VD	IBS	BC	COMMON SCAB RATING[5]	VINE VIGOR[7]	VINE MATURITY[8]	COMMENTS
AOR13064-2	594	643	92	5	87	5	3	1.087	0	40	0	0	0.0	4.0	2.5	good overall appearance
ND113100-1Russ	515	654	79	5	55	24	16	1.071	10	20	0	0	0.0	3.0	2.0	pointed ends
ND13243B-3Russ	503	825	61	14	59	2	25	1.076	0	0	10	0	0.5	3.0	3.5	severe bottlenecking
A11188-1	492	542	91	4	71	20	5	1.064	0	0	0	0	1.0	3.0	3.0	trace growth crack, alligator hide
A10071-1	481	569	85	15	79	6	0	1.071	0	0	0	0	0.0	4.5	4.0	nice dark russet skin type, good appearance
A10595-13sto	477	688	69	25	61	8	6	1.071	10	0	0	20	0.0	4.0	2.0	lighter russet, alligator hide, non uniform
AF5492-6	462	555	83	15	73	10	2	1.079	0	10	0	0	0.0	3.5	3.5	nice type and appearance
OR12133-10	461	754	61	16	54	7	23	1.089	0	0	0	0	0.5	3.5	4.0	pointed, misshapen, non uniform type
A10594-8VR	459	624	74	12	63	11	14	1.093	80	10	0	20	0.0	3.5	5.0	moderate to severe pinkeye, irregular tuber type
COA11013-2	456	460	72	21	70	2	7	1.066	10	20	10	0	0.5	4.0	3.0	gc, misshapen
ND12241YB-2Russ	446	616	73	11	60	13	16	1.089	20	0	20	0	0.5	2.5	2.5	pointed, misshapen
A10007-3	431	525	82	11	71	11	7	1.063	0	10	10	0	0.0	4.0	4.5	moderate alligator hide, non uniform
AOR11217-3	404	560	72	21	71	1	7	1.085	30	20	0	0	0.0	3.5	3.0	tubular
A12115-16sto	385	677	57	34	55	2	9	1.075	0	20	0	0	0.5	3.5	3.5	variable skin color, pointed ends, black dot
A10508-2LB	377	498	76	12	69	7	12	1.077	0	0	30	0	0.5	3.0	3.5	knobs, points, moderate alligator hide
ND13242B-8Russ	374	469	80	15	70	10	5	1.077	0	0	0	0	0.5	2.0	3.0	non uniform tuber type
A10611-3adg	363	571	63	15	62	1	22	1.072	0	20	0	0	0.0	2.5	3.0	bottlenecking, misshapen
A09086-1LB	352	502	70	15	57	13	15	1.092	0	0	0	0	0.5	4.0	4.5	light skin, light russetting
A11194-1	338	415	72	18	71	1	10	1.069	0	10	0	0	0.0	4.0	4.0	
A11326-1	337	602	56	20	56	0	24	1.092	20	10	0	10	0.5	3.0	4.0	heat sprouting, alligator hide
AOR08540-1	333	581	57	29	57	0	14	1.078	50	10	0	10	0.5	3.0	3.0	tubular, bottlenecking
CO11009-3RU	327	446	74	19	70	4	7	1.074	100	0	0	0	1.0	1.0	3.5	nice dark russet skin type, good appearance
A11234-2	327	477	69	22	65	4	9	1.075	0	0	0	0	0.5	3.0	4.0	light russeting
ND13288-2Russ	319	489	65	28	64	1	7	1.083	0	10	0	0	0.5	3.5	2.0	bottleneck
A09119-4LB	318	433	74	14	71	3	12	1.079	0	0	0	0	0.5	3.5	4.0	non uniform tuber type, gc
AOR12149-1	268	567	48	7	44	4	45	1.066	0	40	0	0	0.5	4.0	3.0	tubular, knobby, bottlenecking, gc
A07769-4	267	343	78	20	77	1	2	1.074	0	20	0	0	0.5	3.0	3.0	smaller uniform tuper type
Ranger Russet	**255**	**517**	**49**	**28**	**49**	**0**	**23**	**1.094**	**0**	**0**	**0**	**0**	**0.5**	**3.0**	**3.5**	**tubular, bottlenecking**
A12114-7	217	342	64	23	60	4	13	1.077	0	10	0	0	0.0	3.0	3.0	gc, bottlenecking
A12314-1sto	204	348	58	25	58	0	17	1.078	0	10	0	0	0.5	3.0	3.5	non uniform tuber type
A11737-1LB	198	283	70	23	67	3	7	1.068	0	10	0	0	1.5	3.0	3.0	
AO02183-2	189	502	38	42	38	0	20	1.079	10	20	0	0	0.0	3.0	2.5	poor type and appearance
CO10094-5RU	62	149	41	52	40	1	7	1.075	0	0	0	0	0.0	1.0	3.0	
Russet Burbank	**49**	**540**	**9**	**33**	**9**	**0**	**58**	**1.076**	**0**	**10**	**0**	**0**	**0.0**	**3.5**	**3.0**	**poor quality, many pickouts**
ND13243B-14Russ														2.0	2.0	

WAF14006-6	555	655	84	7	71	13	9	1.072	0	10	10	0	0.0	3.0	2.5	nice appearance, but severe gc in pos
COAF13066-1	554	670	83	12	64	19	5	1.084	0	10	0	0	0.0	3.0	3.0	
AF6073-3	543	679	80	7	50	30	13	1.070	10	10	0	0	0.0	3.0	3.0	has pink eyes
AF6104-11	536	693	77	15	58	19	8	1.069	0	20	0	0	0.5	4.0	2.5	rot, misshapen Pos
AAF10736-2	489	792	62	29	59	3	9	1.081	0	30	0	0	0.5	4.0	3.0	pointed, netting, light russetting
WAF14010-3	481	555	86	11	81	5	3	1.071	0	10	20	0	0.0	3.5	2.0	dark skin, trace black dot
AF6061-1	469	659	71	8	53	18	21	1.083	0	50	0	0	1.0	2.5	4.0	non uniform tuber type
AF6075-1	462	791	59	36	33	26	5	1.066	0	10	0	0	0.0	4.5	3.0	done
NDAF1316Y-1	452	695	66	16	58	8	18	1.074	0	20	0	0	0.0	3.5	2.5	pointed misshapen pos, non uniform tubers
AF6075-9	426	741	58	18	53	5	24	1.061	0	20	0	0	0.0	3.0	3.0	bottleneck, misshapen, heat sprouts
AF6104-6	416	527	79	17	63	16	4	1.071	0	20	0	0	0.0	3.5	3.0	attractive tuber type
COTX08063-2Rus	408	535	76	21	74	2	3	1.102	0	10	0	0	0.5	4.0	3.0	
AF6110-3	408	545	75	10	48	27	15	1.067	20	10	0	10	0.5	3.5	3.0	poor type and appearance
AF6086-7	402	519	77	20	75	2	3	1.072	0	30	0	0	0.0	3.5	1.5	smaller uniform tuber type
COAF13004-1	401	507	79	19	78	1	2	1.082	0	10	0	0	0.0	3.0	2.0	
WAF13027-2	400	450	89	9	74	15	2	1.064	0	10	0	0	0.0	3.0	1.5	very good type and appearance
COAF11018-10	398	458	87	11	85	2	2	1.077	0	20	0	0	0.0	2.5	1.5	nice type and appearance
AF6075-8	393	962	41	10	34	7	49	1.068	0	20	0	0	0.5	4.0	3.0	many misshapen tubers
AAF11263-1	390	457	86	5	62	24	9	1.099	0	10	0	0	0.5	2.0	3.0	minor scurf, trace black dot
AAF09137-1	384	705	54	17	51	3	29	1.078	0	10	10	0	0.0	3.5	3.0	tubular, bottlenecking
WAF14165-7	380	437	87	9	71	16	4	1.073	0	30	0	0	0.0	3.0	1.5	nice dark russet skin type, good appearance
AF5735-8	347	497	70	21	63	7	9	1.070	20	0	0	0	1.0	2.5	3.5	
AF6118-5	329	677	49	8	47	2	43	1.085	0	10	0	0	0.5	2.5	3.5	bottlenecking
AF6132-4	326	818	40	13	31	9	47	1.069	10	10	10	20	0.0	4.0	3.0	light russeting, bottlnecking, misshapen
COTX08322-10Rus	301	445	68	18	58	10	14	1.070	0	30	0	0	0.0	3.0	2.5	growth crack
AF6079-3	277	380	73	23	69	4	4	1.075	0	0	0	0	0.0	3.5	3.5	
AAF10536-3	264	476	55	17	53	2	28	1.089	0	10	0	0	0.0	3.0	2.5	bottlenecking
AF6073-5														4.0	3.0	
MEAN	**381**	**559**	**68**	**18**	**61**	**8**	**14**	**1.077**	**7**	**12**	**2**	**1**	**0.3**	**3.2**	**3.0**	

[1]**SIZE**
Russets
Bs: < 4 oz
As: 4 - 10 oz
OV: > 10 oz
PO: Pickouts

[2]**SPECIFIC GRAVITY**
Data not replicated

[3]**RAW TUBER QUALITY**
(percent of tubers out of 10)
HH: Hollow Heart
VD: Vascular Discoloration
IBS: Internal Brown Spot
BC: Brown Center

[4]**COMMON SCAB RATING**
0.0: Complete absence of surface or pitted lesions
1.0: Presence of surface lesions
2.0: Pitted lesions on tubers, though coverage is low
3.0: Pitted lesions common on tubers
4.0: Pitted lesions severe on tubers
5.0: More than 50% of tuber surface area covered in pitted lesions

[5]**VINE VIGOR RATING**
Date: 6/3/19
Rating 1-5
1: Slow emergence
5: Early emergence (vigorous vine, some flowering)

[6]**VINE MATURITY RATING**
Date: 8/12/19
Rating 1-5
1: Early (vines completely dead)
5: Late (vigorous vines, some flowering)

FIELD DATA

Planting Date	4/16/19
Vine Kill Date	8/19/19
Harvest Date	9/18/19
Days (planting to vine kill)	125
Days (planting to harvest)	155
GDD_{40} MAWN Station	Mendon
GDD_{40} (planting to vine kill)	3243
Seed Spacing	10"

2019 Tablestock Potato Variety Trial
Walther Farms Early Generation Selection

Planting: 5/15/19 Vine Kill: 8/26/19 Harvest: 9/19/19

GDD_{40}: 2781

		CWT/A		PERCENT OF TOTAL[1]						RAW TUBER QUALITY[4] (%)							YELLOW FLESH		RED SKIN				
	LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR[2]	HH	VD	IBS	BC	COMMON SCAB RATING[5]	VINE VIGOR[7]	VINE MATURITY[8]	WAXINESS[7]	FLESH COLOR[8]	WAXINESS[7]	SKIN COLOR[9]	UNIFORMITY[10]	SILVER SCURF[11]	COMMENTS
YELLOW	Queen Anne	312	501	62	36	62	0	2	1.064	0	20	0	0	0.0	3.0	2.0	3.0	3.0					
	ATX05202S-3W/Y	257	373	69	31	69	0	0	1.085	0	0	0	0	0.5	3.5	2.5	2.0	2.0					flattened oval type
	MEAN	285	437	66	33	66	0	1	1.075	0	10	0	0	0	3.3	2.3	2.5	2.5					
RED SKIN TYPE	NDAF113484B-1	502	563	89	7	89	0	3	1.065	0	30	0	0	0.0	4.0	2.0			4.0	4.0	4.0	1.0	high yield, good color, some scurf
	ND1394-5RY	423	455	93	5	93	0	2	1.074	0	40	0	0	0.5	4.0	2.5			3.0	3.0	4.0	3.0	good size, round, slight netting
	FC160106-1R/Y	419	460	91	9	91	0	0	1.071	0	10	10	0	0.5	4.0	3.0			3.5	4.0	4.5	2.0	
	ND13136Y-2R	415	490	85	15	85	0	0	1.081	0	10	0	0	0.0	5.0	1.5			2.0	4.0	4.0	2.5	uniform size, netting, red purple skin
	ND14113Y-5R	409	430	95	4	95	0	1	1.073	0	0	0	0	0.0	3.5	2.5			2.5	2.5	3.0	2.5	good color, oval, sl flattened, some net and scurf
	MSURed Marker #2	355	380	94	5	88	5	2						0.0	4.0	3.0							
	CO00277-2R	341	373	91	7	91	0	2	1.085	0	30	0	0	0.0	2.0	3.0			3.0	4.5	4.0	1.5	good color and size
	ND14113Y-3R	338	413	82	18	82	0	0	1.081	0	0	0	0	0.0	4.0	2.0			2.5	3.0	3.0	3.0	some points and scurf, good shape, some net
	MSAA182-3R	333	474	70	30	70	0	0	1.075	0	30	0	0	0.0	4.0	3.5			4.0	4.0	4.0	0.5	uniform
	CO15205-4R	304	346	88	11	88	0	1	1.079	0	30	0	0	0.0	4.5	2.0			3.5	4.0	4.0	3.0	nice color, round, netted scurf
	NDTX4784-7R	273	292	93	7	93	0	0	1.060	0	20	10	0	0.0	2.0	2.5			4.0	4.0	3.5	1.0	uniform round tuber type
	ND1438Y-6R	269	338	79	21	79	0	0	1.076	0	50	0	0	0.0	2.5	3.0			3.5	3.0	4.0	1.0	sticky stolons, round, medium color
	ND1411Y-1R	267	291	92	8	92	0	0	1.095	0	10	0	0	0.0	4.0	1.5			3.5	2.0	3.0	3.0	some net, nice shape and skin color
	CO15211-5R	266	377	70	29	70	0	1	1.068	0	20	0	0	0.0	4.0	2.0			3.5	6.0	4.0	3.5	oblong to oval shape, nice skin
	ND1466CB-1R	265	322	82	15	82	0	3	1.072	60	10	0	0	0.0	3.0	1.5			2.0	3.0	3.5	4.0	some scurf, but nice type and darker red color
	ND13292B-3R	260	332	78	22	78	0	0	1.076	0	20	0	0	2.0	3.0	2.0			3.5	4.0	3.0	2.0	dark red color, sl pitted scab, sl scurf
	CO14105-1R	254	290	88	12	88	0	0	1.064	0	20	0	0	0.5	3.0	3.0			4.0	4.0	4.0	2.0	oval, some skinning, few gc
	CO14074-1R	249	366	68	32	68	0	0	1.074	0	30	0	0	0.0	3.5	2.5			4.0	4.0	3.5	0.5	small/mini, some scurf, good color
	CO15084-6R	248	406	61	34	61	0	5	1.062	0	10	10	0	0.0	3.0	3.0			3.5	3.5	4.0	1.5	dark skin, scurf
	AF6027-2	232	275	85	9	84	0	6	1.079	0	0	0	0	0.0	3.5	3.0							attractive shape
	CO14040-3R	215	370	58	41	58	0	1	1.071	0	0	0	0	0.0	3.0	2.0			3.5	2.5	4.0	1.5	smooth waxy skin, silver scurf, small and uniform
	CO15219-3R	201	382	53	47	53	0	0	1.085	0	10	0	0	1.0	3.5	3.0			4.0	4.0	3.5	2.5	nice shape, some scurf, mini
	CO14048-2R	188	321	59	40	59	0	1	1.074	0	0	0	0	0.0	3.0	2.0			2.5	2.5	3.5	3.0	nice red skin, oval, consistent type,, silver scurf
	ND13236C-10R	152	287	53	44	53	0	3	1.070	0	30	0	0	0.0	2.5	2.0			3.5	3.5	3.5	2.0	small, uniform, some rhizoc, few pears
	CO15084-4R	145	249	58	42	58	0	0	1.075	0	10	0	0	0.0	2.5	3.0			3.5	3.5	4.0	1.5	dark red min,i some netting
	CO14043-2R	118	208	57	42	57	0	1	1.068	0	20	0	0	0.0	2.5	2.0			1.5	2.0	3.5	3.5	some silver scurf, nice shape and type
	MSFF148-1R	111	457	73	27	73	0	0	1.074	0	0	0	0	0.0	4.5	3.0			4.5	5.0	4.5	0.5	unique purple red, round, sl deep eyes
	CO15233-1R	105	239	44	56	44	0	0	1.076	0	30	0	0	0.0	3.0	2.5			3.5	4.0	4.0	1.0	good color, mini, sl skinning
	CO15206-1R/Y	103	193	54	46	54	0	0	1.073	0	20	0	0	0.0	4.0	1.5			4.0	3.5	4.0	1.0	mini, round, nice skin
	ND13236C-3R	91	207	44	56	44	0	0	1.074	0	20	0	0	0.5	2.5	2.5			3.0	3.5	4.0	1.0	small, mini, uniform
	MSFF305-2R	91	310	88	12	88	0	0	1.082	0	40	0	0	0.0	4.5	3.0			2.5	4.5	4.0	2.0	nice red color, sl deep eyes
	MSFF305-1R	82	276	89	11	89	0	0	1.076					0.0	4.0	3.0			2.5	4.5	4.0	1.0	good color, sl net
	Isle Royale (MSX569-1R)	64	91	70	30	70	0	0	1.053	0	20	0	0	0.0	3.0	2.0			4.0	4.0	4.0	0.5	
	ND13292B-1R	56	152	37	63	37	0	0	1.078	0	30	0	0	0.0	3.5	2.0			3.0	3.5	4.0	2.0	good color, mini, ok shape, some scurf
	MSFF339-2R	40	189	63	38	63	0	0	1.065	0	20	0	0	0.0	4.0	3.0			2.0	3.5	3.5	2.5	good color, some pears
	CO15121-1R	35	145	24	76	24	0	0							4.0	1.5							nice dark skin, mini, round
	MSFF225-04R	26	153	50	49	50	0	0	1.070	0	10	0	0	0.0	3.5	3.0			2.5	2.5	4.0	2.0	unique red purple skin, sl scurf
	CO15121-3R	23	89	25	74	25	0	0	1.078						3.5	1.0							nice, uniform, small, waxy, smooth
	MSFF141-01R	21	134	46	54	46	0	0	1.079	0	20	0	0	0.0	3.5	3.0			4.5	4.5	4.5	2.0	red to purple skin, oval
	MSFF138-04R	11	116	28	72	28	0	0	1.091	0	0	20	0	0.0	2.0	2.5			4.5	4.0	4.0	0.5	no scurf, good shape
	MEAN	207	306	69	31	69	0	1	1.074	2	18	1	0	0.1	3.4	2.4			3.3	3.7	3.8	1.9	
	TRIAL MEAN	**211**	**312**	**69**	**31**	**68**	**0**	**1**	**1.074**	**2**	**18**	**1**	**0**	**0.1**	**3.4**	**2.4**	**2.5**	**2.5**	**3.3**	**3.7**	**3.8**	**1.9**	

[1]**SIZE**
Non-russet tablestock
Bs: < 1 7/8"
As: 1 7/8" - 3 1/4"
OV: > 3 1/4"
PO: Pickouts

[2]**SPECIFIC GRAVITY**
Data not replicated

[3]**RAW TUBER QUALITY**
(percent of tubers out of 10)
HH: Hollow Heart
VD: Vascular Discoloration
IBS: Internal Brown Spot
BC: Brown Center

[4]**COMMON SCAB RATING**
0.0: Complete absence of surface or pitted lesions
1.0: Presence of surface lesions
2.0: Pitted lesions on tubers, though coverage is low
3.0: Pitted lesions common on tubers
4.0: Pitted lesions severe on tubers
5.0: More than 50% of tuber surface area covered in pitted lesions

[5]**VINE VIGOR RATING**
Date: 6/25/19
Rating 1-5
1: Slow emergence
5: Early emergence

[6]**VINE MATURITY RATING**
Date: 8/26/19
Rating 1-5
1: Early (vines completely dead)
5: Late (vigorous vines, some flowering)

FIELD DATA

Planting Date	5/15/19
Vine Kill Date	8/26/19
Harvest Date	9/19/19
Days (planting to vine kill)	103
Days (planting to harvest)	127
GDD_{40} MAWN Station	Fairgrove
GDD_{40} (planting to vine kill)	2781
Seed Spacing	10"

[7]**WAXINESS RATING**
1: Heavy netting, buff
5: Waxy, smooth

[8]**FLESH COLOR**
1: White
5: Dark yellow

[9]**SKIN COLOR**
1: Light pink
5: Dark red

[10]**UNIFORMITY OF SKIN COLOR**
1: Highly variable, non-uniform
5: Highly uniform, color throughout

[11]**SILVER SCURF**
0: No incidence of silver scurf
5: High incidence of silver scurf

Volunteer Potato Control-2019 MPIC Research Report

Erin Burns
Assistant Professor-Weed Science
Department of Plant, Soil, and Microbial Sciences
Michigan State University

Potatoes that are left in the field after harvest are considered volunteer potatoes. Historically harsh winter temperatures kill tubers that remain in the field after harvest. Although, in regions where winters are mild and soil temperatures are not cold enough to kill tubers left in the field, tubers can survive overwinter and become a serious weed problem the following spring. Not only do volunteer potatoes compete with crops and reduce yield, but they also harbor insects, diseases, and nematodes that can infest neighboring or future potato crops. Volunteer potatoes may become more problematic in the future given current climate predictions. Further complicating this problem is the fact that volunteer potatoes are difficult to control. Currently, there are no herbicides available that will completely control volunteer potatoes and significantly reduce the number of daughter tubers produced per plant. Research conducted evaluating volunteer potato control in Michigan was last conducted in 2002. Since 2002, new HPPD (4-Hydroxyphenylpyruvate dioxygenase, pigment inhibitors) inhibiting herbicides have been approved for use in corn and may provide additional options for volunteer potato control. Furthermore, combinations of HPPD and PSII (photosystem II) inhibitors exhibit synergistic activity. Therefore, the objective of this demonstration was to evaluate volunteer potato control with HPPD inhibiting herbicides alone and in combination with the PSII inhibitor atrazine to explore potential beneficial herbicide interactions.

This study was conducted at two locations, the Montcalm Research Center near Lakeview, MI and in St. Johns, MI. With the help of Chris Long (MSU Potato Extension Specialist), volunteer potatoes were "planted" on June 15th by scattering seed pieces by hand and working into the ground with a cultipacker. Herbicide treatments (Table 1) were applied on July 17th. Volunteer potatoes that were 6, 12, and 20 inches tall at the time of application were flagged, dug on August 15th, daughter tubers counted, and weighed. Overall, the addition of atrazine to HPPD inhibiting herbicides improved volunteer potato control and in many treatments prevented daughter tuber formation. In general, as the size of volunteer potatoes increased control decreased. The Michigan Potato Industry Commission supported this research.

Table 1. Postemergence herbicide treatment list applied July 17th.

Herbicide Trade name	Rate (Formulation/A)	Additives
Callisto	3 fl oz	1% COC + 8.5 lb/100 gal AMS
Callisto + Aatrex (atrazine) 90 WG	3 fl oz + 0.5 lb a.i.	1% COC + 8.5 lb/100 gal AMS
Armezon/Impact	0.75 fl oz	1% MSO + 17 lb/100 gal AMS
Armezon/Impact + Aatrex 90 WG	0.75 fl oz + 0.5 lb a.i.	1% MSO + 17 lb/100 gal AMS
Laudis	3 fl oz	1% MSO + 8.5 lb/100 gal AMS
Laudis + Aatrex 90 WG	3 fl oz + 0.5 lb a.i.	1% MSO + 8.5 lb/100 gal AMS
Acuron Flexi	2 qt	0.25% NIS
Acuron Flexi + Aatrex 90 WG	2 qt + 0.5 lb a.i.	0.25% NIS

COC = crop oil concentrate, AMS = ammonium sulfate, MSO = methylated seed oil, NIS = nonionic surfactant

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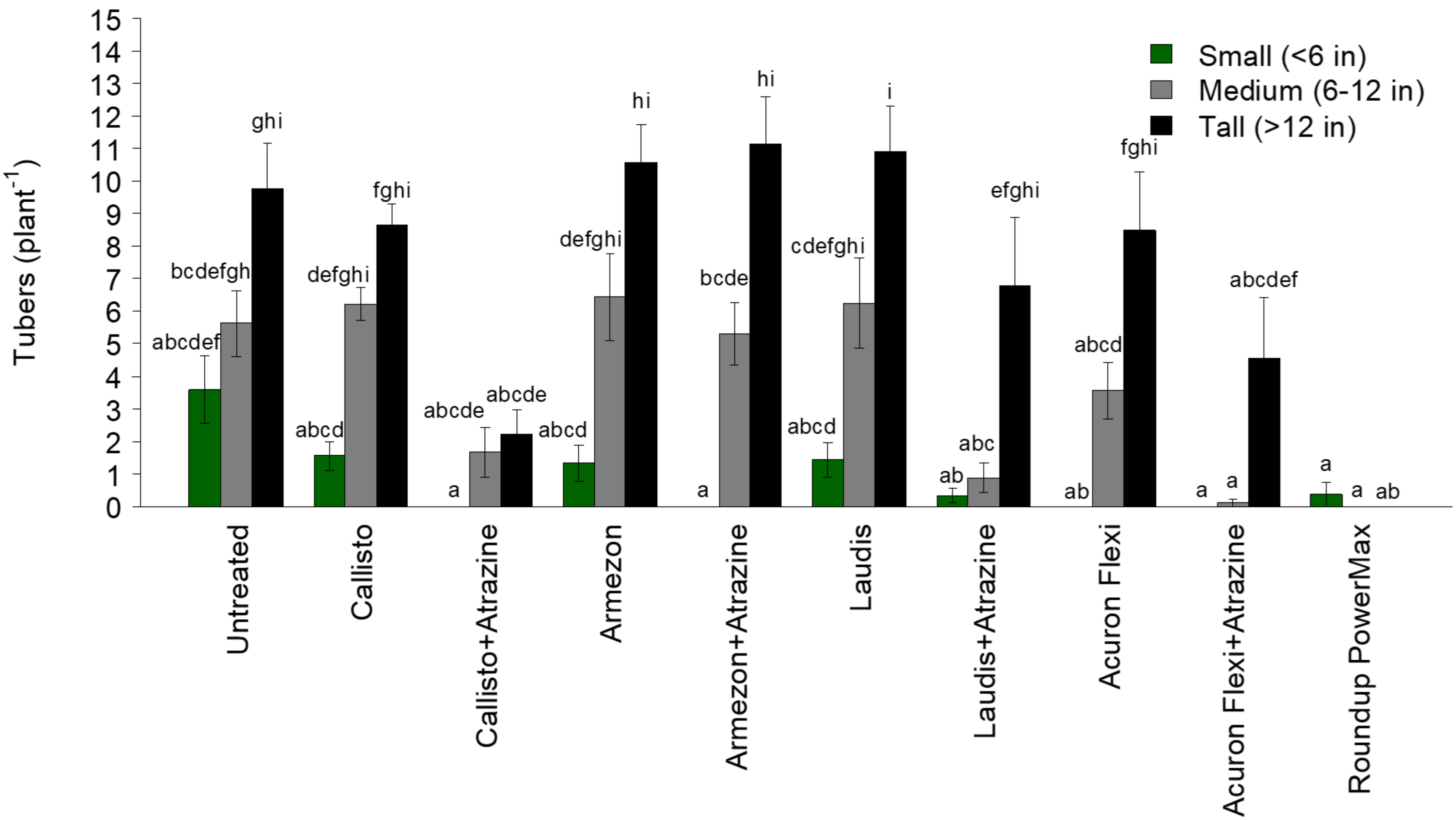

Figure 1. Mean daughter tubers produced per plant at the Montcalm Research Center location. Mean tubers (plant^{-1}) values followed by the same letter are not significantly different ($P \leq 0.05$).

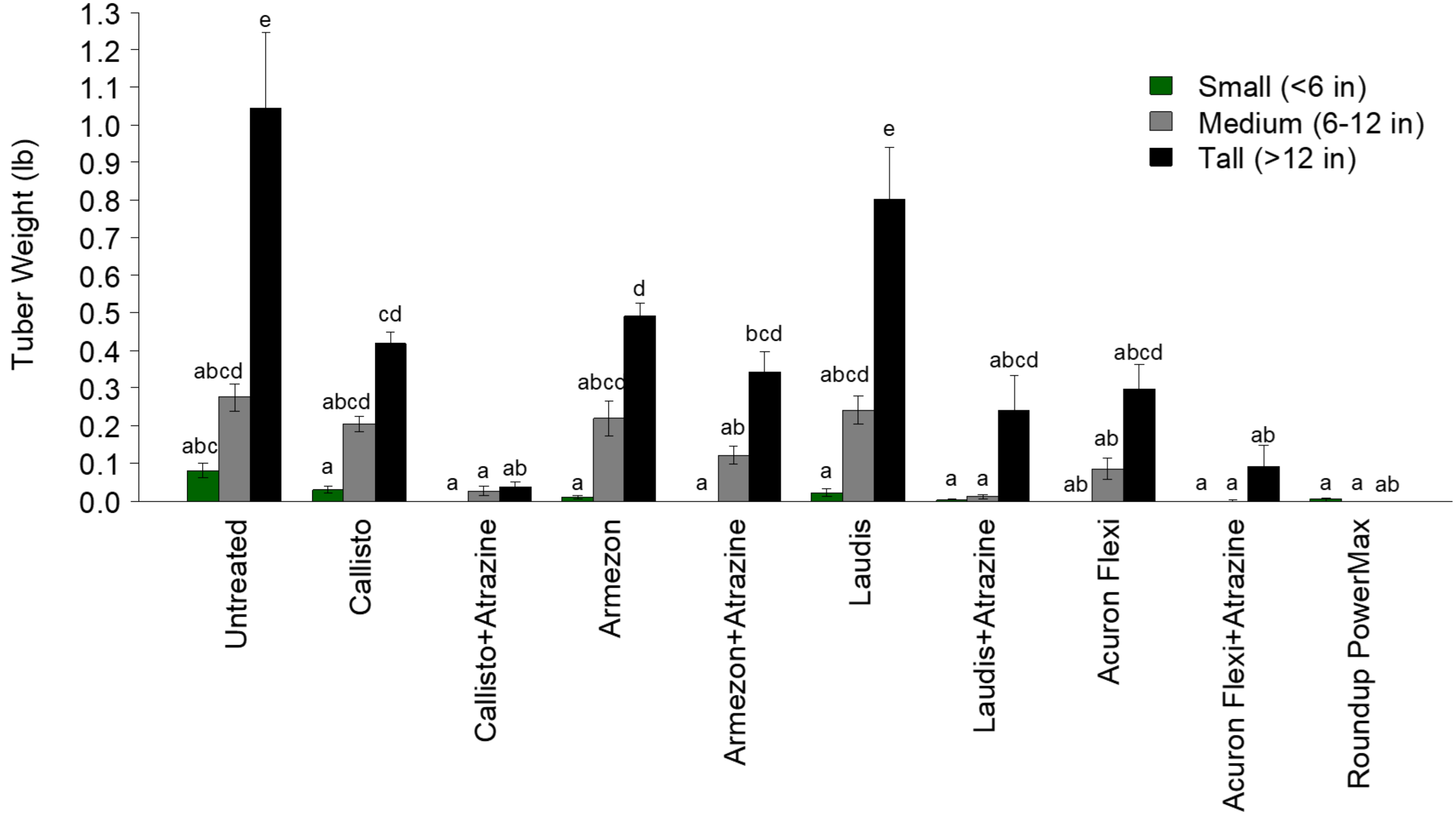

Figure 2. Mean daughter tuber weight at the Montcalm Research Center location. Mean tuber weight values followed by the same letter are not significantly different ($P \leq 0.05$).

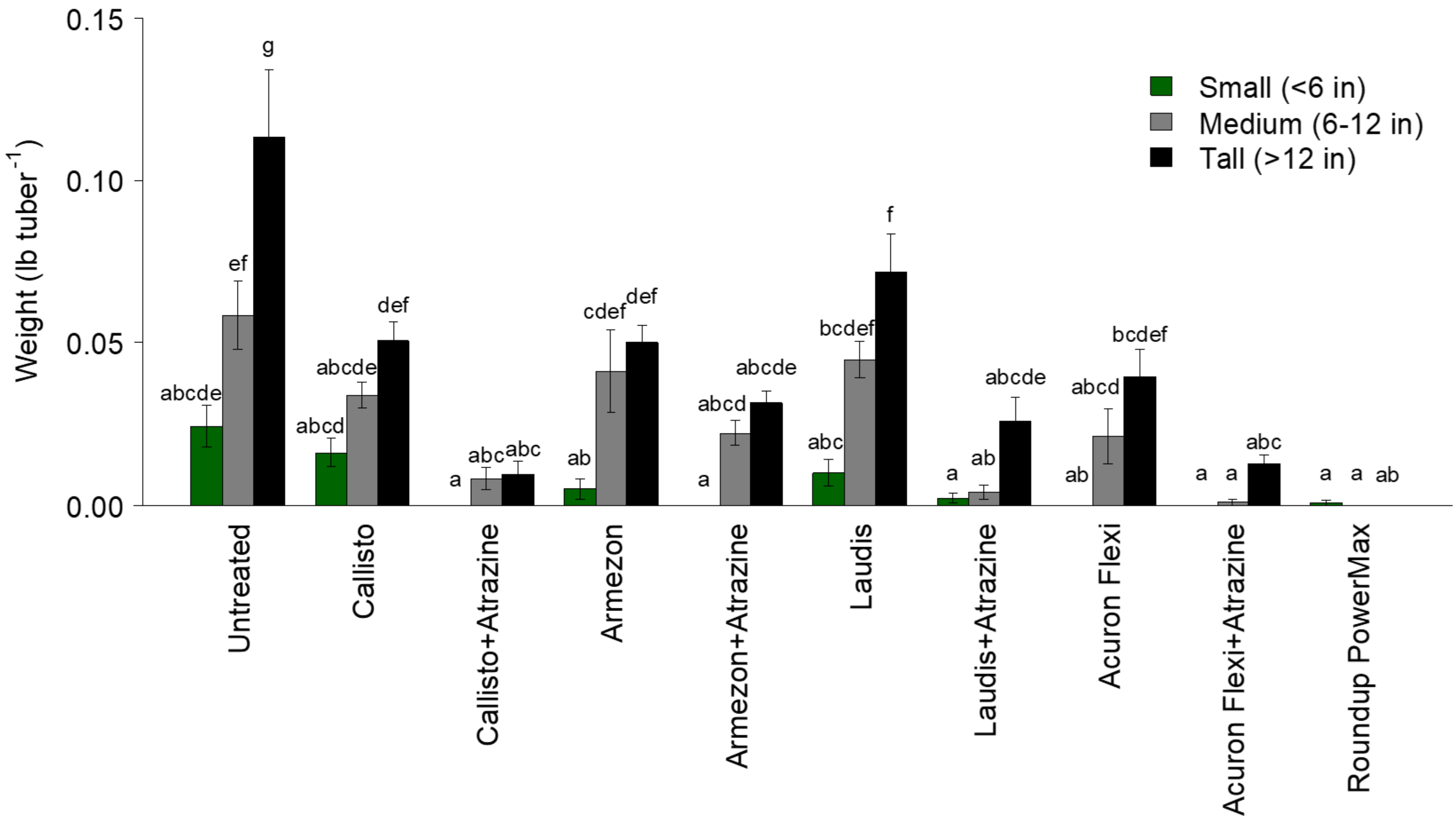

Figure 3. Mean weight per daughter tuber at the Montcalm Research Center location. Mean tuber weight values followed by the same letter are not significantly different (*P* ≤ 0.05).

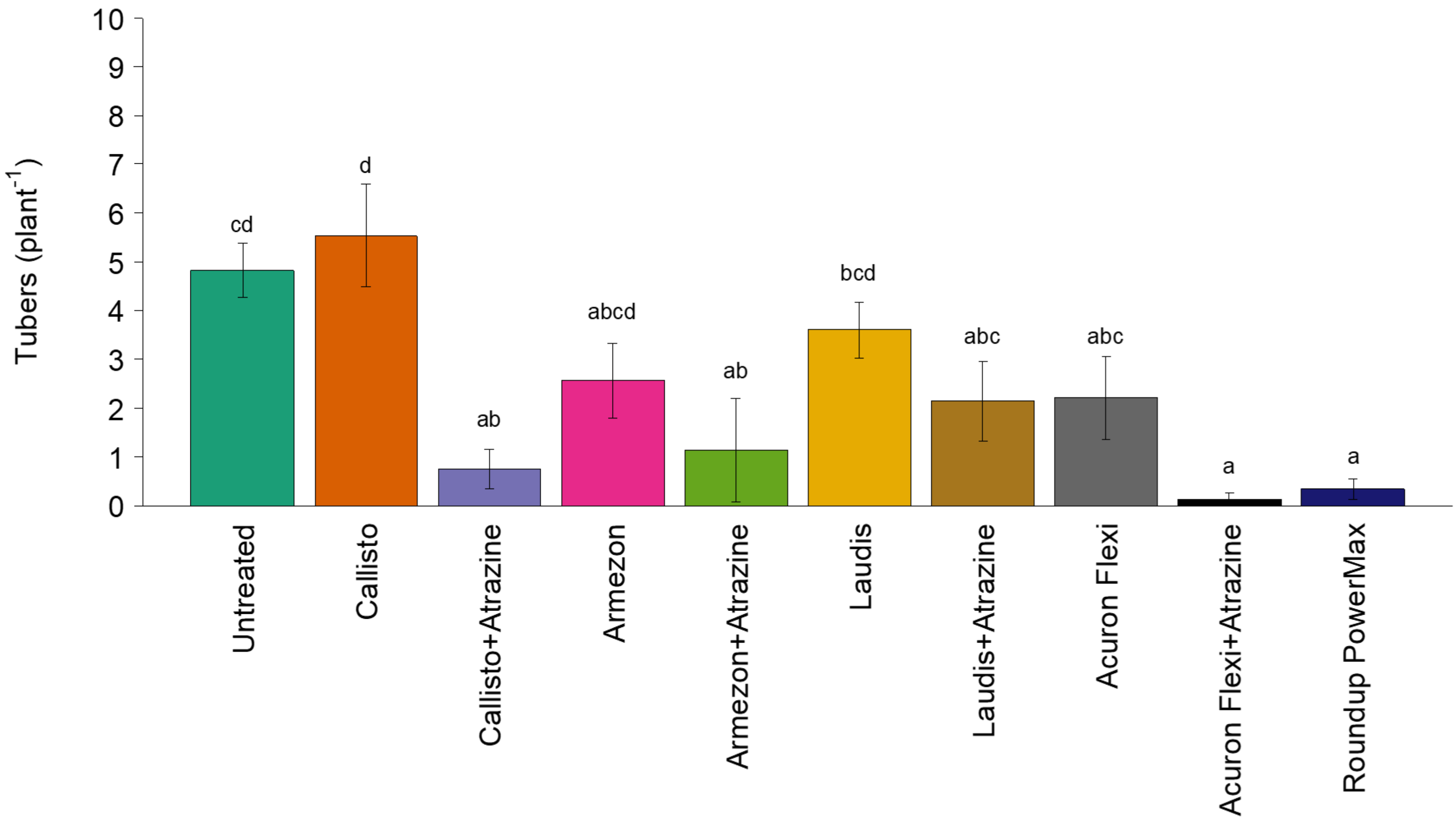

Figure 4. Mean daughter tubers produced per plant at the St. Johns, MI location. Mean tubers (plant^{-1}) values followed by the same letter are not significantly different ($P \leq 0.05$).

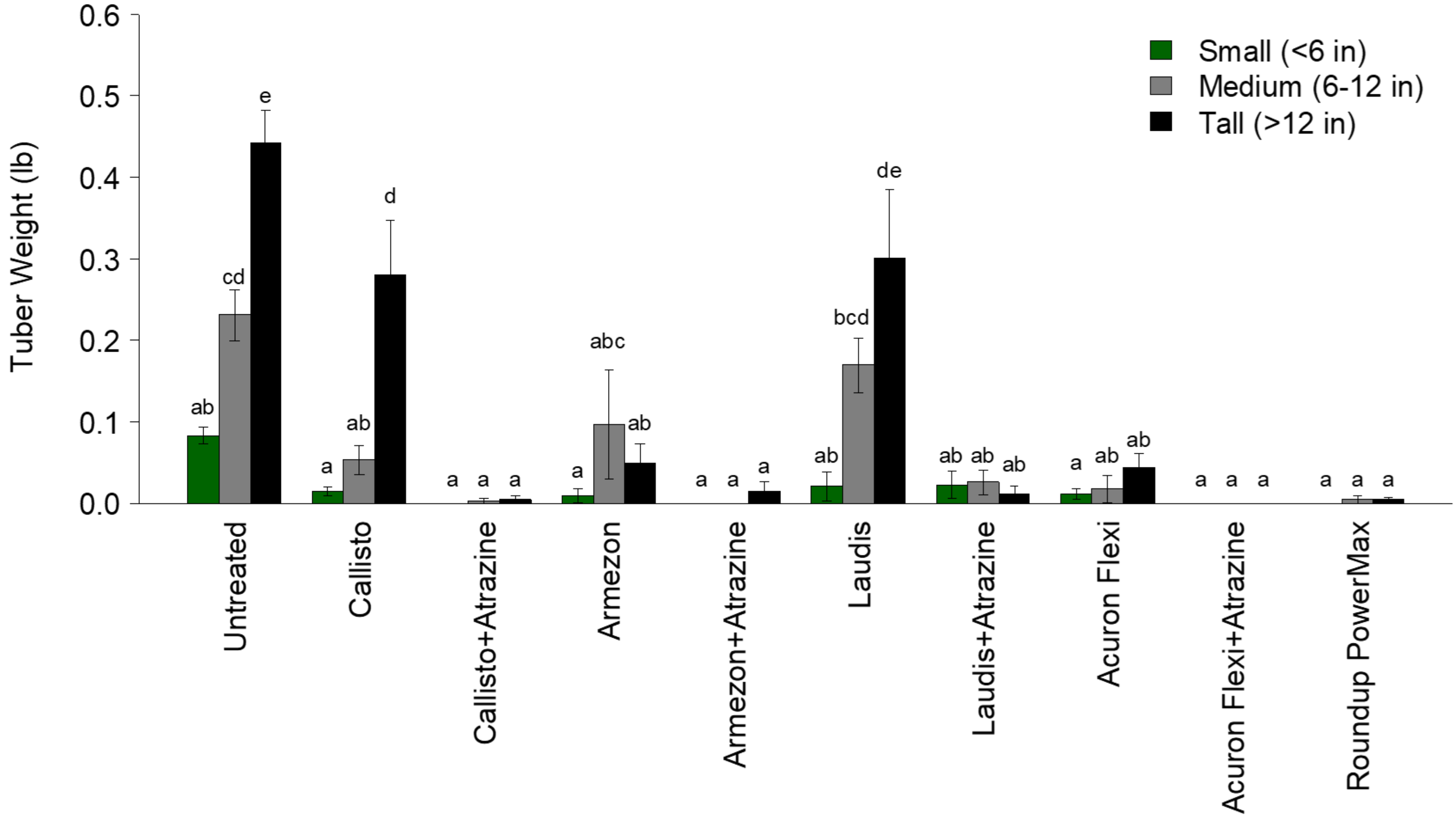

Figure 5. Mean daughter tuber weight at the St. Johns, MI location. Mean tuber weight values followed by the same letter are not significantly different (*P* ≤ 0.05).

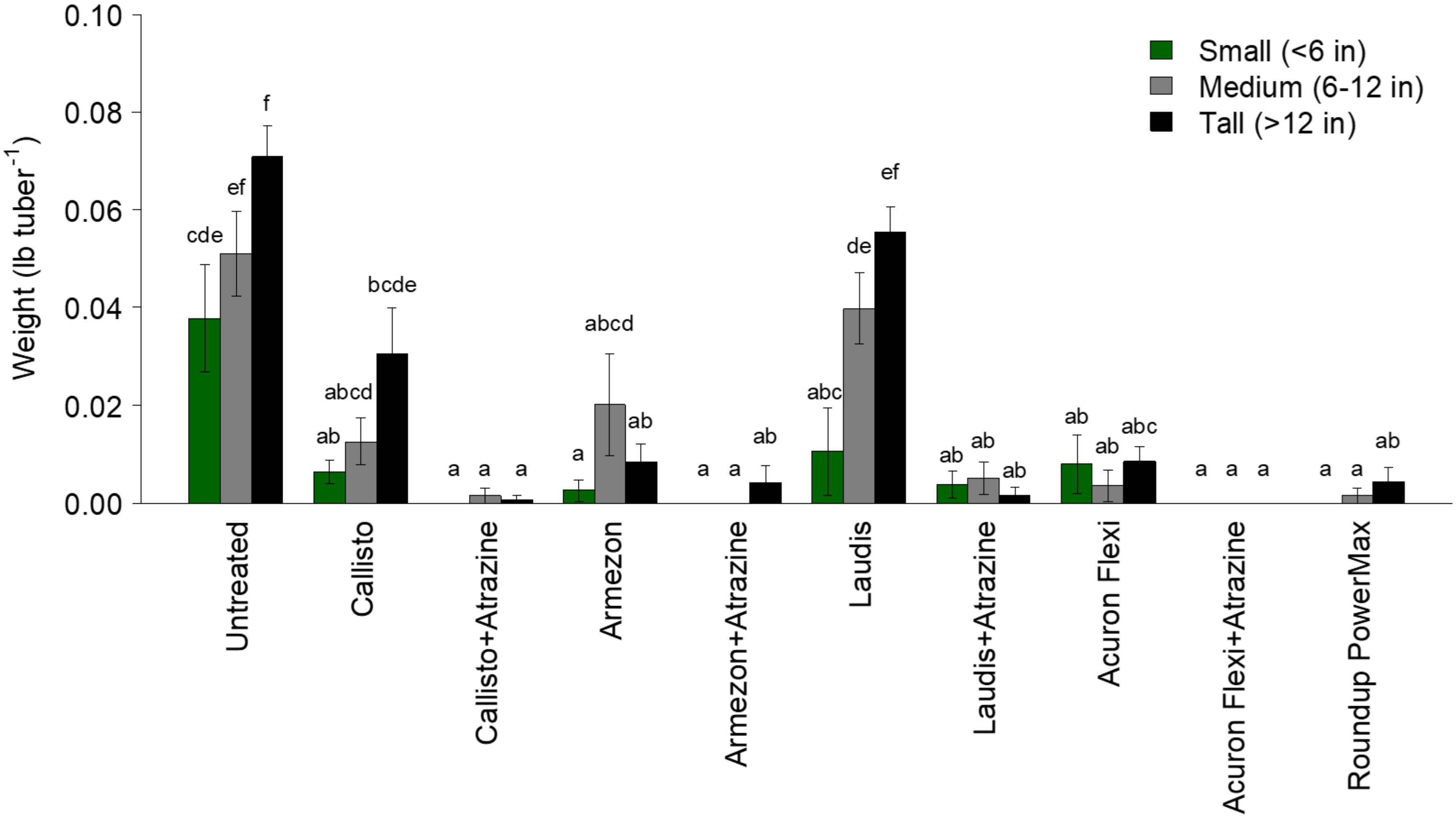

Figure 6. Mean weight per daughter tuber at the St. Johns, MI location. Mean tuber weight values followed by the same letter are not significantly different (*P* ≤ 0.05).

Layering soil residual herbicides for troublesome weed control in potatoes-2019 MPIC Research Report

Erin Burns
Assistant Professor-Weed Science
Department of Plant, Soil, and Microbial Sciences
Michigan State University

Many troublesome weeds (horseweed/marestail, common waterhemp, palmer amaranth, common lambsquarters, and foxtails) in MI are shifting emergence patterns from a single early flush in the spring to extended emergence throughout the summer, therefore outlasting pre-emergence residual herbicide activity. Later emerging weeds can not only have yield impacts, but also be a harvest nuisance. Layering a residual soil-applied herbicide along with the post-emergence herbicide pass is one way to maintain a barrier to weeds emerging later in the growing season. Therefore, objective two is to evaluate layering different group 14 (examples Tuscany/Reflex) and 15 (examples Outlook/Dual) herbicides at two timings for season long weed control. Overall, year one results suggest both group 14 and 15 herbicides provide residual control and layering dual postemergence will improve season long weed control. Data are presented in the table below. The Michigan Potato Industry Commission supported this research.

MSU Weed Science Research Program

Layering residuals for weed control in potatoes

Trial ID: P02-19_Updated
Conducted: Walther Farms (SJ 301)

Study Dir.: Burns, Craft
Investigator: Erin Burns

Planting Date: Mar-27-2019
Variety: Russet
Population:
Soil Type:
Plot Size: 10 X 20 FT

Row Spacing: 34 IN
No. of Reps: 4
% OM:
pH:
Study Design: Randomized Complete Block (RCB)

Tillage/Previous Crops:
Fertilizer:

Crop and Weed Description

Weed	**Code**	**Common Name**	**Scientific Name**
1	CERAR	Field chickweed	Cerastium arvense
2	CHEAL	common lambsquarters	Chenopodium album
3	MALNE	Common mallow	Malva neglecta
4	AMBEL	Common ragweed	Ambrosia artemisiifolia
5	SOLAM	Eastern black nightshade	Solanum ptychanthum
Crop	**Code**	**Common Name**	
1	SOLTU	Potato	

Application Description

	A	**B**
Application Timing:	CRACK	POST
Date Treated:	Apr-23-2019	Jun-7-2019
Time Treated:	12:45 PM	1:45 AM
% Cloud Cover:	95	5
Air Temp., Unit:	55 F	85 F
% Relative Humidity:	57.3	32.2
Wind Speed/Unit/Dir:	7 MPH W	2.5 MPH S
Soil Temp, Unit:	60 F	72 F
Leaf Moist/Dew Presence (Y/N):		
Soil Moist:	3	2

Crop Stage at Each Application

	A	**B**
Crop 1 Name:	SOLTU	SOLTU
Height:		18 IN
Stage:		

Weed Stage at Each Application

	A	**B**
Weed 1 Name:	CERAR	CERAR
Height:		2 IN
Stage:		
Weed 2 Name:	CHEAL	CHEAL
Height:		3 IN
Stage:		
Weed 3 Name:	MALNE	MALNE
Height:		3 IN
Stage:		
Weed 4 Name:	AMBEL	AMBEL
Height:		4 IN
Stage:		
Weed 5 Name:	SOLAM	SOLAM
Height:		4 IN
Stage:		

Application Equipment

Appl	**Sprayer Type**	**Ground Speed**	**Nozzle Type**	**Nozzle Size**	**Nozzle Height**	**Nozzle Spacing**	**Boom Width**	**Spray Volume**	**Carrier**	**Operation Pressure**
A	BACKPA		AIXR	11003	20 IN	20 IN	100 IN	19 GAL/AC	WATER	33 PSI
B	BACKPA		AIXR	11003	20 IN	20 IN	100 IN	19 GAL/AC	WATER	33 PSI

Comments:

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Michigan State University

Layering residuals for weed control in potatoes

Trial ID: P02-19_Updated Location: Walther Farms (SJ 301) Trial Year: 2019
Protocol ID: P02-19* Investigator: Erin Burns
Project ID: Study Director: Burns, Craft
Sponsor Contact:

Pest Code						CERAR		CERAR	ANGR	CHEAL	MALNE	AMBEL
Crop Type, Code					SOLTU		SOLTU					
Rating Date					May-10-2019	May-10-2019	Jun-7-2019	Jun-7-2019	Jun-7-2019	Jun-7-2019	Jun-7-2019	Jun-7-2019
Rating Type					percent	percent	percent	percent	percent	percent	percent	percent
Rating Unit					injury	control	injury	control	control	control	control	control
Trt-Eval Interval					17 DA-A	17 DA-A	45 DA-A	45 DA-A	45 DA-A	45 DA-A	45 DA-A	45 DA-A
Trt No.	Treatment Name	Rate	Rate Unit	Appl Code								
1	Dual II Magnum	1.33	pt/a	A	0.0	100.0	0.0	100.0	85.0	98.8	82.5	82.5
1	Lorox DF	2	lb/a	A								
1	Dual II Magnum	1.33	pt/a	B								
2	Dual II Magnum	1.33	pt/a	A	0.0	97.8	0.0	92.5	96.3	98.8	76.3	100.0
2	Lorox DF	2	lb/a	A								
3	Reflex	1	pt/a	A	0.0	95.8	0.0	92.5	87.5	97.5	83.8	100.0
3	Lorox DF	2	lb/a	A								
3	Matrix	1.5	oz/a	A								
3	Dual II Magnum	1.33	pt/a	B								
4	Reflex	1	pt/a	A	0.0	100.0	0.0	96.3	81.3	98.8	87.5	100.0
4	Lorox DF	2	lb/a	A								
4	Matrix	1.5	oz/a	A								
5	Untreated				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	Valor SX	1.5	oz/a	A	0.0	97.5	0.0	98.8	75.0	98.8	100.0	100.0
6	Matrix	1.5	oz/a	A								
6	Dual II Magnum	1.33	pt/a	B								
7	Valor SX	1.5	oz/a	A	0.0	97.8	0.0	100.0	97.5	100.0	100.0	100.0
7	Matrix	1.5	oz/a	A								
8	Zidua SC	2.5	fl oz/a	A	0.0	96.3	0.0	100.0	82.5	100.0	93.8	100.0
8	Lorox DF	2	lb/a	A								
8	Dual II Magnum	1.33	pt/a	B								
9	Zidua SC	2.5	fl oz/a	A	0.0	97.0	0.0	91.3	77.5	92.5	88.8	98.8
9	Lorox DF	2	lb/a	A								
10	Dual II Magnum	2	pt/a	A	0.0	96.3	0.0	91.3	97.5	100.0	82.5	98.8
10	Lorox DF	2	lb/a	A								
LSD P=.05					.	5.47	.	10.12	22.12	5.19	27.46	16.06
Standard Deviation					0.00	3.77	0.00	6.97	15.25	3.57	18.93	11.07
CV					0.0	4.3	0.0	8.08	19.55	4.04	23.81	12.58

Could not calculate LSD (% mean diff) for columns 1,3,9,10,16 because error mean square = 0.

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Michigan State University

Layering residuals for weed control in potatoes

Trial ID: P02-19_Updated Location: Walther Farms (SJ 301) Trial Year: 2019
Protocol ID: P02-19* Investigator: Erin Burns
Project ID: Study Director: Burns, Craft
Sponsor Contact:

Pest Code				EBN		CERAR	ANGR	CHEAL	MALNE	AMBEL	EBN
Crop Type, Code					SOLTU						
Rating Date				Jun-7-2019	Jul-7-2019	Jul-7-2019	Jul-7-2019	Jul-7-2019	Jul-7-2019	Jul-7-2019	Jul-7-2019
Rating Type				percent	percent	percent	percent	percent	percent	percent	percent
Rating Unit				control	injury	control	control	control	control	control	control
Trt-Eval Interval				45 DA-A	30 DA-B	30 DA-B	30 DA-B	30 DA-B	30 DA-B	30 DA-B	30 DA-B
Trt No.	Treatment Name	Rate Rate Unit	Appl Code								
1	Dual II Magnum	1.33 pt/a	A	100.0	0.0	97.5	90.0	97.5	91.3	92.5	100.0
1	Lorox DF	2 lb/a	A								
1	Dual II Magnum	1.33 pt/a	B								
2	Dual II Magnum	1.33 pt/a	A	100.0	0.0	72.5	76.3	83.8	78.8	80.0	80.0
2	Lorox DF	2 lb/a	A								
3	Reflex	1 pt/a	A	100.0	0.0	92.5	87.5	92.5	88.8	100.0	100.0
3	Lorox DF	2 lb/a	A								
3	Matrix	1.5 oz/a	A								
3	Dual II Magnum	1.33 pt/a	B								
4	Reflex	1 pt/a	A	100.0	0.0	81.3	60.0	78.8	67.5	80.0	80.0
4	Lorox DF	2 lb/a	A								
4	Matrix	1.5 oz/a	A								
5	Untreated			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	Valor SX	1.5 oz/a	A	100.0	0.0	98.8	75.0	98.8	100.0	100.0	100.0
6	Matrix	1.5 oz/a	A								
6	Dual II Magnum	1.33 pt/a	B								
7	Valor SX	1.5 oz/a	A	100.0	0.0	80.0	77.5	80.0	80.0	80.0	80.0
7	Matrix	1.5 oz/a	A								
8	Zidua SC	2.5 fl oz/a	A	100.0	0.0	100.0	85.0	100.0	93.8	100.0	100.0
8	Lorox DF	2 lb/a	A								
8	Dual II Magnum	1.33 pt/a	B								
9	Zidua SC	2.5 fl oz/a	A	100.0	0.0	72.5	66.3	78.8	75.0	80.0	80.0
9	Lorox DF	2 lb/a	A								
10	Dual II Magnum	2 pt/a	A	100.0	0.0	77.5	78.8	80.0	72.5	78.8	80.0
10	Lorox DF	2 lb/a	A								
LSD P=.05				.	.	10.54	18.68	6.90	12.21	7.02	.
Standard Deviation				0.00	0.00	7.26	12.87	4.75	8.42	4.84	0.00
CV				0.0	0.0	9.4	18.49	6.02	11.26	6.11	0.0

Could not calculate LSD (% mean diff) for columns 1,3,9,10,16 because error mean square = 0.

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Improving Productivity and Sustainability in Potato Production Systems by Increasing Cropping System Diversity

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Abstract:

Due to commercial production practices, soils in potato systems in Michigan experience a significant level of degradation. Mineral withdrawal, poor soil structure and soil microbial community disruption caused by intensive management practices are considered the primary drivers of soil degradation. Disruption of microbial communities affects both physical and chemical soil properties as they contribute to aggregate formation and control soil organic matter (SOM) accrual, decomposition, and nitrogen (N) mineralization. We are proposing an additive process for current potato production systems that increases cropping system diversity and rebuilds microbial community diversity and function. We propose that increasing diversity in the cropping system will lead to greater soil microbial activity, improve nutrient cycling and pathogen suppression, increase soil physical structure, and ultimately, improve soil productivity and crop yields. We will begin by identifying grass species that can add large amounts of biomass to potato production systems, and act as non-hosts to *Verticillium dahliae* and *Pratylenchus penetrans*, the two interacting organisms that cause potato early die syndrome. The optimal grass species will then be added to a **legume monoculture** commonly used in potato production systems. Results of our research will establish the value of added diversity in a cropping system and provide the potato industry with management recommendations on the efficacy of pearl millet varieties and grasses to improve cropping system productivity. We will document the additive effects of biodiversity in potato cropping systems by measuring changes in microbial community populations and activity. We will quantify these factors by evaluating overall potato yield and tuber quality. The potato industry in Michigan will then have methods to increase cropping system diversity in potato production systems. Potato growers are seeking to optimize cultural practices and biomass production for these new additive cover crop species. A pearl millet optimization trial will occur at Cousineau's Potato Farm in Hardwood, MI. This demonstration trial seeks to optimize mowing timing, seeding mix diversity and rate as well as variety selection to maximize both above and below ground biomass accumulation.

Background:

Due to commercial production practices, soils in Michigan potato cropping systems experience a significant level of degradation. Mineral withdrawal, poor soil structure and soil microbial community disruption caused by intensive management practices are considered the primary drivers of soil degradation. Disruption of microbial communities affects both soil physical and chemical properties because they contribute to aggregate formation and control soil organic matter (SOM) accrual, decomposition, and nitrogen (N) mineralization (Tiemann and Grandy, 2015; Plaza et al., 2013). Under intensive fumigation and tillage practices, soil microbes no longer function at optimal levels to maintain or improve soil structure, SOM and N cycling (Mbuthia et al., 2015; Klose et al., 2006; Toyota et al., 1999). A diverse microbial community also facilitates competition, which maintains a balanced and healthy soil ecosystem. When soil-borne plant pathogens are unchecked by other soil organisms, production systems become out-of-balance, which leads to pathogen pervasiveness and crop failure (Garbava et al., 2004; van Elsas et al., 2002). We propose that increasing diversity in the cropping system will lead to greater soil microbial activity, improve nutrient cycling and pathogen suppression, increase soil physical structure, and ultimately, improve soil productivity and crop yields (Tiemann et al., 2015; van Elsas et al., 2002). We will start by identifying grass species that can add relatively large amounts of biomass to potato production systems, and act as non-hosts to *Verticillium dahliae* and *Pratylenchus penetrans*, the two interacting organisms that cause potato early die syndrome (Phase 1). The optimal grass species will then be added to a legume monoculture commonly used in potato production systems (Phase 2). The addition of one grass species into a potato production system is a relatively small increase in cropping system diversity, but even this small change can help maintain or increase soil health (Tiemann et al., 2015; McDaniel et al., 2014) and increase the productivity of potato cropping systems.

Potato systems that include alfalfa as part of the rotation may see the greatest benefits of increasing cropping system diversity through the addition of a grass species. Several studies have shown that the combination of a grass and legume can have positive effects on microbial community diversity, activity, N mineralization and subsequent crop yields beyond those observed with grass or legume alone (Garbeva et al., 2004; Sainju et al., 2005; Altieri et al., 1999; Wagger et al., 1998). For example, compared to either crop as a monoculture, hairy vetch combined with rye produced greater cover crop biomass and greater subsequent crop biomass and grain yields (Sainju et al. 2005). Additionally, these same cover crop mixtures compared to monocultures had different effects on microbial biomass (Sainju et al., 2006). In a controlled laboratory soil incubation, decomposition of legume-grass mixtures resulted in increased microbial biomass and more even release of N (McDaniel et al., 2014; McDaniel et al., in revision). We hypothesize that the mixture of legume and grass species in a potato system rotation could provide some of these same benefits.

Potato cropping systems in Michigan's Upper Peninsula offers an ideal location to explore different culture practices in cover crop species (Phase 3). We will investigate the effects of mowing timing, variety, variety combinations and seeding rate on biomass accumulation. Pearl millet (*Pennisetum glaucu*) and associated cultivars are warm season grasses that can produce large amounts of biomass. Foxtail or German millet (*Setaria italic*) and Japanese millet (*Echinochloa esculenta*) are other grass species with grower interest for biomass production in the Upper Peninsula. Additionally, the effect of mowing timing can delay bolting, prolong heading and delay maturation, thus increasing biomass production.

Phase 1: Identification of Optimal Grass Species

<u>Objective 1</u>: Identify pearl millet varieties and other grass species that produce the greatest amount of above and below ground biomass.

<u>Objective 2</u>: Identify which grass species are the poorest hosts to *V. dahliae* and *P. penetrans*.

In the spring of 2015, 2016, and 2018, grass species comparison trials occurred at the Montcalm Research Center (MRC), Montcalm County, MI comparing performance of the grass varieties. We chose the grass species used in the 2015 trial based on previous research and anecdotal evidence that these species enhance disease and pest suppression in potato systems. The varieties were evaluated for production of above and below ground biomass, maturity (as a function of bolting), and likelihood of being a non-host or nematode-antagonistic with respect to *P. penetrans* root lesion nematode. In 2015, the following species were evaluated: common oat, (*Avena sativa*, 'IDA'); pearl millet, (*Pennisetum glaucum*, 'Tifleaf 3', 'Millex 32', 'CFPM 101'); proso millet, (*Panicum miliaceum*, 'White'); German millet, (*Setaria italica)*; foxtail millet, (*Setaria italica*, ‘White Wonder’) and; Japanese millet, (*Echinochloa esculenta*). It was determined that the pearl millet varieties produced the highest amounts of biomass, while the Japanese millet varieties produced the lowest amount (Table 1). Although not statistically significant, the pearl millet varieties tended to have fewer nematodes present in the soil and on the root tissue than the other grass species tested (Table 1).

In 2016, this land was planted with the potato variety ‘Superior.’ Based on previous grass crop history in 2015, potato yield, tuber quality and presence of *V. dahliae* and *P. penetrans* were evaluated. Potato production in the pearl millet treatments, specifically Tifleaf and Millex 32, although not significantly significant, produced higher total yields (Table 2). Root lesion nematode numbers were not significantly different between treatments, but pearl millet CFPM 101 had the lowest *Verticillium* concentration.

In the spring of 2016, the three pearl millet varieties and four other grass species [corn, (*Zea mays spp*.), sorghum sudangrass (*Sorghum bicolor x Sorghum bicolor* var. Sudanese), teff (*Eragrostis tef*) and one other pearl millet variety (*P. glaucum* ‘Wonderleaf’)] underwent side-by-side screening at MRC to compare above and below ground biomass production and their effects on *V. dahlia* and *P. penetrans* abundance. The 2016 total biomass accumulation results are listed in Table 3. The corn control treatment produced the highest total biomass, but the grains were included in weight calculation, artificially inflating it. There was no significant difference in total biomass produced between the remaining grass species. *Sorghum bicolor x S. bicolor* var. Sudanese and teff ‘Dessie’ produced the least amount of biomass.

In 2017, we proposed repeating parts 1 and 2 of phase one of this proposal. Due to a trial planting error, part one of the study was not planted and will be delayed until the Spring of 2018. No cover crop biomass data was collected in 2017. Part two is replanting the 2016 cover crop study to the potato variety the following season (2019). Cover crop treatment effects on potato yield and quality performance in 2017 are presented in Table 4.

In 2018 six of the same cover crop species that were planted in 2016 were grown again in 2018. Pearl Millet ‘Millex 32’ was not grown. The same experimental design from previous years was used for this trial at the MRC. As in 2016, corn produced the highest above ground and total biomass as the ears were included in the weight calculations. However, the sorghum sudangrass had the highest biomass at the first cutting and pearl millets ‘Wonderleaf’ and ‘CFPM 101’ had the highest biomass at the second cutting. In 2018, biomass was measures on July 19th, August 14th, and finally on October 19th. The two initial cuttings excluded the corn control treatment. Pearl millet ‘CFPM 101’ was also the tallest cover crop at the first and second cutting. The 2018 total biomass accumulation results are listed in Table 5.

2018 was the last year of cover crop trials in Phase 1 of this project. Summary data is presented in Table 6. Twelve different cover crop varieties were evaluated in 2015, 2016, and 2018. While dates were variable between years, there were significant differences in cover crop above ground biomass at each of the three cutting dates. Common oat ‘Ida’ produced the most biomass at the first cutting while pearl millet ‘Millex 32’ produced the most biomass at the second cutting. Corn had the highest biomass at the third cutting as it was excluded from the first two cuttings and grain weight was included in the biomass. Therefore, corn had the highest total biomass over all three ears, followed by Teff and pearl millet ‘Wonderleaf.’ When below ground biomass was included in the total biomass calculation, pearl millet ‘Millex 32’ had the highest total root and shoot biomass after corn. When considering only below ground biomass, common oat ‘Ida’ had the second highest root biomass after corn.

In 2019, potatoes were planted for a final year. The seven cover crop treatments in the 2017 potato evaluation were used again in 2019. As in previous years, the Pearl Millet species, including Millex 32 and Tifleaf 3 had higher yields, but were not statistically significant (Table 7). Excluding the percentage of pick outs, there were no statistically significant differences between cover crop treatments in 2019.

Summary data of the three years of potato production is presented in Table 9. The Japanese Millet, Foxtail Millet, German Millet, and Oats treatments were only used in 2016. Treatments used all three years include Pearl Millet CFPM 101, Pearl Millet Millex 32, and Pearl Millet Tifleaf 3. All other treatments, including Pearl Millet Wonderleaf, Teff, Corn, and Sorghum Sudangrass were used in both the 2017 and 2019 potato crop. Potatoes planted after Pearl Millet Wonderleaf had the highest average total yield in 2017 and 2019. The Pearl Millet Millex 32 and Tifleaf 3 treatments also had high total yields. There was some segregation between treatments in Root Lesion Nematode concentration. The Pearl Millet Wonderleaf treatment also had the lowest number of nematodes present per one gram of root tissue. The Teff, Pearl Millet Tifleaf 3, Sorghum Sudangrass, and Pearl Millet Millex 32 also had lower than average concentrations of nematodes in the root tissue.

Table 1: 2015 Total Shoot Biomass and Mean Root Lesion Nematode Counts

Cover Crop Treatment Information				Agronomic Data		
Species	**Common Name**	**Variety**	**Source**	**Total Shoot Biomass**	**RLN Soil**	**RLN Roots**
Avena sativa	Common Oat	Ida	Michigan Crop Improvement	3880^{bc}	0.7	9.0
Pennisteum glaucum	Pearl Millet	Tifleaf 3	Gayland Ward Seeds	6743^{ab}	1.3	4.7
Pennisteum glaucum	Pearl Millet	Millex 32	Sorghum Partners	8582^{a}	1.0	0.7
Pennisteum glaucum	Pearl Millet	CFPM 101	AERC, Inc.	8614^{a}	1.3	5.3
Panicum miliaceum	Proso Millet	White	Green Cover Seed	2105^{cd}	2.3	11.3
Setaria italica	German Millet	N/A	Green Cover Seed	3992^{bc}	0.3	0.0
Setaria italica	Foxtail Millet	White Wonder	Green Cover Seed	3769^{bc}	2.3	4.3
Echinochloa esculenta	Japanese Millet	N/A	Green Cover Seed	709^{d}	1.3	10.7
Echinochloa esculenta	Japanese Millet	N/A	Athens Seed Co.	714^{d}	1.3	8.7
			ANOVA:	<.0001	NS	NS

Treatments followed by different superscript letters have a stastically significant differences using Tukey's HSD test (a=.05). NS indicates no significant differences
RLN= root lesion nematodes, extracted from 100g of soil and 1g of plant root tissue. Testing performed by MSU Diagnositic Services

Table 2: 2016 'Superior' Potato Tuber Yield, Quality, and Disease Evaluation

2016 MRC Millet Trial Potato Quality and Yield Data
Montcalm Research Center, Entrican, MI

	CWT/A		PERCENT OF TOTAL[1]					RAW TUBER QUALITY[2] (%)				COMMON SCAB	ROOT LESION NEMATODE		VERTICILLIUM DAHLIAE
Cover Crop Treatment	US#1	TOTAL	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	RATING[3]	(#/100 g soil)	(#/1 g root tissue)	(# of stems positive out of 10
Pearl Millet (Tifleaf 3)	252^{a}	306^{a}	16.7	81.3	0.3	1.7	1.071	0	19	2	11	2.7	2.7	5.3	3.6^{bc}
Pearl Millet (Millex 32)	247^{ab}	298^{a}	15.6	81.7	0.8	1.8	1.076	0	18	1	11	2.6	3.0	6.3	4.6^{ab}
Pearl Millet (CFPM 101)	235^{ab}	282^{ab}	15.6	83.2	0.0	1.1	1.072	1	17	2	9	2.7	1.7	16.6	1.3^{c}
German Millet	231^{abc}	286^{ab}	17.6	80.7	0.0	1.7	1.071	2	28	2	10	2.7	2.0	9.0	7.0^{a}
Japanese Millet	202^{abc}	250^{abc}	19.6	78.8	0.2	1.4	1.069	3	25	3	11	2.5	4.0	14.3	2.3^{bc}
Foxtail Millet	185^{bc}	235^{bc}	24.0	77.7	0.2	0.9	1.070	1	22	3	4	2.5	4.0	11.6	2.3^{bc}
Oats	166^{c}	219^{c}	17.6	74.0	0.2	1.8	1.070	2	17	4	8	2.5	0.0	5.0	3.0^{bc}
MEAN	**217**	**268**	**18**	**80**	**0**	**1**	**1.071**	**1**	**21**	**2**	**9**	**2.6**	**2.5**	**9.7**	**3.4**
ANOVA[4]	**0.0006**	**<0.0001**	0.41	0.39	0.19	0.82	0.27	0.52	0.16	0.67	0.50	0.91	0.52	0.74	**0.04**
HSD	**60**	**6**													

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

[2]TUBER QUALITY
HH: Hollow Heart
VD: Vascular Discoloration
IBS: Internal Brown Spot
BC: Brown Center

[3]COMMON SCAB RATING
0.0: Complete absence of surface or pitted lesions
1.0: Presence of surface lesions
2.0: Pitted lesions on tubers, though cove
3.0: Pitted lesions common on tubers
4.0: Pitted lesions severe on tubers
5.0: More than 50% of tuber surface area covered in pitted lesions

[4]ANOVA
Analysis was performed on non-aggregated data where each cover crop treatment had 16 replicates that are averaged here.
Connecting letters reports were determined using Tukey-Kramer HSD with p<0.05
HSD= Honest Significant Diference.

Treatments followed by different superscript letters have a stastically significant differences using Tukey's HSD test (a=.05)

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Table 3: 2016 Grass Cover Crop Total Biomass (lb/A) and Height (In)

Species	Common Name	Variety	Total Biomass (lb/A)	Maximum Height (In)
Zea mays	Corn	-	41077^{a}	93
Pennisteum glaucum	Pearl Millet	CFMP 101	13879^{b}	103
Pennisteum glaucum	Pearl Millet	Millex 32	13289^{b}	96
Pennisteum glaucum	Pearl Millet	Tifleaf 3	11022^{b}	54
Pennisteum glaucum	Pearl Millet	Wonderleaf	13847^{b}	92
Eragrosis tef	Teff	Dessie	9028^{b}	76
Sorghum bicolor x S. bicol var. sudanese	Sorghum sudangrass	Sweet Bites	10274^{b}	40

Treatments followed by different superscript letters have a stastically significant differences using Tukey's HSD test (a=.05)

Corn aboveground biomass includes grain weight

Maximum height was measured on 9/12/17

Table 4: 2017 'Superior' Potato Tuber Yield, Quality, and Disease Evaluation

2017 MRC Millet Trial Potato Quality and Yield Data
Montcalm Research Center, Entrican, MI

	CWT/A		PERCENT OF TOTAL[1]					RAW TUBER QUALITY[2] (%)				COMMON SCAB	[5]VERTICILLIUM DAHLIAE	ROOT LESION NEMATODE
Cover Crop Treatment	US#1	TOTAL	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	RATING[3]	cycle threshold	(#/1 g root tissue)
Pearl Millet (CFPM 101)	281^{a}	350^{a}	13.2	80.1	0.0	6.7	1.075	0	2	0	2	1.9	32.1^{a}	0.8^{ab}
Pearl Millet (Wonder Leaf	266^{ab}	347^{a}	15.7	76.4	0.0	7.9	1.075	0	3	0	2	1.9	32.5^{a}	0.1^{b}
Pearl Millet (Millex 32)	255^{abc}	335^{ab}	16.4	76.1	0.0	7.5	1.077	0	3	0	2	1.8	30.4^{b}	0.4^{b}
Teff	229^{bcd}	310^{abc}	19.3	73.8	0.0	6.8	1.074	0	3	0	2	1.8	32.1^{a}	1.4^{ab}
Sorghum Sudangrass	224^{bcd}	293^{bc}	17.7	76.2	0.0	6.1	1.073	0	4	0	1	1.8	31.8^{ab}	1.9^{ab}
Pearl Millet (TIFLEAF 3)	209^{cd}	285^{c}	22.5	70.6	0.1	6.8	1.073	0	3	0	2	1.7	30.6^{b}	0.6^{ab}
Corn	205^{d}	287^{c}	23.2	71.1	0.1	5.5	1.074	0	3	0	2	1.9	31.5^{ab}	6.0^{a}
MEAN	**238**	**315**	**18**	**75**	**0**	**7**	**1.074**	**0**	**3**	**0**	**2**	**1.8**	**31.6**	**1.6**
ANOVA[4]	**<.0001**	**<.0001**	**<.0001**	**0.001**	0.55	0.68	**0.004**	0.06	0.25	0.18	0.27	0.59	**0.03**	**0.03**
HSD	**46.9**	**46.0**	**6.3**	**7.0**									**1.5**	**5.6**

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

[2]TUBER QUALITY
(percentage of tubers out of 10)
HH: Hollow Heart
VD: Vascular Discoloration
IBS: Internal Brown Spot
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[3]COMMON SCAB RATING
0.0: Complete absence of surface or pitted lesions
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5.0: More than 50% of tuber surface area covered in pitted lesions

[4]ANOVA
Analysis was performed on non-aggregated data where each cover crop treatment had 16 replicates that are averaged here.
Connecting letters reports were determined using Tukey-Kramer HSD with p<0.05
HSD= Honest Significant Diference.

[5]Cycle threshold describes the amount of time to amplify DNA. Higher cycle thresholds correspond to lower amounts of viral DNA
Treatments followed by different superscript letters have a stastically significant differences using Tukey's HSD test (a=.05)

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Table 5: 2018 Grass Cover Crop Total Biomass (lb/A) and Height (In)

Species	Common Name	Variety	Total Biomass (lb/A)	Maximum Height (In)
Avena Sativa	Corn	-	9874[a]	72[a]
Pennisetum glaucum	Pearl Millet	Tifleaf 3	4680[b]	51[ab]
Pennisetum glaucum	Pearl Millet	Wonder Leaf	4765[b]	44[bc]
Pennisetum glaucum	Pearl Millet	CFPM 101	6246[ab]	60[ab]
Eragrosis tef	Teff	White	2400[b]	21[c]
Sorghum bicolor x S. bicolor var sudanese	Sorghum Sudan Grass	Sweet Bites	4268[b]	44[bc]

*Treatment means followed by the same letter are not considered significantly different based on Tukey's HSD test (α=0.05)

Corn aboveground biomass includes grain weight

Maximum height was measured on 10/19/18

Table 6: Cover Crop Above and Below Ground Biomass Averages from 2016, 2016, and 2018

Cover Crop Treatment Information				Dry Weight Shoot Biomass												
Species	Common Name	Variety	Code	Year(s) Grown	1st Cutting	Letter	2nd Cutting	Letter	3rd Cutting	Letter	Total Shoot Biomass	Letter	Total Root Biomass	Letter	Total Root and Shoot Biomass	Letter
Zea mays	Corn	N/A	CN	16, 18	128	F	-	-	20059	A	20059	A	5416	A	25475	A
Pennisetum glaucum	Pearl Millet	Millex 32	PM2	15, 16	1517	B	7401	A	1964	B	10882	B	913	B	11534	B
Pennisetum glaucum	Pearl Millet	CFPM 101	PM3	15,16,18	1253	BCD	5018	AB	2200	B	8472	BC	1879	B	10008	BC
Pennisetum glaucum	Pearl Millet	Wonderleaf	PM4	16, 18	926	CDE	4820	AB	2405	B	8151	BCD	1155	B	9305	BCD
Pennisetum glaucum	Pearl Millet	Tifleaf 3	PM1	15, 16, 18	946	CDE	3928	BC	1868	B	6742	BCD	1411	B	7896	BCD
Setaria italica	Sorghum Sudan Grass	N/A	SS	16, 18	773	DEF	-	-	1956	B	5558	BCD	1712	B	7271	BCD
Panicum miliaceum	Teff	White	TF	16, 18	359	F	-	-	2770	B	4774	CD	940	B	5714	BCD
Avena Sativa	Common Oat	Ida	OAT	15	3561	A	320	CD	0	B	3880	BCD	1039	AB	4227	BCD
Setaria italica	German Millet	N/A	GM1	15	1514	BC	2479	BCD	0	B	3992	BCD	-	-	3992	BCD
Setaria italica	Foxtail Millet	White Wonder	FM1	15	1397	BCD	2372	BCD	0	B	3769	BCD	-	-	3769	BCD
Panicum miliaceum	Proso Millet	White	PROM1	15	1887	B	219	D	0	B	2105	CD	-	-	2105	CD
Echinochloa esculenta	Japanese Millet	N/A	JM2	15	272	EF	442	CD	0	B	714	D	-	-	714	D
Echinochloa esculenta	Japanese Millet	N/A	JM1	15	-	F	581	CD	0	B	709	D	-	-	709	D
			ANOVA:		**<.0001**		**0.0009**		**<.0001**		**<.0001**		**0.0209**		**<.0001**	
			LSD:		855		3011		4823		5757		2540		6582	

Table 7: 2019 'Superior' Potato Tuber Yield, Quality, and Disease Evaluation

2019 MRC Millet Trial Potato Quality and Yield Data
Montcalm Research Center, Entrican, MI

Cover Crop Treatment	CWT/A		PERCENT OF TOTAL[1]					RAW TUBER QUALITY[2] (%)				COMMON SCAB
	US#1	TOTAL	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	RATING[3]
Pearl Millet (Wonder Leaf)	195	289	31.3	66.2	0.0	2.5	1.071	0	18	3	15	1.3
Pearl Millet (Tifleaf 3)	188	289	33.4	64.6	0.0	2.1	1.070	0	28	1	11	1.3
Pearl Millet (Millex 32)	176	282	35.9	61.7	0.0	2.2	1.070	13	24	2	11	1.3
Corn	176	277	38.1	59.3	0.0	2.7	1.072	0	22	1	16	1.0
Pearl Millet (CFPM 101)	168	255	31.5	64.6	0.0	3.9	1.069	0	13	3	4	1.2
Sorghum Sudangrass	151	233	33.9	64.1	0.0	2.1	1.070	0	20	3	10	0.9
Teff	150	248	39.1	58.4	0.0	2.5	1.070	13	21	5	9	1.4
MEAN	**172**	**267**	**35**	**63**	**0**	**3**	**1.070**	**4**	**21**	**3**	**11**	**1.2**
ANOVA	0.21	0.08	0.11	0.12	-	**0.0379**	0.34	0.11	0.16	0.55	0.58	0.21
HSD						**1.7**						

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[4]ANOVA
Analysis was performed on non-aggregated data where each cover crop treatment had 16 replicates that are averaged here.
Connecting letters reports were determined using Tukey-Kramer HSD with p<0.05
HSD= Honest Significant Diference.

Treatments followed by different superscript letters have a stastically significant differences using Tukey's HSD test (a=.05)

Table 8: Summary of 'Superior' Potato Tuber Yield, Quality, and Disease Evaluation

2016, 2017, and 2019 MRC Millet Trial Potato Quality and Yield Data
Montcalm Research Center, Entrican, MI

	Year(s)	Cover Crop Treatment	CWT/A		PERCENT OF TOTAL[1]					RAW TUBER QUALITY[2] (%)				SCAB	ROOT LESION NEMATODE[5]
			US#1	TOTAL	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	RATING[4]	(#/1 g root tissue)
PM4	17, 19	Pearl Millet (Wonderleaf)	266	301^{a}	28	68	0	4	1.072	0	15	3	12	1.4	0.1^{d}
PM3	16,17, 19	Pearl Millet (CFPM 101)	261	275^{abcd}	26	70	0	4	1.070	0	14	2	7	1.5	5.1^{bcd}
PM2	16,17, 19	Pearl Millet (Millex 32)	251	293^{ab}	30	67	0	3	1.072	1	20	1	9	1.6	2.0^{cd}
GM1	16	German Millet	232	286^{abcd}	17	81	0	2	1.071	2	28	2	10	2.7	9.0^{abc}
TF	17, 19	Teff	229	261^{bcd}	36	61	0	3	1.070	1	18	4	8	1.5	1.4^{cd}
PM1	16,17, 19	Pearl Millet (Tifleaf 3)	227	290^{abc}	29	68	0	3	1.070	0	23	1	9	1.5	1.9^{cd}
SS	17, 19	Sorghum Sudangrass	224	245^{d}	31	66	0	3	1.071	0	17	3	8	1.1	1.9^{cd}
Corn	17, 19	Corn	205	279^{abcd}	35	62	0	3	1.072	0	18	1	13	1.2	6.0^{abcd}
JM2	16	Japanese Millet	202	250^{abcd}	20	79	0	1	1.070	3	25	3	11	2.5	14.3^{a}
FM1	16	Foxtail Millet	185	235^{abcd}	21	78	0	1	1.070	1	22	3	4	2.6	11.7^{ab}
Oat	16	Oats	166	219^{cd}	24	74	0	2	1.070	2	17	4	8	2.5	5.0^{abcd}
		MEAN	**223**	**267**	**27**	**70**	**0**	**3**	**1.071**	**1**	**20**	**2**	**9**	**1.8**	**5.3**
		ANOVA[6]	0.23	**0.007**	**0.025**	**0.004**	0.25	0.40	0.77	0.05	0.44	0.82	0.87	**<0.0001**	**0.02**
		HSD		**38**	**7**	**16**								**1.0**	**10.4**

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

[2]TUBER QUALITY (percentage of tubers out of 10)
HH: Hollow Heart
VD: Vascular Discoloration
IBS: Internal Brown Spot
BC: Brown Center

[4] COMMON SCAB RATING
0.0: Complete absence of surface or pitted lesions
1.0: Presence of surface lesions
2.0: Pitted lesions on tubers, though coverage is low
3.0: Pitted lesions common on tubers
4.0: Pitted lesions severe on tubers
5.0: More than 50% of tuber surface area covered in pitted lesions

[5] ROOT LESION NEMATODE
Data is from 2016 and 2017
2019 data not available at time of reporting

[6]ANOVA
Analysis was perfomed on non-aggregated data where each cover crop treatment had 16 replicates that are averaged here.
Connecting letters reports were determined using Tukey-Kramer HSD with p<0.05
HSD= Honest Significant Diference.

Treatments followed by different superscript letters have a statistically significant difference using Tukey's HSD Test (a=.05)

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Phase 2: Incorporation of a Grass into a Potato Production System

Objective 1: Determine how an increase in cropping system diversity affects SOM decomposition, N mineralization, soil microbial community diversity, and soil aggregation.

Objective 2: Determine which grass species confers the greatest benefits when used to increase cropping system diversity.

In the spring of 2016, two separate cover crop plots were planted at Kitchen Farms, Elmira, MI. One plot was planted into a bare soil field, previously potatoes in 2015. The second plot was planted into a one-year-old alfalfa crop (two years out of potatoes). This plot was planted just after the first cutting of alfalfa. Both seedings used the same eight treatments. The first treatment was alfalfa alone followed by the three pearl millet varieties from the 2015 grass species trial, sorghum-sudan grass, teff, cereal rye, and annual rye grass. The grasses were co-seeded with alfalfa in the year one planting and were drilled into the standing alfalfa in the second year planting. All treatments were no-till drilled in a randomized complete block design with four replications. In these grass plus alfalfa plots, we measured above and below ground biomass production, soil respiration, potentially mineralizable C and N, and extra-cellular enzyme activities.

From the co-seeded plot data (Table 9) the warm season grasses with the exception of teff and annual ryegrass produced the most total biomass and reduced alfalfa biomass accumulation compared to the alfalfa alone treatment. Pearl millet 'CFPM 101' had the highest above ground biomass. All treatment seeding rates will be adjusted as we proceed to balance the biomass production of both species. The interseeded plot data (Table 10) shows that pearl millet Tifleaf 3 outperformed all other treatments except Millex 32 in biomass production. This demonstrates that cultivar specificity is important in relative competition with alfalfa. None of the interseeded grass species significantly reduced alfalfa production.

In 2017, planting rates were adjusted and the number of grass species and cultivars tested were reduced to the most promising. Mowing times were inconsistent among years. The 2017 treatments were planted June 14th and included pearl millet (Canadian forage pearl millet 10, Millex 32, Tifleaf 3) and sorghum sudangrass (Super sugar), plus a control treatment with only alfalfa. In 2017, the alfalfa alone treatment in the co-seeded plot produced a significantly higher amount of biomass. In the interseeded plots, there was not significant differences, but Millex 32 and Super sugar produced the largest amount of total biomass in conjunction with alfalfa (Table 10).

Cover crop research at Kitchen Farms concluded in 2017. The results of both the co-seeded and interseeded plots are summarized in Tables 11 and 12, respectively. In the co-seeded trial Sorghum sudangrass produced the most belowground biomass at 1827 lb/A, while pearl millet 'CFPM 101' produced the least. Sorghum sudangrass and 'CFPM101' produced the most total biomass, although there was no statistically significant difference between the cover crop species. Alfalfa produced the highest biomass when co-seeded with pearl millet 'Tifleaf 3' and 'CFPM 101.' Finally, there was the lowest amount of weed biomass in the 'CFPM 101,' 'Tifleaf 3,' and sorghum sudangrass co-seeded plots. There was no significant difference in the number of nematodes present between cover crop treatments in these two years in both the co-seeded and interseeded plots. In the interseeded trial pearl millet 'Tifleaf 3' produced the highest above ground biomass while Teff produced the lowest. Alfalfa produced the higest biomass when grown in conjunction with Teff, but this was likely due to the poor stand of Teff and resulted in an imbalanced grass:alfalfa biomass ratio. In all treatments, the alfalfa biomass was a factor of 10 larger than the grass biomass (Table 11).

In 2018, 'Superior' potatoes were planted over the co-seeded and interseeded plots at Kitchen Farms. Potatoes grown over the co-seeded CFPM 101 pearl millet treatment had the highest yield in the co-seeded trial, while potatoes grown over Interseeded Tifleaf 3 had the highest total yield in the Interseeded trial (Table 13). There were no statistically significant differences in yield, size breakdown, or potato internal quality in 2018. Additionally, there was no significant difference in root lesion nematode concentration between the co-seeded and Interseeded trial or between different cover crop treatments within a trial.

Table 9: 2016 Crop Biomass (lb/A) at Kitchen Farms

		Co-Seeded Plots			Interseeded Plots	
Species	Variety	Grass total dry biomass	Alfalfa Total Dry Biomass	Weed Total Dry Biomass	Grass total dry biomass	Alfalfa Total Dry Biomass
Alfalfa only	-	-	1399^{a}	4627^{a}	-	4911
Pearl Millet	CFPM 101	9880^{a}	485^{bc}	606^{c}	292^{bc}	4639
Pearl Millet	Millex 32	9600^{a}	610^{bc}	814^{bc}	530^{ab}	4885
Pearl Millet	Tifleaf 3	8797^{ab}	308^{c}	623^{c}	776^{a}	4093
Sorghum sudangrass	Super sugar	10009^{a}	434^{c}	572^{c}	303^{bc}	4766
Teff	Dessie	4736^{bc}	363^{c}	1327^{bc}	16^{c}	5547
Cereal Rye	Guardian	2882^{b}	1195^{a}	2193^{b}	248^{bc}	5148
Annual Ryegrass	Centurion	4571^{bc}	995^{ab}	1249^{bc}	126^{c}	4408

Treatments followed by different superscript letters have a stastically significant differences using Tukey's HSD test (a=.05)

Table 10: 2017 Crop Biomass (lb/A) at Kitchen Farms

		Co-Seeded Plots			Interseeded Plots	
Species	Variety	Grass total dry biomass	Alfalfa Total Dry Biomass	Weed Total Dry Biomass	Grass total dry biomass	Alfalfa Total Dry Biomass
Alfalfa only	-	-	8313^{a}	4627^{a}	-	4677
Pearl Millet	CFPM 101	4602	4060^{b}	606^{c}	675	3844
Pearl Millet	Millex 32	4539	3666^{b}	814^{bc}	441	5249
Pearl Millet	Tifleaf 3	3507	4448^{b}	623^{c}	888	4005
Sorghum sudangrass	Super sugar	6586	2797^{b}	572^{c}	786	4677
		NS	<.0001		NS	NS

Treatments followed by different superscript letters have a stastically significant differences using Tukey's HSD test (a=.05). NS indicates no significant differences

Table 11: 2016 and 2017 Co-Seeded Crop Biomass at Kitchen Farms

		Co-Seeded Season Total Dry Biomass								
		Grass			Alfalfa			Weeds		
		Above	Below	Total	Above	Below	Total	Above	Below	Total
Common Name	Variety	lb/A								
Alfalfa only		-	-	-	3521ᵃ	1335ᵃ	4856ᵃ	4,045ᵃ	582ᵃ	4627ᵃ
Pearl millet	CFPM 101	6812	429ᶜ	7241	1625ᵇ	647ᵇ	2272ᵇ	389ᶜ	217ᵇ	606ᶜ
Pearl millet	Millex 32	6517	552ᶜ	7069	1642ᵇ	469ᵇ	1919ᵇ	613ᵇᶜ	200ᵇ	814ᵇᶜ
Pearl millet	Tifleaf 3	5594	559ᶜ	6152	1651ᵇ	727ᵃᵇ	2378ᵇ	516ᶜ	107ᵇ	623ᶜ
Sorghum sudangrass	Super sugar	6656	1827ᵃ	8542	1082ᵇ	534ᵇ	1616ᵇ	484ᶜ	88ᵇ	572ᶜ
Teff	Dessie	4095	642ᶜ	4736	222ᵇ	141ᵇ	363ᵇ	1,147ᵇᶜ	180ᵇ	1327ᵇᶜ
Cereal rye	Guardian	1907	973ᵇᶜ	2880	803ᵇ	392ᵇ	1195ᵇ	1,979ᵇ	214ᵇ	2193ᵇ
Annual ryegrass	Centurion	3058	1513ᵃᵇ	4571	657ᵇ	337ᵇ	995ᵇ	1,037ᵇᶜ	212ᵇ	1249ᵇᶜ
	MEAN	5474	875	6331	1594	641	2208	1276	225	1501
	ANOVA	0.086	**0.001**	0.163	**0.029**	**0.045**	**0.029**	**0.000**	**0.015**	<0.0001
	LSD		655		1619	608	2192	1381	248	1454

Treatments followed by different superscript letters have a statistically significant different using Student's T-Test (a=.05)

Table 12: 2016 and 2017 Interseeded Crop Biomass at Kitchen Farms

		Interseeded Season Total Dry Biomass					
		Grass			Alfalfa		
		Above	Below	Total	Above	Below	Total
Common Name	Variety	lb/A					
Alfalfa only		-	-	-	3225	1468	4692
Pearl millet	CFPM 101	313bᶜ	170	484ᵇ	3178	1480	4658
Pearl millet	Millex 32	355ᵇᶜ	131	485ᵇ	2950	1415	4365
Pearl millet	Tifleaf 3	669ᵃ	155	824ᵃ	3173	1498	4671
Sorghum-sudangrass	Super sugar	380ᵇ	164	545ᵃᵇ	2909	1476	4385
Teff	Dessie	8ᵈ	8	16ᵇ	3552	1995	5547
Cereal rye	Guardian	183ᵇᶜᵈ	65	248ᵇ	3257	1892	5148
Annual ryegrass	Centurion	79ᶜᵈ	47	126ᵇ	2752	1656	4408
	MEAN	284	106	390	3125	1610	4734
	ANOVA	**0.001**	0.183	**0.013**	0.852	0.266	0.625
	LSD	241		347			

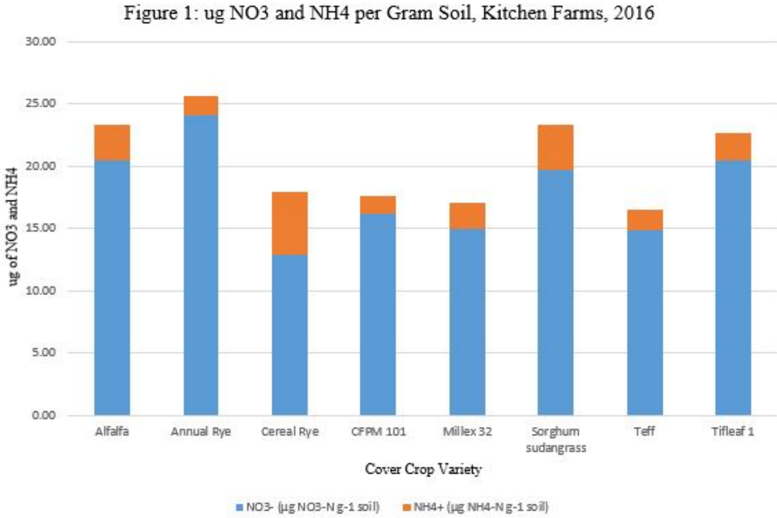
Treatments followed by different superscript letters have a statistically significant different using Student's T-Test (a=.05)

Table 13: Potato Yield at Kitchen Farm

2018 Kitchens Farms Potato Yield Trial

	LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR[2]	RAW TUBER QUALITY[3] (%) HH	VD	IBS	BC	COMMON SCAB RATING[4]
Co-seeded	Pearl Millet (CFPM 101)	296	457	65	16	65	0	19	1.071	0	10	0	0	0
	Cereal Rye	294	457	64	9	64	0	27	1.071	0	10	3	5	0
	Alfalfa	289	456	63	8	63	0	29	1.071	0	13	3	0	0
	Sorghum Sudangrass	289	449	64	16	64	0	20	1.071	0	5	8	5	0
	Pearl Millet (Tifleaf 3)	281	412	69	13	69	0	18	1.071	0	8	0	0	0
	Teff	250	461	55	12	55	0	33	1.072	0	5	0	0	0
	Annual Rye	239	437	55	11	55	0	34	1.069	0	8	10	0	0
	Pearl Millet (Millex 32)	239	444	54	13	54	0	33	1.070	0	5	10	0	0
		272	**447**	**61**	**12**	**61**	**0**	**27**	**1.071**	**0**	**8**	**4**	**1**	**0**
	ANOVA	0.547	0.979	0.222	0.124	0.222	-	0.056	0.363	-	0.934	0.205	0.553	-
Interseeded	Pearl Millet (Tifleaf 3)	331	455	72	12	72	0	16	1.070	8	8	5	3	0
	Pearl Millet (Millex 32)	314	447	70	14	70	0	16	1.071	0	0	0	0	0
	Pearl Millet (CFPM 101)	311	468	67	13	66	1	20	1.073	0	8	0	0	0
	Alfalfa	308	425	73	12	73	0	15	1.070	0	3	0	0	0
	Sorghum Sudangrass	298	463	65	13	65	0	22	1.069	3	10	3	0	0
		312	**452**	**69**	**13**	**69**	**0**	**18**	**1.071**	**2**	**6**	**2**	**1**	**0**
	ANOVA	0.943	0.871	0.354	0.919	0.310	0.438	0.319	0.073	0.177	0.444	0.544	0.438	-

Figure 1: ug NO3 and NH4 per Gram Soil, Kitchen Farms, 2016



Phase 3: Determine Best Management Practices for Pearl Millet Growth in the Upper Peninsula

Objective 1: Determine best management practices for optimizing pearl millet growth in the Upper Peninsula.

For the past two seasons a grass cover crop demonstration trial has been planted at the Cousineau’s seed potato farm in Hardwood, MI. In addition, the Cousineau family has been planting various millet species on a larger scale in the year before potatoes. It is unclear how planting time and mowing impacts biomass production at this northern latitude. Based on observations, plants that emerged following a mid-May planting but appeared stunted, whereas planting in late-May or early-June resulted in more vigorous growth during the shorter growing season of these warm-season grasses. Mowing could benefit this system by potentially increasing biomass accumulation and breaking up residues that can impede field operations during the potato season. At the end of the season, total biomass was calculated for each planting rate and mowing treatment. The highest yield occurred in the 22 lbs/A mowed treatment, and the lowest yield occurred in the 15 lbs/A non-mowed treatment (Table 14). No statistical analysis was conducted.

Table 14: Planting Rate, Mowing Treatment, and Total Biomass of CFPM 101 in 2017

Planting rate (lbs/A)	Mowing	Total biomass (lbs/A)
15	no	5057
15	no	3698
15	no	1505
15	yes	8676
15	yes	3303
15	yes	1238
22	no	5271
22	no	3986
22	no	3930
22	yes	5873
22	yes	4233
22	yes	1580

Materials and Methods:

Phase 1

The first part of this phase of the project is the pearl millet screening study. Nine grass species were planted in 2015 in a four replication, randomized block design at the MRC in early June. . Each plot is 20 by 45 feet. Each grass species was seeded at a depth of one inch and at a rate of fifteen lbs/A. Each grass plot was evaluated for above ground biomass production using one 0.25 m^2 quadrat prior to each mowing during the growing season and prior to the killing frost. Below ground biomass was evaluated once just prior to a killing frost.

In 2016 'Superior' potatoes were planted over the cover crop plots. Root lesion nematode concentration in the soil and plant roots was evaluated, and plant stems were tested for the presence of *V. dahliae*. The potatoes were harvested, graded, evaluated for internal quality and common scab. Also in 2016, seven cover crop species were planted using the same experimental design in 2015.

In 2017, the potato variety 'Superior' was planted over the 2016 grass species trial at MRC. Sixteen, 34 inch rows were planted perpendicular to the grass trial plots. The in-row seed spacing for the 'Superiors' was 10 inches. Four, 15 foot plots were harvested from the potatoes in each of the grass plots in the fall. Each potato plot was evaluated for US#1 and total yield, internal tuber quality, specific gravity, early die syndrome, vine maturity and the abundance of *V. dahliae* and *P. penetrans* (2016 only).

In 2018 six cover crop species were planted using the same experimental design as in 2017.

Phase 2

This experiment was set up as a randomized complete block with eight treatments in 2016 and five treatments in 2017. The 2016 grass species were planted June 17th and included pearl millet (Canadian forage pearl millet 101, Millex 32, Tifleaf 3), sorghum sudangrass (Super sugar), cereal rye (Guardian), teff (Dessie), and annual ryegrass (Centurion), and a no grass control treament. The 2017 treatments were planted June 14th and included pearl millet (Canadian forage pearl millet 10, Millex 32, Tifleaf 3) and sorghum sudangrass (Super sugar), plus a control treatment with no grass. In each year there were two plots, one planted at the same time as alfalfa (co-seeded) and one planted into 2nd year, established alfalfa at the time of first cutting (interseeded). Plots received overhead irrigation per the schedule set by the Kitchens. Weeds within the plots were not controlled during the year grasses were present due to lack of herbicide options. During the alfalfa only years weeds were controlled with glyphosate on Roundup Ready alfalfa.

Prior to each mowing, aboveground biomass (cut at mowing height) was measured for both the alfalfa and the grass species. Prior to frost (co-seeded) or termination (interseeded), above- and belowground biomass were recorded. We collected soil samples from the experimental plots after grasses were established.

We assessed microbial activity in two ways: extracellular enzyme activity (EEA) and respiration rates. We measured the enzyme activity to asses the presence and concentration of microbes that make nitrogen, carbon, and phosphorous available in the soil. Soil respiration rate assessment quantified the level of microbial activity, SOM content, and decomposition rate. We performed microbial community structure analyses and *V. dahliae* colonization on soil and potato plant tissue samples respectively collected in 2018.

Phase 3

In 2017, our experiment was designed to study the effect of planting date and mowing frequency on pearl millet biomass production. However, due to the unusually wet and somewhat cool spring, the first two planting dates (May 15 and May 31) resulted in no pearl millet stand. There were 20.37 inches of rain between May and September compared to a 24 year average of 15.78 inches. We then chose to look at the impact of planting rate and mowing frequency on pearl millet biomass production with the final planting date (June 13). The experiment was set up in a split plot design with three replications. The main plot factor was planting rate (treatments of 15 and 22 lbs/A) and the subplot factor was mowing regime (treatments of one mowing and not mown). Based on previous research conducted at the MRC, 'CFPM 101' was used. Cover crop emergence was recorded one month after planting by counting the number of plants in three 0.25 m^2 quadrat in each plot. At the time of mowing (August 22), aboveground biomass (cut at mowing height) was measured. Prior to termination and frost (September 11), total biomass were recorded.

Outcomes:

Results of this research provide the potato industry with information regarding the efficacy of pearl millet varieties and grasses to improve cropping system productivity. This project has established the value of added diversity in a cropping system. Our experiment documented the additive effects of biodiversity in a cropping system by measuring changes in microbial community populations and activity. We quantified these factors by evaluating potato yield and tuber quality. As a result of this work, the potato industry in Michigan will have strategies to increase cropping system diversity in potato production systems and understand best practices for warm season grass production in Michigan.

Phase 1

In 2015, thee pearl millet varieties (Tifleaf 3, Millex 32, and CFPM 101) produced the most biomass using statistical analysis. The potato yields of 'Superior' the following year partially support our hypothesis. There is a statistically significant higher US #1 and total yield of potatoes in 2016 grown in the Tifleaf 3 and Millex 32 plots compared to those grown in the foxtail millet and oats plot. Potatoes grown after CFPM 101 also had a statistically higher total yield than those grown after oats. While the data does not show a "best" cover crop variety for increased potato yield the following year, it does indicate that the pearl millet varieties tend to support higher potato yields. This is further confirmed by the potato yield data in 2017. Potatoes grown after CFPM 101 and pearl millet Wonder Leaf had a significantly higher yield that those grown after sorghum sudangrass and corn. Future study on Tifleaf 2, CFPM 101, and Wonder leaf are recommended to create best practices for planting date, spacing, and mowing time that result in the highest yield increase the following year.

In 2017, we observed a statistically significant lowest incidence of *V. dahliae* in German millet, and the lowest amount of fungal DNA from the species in pearl millet CFPM 101 and Wonder Leaf, and teff. In 2016, there was no significant difference in the incidence of plant or soil root lesion nematode. This data was not available for 2017. Plant available nitrogen at each cover crop treatment site in 2016 was also assessed at Kitchen's Farms. While there was not a statistically significant difference, teff and Millex 32 had the lowest amount of plant available nitrogen while annual rye, Sorghum sudangrass, and alfalfa had the highest amount (Figure 1). This indicates the presence and productivity of soil microbes producing enzymes that break down inaccessible nitrogen in the soil and make it available for plant uptake.

In 2018, corn produced the highest biomass due to the inclusion of grain weight, but pearl millet CFPM produced the second highest biomass. Summary data of cover crops in 2015, 2016, and 2018 indicate that after corn, Millex 32 had a statistically significant higher total root and shoot biomass than other cover crops. CFPM 101 also had a higher total biomass than 10 other cover crop treatments. While the results varied from year to year, the summary data in Table 6 show that on average, the four pearl millet species (Millex 32, CFPM 101, Wonderleaf, and Tifleaf) had a higher biomass than Teff, Oat, Sorghum sudangrass and the five millet species. Additionally, the pearl millet species all had a lower than average weed biomass at the second cutting, indicating that effective weed control is possible with these cover crops (data not shown).

Limited data segregation was observed in the 2019 potato crop, with no statistical significance between treatments in total yield or size profile, excluding the percentage of pickouts (Table 8). The summary data show that Pearl Millets Wonderleaf, CFPM101, and Millex 32 had the highest US#1 yields. Wonderleaf also has a statistically significant highest total yield of 301 cwt/A, compared to the trial average of 267 cwt/A. Additionally, the Wonderleaf treatment had the lowest concentration of Root Lesion Nematodes per gram of root tissue, suggesting this treatment as the most beneficial to both act as a non-host of *P. penetrans* and support higher total potato yields. Wonderleaf did not produce the highest biomass in the cover crop production phase of this research, corn, CFPM 101 and Millex 32 all produced more biomass (Table 6). These three species of *Pennesitum glacum* display higher than average biomass production, support higher total and US#1 potato yields, and may act as a non-host for *P. penetrans,* especially Wonderelaf and Millex 32.

Phase 2

In 2016, the co-seeded plots were dominated by the grass species with poor alfalfa establishment. Weed populations were also problematic in the poor stands of 2016. Most of the pearl millet varieties and the sorghum sudangrass produced more biomass compared to the other varieties, which were then oitted in 2017. The better establishment of alfalfa in 2017 and the 50% reduction in planting rate reduced grass biomass accumulation by approximately 3,500-4,000 lbs/A compared to 2016. However, the grass to alfalfa biomass ratio was about 50:50. The total biomass produced in these plots (grass and alfalfa) ranged from 8,000 to 9,400 lbs/A.

In 2016, the interseeded plots had very low grass biomass accumulation, ranging from 16 to 776 lbs/A (Table 10). Again, the cereal rye, annual ryegrass, and teff plantings were not competitive in this environment and were omitted in 2017. In 2017, the grass biomass accumulation ranged from 440-890 lbs/A (Table 11), about 10-20% of the alfalfa biomass. Significant gains were not made by increasing the seeding rates by 50% from 2016 to 2017. The data show that co-seeding is preferable to interseeding to obtain a balanced mix of Alfalfa and a grass species. In 2018 potatoes were grown over both the co-seeded and Interseeded plots. No statistically significant difference was found within or between co-seeded and Interseeded trials in terms of yield, tuber internal quality, and size profile. No significant difference in root lesion nematode concentration was found in these plots in 2018.

Phase 3

No biomass difference was observed at different planting rates in 2017, so future plantings will be conducted with seedings of 15 lbs/A. The data from 2017 indicate that a later planting date is preferable, so only the latest planting date will be used in 2018. We propose the following experimental design consisting of five grass treatments (including two equal mixtures) and three moving treatments (no mowing, early mowing, and mid-season mowing). We predict that earlier mowing will increase millet biomass production, which in turn will support a higher potato yield. Cousineau farms has taken over this portion of the research. Additional findings are available by contacting Monica Jean, field crops educator, at atkinmon@msu.edu.

Table 15: Proposed Experimental Design for Phase 3 CFPM 101 Evaluation

	Ger	Jap	Perl	GerP	JapP
mow 2					
mow 1					
no mow					
mow1					
mow 2					
no mow					
no mow					
mow 1					
mow 2					
no mow					
mow 2					
mow 1					

Mow 1	Early mowing (3 weeks after planting)
Mow2	Mid-mowing (6 weeks after planting)
No mow	Late mowing/termination (Sept 15)
Ger	German Millet
Jap	Japanese Millet
Perl	Pearl Millet
GerP	50/50 German/Pearl Millet
JapP	50/50 Japanese/Pearl Millet

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Re-Examining Potato Phosphorus Use Guidelines in Michigan

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Kurt Steinke, Associate Professor, Soil Fertility & Nutrient Management
Michigan State University
See soil.msu.edu for more information

Locations: Montcalm Research Farm (MRF) and 6 on-farm locations	**Tillage:** Conv., 34-in. row
Planting Date: May 8, 2019	**Treatments:** See below
Soil Type: Loamy sand; 1.8 OM; 6.7 pH; 168 ppm P; 98 ppm K; CEC: 2.9	**Emerge**: June 5; **Hill:** June 21
Variety: Lamoka	**Replicated:** 4 replications

Table 1. Potato (var. Lamoka) response to phosphorus (P) fertilizer application rates at the MSU Montcalm Research Farm, MI, 2019.

P Treatment lbs P_2O_5/A	Pet. P 30 DAE	Pet. P 45 DAE	Total Tuber Count B's	Yield A's	Yield Total	Specific Gravity
	%	%	tubers/A	cwt/A	cwt/A	
0	0.370 bc†	0.265 b	26173 a	81.9 c	114.7 c	1.068 d
40	0.348 bc	0.238 b	30984 a	152.8 ab	193.4 ab	1.071 bc
80	0.333 c	0.235 b	38985 a	162.3 ab	216.0 a	1.072 bc
120	0.333 c	0.253 b	30932 a	134.4 b	176.6 b	1.070 c
160	0.388 b	0.258 b	27820 a	141.7 b	178.9 ab	1.075 a
200	0.448 a	0.305 a	28003 a	178.6 a	216.6 a	1.073 ab
Pr > F	0.0035	0.0370	0.6299	0.0038	0.0048	0.0019

†Means in each column followed by the same letter are not sig. different at $P \leq 0.10$.

Summary: Seven research trials in total established across Michigan including Three Rivers (2), Dundee, Entrican (MRF), Cass City, and Newberry (2). Potato varieties at each site included either chip processing, tablestock, or chip seed production. All P_2O_5 applications were twin-banded in-furrow as 2x2 at plant. Nitrogen contributions due to P-source were balanced at emergence time. At Entrican, all treatments received 225 N and 300 K_2O. Nitrogen was split into 3 application timings: emergence, hilling, and post-hilling. Potassium was split-applied as 75 units in-furrow and 225 units pre-plant incorporated. Despite overall low yields at Entrican, potato growth and yield responded to P application. Market class 'A' and total tuber yields were increased with 40 lbs P_2O_5/A but no benefit at greater rates (Table 1). In a similar manner, total and 'A' market class tuber numbers responded to 40 lbs P_2O_5/A, while 'B' tuber numbers were not affected by P application. Canopy biomass at 30 and 45 DAE was increased with P rates up to 80 lbs P_2O_5/A indicating increased early biomass production as a result of P applications may not correspond to final tuber yield. Petiole P concentrations were greatest when P application rates were highest but did not correspond to final yield. Please visit soil.msu.edu for further details and research results. Trials will continue in 2020.

Potato (*Solanum tuberosum*) ‘Superior’
Potato Early Die; *Verticillium dahliae, Pratylenchus penetrans*

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In-furrow and foliar treatment programs for control of potato early die (PED)-Clarksville, 2019

A field trial was established 11 June (42°52'29.2"N and longitude - 85°15'09.3"W) at the Clarksville Research Center, Clarksville MI to evaluate selected in-furrow and foliar fungicides, fumigants and nematicides for early die control (Table 1). US#1 ‘Superior’ tubers were mechanically cut into approximately 2 oz seed pieces 28 May and allowed to heal before planting. These trials were conducted using potato cultivar ‘Superior’ due to its susceptibility to Verticillium wilt and its commercial use throughout the state of Michigan and the Midwestern US potato growing region. A randomized complete block design with four replications was used for the experiment, with each plot consisting of four 25-ft-long rows spaced 34 in. apart with seed pieces 10 in. apart in the row. A 5-ft not-planted alley separated the four-row beds. 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). Treatment application times included: Pre-planting/pre-plant incorporated (A); Seed treatment (B); In-furrow at planting (C); 2 in emergence (D); 7 Days after 2 in emergence (E). In-furrow, at-planting applications of fungicide were delivered with a hand-held R&D spray boom delivering 10 gal/A (50 p.s.i.) and using one XR8002VR nozzle per row. A non-treated control was compared with 12 different treatment programs to evaluate their efficacy in controlling potato early die (PED) based on application time (Table 1). 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 Makaze at 2 qt/A 10 DAP, Matrix at 0.75 oz/A 20 and 40 DAP and Metribuzin 75 at 0.3 lb/A 60 DAP. Insects were controlled with Sevin 80S at 1.25 lb/A 30 and 60 DAP, Thiodan 3 EC at 2.33 pt/A 65 and 90 DAP and Pounce 3.2EC at 8 oz/A 48 DAP.

Plant stand was rated 35 (16 Jul) and 42 (23 Jul) DAP and relative rate of emergence was calculated as the Relative Area Under the Emergence Progress Curve [RAUEPC from 0–42 DAP, maximum value = 1.00]. Plots were not inoculated but relied on natural infestation of *Verticillium dahliae* for disease establishment. Severity of PED was measured using the Horsfall-Barratt rating scale. Severity of PED was rated 79 (29 Aug), 85 (4 Sep) and 91 (10 Sep) days after planting and the relative rate of disease progression was calculated as the Relative Area Under the Disease Progress Curve [RAUDPC from 0–91 DAP, maximum value = 1.00]. Plots (1 x 25-ft row) were machine-harvested on 24 Oct (135 DAP) and individual treatments were weighed and graded. Randomly selected samples of 10 tubers per plot were washed and assessed for stem end vascular beading incidence (%).

Meteorological Data

Meteorological variables were measured with a Campbell weather station located at the farm from 1 May to 24 Oct. Average daily air temperature (ºF) was 55.5, 67.4, 73.3, 67.9, 67.2 and 51.7 (May, Jun, Jul, Aug, Sep and through 24 Oct respectively) and the number of days with maximum temperature >90ºF over the same period was 0 for each month except July, with 2 days. Average daily relative humidity (%) over the same period was 73.5, 72.0, 68.2, 71.2, 81.2 and 74.9. Average daily soil temperature at 4 in. depth (^{o}F) over the same period was 56.5, 71.7, 75.3, 71.6, 68.4 and 59.3. Average daily soil moisture at (0-12) in. depth over May, Jun, Jul and Aug was 0.33, 0.34, 0.27 and 0.22. Average daily soil moisture at 8 in. depth over September and October was 0.33 and 0.37. Precipitation (in.) over the same period was 4.53, 5.22, 2.87, 2.71, 7.34 and 4.02”. Plots were irrigated to supplement precipitation to about 0.1 in./A/4-day period with overhead sprinkle irrigation.

Results

The 2019 growing season provided environmental extremes of excessive moisture in May, Jun, Sep and Oct but, mild temperatures throughout the season. Therefore, weather of the 2019 growing season was not conducive to PED establishment and development. There was one treatment; CruiserMaxx 0.31 oz/CWT

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(B)+Aprovia 0.75 l/a (C), that had a significantly higher final plant stand compared to the non-treated control (Table 2). Two treatments including: Nimitz 7 pt/a (A) and PicPlus 116 lb/a (A) were significantly lower final plant stand compared to treatment CruiserMaxx 0.31 oz/CWT (B)+Aprovia 0.75 l/a (C). There was no significant difference in PED disease severity (91 DAP) compared to the non-treated control (Table 1). However, treatment; Vydate 310 SL 725 g ai/ha (C)+Vydate 310 SL 362.4 g ai/ha (D)+Vydate 310 SL 362.4 g ai/ha (E) was significantly higher in PED disease severity compared to treatment; Emesto silver 0.31 fl oz/cwt (B)+Vydate 310 SL 1450 g ai/ha (C)+Velum prime 237.5 g ai/ha (C)+Luna tranquility 409 g ai/ha (D). There was no significant difference in RAUDPC values compared to the non-treated control (Table 1). However, there were two treatments including: Vydate 310 SL 725 g ai/ha (C)+Vydate 310 SL 362.4 g ai/ha (D)+Vydate 310 SL 362.4 g ai/ha (E) and CruiserMaxx 0.31 oz/CWT (B)+Aprovia 0.75 l/a (C) that had a significantly lower RAUDPC value compared to treatments Emesto silver 0.31 fl oz/cwt (B)+Vydate 310 SL 1450 g ai/ha (C)+Velum prime 237.5 g ai/ha (C)+Luna tranquility 409 g ai/ha (D) and Emesto silver 0.31 fl oz/cwt (B)+Vydate 310 SL 1450 g ai/ha (C)+Luna tranquility 409 g ai/ha (D)+Vydate 310 SL 724 g ai/ha (D). There were numerical differences, but no treatments were significantly different in total and US#1 size yield (CWT) compared to the non-treated control (Table 2). However, there were two treatments including: CruiserMaxx 0.31 oz/CWT (B) + Aprovia 0.75 l/a (C) and Emesto silver 0.31 fl oz/cwt (B)+Velum prime 237.5 g ai/ha (C)+Luna tranquility 409 g ai/ha (D) that had significantly higher B size yield (CWT) compared to the non-treated control (Table 2). There were two treatments including: Emesto silver 0.31 fl oz/cwt (B)+Vydate 310 SL 1450 g ai/ha (C)+Luna tranquility 409 g ai/ha (D)+Vydate 310 SL 724 g ai/ha (D) and Vapam 45 gal/a (A) that had significantly higher vascular discoloration compared to the non-treated control and treatment Nimitz 7 pt/a (A) (Table 2). There was no significant difference in compared to the non-treated control (Table 2). However, four treatments including: Nimitz 7 pt/a (C), Emesto silver 0.31 fl oz/cwt (B)+Velum prime 237.5 g ai/ha (C)+Luna tranquility 409 g ai/ha (D), Emesto silver 0.31 fl oz/cwt (B)+Vydate 310 SL 1450 g ai/ha (C)+Velum prime 237.5 g ai/ha (C)+Luna tranquility 409 g ai/ha (D) and Vapam 45 gal/a (A) had significantly lower specific gravity vascular discoloration compared to treatment: Nimitz 7 pt/a (A). No phytotoxicity was observed from any treatments.

Table 1. Effects of in-furrow, at planting, and foliar treatments on severity of Verticillium wilt and rate of disease progression.

Treatment and rate[a]	PED[b] 29 Aug 79 DAP[c,d]	PED 4 Sep 85 DAP	PED 10 Sep 91 DAP	RAUDPC[e] 0 – 91 DAP
1. Non-Treated	19.9 abc	25.8 abc	40.6 abc	0.720 abc
2. Vydate 310 SL 725 g ai/ha (C) Vydate 310 SL 362.4 g ai/ha (D) Vydate 310 SL 362.4 g ai/ha (E)	40.7 a	41.9 ab	54.8 a	0.552 c
3. Nimitz 7 pt/a (A)	20.0 abc	25.0 abc	24.9 bc	0.763 abc
4. Nimitz 7 pt/a (C)	16.4 bc	32.0 abc	36.7 abc	0.707 abc
5. CruiserMaxx 0.31 oz/CWT (B) Elatus 0.5 fl oz/1000 row-ft (D)	35.6 ab	36.7 abc	45.3 ab	0.614 abc
6. CruiserMaxx 0.31 oz/CWT (B) Aprovia 0.75 l/a (C)	38.9 a	46.1 a	46.1 ab	0.557 c
7. Emesto silver 0.31 fl oz/cwt (B) Velum prime 237.5 g ai/ha (C) Luna tranquility 409 g ai/ha (D)	17.6 bc	24.6 abc	24.6 bc	0.772 abc
8. Emesto silver 0.31 fl oz/cwt (B) Serenade Soil 1 qt/a (C) Velum prime 237.5 g ai/ha (C) Luna tranquility 409 g ai/ha (D)	24.7 abc	31.8 abc	37.9 abc	0.685 abc
9. Emesto silver 0.31 fl oz/cwt (B) Vydate 310 SL 1450 g ai/ha (C) Velum prime 237.5 g ai/ha (C) Luna tranquility 409 g ai/ha (D)	15.0 bc	18.5 bc	18.5 c	0.824 ab
10. Emesto silver 0.31 fl oz/cwt (B) Vydate 310 SL 1450 g ai/ha (C) Luna tranquility 409 g ai/ha (D) Vydate 310 SL 724 g ai/ha (D)	12.9 c	14.1 c	23.4 bc	0.839 a
11. TerraGrow 137 oz/100 ga (C)	27.3 abc	43.0 ab	47.7 ab	0.598 bc
12. Vapam 45 gal/a (A)	12.9 c	29.7 abc	36.7 abc	0.728 abc
13. PicPlus 116 lb/a (A)	23.0 abc	27.3 abc	40.2 abc	0.706 abc

[a] Application time; A=Pre-planting/pre-plant incorporated; B=Seed treatment; C=In-furrow at planting; D=2” emergence; E=7 Days after 2” emergence.

[b] PED=Potato Early Die severity rated on a Horsfall-Barratt scale of 0 (no infection) to 11 (all foliage and stems dead). Ratings were converted to percentages.

[c] DAP = days after planting on 11 June.

[d] Means followed by same letter are not significantly different at $P = 0.10$ (Fishers LSD).

[e] RAUDPC=relative area under the disease progress curve from planting to 91 days after planting.

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Table 2. Effects of in-furrow, at planting, and foliar treatments on percent plant emergence, rate of emergence, total and marketable yield in hundred-weight per acre, vascular discoloration of tubers, and specific gravity.

Treatment[a]	Plant stand[b] 42 DAP[c,d] (%)	RAUEPC[e] 0 – 42 DAP	Yield (CWT) Total	Yield (CWT) US #1	Yield (CWT) B Size	VD[f] (%)	Specific Gravity[g]
1. Non-Treated	65.4 b	0.317 ab	112.8 ab	30.4 ab	55.2 bcd	38 abc	1.072 b
2. Vydate 310 SL 725 g ai/ha (C) Vydate 310 SL 362.4 g ai/ha (D) Vydate 310 SL 362.4 g ai/ha (E)	77.0 ab	0.177cd	139.0 ab	29.4 ab	70.6 a-d	34 bc	1.077 ab
3. Nimitz 7 pt/a (A)	65.7 b	0.346 a	121.9 ab	13.7 b	67.2 a-d	53 a	1.072 b
4. Nimitz 7 pt/a (C)	76.9 ab	0.185 bcd	94.0 b	15.6 ab	43.8 d	28 c	1.074 ab
5. CruiserMaxx 0.31 oz/CWT (B) Elatus 0.5 fl oz/1000 row-ft (D)	74.5 ab	0.204 bcd	141.3 ab	32.6 ab	76.5 a-d	33 bc	1.075 ab
6. CruiserMaxx 0.31 oz/CWT (B) Aprovia 0.75 l/a (C)	80.9 a	0.152 d	142.3 ab	27.8 ab	92.1 a	34 bc	1.076 ab
7. Emesto silver 0.31 fl oz/cwt (B) Velum prime 237.5 g ai/ha (C) Luna tranquility 409 g ai/ha (D)	68.8 ab	0.291 a-d	164.6 a	40.2 a	89.2 a	25 c	1.077 ab
8. Emesto silver 0.31 fl oz/cwt (B) Serenade Soil 1 qt/a (C) Velum prime 237.5 g ai/ha (C) Luna tranquility 409 g ai/ha (D)	72.7 ab	0.247 a-d	153.8 a	36.9 ab	87.6 ab	46 ab	1.076 ab
9. Emesto silver 0.31 fl oz/cwt (B) Vydate 310 SL 1450 g ai/ha (C) Velum prime 237.5 g ai/ha (C) Luna tranquility 409 g ai/ha (D)	71.3 ab	0.264 a-d	122.0 ab	13.3 b	77.6 abc	21 c	1.077 ab
10. Emesto silver 0.31 fl oz/cwt (B) Vydate 310 SL 1450 g ai/ha (C) Luna tranquility 409 g ai/ha (D) Vydate 310 SL 724 g ai/ha (D)	74.0 ab	0.231 a-d	145.1 ab	21.4 ab	88.5 ab	38 abc	1.078 a
11. TerraGrow 137 oz/100 ga (C)	67.3 ab	0.308 abc	119.3 ab	30.3 ab	52.6 cd	30 bc	1.076 ab
12. Vapam 45 gal/a (A)	70.2 ab	0.260 a-d	131.2 ab	28.7 ab	71.8 a-d	28 c	1.078 a
13. PicPlus 116 lb/a (A)	65.5 b	0.324 ab	158.1 a	39.2 a	85.1 abc	34 bc	1.076 ab

[a] Application time; A=Pre-planting/pre-plant incorporated; B=Seed treatment; C=In-furrow at planting; D=2” emergence; E=7 Days after 2” emergence.

[b] Plant stand expressed as a percentage of the target population of 120 plants/100ft. row from a sample of 1 x 25 ft rows per plot.

[c] DAP = days after planting on 11 June.

[d] Means followed by same letter are not significantly different at $P = 0.10$ (Fishers LSD).

[e] RAUEPC=relative area under the emergence progress curve from planting to 42 days after planting.

[f] VD=Vascular discoloration of the stem end; percentage calculated from 10 tubers.

[g] Specific gravity = (weight in air) divided by [(weight in air) - (weight in water)].

Potato (*Solanum tuberosum*) 'Silverton Russet'
Pythium Leak; *Pythium ultimum,*

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Evaluation of Management Programs for Pythium Leak in Michigan Potato Production-Dowagiac, 2019

A field trial was established 22 May (42.018462, -86.073213) in a commercial potato field, near Dowagiac in south west MI to evaluate selected in-furrow fungicides for post-harvest Pythium leak suppression (Table 1). US#1 'Silverton Russet' tubers were mechanically cut into approximately 2 oz. seed pieces 20 April and allowed to heal before planting. These trials were conducted using potato cultivar 'Silverton Russet' due to its susceptibility to Pythium leak and its commercial use throughout the state of Michigan and the Midwestern US potato growing region. A randomized complete block design with five replications was used for the experiment, with each plot consisting of four 50-ft-long rows spaced 34 in. apart with seed pieces 10 in. apart in the row. Fertilizer was spread as needed for the commercial field surrounding the plot before planting, formulated according to results of soil tests. Additional nitrogen (final N 50 lb/A) was applied to the growing crop with irrigation 45 DAP (days after planting). Treatment application times were in-furrow at planting and for two of the treatments a dribble over the hill application occurred at potato emergence. In-furrow, at-planting applications of fungicide were delivered with a hand-held R&D spray boom delivering 10 gal/A (50 p.s.i.) and using one XR8002VR nozzle per row. A non-treated control was compared with 6 different treatment programs to evaluate their efficacy in suppression of pythuim leak in storage after harvest as well as any agronomic benefits that may be provided to the plant (Table 1). Protectant fungicides such as Bravo WS and Manzate were applied at labeled rates to the commercial field and plot on a seven-day interval, a total of 10 applications were made by air, for foliar disease control. Weeds were controlled by with Dual 8E at 1.5 pt/A 10 DAP, Metribuzin at 4 oz/A 10 and 45 DAP and Matrix at 1.5oz/A 45 DAP. Insects were controlled with Admire Systemic Pro at 7 oz/A at planting, Baythroid xL 1.5oz/A 45 DAP, and Bifenthrin 3 oz/A 70 DAP. A vine kill application of Reglone at 16 oz/A was made by a commercial ground rig applicator 27 Aug 104 DAP and 2 Sept 110 DAP completely desiccating the crop10 days prior to harvest.

Plots (1 row x 25-ft row) were machine-harvested on 12 Sept (120DAP) and individual treatments were graded by size, weighed, bagged and transported to Clarksville Research Center. At the Carksville Research Center all bag samples were opened, tubers counted and placed into plastic individual plastic crates and stored on shelving at 65 ºF for three weeks. After the storage period of three weeks, each tuber was evaluated for symptoms of Pythium leak and counted to calculate % incidence of tuber infection.

Meteorological Data

Meteorological variables were measured with a Campbell weather station located in the Dowagiac area from 1 May to 13 Sept. Average daily air temperature (ºF) was 56.9, 67.1, 74.6, 69.2 and 67.1 (May, Jun, Jul, Aug, and 13 Sep respectively) and the number of days with maximum temperature >90ºF over the same period was 0 for each month except July with 6 days. Average daily soil temperature at 4 in. depth (ºF) over the same period was 59.6, 69.7, 79.1, 74.3 and 70.0. Precipitation (in.) over the same period was 4.1, 3.75, 3.0, 2.6 and 2.3". Plots were irrigated to supplement precipitation for an accumulative total of .5 in/4-day period with overhead sprinkle irrigation.

Results

The 2019 growing season provided environmental extremes of excessive moisture in May and June and cool temperatures over most the growing season. However, a period of dry weather in Aug and Sept resulted in environmental conditions that were not conducive to *Pythium ultimum* establishment and development resulting less % incidence of tuber infection than seen by the grower in past years. There was no significant difference in final plant stand compared to the non-treated control (Table 1). However, plots treated with Ultra Fourish (grower standard) 13 oz/A had significantly higher tubers per plant compared to Elumin 8oz/A (A) + 8 oz/A (B). There were no significant differences in yield for size USA1 (cwt/A) between treatments. Ultra Flourish at

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13 oz/A (A) had the highest size B yield (cwt/A) being significantly higher than all treatments except Tifi 1 lb/A (A). The only significant difference in total yield (cwt/A) was Tifi 1lb/A (A) being higher than Orondis Gold 6.5 oz/A + Ultra Flourish 9.6 oz/A (A). The only significant difference in % incidence in tuber infection after the three-week storage period was Tifi 1lb/A (A) having higher % incidence compared to Ultra Flourish 13oz/A (A).

Table 1. Evaluation of management treatments on suppression of pythium leak in storage of potatoes.

Treatment and rate[a]	Emergence (%)	Tubers per Plant	Yield USA1	Yield B size	Yield Total	Incidence Tuber Infection (%)
1. Non-Treated	94.5 a	6.86 ab	151.9 a	158.4 c	310.3 ab	0.17 a
2. Ultra Flourish 13 fl oz/a (A) Admire Pro 281.3 g ai/ha (A) Quadris .08 fl oz/1000 row-ft (A)	93.4 a	7.8 a	129.1 a	210.1 a	339.2 ab	0.0 b
3. Ranman 5.8 fl oz/a (A) Admire Pro 281.3 g ai/ha (A) Quadris .8 fl oz/1000 row ft (A) Ranman 2.75 fl oz/A (B)	91.4 a	7.1 ab	160.0 a	169.0 bc	329.0 ab	0.24 ab
4. Elumin 8 fl oz/a (A) Admire Pro 281.3 g ai/ha (A) Quadris .8 fl oz/1000 row-ft (A) Elumin 8 fl oz/a (B)	94.8 a	6.7 b	142.9 a	169.1 bc	312.0 ab	0.18 ab
5. Tiffi 1 lb/a (A) Admire Pro 281.3 g ai/ha (A) Quadris .08 fl oz/1000 row-ft (A)	91.4 a	7.4 ab	158.2 a	191.6 ab	349.8 a	0.49 a
6. Orondis Gold 200 6.5 fl oz/a (A) Ultra Flourish 9.6 fl oz/a (A) Admire Pro 281.3 g ai/ha (A) Quadris .08 fl oz/1000 row-ft (A)	89.0 a	7.1 ab	132.7 a	172.3 bc	305.0 b	0.17 ab
7. Previcur Flex 19.2 fl oz/a (A) Admire Pro 281.3 g ai/ha (A) Quadris .08 fl oz/1000 row-ft (A)	91.6 a	6.8 ab	160.1 a	157.8 c	317.9 ab	0.12 ab

[a] Application time; A= In-furrow at planting; B= Emergence dribble over row.

[b] Means followed by same letter are not significantly different at $P = 0.05$ (Fishers LSD).

Project title: New strategies for managing Colorado potato beetles in Michigan
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In Michigan, Colorado potato beetles (CPB) are managed with insecticides that rely on an at-planting neonicotinoid treatment followed by foliar applications throughout the growing season. The potato industry's priority is to maintain the efficacy of neonicotinoids for CPB management. The registration of neonicotinoid insecticides in 1995 saved millions of dollars for the potato industry in control costs against CPB. Currently, imidacloprid or thiamethoxam are used on ~80% of Michigan's potato acreage annually as either an in-furrow or seed treatment. The high selection pressure provided by the repeated application of neonicotinoids is the cause for the gradual loss of the effectiveness of this insecticide class for CPB control. Without alternative solutions, the current situation could have serious impacts. Here we tested strategies that rotate insecticide classes to provide longevity to particular insecticides. Our goal is to generate information on the performance of insecticide programs that do not rely on neonicotinoids.

In order to avoid creating populations of beetles that are resistant to a particular toxin, it is recommended that growers rotate insecticide classes (mode of action). Here we compared the efficacy of different programs that combine in-furrow applications with foliar insecticides or just use foliar insecticides without at-planting treatments to explore alternative insecticide programs for Colorado potato beetle management. We tested the efficacy of insecticide programs that do not contain neonicotinoid insecticides.

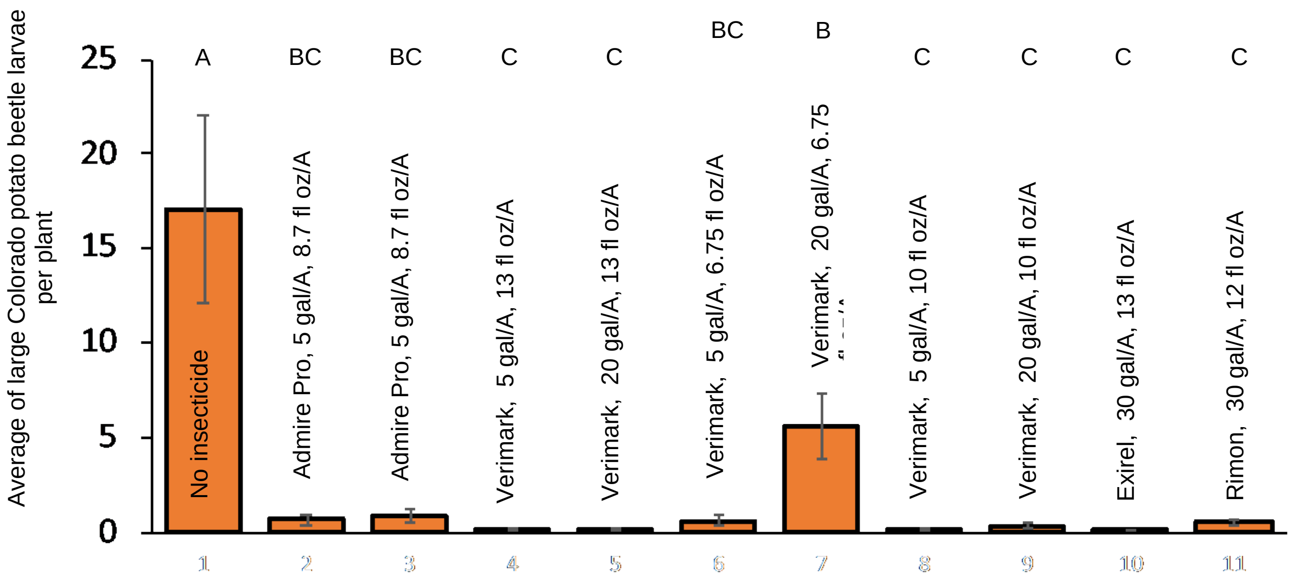
Evaluate insecticide programs in field tests for CPB control

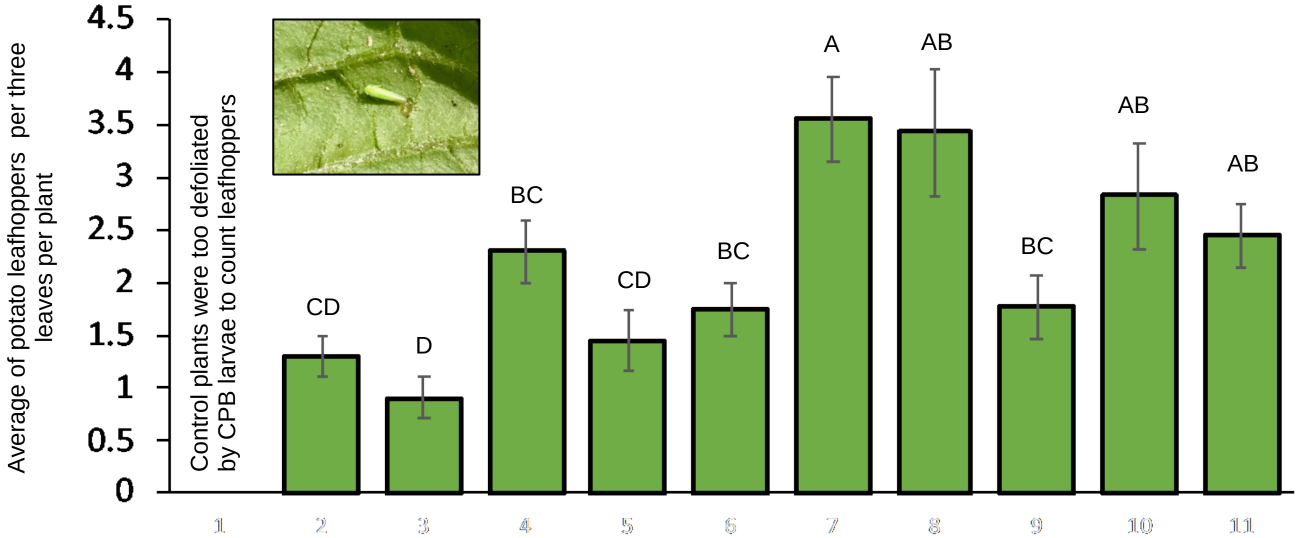
We evaluated the efficacy of insecticide programs for CPB control in field trials at the Montcalm Potato Research Farm during the 2019 growing season. The trial was focused on managing the overwintered or early season population. Some of the tested insecticides are alternatives to neonicotinoids and therefore may be of great value to growers in the future. The field trials were set up in 20-foot long, 3 row wide plots, and replicated 4 times with buffer rows between plots. Insecticides were applied with a CO2 backpack sprayer with a single nozzle, and the field was managed for weeds and diseases using a grower-standard spray program. Insecticides were applied at the recommended label rates and were timed for 50% egg hatch, or 1 large larva per plant. Rimon was applied as a series of two, successive applications spaced 7–10 d apart. Weekly counts of Colorado potato beetles on 5 plants per plot were conducted to compare the efficacy of each program. We used analysis of variance followed by Tukey's means separation to determine statistically significant differences among treatments.

At planting insecticides:
Verimark - FMC
Admire Pro - Bayer

Foliar insecticides:
Exirel - FMC
Rimon - Arysta Lifescience

- Insects counted on July 2, 22
- Rimon and Exirel timed for 50% egg hatch (June 26)
- Rimon applied twice 7 days apart (June 26, July 3)





- all applications were made with a backpack sprayer using a flat fan nozzle
- bars with the same letters are not statistically different

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Survey of postharvest disease in Michigan potato storages, 2019

Emma Schlachter, Ray Hammerschmidt, Noah Rosenzweig, Jaime F. Willbur, Chris Bloomingdale;
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Tuber shrinkage and loss in storage can result in substantial economic consequences in Michigan, making postharvest disease management a priority. Persistent rainfall throughout the growing season and warm temperatures during late harvest favor fungal and bacterial development in the field and storage. Preliminary surveys performed by MSU researchers in 2012-2014 found that growers were concerned with dry rot (Gachango et al. 2012a,b), bacterial soft rot and blackleg (caused by *Dickeya* and *Pectobacterium* spp.), and Pythium leak (Long and Hammerschmidt 2014) contributing to tuber breakdown in storage.

Through this survey we will: 1) characterize postharvest diseases impacting Michigan growers, 2) identify disease progression of prevalent pathogens in storage, and 3) devise integrated pest management strategies to minimize loss.

Materials and Methods:

In 2019, tubers were received from 12 fields across six counties after harvest from September - October. Tubers were collected from five areas of a field and separated into two samples of 50 tubers for monitoring in storage and 50 tubers for pre-storage destructive sampling. Destructive preharvest sampling was performed in the laboratory from September – October. Storage samples were placed in the Montcalm Research Center Storage Facility in standard storage conditions (48 F) after harvest and will be monitored at four timepoints for disease progression and shrinkage. In April – May 2020, these samples will be destructively sampled.

At the time of destructive sampling, external and internal tissues were examined for abiotic and biotic symptoms and signs of disease. A scrape was defined as an injury that removed layers of the periderm but did not extend into the cortex. A wound was an injury which extended into the cortex and may have included complete removal of portions of the tuber. Symptomatic and asymptomatic tissues were chosen for further isolations.

Tissues exhibiting abiotic or biotic symptoms, signs of disease, damage or injury, or asymptomatic tissue were excised as 1 cm^2 samples. Samples of epidermal and vascular tissue were taken for all tubers and surface disinfested and plated on 1.5% water agar. Fungal growth was isolated by hyphal tipping after three to five days. Tubers with visible soft rot symptoms were streaked using an inoculation hoop onto crystal violet agar media (CVA) and observed for pitting (common characteristic of pectolytic bacteria, e.g. *Dickeya* and *Pectobacterium* spp.). Morphological characteristics of fungi were observed through microscopic observation and assigned putative genera. Molecular characterization will be performed on randomly selected representatives of each sample isolated in order to confirm identities. Further characterization of pathogenicity will be conducted through inoculated tuber experiments.

Results and Conclusions:

A total of 679 tubers underwent preharvest destructive sampling. Eight tubers were asymptomatic and undamaged. The following internal and external abiotic symptoms were observed: 48% scrape, 31% wounding, 12% bruising, 3% pink eye, 2% vascular discoloration, 2% asymptomatic, 1% internal brown spot, 1% hollow heart (Figure 1). Symptoms and signs of the following diseases were also observed: 60% scab, 17% black dot, 6% black scurf, 6% soft rot, 4% silver scurf, 4% dry rot, 2% leak, 1% asymptomatic (Figure 2).

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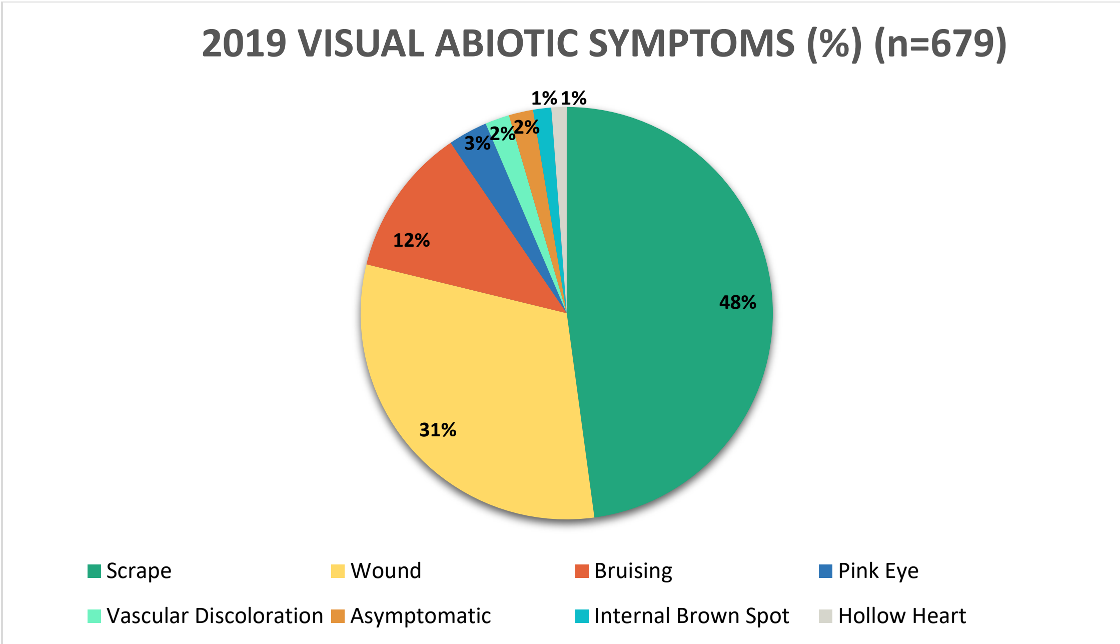

Figure 1. Abiotic damage and physiological disorders observed on tubers selected for at-harvest destructive sampling.

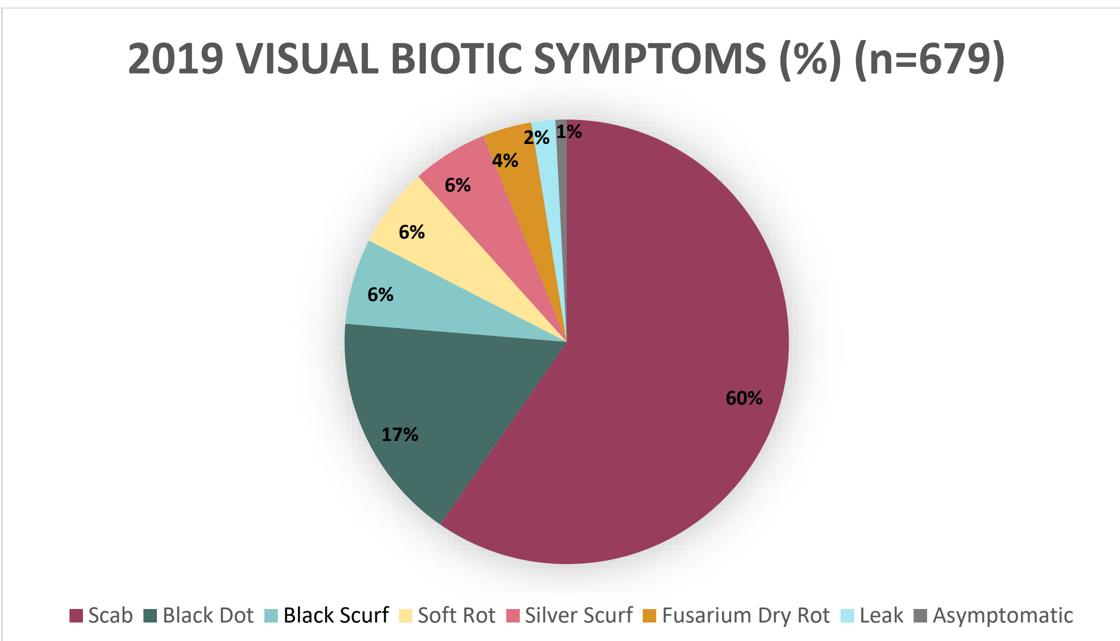

Figure 2. Biotic signs and symptoms of disease observed on tubers selected for at-harvest destructive sampling.

The following relative frequencies of known pathogenic genera have been observed from 570 tubers: *Fusarium* (25%), *Rhizoctonia* (24%), *Pythium* (17%), *Alternaria* (15%), *Colletotrichum* (7%), *Streptomyces* (3%), *Phytophthora erythroseptica* (0.3%), and *Geotrichum* (0.3%). Putative bacterial pathogens (9%) are currently being characterized with the help of the MSU Plant and Pest Diagnostic Clinic and Dr. Noah Rosenzweig (Figure 3).

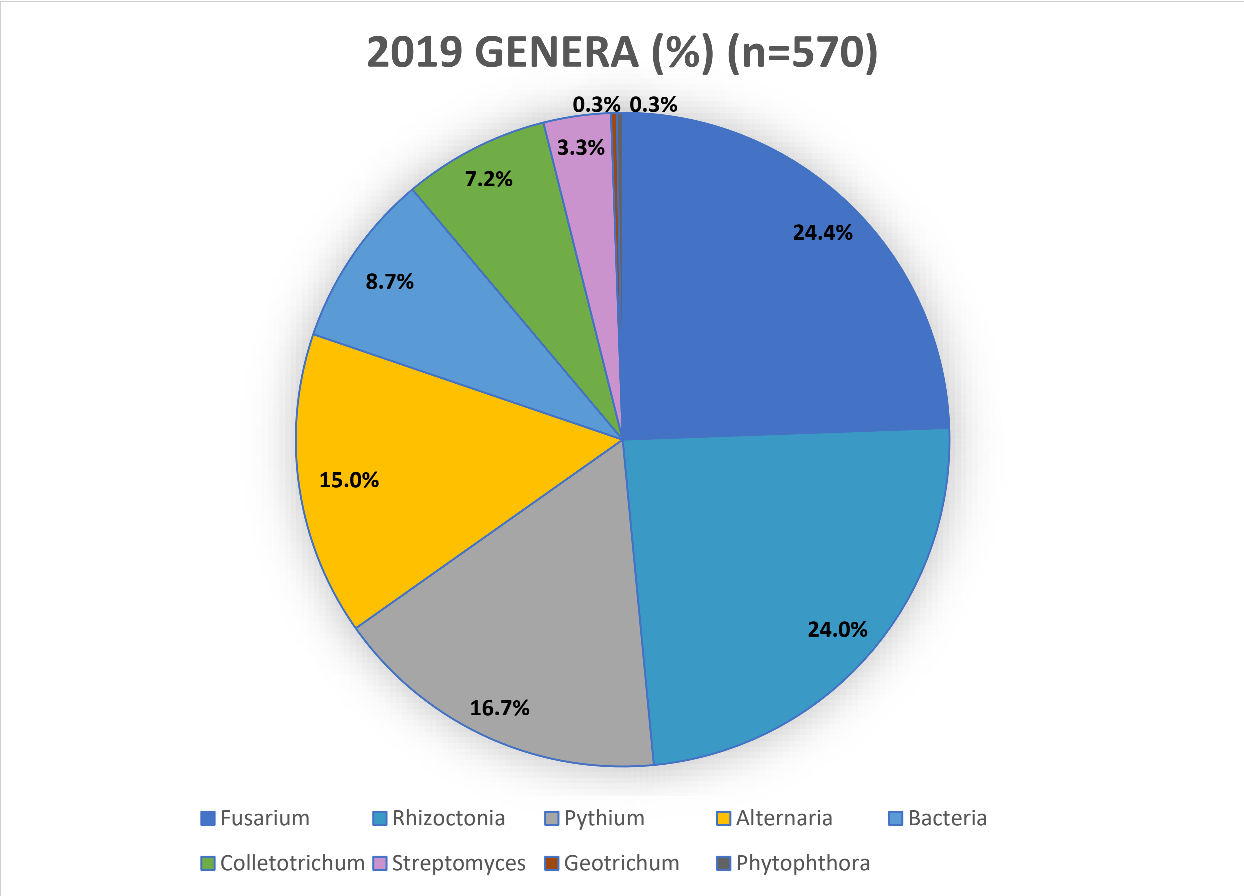

Figure 3. Relative frequencies of known pathogenic genera isolated from tubers, excluding samples without identified pathogens.

Correlations between abiotic and biotic symptoms were calculated using Kendall's tau B coefficient (SAS v. 9.4) and evaluated at the α=0.05 significance level. Highly significant correlations were found between dry rot and wound (r = 0.2082, P < 0.0001) and dry rot and internal bruising (r = 0.3726. P < 0.0001). These results support that damage inflicted upon tubers increases susceptibility to disease. Signs and symptoms of disease were low in initial samples, however, pathogen genera were detected on 83% of the tubers sampled at-harvest. We hypothesize that correlations between symptoms and genera observed will be higher at postharvest sampling due to advanced disease progression.

Acknowledgements:

We would like to thank the grower cooperators and key industry representatives and researchers who participated in this survey. We specifically thank other MSU Extension programs, Agri-business Consultants, Inc., Walther Farms, and MSU AgBioResearch for their contributions and support.

Diagnostic optimization of viral detection and characterization for the Michigan seed potato certification program, 2019

Stefanie Rhodes[1], Emma Schlachter[2], Chris Bloomingdale[2], Cameron Pincumbe[2], Elizabeth Dorman[1] and Jaime Willbur[2]; [1]Michigan Department of Agriculture and Rural Development, Pesticide and Plant Pest Management Division, Plant Pathology; [2]Michigan State University, Dept. Plant, Soil and Microbial Science, Potato and Sugar Beet Pathology

Potato virus Y (PVY) is one of the primary diseases monitored and tested for in the seed certification process and is one of the top Michigan potato industry research priorities. The industry has expressed interest for in-state screening of tuber testing for seed certification, however, current protocols for viral testing in Michigan are both time and labor intensive. Current methods rely on winter grow out assays which detect viruses in sprouts or plantlets after breaking tuber dormancy. While effective, the current seed certification staff and facilities are limited by the time and space necessary to process large quantities of samples. To enable the Michigan Department of Agriculture and Rural Development (MDARD) to increase handling capacity and efficiency, the Potato and Sugar Beet Pathology (PSBP) program proposed to assist in optimizing the viral detection and diagnostic protocols used in winter testing. Through this work we: 1) investigated improved detection options to identify accurate, timely, and cost-effective methods for use in the Michigan seed potato certification and 2) monitored PVY strain prevalence in Michigan seed potatoes. The results of this work will help develop standard protocols for high-throughput, in-state tuber testing. Future studies will focus on improving virus and vector management in Michigan potato crops.

Materials & Methods:

Tuber testing methods which do not require breaking tuber dormancy to sample from resulting sprouts or plantlets were investigated. General (Mackenzie et al. 2015) and multiplex (Lorenzen et al. 2006) reverse-transcriptase (RT) high-fidelity polymerase chain reaction (PCR) protocols were tested and compared to existing plantlet assays involving enzyme-linked immunosorbent assay (ELISA). Four samples of 300-400 tubers each taken from a single seed potato lot with high levels of visual foliar symptoms of PVY in the field. Samples were divided into 10-tuber subsamples (N=number of subsamples) and subjected to the following tests: 1) dormant tuber (RT-PCR), 2) standard Michigan grow out with leaflets (ELISA), 3) dormant tuber (RT-PCR) and standard grow out (ELISA), and 4) standard Hawaii grow out with leaflets (ELISA). ELISA and RT-PCR methods were compared in leaflets from samples 2, 3, and 4. Sensitivity, accuracy, and agreement of the various methods, as well as the time and labor costs involved, were compared with existing methods. Strain prevalence was determined using preliminary observations collected from nine PVY positive lots (19 subsamples, 265 individual plants) tested in 2018-19. In 2019, testing will be conducted using five seed potato lots. Positive samples will be subjected to strain analysis.

Results & Conclusions:

Dormant tuber and standard grow out methods both identified high levels of PVY (75-87%) in tested subsamples (Table 1). Michigan and Hawaii grow out tests were very similar, 87 and 89% positive for PVY respectively. Testing is in-progress for test method 3, where the tubers and leaflets of the same plants were tested using different methods. Cost estimates are being developed based on these experiments.

Table 1. Comparison of ELISA and RT-PCR results based on positive PVY detections (%) using dormant tuber and standard leaflet grow out methods (in-progress).

#	Test method	N	ELISA (+)	RT-PCR (+)
1	Dormant tubers	32	NA	**75%**
2	Standard leaflet grow out	32	**89%**	(in-progress)
3	Dormant tubers <u>and</u> leaflet grow out	36	NA; **44% (in-progress)**	**64% (in-progress);** (in-progress)
4	Hawaii leaflet grow out	53	**87%**	(in-progress)

In 2018, 12% of plant samples tested positive for PVY (strains O, N:O, N-Wi) and 2% tested positive for PVY^{N} (strains N, NTN). A subset of positive samples from five lots were sent for testing (Karasev); 90% of samples were positive for $PVY^{N\text{-}Wi}$ and 10% were positive for $PVY^{N:O}$. In 2019 testing, the PVY strain types from potato tubers and leaves were successfully identified using a multiplex RT-PCR. As in 2018, the majority of tested samples were positive for $PVY^{N:O/N\text{-}Wi}$, however, testing is ongoing.

Evaluation of foliar fungicides to manage white mold of potato in Michigan, 2019.

Chris Bloomingdale and Jaime Willbur
Dept. Plant, Soil and Microbial Science, Michigan State University

A foliar fungicide efficacy trial was established at the Montcalm Research Center in Lakeview, MI. The trial objective was to determine the efficacy of commercially available fungicides for managing white mold. A randomized complete block design, with four replicates, was used. Potato seed were cut from US#1 'Lamoka' tubers and treated with Cruiser Maxx Potato Extreme (0.31 fl oz/100 lb seed), then allowed to suberize before planting. The trial was hand-planted 14 May. Plots were four rows wide (34-in. row spacing) by 20 ft long and a 10-in seed spacing was used. Standard grower practices were followed to manage non-target pests. The first fungicide applications were made 26 Jun, with a 7-d spray interval until 13 Aug. A CO_2 powered backpack sprayer, equipped with two TJ 8004XR flat fan nozzles and operating at a boom pressure of 38 psi, was used to apply fungicides at 20 gal/A. A standard fungicide program was also applied to control plots to prevent creating an entry point for late blight in a major potato producing region of MI. While in flower, plots were inoculated with *S. sclerotiorum*-infested millet at a rate of 0.0125 lb/rw-ft on 12 Jul and 25 Jul. Disease data were collected regularly until a chemical vine kill 30 Aug. Twenty stems were arbitrarily rated from the center two rows of plots and assigned a disease severity (0-3). The severity ratings were: 0 = no disease, 1 = infection on secondary stem or petiole, 2 = infection on main stem but not girdling, 3 = infection girdling mainstem, resulting in wilting and/or death. The ratings were used to calculate a disease index and mean severity, which were then used to calculate a plot disease index. The center two rows of plots were harvested 27 Sep, potatoes were washed, and the marketable yield (cwt/A) determined. A generalized linear mixed model procedure was used to conduct the ANOVA and mean separations at α=0.05.

Mean disease index (DX) values ranged between 19 and 24%, but were not significantly different among treatments (P>0.05). Estimated marketable yields (range: 114-166 cwt/A) were not different among tested fungicide programs (P>0.05). Numerically, program 1 (treated control) had the highest DX and lowest marketable yield, with values of 24.2% and 114.8 cwt/A, while program 4 had the lowest DX and highest marketable yield of 19.0% and 166.0 cwt/A, respectively. The lack of differences among treatments is believed to be caused by a large infestation of potato leafhoppers (*Empoasca fabae*), which resulted in an early vine kill. In the first week of Aug, leafhoppers infested the research field and surrounding grower fields. Insecticide applications were made, but hopper pressure remained high as insects migrated in from external fields. If insect pests had not caused vines to prematurely senesce, disease may have continued to develop enough for differences to be observed.

Other pathology trials for potatoes in Michigan, 2019.

A second trial was conducted at the Montcalm Research Center to investigate the management of potato early die using different russet varieties with and without a fall fumigation program. Methods were similar to those previously described here. These experiments are still in early stages, but results are available upon request.

Table 1.

No.	Treatment, Rate[z], and Timing[y]	Disease Index (%)[x, w]	Marketable Yield (cwt/A)
1[v]	Bravo Weather Stik (1.5 pt) ACEG + Manzate Max (1.6 qt) BDF	24.2	114.8
2	Bravo Weather Stik (1.5 pt) ABCDEFG + Luna Tranquility (11.2 fl oz) DF	20.0	159.5
3	Bravo Weather Stik (1.5 pt) ACDFG + Previcur Flex (19.2 fl oz) BE + Serenade ASO (32 fl oz) BE + Luna Tranquility (11.2 fl oz) DF	21.2	142.3
4	Bravo Weather Stik (1.5 pt) ACEG + LifeGard WG (4.5 oz/100gal) ACEG + Manzate Max (1.6 qt) BDF	19.0	166.0

[z] All rates, unless otherwise specified, are listed as a measure of product per acre.
[y] Fungicide applications were initiated at row touch. Application letters code for the following dates: A = 26 Jun, B = 9 Jul, C = 15 Jul, D = 23 Jul, E = 30 Jul, F = 8 Aug, G = 13 Aug.
[x] Disease index was calculated by multiplying the disease incidence (0-100%) by the mean severity (0-3), then dividing by 3.
[w] Column values followed by the same letter were not significantly different based on Fisher's Protected LSD (α=0.05); if no letter, then the effect was not significant.
[v] Treated control.

Evaluation of foliar fungicides to manage late blight of potato in Michigan, 2019.

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Dept. Plant, Soil and Microbial Science, Michigan State University

Commercially available fungicides were tested to determine their efficacy for managing potato late blight. A field trial was established at the Michigan State University Plant Pathology Farm in Lansing, MI. A randomized complete block design was used, and treatments were replicated four times. US#1 'Lamoka' potatoes were cut into 2-oz seed pieces, treated with Cruiser Maxx Potato Extreme (0.31 fl oz/100 lb seed), and then left to suberize. The trial was planted 27 Jun. Plots were two rows wide (36-in row spacing) by 20 ft long (10-in seed spacing) and were planted by hand. Equipment was used to open and close furrows. Potatoes and non-target pests were managed following standard grower practices. First fungicide applications occurred the morning of 20 Sep, and were repeated weekly until 8 Oct. A CO_2 powered backpack sprayer, equipped with two TJ 8004XR flat fan nozzles and operating at a boom pressure of 38 psi, was used to apply fungicides at 20 gal/A. Inoculations were postponed until 20 Sep, pending an earlier in-state detection. At sunset on 20 Sep, liquid *P. infestans* inoculum (2.0×10^3 sporangia/mL) was applied using the previously mentioned spray equipment, which was sanitized before and after use. To document disease progression, disease ratings were conducted regularly until vines were chemically killed 8 Oct. The plot disease incidence (0-100%) and plot disease severity (0-100) were estimated and then used to calculate a plot disease index. Tubers were harvested from both rows 24 Oct and washed and graded to determine marketable yield (cwt/A). A generalized linear mixed model procedure was used to conduct the ANOVA (α=0.05) and mean separations.

End of season disease incidence and disease severity ratings were used to calculate a disease index (DX) value for each treatment. Mean index values for treated plots ranged from 0.02% to 10.13% and, though not different from each other, were significantly lower than the non-treated control (85.06%; P<0.001). Marketable yield was not different among treatments (P>0.05), and ranged between 265 and 300 cwt/A. The lack of differences among treatments, despite strong disease pressure, was likely due to the short period of disease progression. At the requests of Michigan potato growers, the trial was terminated within 3 wk of the first late blight detection. Had disease onset occurred earlier, or disease continued to progress, it is possible significant differences among treatment yields would have been observed.

Table 1.

No.	Treatment, Rate[z], and Timing[y]	Disease Index (%)[x, w]	Marketable Yield (cwt/A)
1	Non-Treated Control	85.06 a	273.9
2	Bravo Weather Stik (1.5 pt) ABC	10.13 b	300.4
3	Orondis Opti (2.5 pt) A + Bravo Weather Stik (1.5 pt) BC	5.01 b	262.4
4	Orondis Opti (2.5 pt) A + Revus Top (5.5 fl oz) B + Bravo Weather Stik (1.5 pt) C	0.02 b	265.7

[z] All rates are listed as a measure of product per acre, and all tank mixes contained MasterLock at a rate of 0.25 % v/v.
[y] Application letters code for the following dates: A= 20 Sep, B= 25 Sep, C= 4 Oct.
[x] Disease index was calculated by multiplying the disease incidence (0-100%) by the mean severity (0-100), then dividing by 100.
[w] Column values followed by the same letter were not significantly different based on Fisher's Protected LSD (α=0.05); if no letter, then the effect was not significant.

Other pathology trials for potatoes in Michigan, 2019.

Another trial was conducted at the Plant Pathology Research Farm to investigate the efficacy of a foliar applied experimental compound at managing early blight. Methods are similar to those described here. These experiments are still in early stages, but results are available upon request.

Remote Sensing to Quantify Spatial Variability of Crop Nitrogen (N) Status and Optimize N Fertilizer in Potato Fields
(Third year – continuation grant)

Michigan Potato Industry Commission Report

Bruno Basso, PhD.
University Foundation Professor
Department of Earth & Environmental Sciences
Michigan State University

Rationale

Precision agriculture (PA) technologies have been shown to benefit producers by utilizing systems built into traditional row-crop machinery. High accuracy global positioning systems (GPS) coupled with on-board computers continuously record quantifiable variables like implement speed, direction, seeding-rates, fertilizer and pesticide applications, and grain yield. These data allow producers to visualize trends of productivity from their fields that help them understand the causes of these spatial variations that are inherent to every field in Michigan. The potato (*Solanum tuberosum* L.) is a high-value crop that is an important component in Michigan's diverse agricultural system. It is commonly rotated with corn, soybeans, wheat, peas, dry-edible beans and others. Nitrogen (N) is an important resource that drives the production of these crops, notably potato, corn, and wheat. However, each crop reacts differently to the various types of N application method, amount, and formulation. van Evert et al. (2012) reported using the index weighed difference vegetation index (WDVI) as a novel method for determining N side-dress rates. This proposal's primary objective was to use data available from Michigan potato producers to test the ability of remotely sensed imagery to determine N uptake in their crop. Additionally, farmers know that PA must play a vital role in driving the knowledge behind management decisions in Michigan potato production, and PA encourages adoption of these practices to further enhance their productivity.

Objectives

The goal of this proposal is to link PA tools such as remote sensing and variable rate application into a protocol that is available for potato farmers to use to monitor crop N uptake, apply N in a spatially variable manner, and improve their productivity.

Methodology

Field Descriptions

Two fields in Pine Township were selected to use as experimental trials in cooperation with Main Farms. The field "P_38" is located in Montcalm County. It is an irrigated field totaling 17.4 acres. The field contains 3 soil types, but is dominated by Plainfield-Spinks sands, 0-6 percent slopes, making up 15 acres (86.1%). The remaining soil types are classified as Plainfield-Spinks sands, 6-18 percent slopes at 1.6 acres (9.4%) and Tekenink-Elmdale loamy sands, 2-6% slopes at 0.8 acres (4.5%). The field "P_01" is located adjacent to P_38 with two center pivots pulling from a large waste area in the middle of the field totaling 37.9 acres. It contains 5 soils types and is dominated by Plainfield-Spinks sands, 0-6 percent slopes at 20.0 acres (52.8%). The other major soil types are Tekenink-Elmdale loamy sands, 2-6 percent slopes at 11.8 acres

(31.1%) and Tekenink-Spinks loamy sands, 6-12 percent slopes at 6.0 acres (15.7%). Table 1 contains the field names, rotation, and field size.

Experimental Design
Yield monitor data provided by the cooperator led to the creation of yield stability maps (YSM). First, areas of high, medium, and low levels of production were mapped with an algorithm to determine yield productivity levels. Second, a temporal variance map was created to show areas of stable and unstable production. The combination of these maps led to the YSM that shows how these areas perform across the field (spatially) and year after year (temporally) (Figure 1). The field trial was setup accounting for these patterns of yield level variability present and visible from the YSMs.

Varied Plant Populations & Varied Nitrogen Management
At planting, seed piece densities were varied in coordination with the farm-standard (17,000 pl ac^{-1}) for that particular farm. A low density (14,500 pl ac^{-1}) and high density (19,500 pl ac^{-1}) were also included as treatments. Planting densities were counted by hand a few weeks after emergence. Both fields received consistent rate of N at pre-plant (dry Urea/AMS blend) and planting (liquid). A consistent rate in combination of dry and liquid was applied at hilling. Lastly, a 50/50 blend of urea and AMS was spread at both fields in coordination with a prescription from the Basso Lab (Table 2). The prescription was varied with multiple rates fitting the yield stability zones to determine the yield response. (Figure 2).

Remotely Sensed Imagery & Field Sampling
Remotely sensed imagery was collected throughout the season using UAVs (unmanned aerial vehicles), airborne systems (AirScout®), and satellites in order to assess plant health based on multiple vegetation indices (VIs). Remote sensing is a tool that captures plant and soil reflectance which is an indication of plant health at the field-scale. The VIs related to potato production, like the weighted difference vegetation index (WDVI), are important because potatoes are planted in wide rows and they achieve full canopy later in the season, so typical VIs like normalized difference vegetation index (NDVI) and normalized red edge index (NDRE) are not optimal (Table 3). Petiole samples were collected at various point within the population trial and at 2 sample dates: 7/23/19 & 9/9/2019. Shortly before machine harvest, a single 7-ft row was hand dug at 3 replicates at 48 sample points across both fields, and the potatoes were weighed by each grade, or the size of the tuber. A subsample of potatoes was brought back to the MSU Agronomy Farm where their specific gravity was measured and processed for N accumulation. Unfortunately, due to the delayed planting in the spring, the field was projected to be harvested in late fall and the effects of a hard frost in November rendered the field damaged, so it was not machine harvested. Yield monitor data from machine harvested potato fields has proven very valuable in getting a complete picture of field-scale variability.

Results
Yield Stability Analysis
An unusually wet spring impacted every farm in the Midwest. These fields were the selected for this study after the original fields were abandoned due to conditions that delayed planting. Yield stability analysis revealed a trend of the low and stable zones being found around the field borders. This is consistent with the findings of Basso and Maestrini, 2018. High and stable zones

in the middle of the field consistently produce the highest yields, while the unstable zones fluctuate based on the particular year and are typically dominated by unique positions in the landscape, i.e. hilltops, slopes, and depressions.

Remotely Sensed Imagery

Imagery collected via UAVs and airborne systems reveals spatial patterns of variability in potato vegetation growth. These patterns reflect the inherent nature in differences of potato vegetation and not any difference in management. Eight images collected via AirScout® remote sensing service show the pattern of plant health through their advanced difference vegetation index (ADVI®) (Figure 3). Imagery captured after the varied N application on July 23 shows no signs of differences related to N (Images on July 31, August 19, and September 14). The plants began to senesce, and vine-kill took place shortly after the final image on September 14. The final image at October 7 shows the field with no living vegetation. The capability of remote sensing to detect differences in N uptake in plants is well documented in the literature, however there is no visible response to the varied N in these later images. This indicates that there was no response by the plants to the 3 varied rates, 0, 100, and 200 lb N ac^{-1}. The WDVI imagery captured from the UAV reveals similar patterns of variability in vegetation that is not in response to the N treatments at P_01 and P_38 (Figures 4 and 5).

Yield, Nitrogen, and Potato Grades

Petiole samples collected in July and September revealed a difference in mean N concentration by date, but no significant differences in the means by either field, planting density, or yield stability zone (Table 4). These results indicate that varying N in potatoes needs to be taken into consideration before hilling, since the effect is not represented in both remotely sensed imagery and samples taken by hand. Results from the hand digs show that potato yields were slightly lower at the 0 lb N ac^{-1} side-dress, but the differences were not significant (Figure 6). Each treatment produced around the same amount of No.1 graded potatoes (39-45). The results did not show any significant differences when analyzed by their position in the field.

Conclusions

Each year brings new opportunity and new challenges that the grower faces if they wish to have successful and profitable crop growth. Large precipitation events, like spring 2019, cause delays in completing field work like spreading fertilizer, tillage, and planting. These delays also deter what would normally be expected of the crop N cycle. Yield stability maps provide the visual representation of field scale variability regardless of management practices. Here, planting densities, variable rate nutrients, and irrigation scheduling decisions are made from a more informed perspective that saves producers valuable input costs.

References

Maestrini, B. & Basso, B. (2018). Drivers of within-field spatial and temporal variability of crop yield across the US Midwest. *Scientific Reports,* 8(1), 2045-2322.

van Evert, Frits & Booij, Remmie & Jukema, Jan & M, Berge & Uenk, Dik & Meurs, E.J.J. & Van Geel, Willem & Wijnholds, Klaas & Slabbekoorn, J.J. (2012). Using crop reflectance to determine sidedress N rate in potato saves N and maintains yield. *European Journal of Agronomy* 43 (58-67).

Field Name	Yrs. of Yield Data	Cropping History	Field Size (ac)
P_01	5	Corn-Soybean-Corn-Potato	37.88
P_38	5	Corn-Soybean-Corn-Potato	17.39

Table 1. Field names, available field data, rotation, and field size for the 2 studied potato fields.

Treatment	Pre-Plant June 3 (lb N/ac)	Planting June 4-5 (lb N/ac)	Hilling July 8 (lb N/ac)	Post-Hilling July 23 (lb N/ac)	Total N
Low	33.0	55.1	110.0	0	198.1
Conventional	33.0	55.1	110.0	100	298.1
High	33.0	55.1	110.0	200	398.1

Table 2. Nitrogen management information related for the 2019 season.

Index	Equation	Description	Reference
NDVI	$ndvi = \frac{(nir - red)}{(nir + red)}$	Estimates leaf area index (LAI) as a proxy for biomass accumulation	
NDRE	$ndre = \frac{(nir - red\ edge)}{(nir + red\ edge)}$		Sharma et al. 2017
WDVI	$wdvi = nir_{canopy} - \frac{(nir_{soil})}{(green_{soil})}\ green_{canopy}$	Removes soil reflectance before plant canopy is covered	Clevers 1992
GC	$GC = 196.6\ x\ wdvi\ if\ wdvi < 0.29$ $GC = -8.05 + 228.5\ x\ wdvi\ if\ wdvi \geq 0.29$	Estimates amount of ground cover	Bouman et al. 1992

Table 3. Remotely sensed imagery is transformed into vegetation indices (VIs) that describe the spatial variability of potato growth.

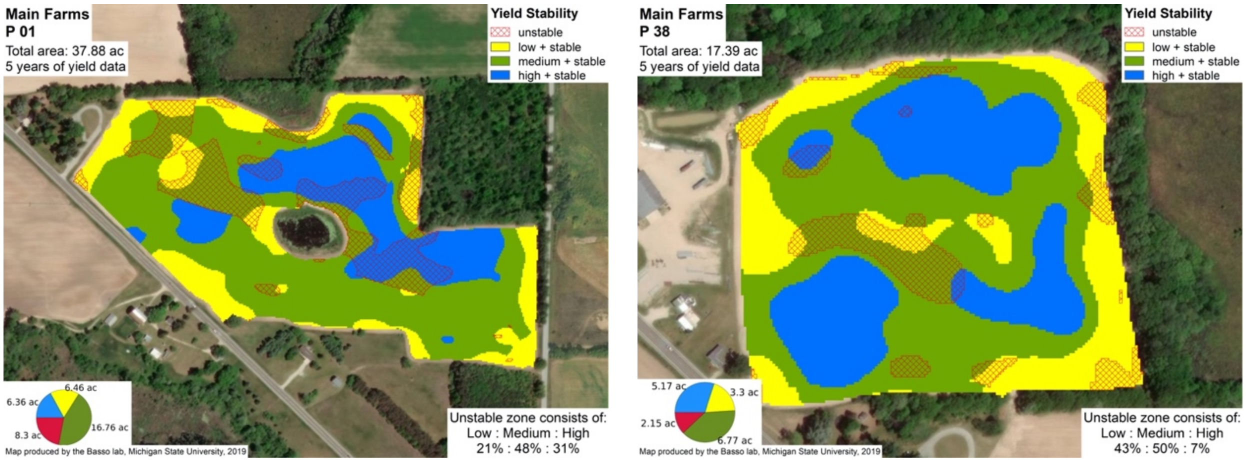
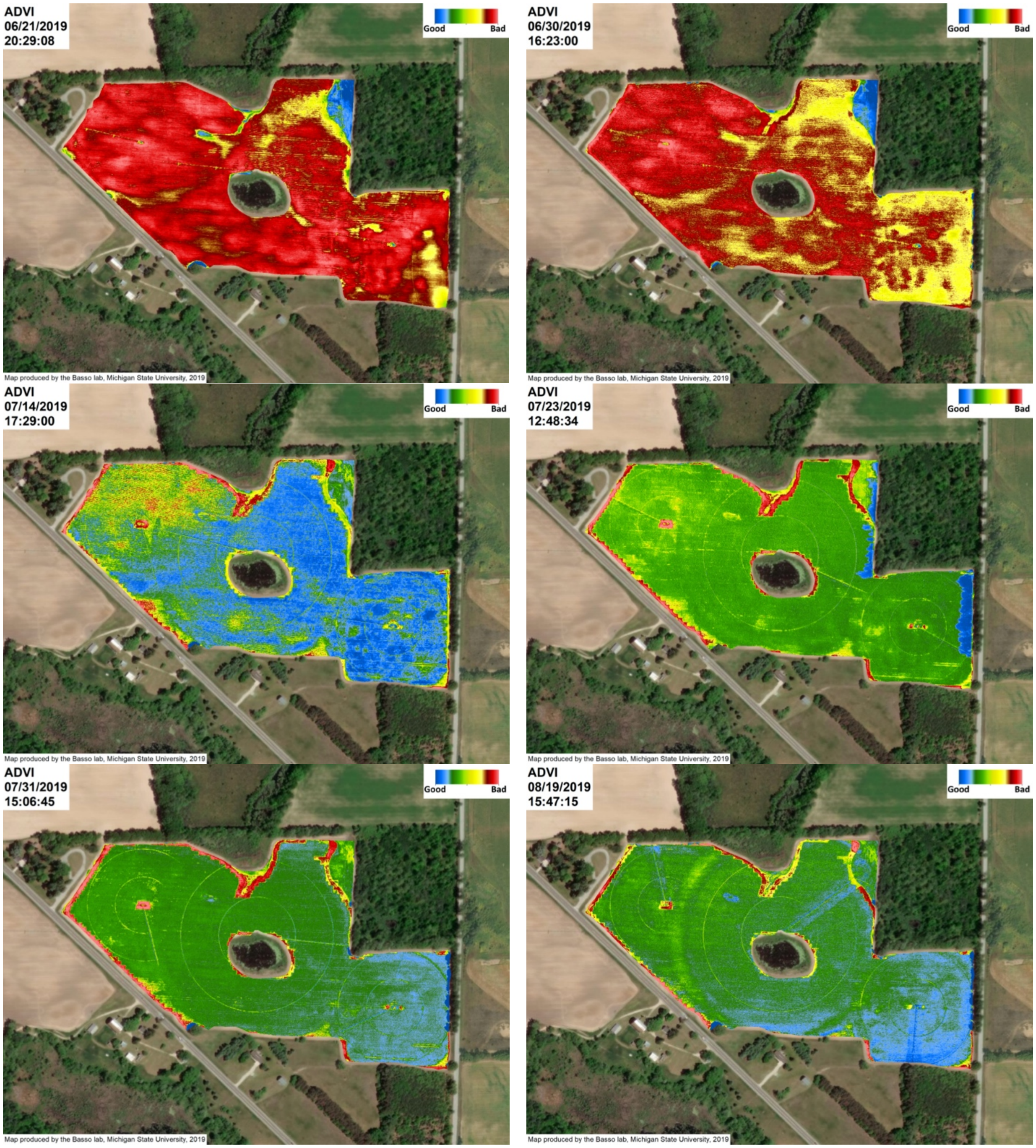


Figure 1. Historical cropping yield reveals trends of yield stability in both potato fields.

Figure 2. Experimental design of both fields encompassing 3 planting densities and 3 different N rates.



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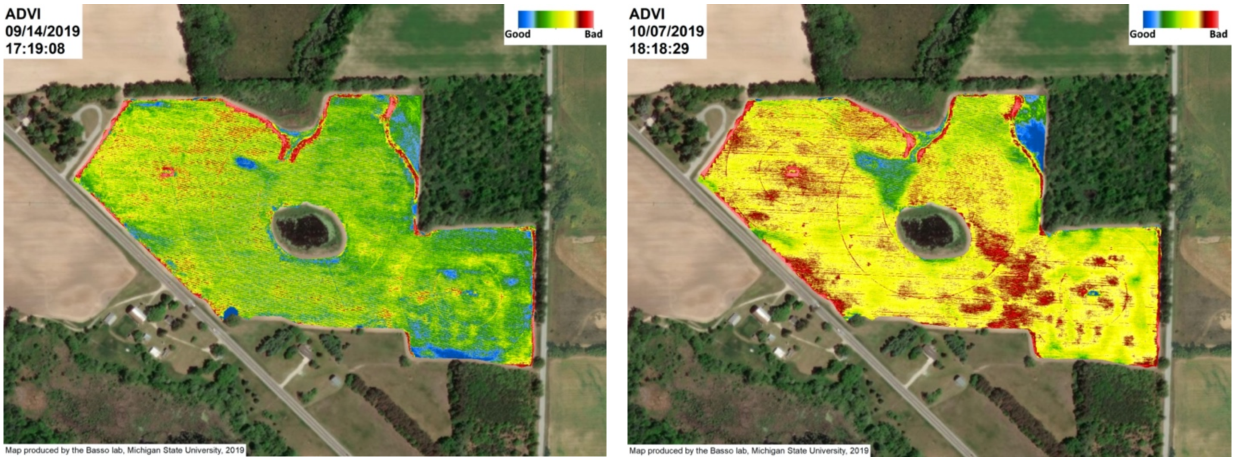

Figure 3. AirScout® imagery of ADVI from 6/21/19 to 10/7/19 of P_01.

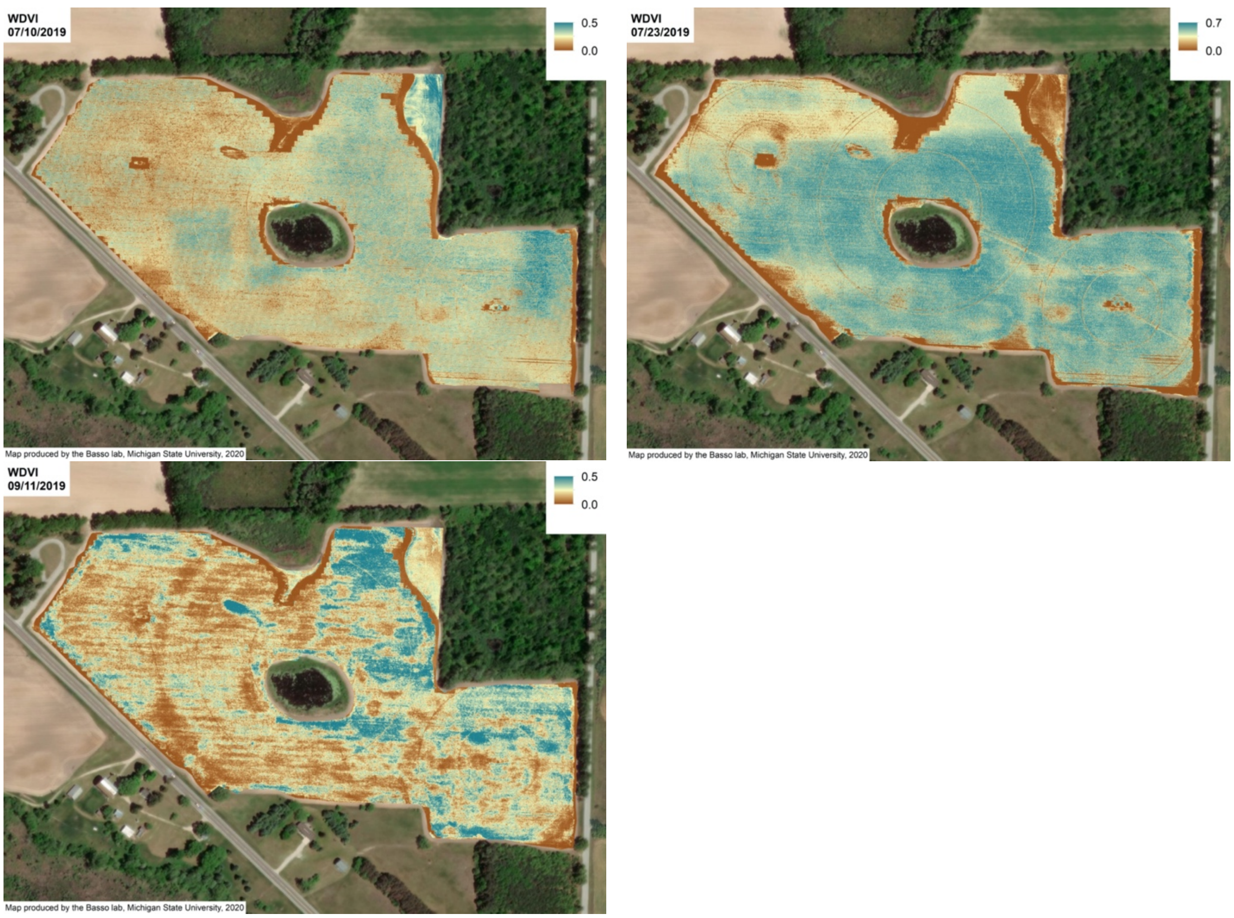

Figure 4. WDVI created from UAV imagery at P_01.

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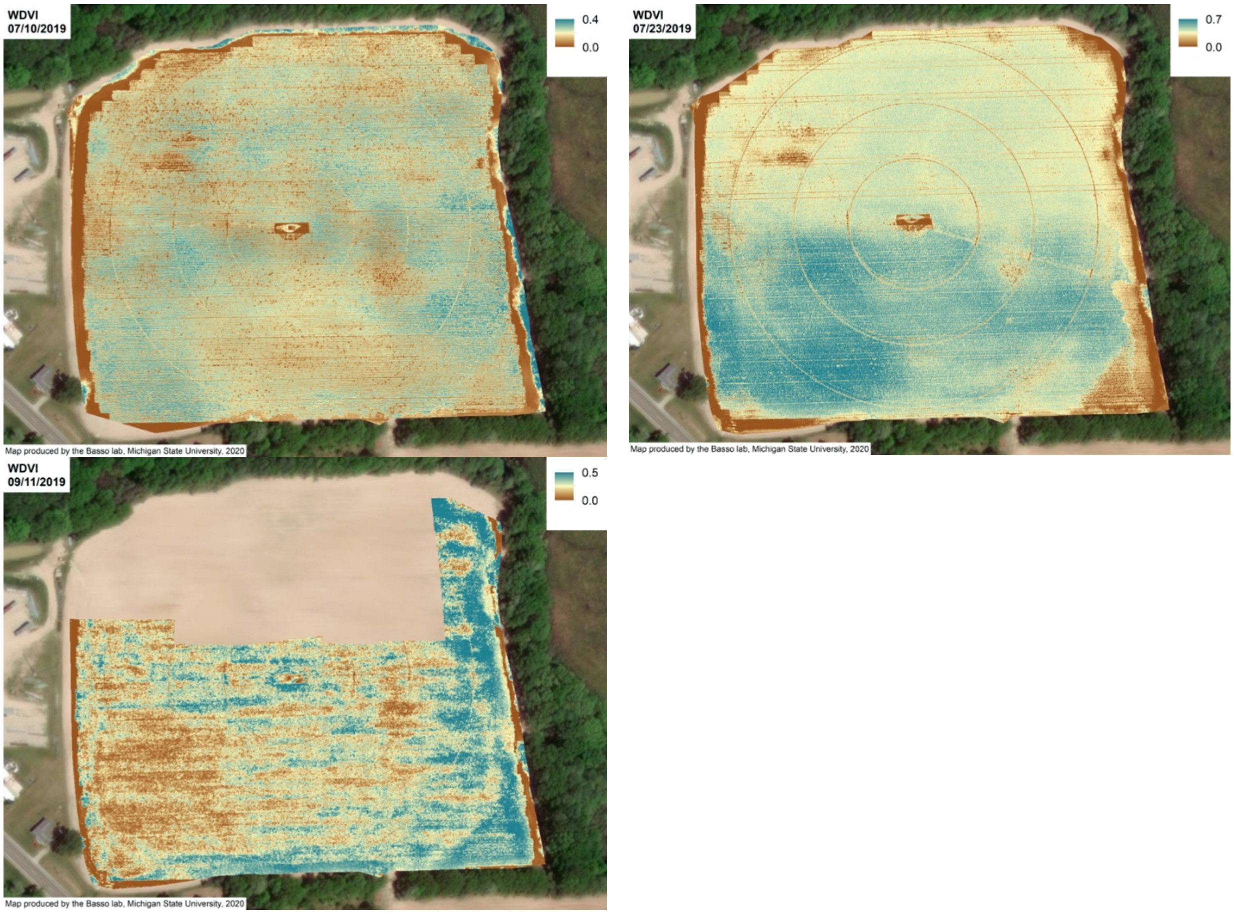

Figure 5. WDVI captured at P_38.

Sampling Date	Field	Planting Density	Yield Stability Zone	Percent N in Petiole
7/23/19	P_01	14,500	High and Stable	4.02
7/23/19	P_01	14,500	Medium and Stable	4.02
7/23/19	P_01	17,000	High and Stable	3.72
7/23/19	P_01	17,000	Medium and Stable	4.32
7/23/19	P_01	17,000	Unstable	3.17
7/23/19	P_01	19,500	High and Stable	3.65
7/23/19	P_01	19,500	Medium and Stable	3.39
7/23/19	P_01	19,500	Unstable	2.32

Sampling Date	Field	Planting Density	Yield Stability Zone	Percent N in Petiole
7/23/19	P_38	14,500	High and Stable	4.54
7/23/19	P_38	14,500	Medium and Stable	4.26
7/23/19	P_38	17,000	High and Stable	4.35
7/23/19	P_38	19,500	High and Stable	4.24

Sampling Date	Field	Planting Density	Yield Stability Zone	Percent N in Petiole
9/9/19	P_01	14,500	High and Stable	1.15

9/9/19	P_01	14,500	Medium and Stable	1.14
9/9/19	P_01	17,000	High and Stable	1.22
9/9/19	P_01	17,000	Medium and Stable	1.11
9/9/19	P_01	17,000	Unstable	1.07
9/9/19	P_01	19,500	High and Stable	1.06
9/9/19	P_01	19,500	Medium and Stable	1.12
9/9/19	P_01	19,500	Unstable	1.08

Sampling Date	Field	Planting Density	Yield Stability Zone	Percent N in Petiole
9/9/19	P_38	14,500	High and Stable	1.11
9/9/19	P_38	14,500	Medium and Stable	1.07
9/9/19	P_38	17,000	High and Stable	1.17
9/9/19	P_38	19,500	High and Stable	1.25

Table 5. Petiole results from each field, planting density, and yield stability zone at 2 sampling dates.

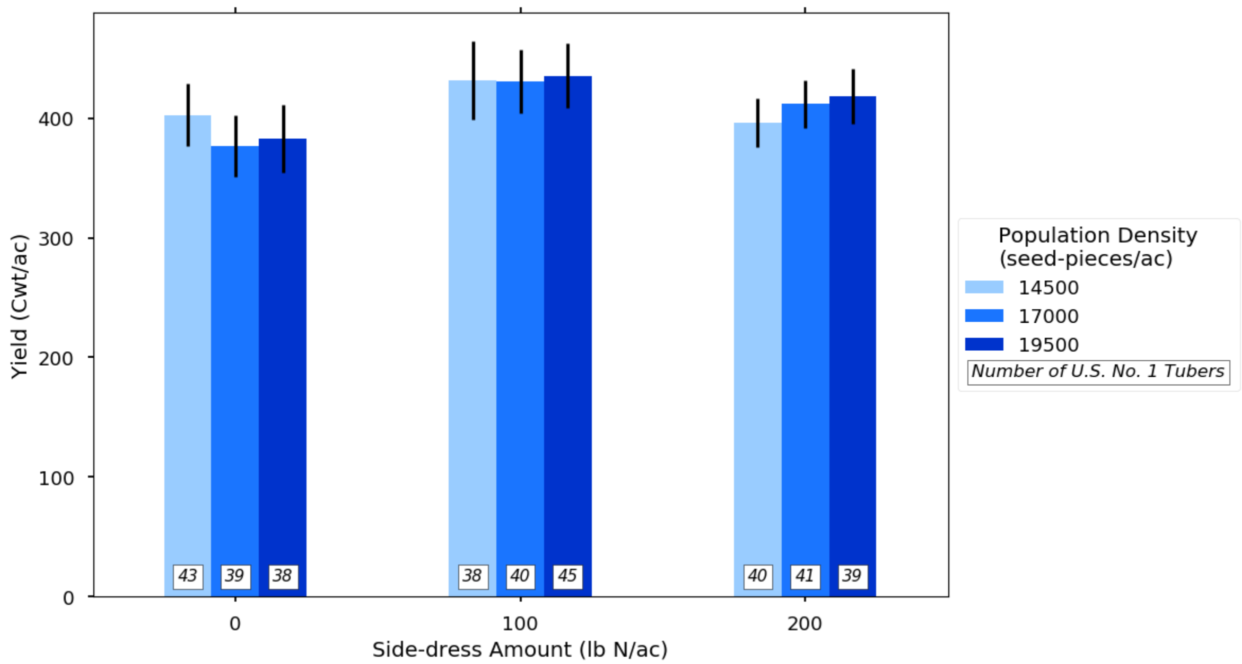

Figure 6. Yield results from hand-digs at the multiple population densities and side-dress amounts.

Improving Productivity and Sustainability in Potato Production Systems by Increasing Soil Biodiversity and Health

Two field trials were conducted in 2019, one at the Montcalm Research Center in Entrican, MI and the other at Walther's Farms in Cassopolis, Michigan to evaluate the effects of nematicides and compost/manures on potato early die complex for a second year. Ten treatments were tested at the Montcalm site which included: Untreated Control, Poultry Manure High (5 tons/acre), Poultry Manure Low (1.25 tons/acre), Layer Ash Blend High (5 tons/acre), Layer Ash Blend Low (1.25 tons/acre), Layer Ash Blend Low (1.25 tons/acre) plus Vydate (oxamyl) and a grower standard which was Vydate. At Montcalm, composts and manures were applied 1 day prior to planting and plots were planted on May 16th, 2019. Each treatment was replicated 4 times in 12'x50' plots. On October 4^{th}, 2019, one 25ft was harvested from each plot and subsequently weighed and graded to determine yield on a per acre basis.

At Walthers, plots were planted on May 24th, 2019 and twenty treatments were tested. The compost treatments were the same as in Montcalm but in addition, nematicides available on the market which included: Salibro (sulfonamide) low plus three applications of Vydate low, Salibro high plus three applications of Vydate high, two applications of Salibro low plus an application of Vydate low, Salibro low plus two applications of Vydate low, four applications of Vydate low, Velum Prime plus Movento, Emesto Silver plus Velum Prime and Luna Tranquility, Emesto Silver plus Velum Prime and Serenade, Emesto Silver plus Velum Prime and Vydate, and an Untreated Control. Again, all treatments were replicated four times. In furrow nematicide and compost/manure treatments were applied one day prior planting. On September 27th, 2019, one 25ft row was harvested from each plot, weighed and graded to determine yield on a per acre basis. At Montcalm, data collected included nematode populations at pre-planting and at harvest. As for Walthers, data was collected pre-planting, mid-season and at harvest for both chemical and compost trials. In addition, during mid-season stems were collected from ten random plants in each plot to establish *Verticillium dahliae* incidence at Walthers. Finally, for both sites, yield was recorded in CTW/ac.

We are currently still processing nematode samples from Walthers and statistics are forthcoming but preliminary data is shown below. The 2019 trials have demonstrated that poultry manure and Layer Ash Blend at both rates have high effectiveness in controlling root lesion nematode, for a second year. It is important to mentioned that, regarding potato yield, there was significant differences between locations. The yields recorded at Walthers were significantly higher than in Montcalm, this could be due to better cropping techniques, high disease pressure and frequent potato cropping in the same fields. Results from these trials were recently presented at the Great Lakes Expo in Grand Rapids, Michigan in the form of a talk and poster (see attached poster). For 2020, we are looking to determine if the mechanism by which these organic amendments suppress root-lesion nematode is by the presence of antagonistic microorganisms and establish if there is a significant impact on soil nutrient availability. Also, we are planning to integrate these organic amendments with biological nematicides available in the market and see if there is an improvement in efficacy. Lastly, we intend on producing extension materials to provide recommendations to growers.

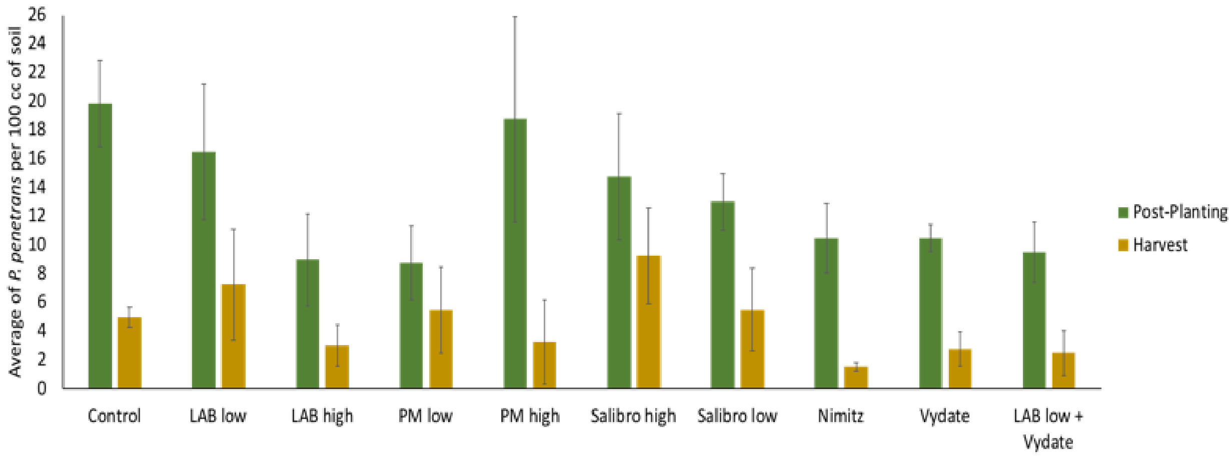

Figure 1. Average number of *P. penetrans* per 100 cc of soil at Montcalm. The recorded data is from post-planting and at harvest. There was not significant different among treatments, however, there was significant differences between sample dates for LAB low, PM high and LAB low+Vydate. Error bars indicates the standard error of the mean.

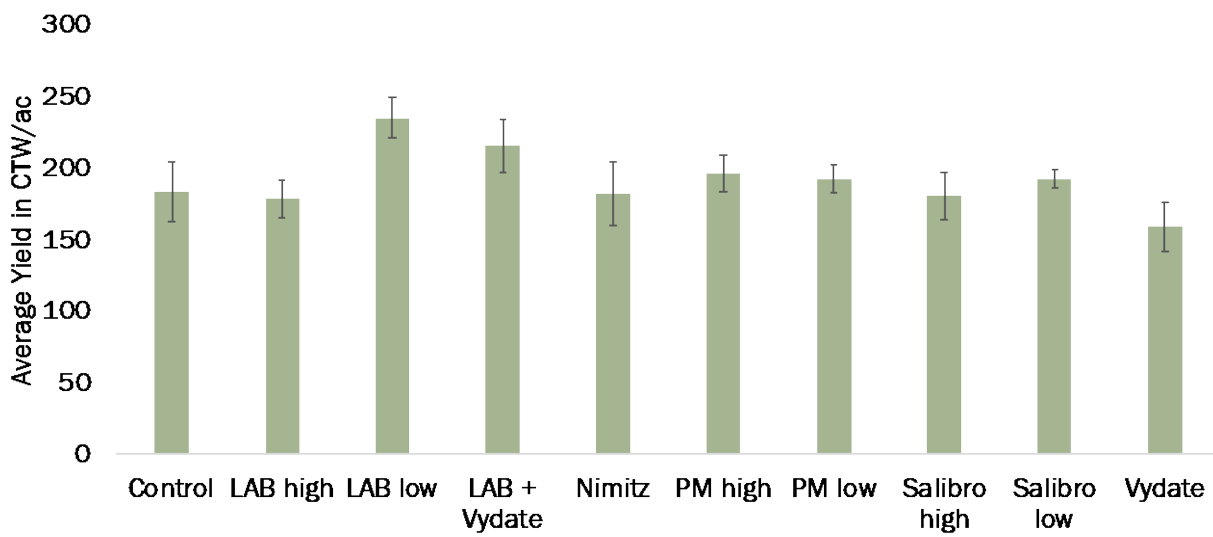

Figure 2. Average yield in CTW/acre at Montcalm. There were no significant differences between treatment. Error bars indicates the standard error of the mean.

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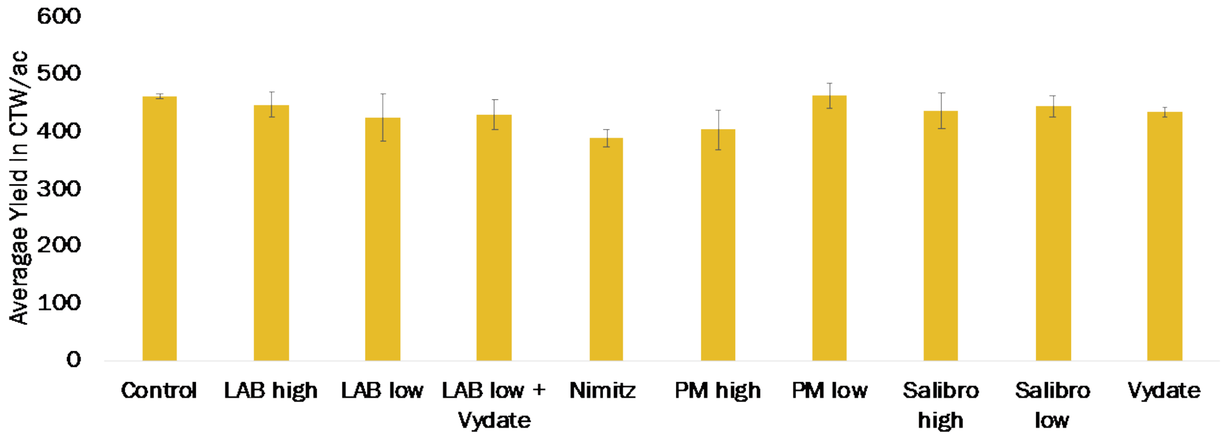

Figure 3. Average yield in CTW/acre at Walthers for the compost trial. There were no significant differences between treatments. Error bars indicates the standard error of the mean.

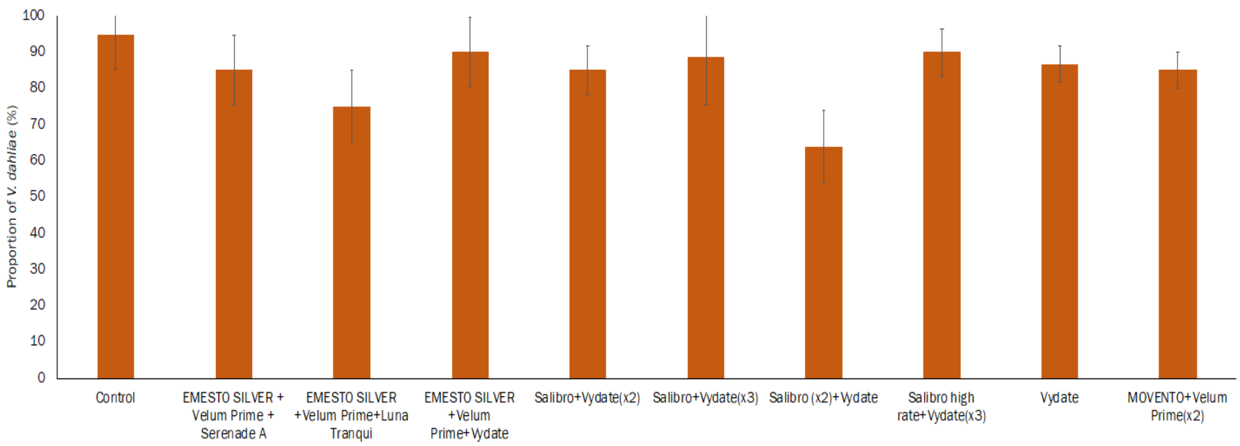

Figure 4. *V. dahliae* incidence in stems under chemical treatment at Walthers. There were no significant differences between treatments. Error bars indicates the standard deviation of the mean.

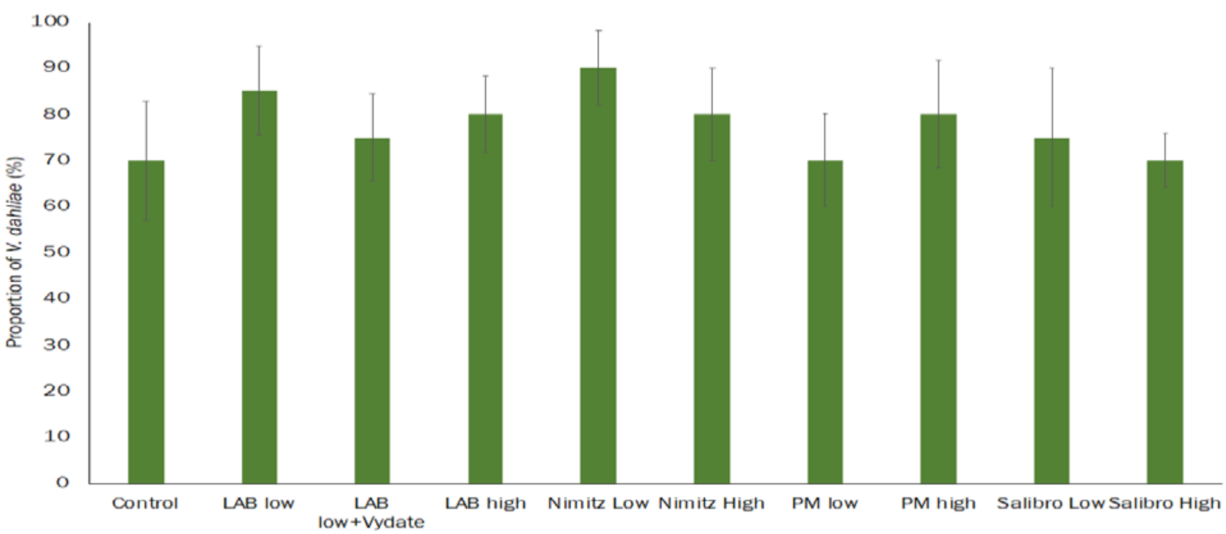

Figure 5. *V. dahliae* incidence in stems under compost treatment at Walthers. There were no significant differences between treatments. Error bars indicates the standard error of the mean.

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Effect of Compost, Manure and Non-Fumigant nematicide Application on Potato Early Die (PED)

Luisa Parrado, Emilie Cole, Brian Levene, and Marisol Quintanilla[1]
[1]Applied Nematology Lab, Michigan State University (East Lansing, MI)

Potato Early Die and its Damage on Potato

- PED is a disease caused by the association between *Pratylenchus penetrans* (root-lesion nematode) and *Verticillium dahliae* (soil-borne pathogen).
- PED can cause yield losses up to 50%
- Currently, growers use Vydate (oxamyl) and Elatus, to control the nematode and the fungi, respectively.
- *BUT…*is there a greener and more beneficial alternative that will not only control PED but also improve soil and plant health?

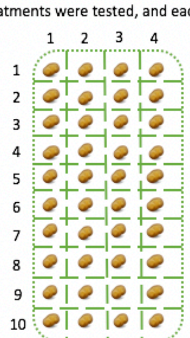
Goals

- Identify optimal products between organic amendments and non-fumigant nematicides and rates of application to reduce PED incidence and increase potato yield under field conditions (continuation from 2018)

How Did We Do It?

2 locations: Montcalm Research Center (Central MI) and Walther's Farms (Southern MI). In southern MI, a chemical trial was also conducted; however, soil samples are still on process. Therefore, here we only present results from Central MI.

10 treatments were tested, and each had 4 replicates, for a total of 40 plots.

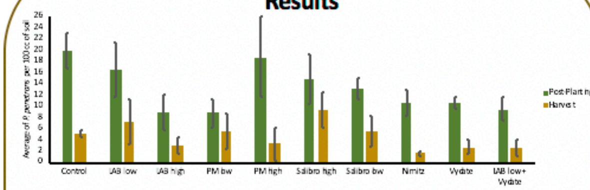


Treatment	Rate
Layer Ash Blend (LAB low)	1.25 tons/acre
Layer Ash Blend (LAB high)	5 tons/acre
Chicken Manure (PM low)	1.25 tons/acre
Chicken Manure (PM high)	5 tons/acre
Salibro (Q8U80) (low)	100g al/kg
Salibro (Q8U80) (high)	200g al/kg
Vydate	Seed treatment
Nimitz	Seed treatment
LAB + Vydate	1.25tons/acre+ST
Untreated	-

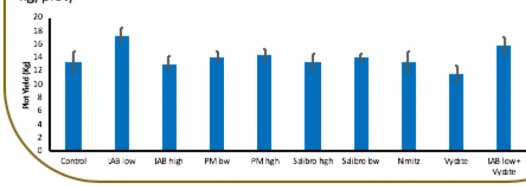
Measurements

✓Soil samples at post-planting, mid-season and harvest where collected for **Root-lesion nematode count.** Stems were taken from each plot to calculate the **proportion of *V. dahliae* and potato yield** was recorded

Results



- Samples were taken on June 21st (Post-Planting) and October 9th (Harvest). Although, we did not find significant differences between treatments, substantial decrease of *P. penetrans* was found in plots treated with PM high, LAB high, LAB low + Vydate, Nimitz and Vydate. However, is clear that under every treatment there was a decrease in nematode populations between post-planting and harvest samples. Regarding yield, there was no significant deference among treatments; nonetheless, the highest yield was achieved under the LAB low treatment (17,38 kg/plot)



Conclusions and Recommendations

- Based on the results obtained in 2018 and 2019, we conclude that layer-ash blend at a rate 1.25 – 5 tons/acre alone or plus one application of Vydate, poultry manure (same rate) and Salibro plus one application of Vydate are the treatments that reduced PED incidence and increase potato yield. Therefore, **we encourage** the use of these composts and manures that not only will reduce PED incidence and increase potato yield but are less toxic. The use of these organic amendments may also lead to a boost in soil and plant health, potato quality and applicator safety. Is also important to mention that by integrating these sustainable amendments, benefits may be constant over time.

What's Next?

- The next step for PED control is to determine what are the key factors that are influencing the incidence of PED in potato fields treated with poultry manure and Layer Ash Blend. We hypothesize that the addition of such soil amendments will increase nutrient availability as well as beneficial microbial communities that may have antagonistic effects over *P. penetrans* and *V. dahliae*.
- An integrated pest management program could lead to a greater effectiveness, therefore, a combination of the different treatments (organic and non-fumigant) that reduced PED incidence should be tested.

Acknowledgements

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2018-2019 MICHIGAN POTATO DEMONSTRATION STORAGE ANNUAL REPORT MICHIGAN POTATO INDUSTRY COMMISSION

Chris Long, Coordinator, Trina Zavislan, and Damen Kurzer

Introduction and Acknowledgements

Round white potato production for chip processing continues to lead the potato market in Michigan. Michigan growers continually look for promising new round white varieties that meet necessary production and processing criteria. There are many variety trials underway in Michigan that are evaluating chipping varieties for yield, solids, disease resistance, desired tuber size profile and chipping quality with the hope of exhibiting the positive attributes of these lines to growers and processors. Extended storage chip quality and storability are of extreme importance in round white potato production. Therefore, any new chip processing varieties with commercialization potential will have storage profiles developed. Examining new varieties for long-term storage and processing quality keeps the Michigan chip industry at the leading edge of the snack food industry. The information in this report allows 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, allows the Michigan potato industry to generate storage and chip quality data on newly identified chip processing clones. This information helps to establish the commercial potential of new varieties. This demonstration storage facility utilizes six, 550 cwt. bulk bins (bins 1-6) that have independent ventilation systems. The Ben Kudwa Building, built in 2008, has three independently ventilated, 600 cwt. bulk bins. The first of these bulk bins, bin 7, was converted to 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 point into storage profiling that allows the industry to learn about a varieties' physical and chemical storability before advancing to the bulk bin level. A variety is evaluated for 4-6 years 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

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trial. A storage profile consists of bi-weekly sampling of potatoes to obtain: sucrose and glucose levels, chip color and defect values. In addition, we evaluate each variety for weight loss or shrinkage and pressure bruise. With this information, we can create the storage profile of a variety, 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 used to evaluate the post-harvest physiology of potatoes. The facility can be used to evaluate storage pathology or sprout inhibitor products. The Michigan industry recognizes the importance of controlling disease and sprout development in storage and is committed to doing research in these areas.

This sixteenth annual Demonstration Storage Report contains the results of the storage work conducted in the facility during the 2018-2019 storage season. Section I, "2018-2019 New Chip Processing Variety Box Bin Report", contains the results and highlights from our 10 cwt. box bin study. Section II, "2018-2019 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 funding and financial support for this facility, and the research 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 and John Crooks, Crooks Farms, Inc.; Brian Sackett, Sackett Potatoes; Kyle Lennard, Lennard Ag. Co., and Karl Ritchie and Brice Stine of Walther Farms for 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 and Elis Cole of Herr Foods, 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), Mathew Klein (Farm Manager, MSU Montcalm Research Center), and Tim and Matt Wilkes (Potato Services of Michigan). All played a role in making this facility useful to the Michigan potato industry.

Overview of the 2018 Production Season

The overall 6-month average maximum and minimum temperatures during the 2018 growing season in central Michigan were slightly warmer than the 15-year average of 73°F and 50°F respectively (Table 1). Temperatures were slightly cooler than average in April and warmer than average in May, July, and September. Extreme heat events were higher than average in 2018 (Table 2), with 26 hours over 8 days exceeding 90°F during the entire summer. High nighttime temperatures (over 70°F) were also higher than average with 215 hours over 46 days.

Rainfall for April through September was 22.76 inches, 5.49 inches above the 15-year average (Table 3). August had a high rainfall of 7.73 inches, more than twice the 15-year average of 3.16 inches for the month. The remaining months had more typical precipitation in line with the 15-year averages.

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.
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	78	48	73	49
2014	55	33	68	45	78	57	77	54	79	56	72	47	72	49
2015	58	34	71	48	76	54	80	56	77	57	77	54	73	51
2016	53	32	70	45	78	53	82	59	85	60	78	54	74	51
2017	61	39	67	44	78	55	81	58	77	54	77	50	74	50
2018	**54**	**31**	**75**	**48**	**78**	**56**	**82**	**62**	**79**	**60**	**77**	**51**	**75**	**51**
15-Year Average	58	35	69	46	78	55	81	58	80	57	75	50	73	50

Table 2. Six-year heat stress summary (from May 1st – Sept. 30th)*

Temperatures > 90°F		Night (10pm-8am) Temperatures > 70°F	
Hours	Days	Hours	Days
14	3	140	28
0	0	58	15
0	0	114	31
26	7	248	50
23	3	124	29
26	**8**	**215**	**46**
15	4	150	33

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Table 3. 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
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
2014	4.24	5.51	3.25	3.71	1.78	2.35	20.84
2015	3.71	2.95	4.79	1.72	2.42	3.90	19.49
2016	2.25	2.77	1.33	3.42	5.35	3.05	18.17
2017	4.45	1.98	6.37	0.92	1.36	0.70	15.78
2018	**2.04**	**5.51**	**3.64**	**1.19**	**7.73**	**2.65**	**22.76**
15-Year Average	3.03	3.36	2.94	2.55	3.16	2.24	17.27

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

I. 2018-2019 New Chip Processing Variety Box Bin Report

(Chris Long, Trina Zavislan, Damen Kurzer, and Brian Sackett)

Introduction

This project evaluated new chip processing varieties from national and private breeding programs for processing quality after storage conditions. We evaluated a variety's response to pile temperature, as reflected in sucrose and glucose levels, as well as weight loss and pressure bruise susceptibility. Bin 7 contained 36 10 cwt. boxes. We organized the 36 boxes in to six stacks of six. The box design allows air to travel in from a header, or plenum wall, through the forklift holes of each box and up through the potatoes within it. The air continues to flow up through the next box until it reaches the top and is drawn off the top of the chamber. The air is then 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 we sampled tubers for bi-weekly or monthly quality evaluations.

Procedure

In 2018, we evaluated and compared 32 new varieties to the check varieties Manistee, Snowden, and Lamoka. Once the varieties were chosen, 1 cwt. of each variety was planted in a single 34-inch wide row, on April 27th at the MSU, Montcalm Research Center, Entrican, MI. We planted the varieties at a 10" in-row seed spacing. All varieties received fertilizer in the rates of: 273 lb. N/A, 99 lb P_2O_5/A and 261 lb K_2O/A. The varieties were vine killed after 131 days and allowed to set skins for 37 days before harvest on October 12th, 2018; which was 168 days after planting. We did not account for variety maturity in harvest timing due to storage and handling restrictions.

We placed approximately 10 cwt. of each variety in a box bin and stacked the boxes in bin 7. The average storage temperature for all the box bins (box bin 7) was 54.0ºF for the 2018-2019 season. At harvest, we collected nine, 20 lb. samples from each variety for weight loss and pressure bruise evaluation. We describe the varieties, their pedigree and scab ratings in Table 4. We also recorded yield, size distribution, chip quality, and specific gravity at harvest (Table 5). We graded the varieties to remove all "B" size tubers and pick-outs, ensuring the tubers began storage in good physical condition.

The storage season began October 8, 2018, and ended July 1, 2019. Bin 7 was gassed with CIPC on November 7, 2018. We began variety evaluations on October 8, 2018, followed by a bi-weekly sampling schedule until early June. We randomly selected forty tubers from each box every two weeks and sent them to Techmark, Inc. for sucrose, glucose, chip color and defect evaluation. We also evaluated pressure bruising by placing nine pressure sample bags for each variety in one of the bulk bins at the storage facility. We placed three bags at each of 3’, 8’ and 14’ from the pile floor. When that bin was unloaded, we weighed the sample bags and calculated percent weight loss. We evaluated a 25-tuber sample from each of the nine bags for the presence or absence of pressure bruise. We recorded the number of tubers and severity of bruise. All pressure bruises were evaluated for discoloration.

This report is not an archive of all the data that we generated for the box bin trial, but rather a summary of the data from the most promising lines. The purpose of this report is to present a summary of information from the best performing 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 at (517) 355-0277 or longch@msu.edu. Additional data is available on the program website, https://www.canr.msu.edu/potatooutreach.

Table 4. 2018-19 MPIC Demonstration Box Bin Variety Descriptions

Entry	Pedigree	2018 Scab Rating*	Characteristics
Lamoka (NY139)	NY120 X NY115	0.0	High yield, mid- late season maturity, medium specific gravity, oval to oblong tuber type, low internal defects, long term chip quality
Manistee (MSL292-A)	Snowden X MSH098-2	1.0	Average yield, scab resistance similar to Snowden, medium specific gravity, long storage potential, uniform, flat round tuber type, heavy netted skin
Snowden (W855)	B5141-6 X Wischip	2.0	High yield, late maturity, mid-season storage, reconditions well in storage, medium to high specific gravity
AC00206-2W	AC87340-2 X Dakota Pearl	0.5	Below average yield, earlier maturity, lower than average specific gravity
AC03452-2W	A98423-1C X COA96141-2C	2.0	Above average yield, deep apical ends, common scab succeptible
AC05153-1W	A91814-5 X Chipeta	0.0	Smaller size profile with more B-sized tubers than average, good internal quality
AF5040-8	AF2376-5 X Lamoka	2.5	Large pitted scab lesions visible in 2018, below average yield potential
B2869-29	B0564-8 X B1316-5	0.0	High specific gravity, flatter tuber type, very early maturity
B2904-2	B1873-6 X CoastalChip	0.0	Attractive, round tubers, very high specific gravity, susceptible to vascular discoloration
BNC311-4	BNC41-7 X NCB2489-5	0.5	Below average yield and specific gravity, smaller vine type
CO02033-1W	A91790-13W X S440	0.0	Smaller tuber size profile, earlier vine maturity, above average specific gravity
CO10076-4W	CO03243-3W X CO02024-9W	0.0	High yield, susceptible to vascular discoloration, lower specific gravity

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Huron Chipper (MSW485-2)	MSQ070-1 X MSR156-7	0.5	Scab resistant with moderate late-blight resistance, high specific gravity and attractive tuber shape
Lady Liberty (NY152)	B38-14 X Marcy	0.0	High yield potential, medium specific gravity, moderate resistance to common scab, medium-late maturity
Mackinaw (MSX540-4)	Saginaw Chipper X Lamoka	0.5	Medium/high yield potential, common scab, late blight and PVY resistant, high specific gravity, currently in Fast Track program
MSV111-2	MSJ316-A x MSN105-1	0.0	Later vine maturity, lower specific gravity, mild vascular discoloration
MSV498-1	Snowden X MSQ283-2	0.0	Deep apical ends, low specific gravity, earlier vine maturity
MSW044-1	Kalkaska X Lamoka	0.0	Bright skin, attractive round tuber profile, high specific gravity, common scab tolerant
MSY156-2	MSK061-4 X Kalkaska	0.0	High percentage A-sized tubers, good internal quality
MSZ062-10	MSR127-2 X McBride	0.0	Darker netted skin, high yield, susceptible to vascular discoloration, early vine maturity
MSZ096-3	Boulder X MSR127-2	0.0	Flattened tuber shape, full season maturity, very high yield
MSZ120-4	Kalkaska X MSQ086-3	0.0	High yield, bright skin, common scab tolerant, full season maturity
MSZ219-1	Saginaw Chipper X MSR127-2	0.0	Average yield, good off the farm chip score, darker netted skin
MSZ219-13	Saginaw Chipper X MSR127-2	0.0	High yield potential, some skinning, high proportion A-sized tubers
MSZ219-14	Saginaw Chipper X MSR127-2	0.5	Average yield, susceptible to vascular discoloration, mid- to full season maturity
MSZ219-46	Saginaw Chipper X MSR127-2	0.0	Above average yield, smaller vine type, below average specific gravity

MSZ222-19	MSR127-2 X Tundra	0.0	Misshapen tubers in pickouts, good internal quality, high yield potential
MSZ242-13	MSR168-8Y X MSU383-A	0.0	Very high specific gravity, moderate skinning, high yield potential
MSZ242-7	MSR168-8Y X MSU383-A	0.0	Slight vascular discoloration, common scab tolerant, average yield
MSZ242-9	MSR168-8Y X MSU383-A	1.0	Very high specific gravity, good internal quality, high yield potential
MSZ248-10	Snowden X	1.5	Small vine type and early vine maturity, below average yield and specific gravity
NY162	NYE106-2 X NYE48-2	0.0	High percent US #1 tubers, good internal quality, misshapen tubers in pickouts
Petoskey (MSV030-4)	Beacon Chipper X MSG227-2	0.0	Above average yield and specific gravity, slight pink eyes, flattened round tuber type
W9968-5	Fasan X Nicolet	1.5	High yield, pear shaped tubers, oval to oblong tuber type with heavier netting
Winterset (CO02321-4W)	NY115 X BC0894-2W	1.0	Good internal quality, below average yield, good fresh chip quality

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. Common scab data and qualitative descriptions provided by Potato Outreach Program (P.O.P.), MSU Potato Breeding and Genetics Program and other potato breeding programs.

Table 5. 2018 Storage Chip Processing Potato Variety Trial
MRC Box Bin

Planting: 4/27/18 Vine Kill: 9/5/18 Harvest: 10/12/18

GDD_{40}: 3567

LINE	CWT/A		PERCENT OF TOTAL[1]							RAW TUBER QUALITY[4] (%)							
	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR[2]	OTF CHIP SCORE[3]	HH	VD	IBS	BC	COMMON SCAB RATING[5]	VINE VIGOR[6]	VINE MATURITY[7]	COMMENTS
AC00206-2W	187	295	63	36	63	0	1	1.072	1.0	0	0	0	0	0.5	2.0	2.5	
AC03452-2W	575	700	82	17	82	0	1	1.068	1.0	0	10	10	0	2.0	2.0	3.0	deep apical ends
AC05153-1W	159	233	68	32	68	0	0	1.079	1.0	0	0	0	0	0.0	2.0	2.0	
AF5040-8	245	318	77	22	75	2	1	1.078	1.0	0	0	0	0	2.5	2.0	2.5	large pitted scab lesions
B2869-29	302	410	74	25	74	0	1	1.087	1.0	0	20	0	0	0.0	1.5	1.0	flatter tuber type
B2904-2	333	386	86	13	86	0	1	1.092	1.5	10	50	0	0	0.0	1.5	1.5	round tubers
BNC311-4	225	278	81	19	81	0	0	1.073	1.0	0	0	0	0	0.5	1.5	3.0	
CO02033-1W	270	382	71	29	71	0	0	1.087	1.0	0	10	0	0	0.0	1.5	1.5	smaller tuber size profile
CO02321-4W	292	368	79	20	79	0	1	1.086	1.0	0	0	0	0	1.0	3.0	2.0	
CO10076-4W	432	515	84	16	84	0	0	1.074	1.5	0	40	0	0	0.0	2.5	3.5	
Lamoka	**368**	**419**	**88**	**11**	**88**	**0**	**1**	**1.080**	**1.0**	**0**	**0**	**0**	**0**	**0.0**	**1.5**	**1.5**	**pointed tubers in POs**
Mackinaw (MSX540-4)	282	357	79	21	79	0	0	1.086	1.0	0	10	0	0	0.5	1.0	2.5	smaller tuber size profile
Manistee	**292**	**334**	**87**	**12**	**87**	**0**	**1**	**1.079**	**1.0**	**0**	**0**	**0**	**0**	**1.0**	**1.5**	**1.0**	**deep apical ends, mod skinning**
MSV030-4	352	415	85	14	85	0	1	1.078	1.0	0	10	0	0	0.0	1.0	2.0	
MSV111-2	389	486	80	20	80	0	0	1.070	1.5	0	20	0	0	0.0	1.0	4.0	missahpen Pos
MSV498-1	297	338	88	10	88	0	2	1.065	1.5	0	30	0	0	0.0	1.5	2.5	deep apical ends
MSW044-1	371	494	75	25	74	1	0	1.089	1.0	0	10	0	0	0.0	2.0	3.0	bright skin, attractive round tuber profile
MSW485-2	558	621	90	9	90	0	1	1.089	1.0	0	40	0	10	0.5	1.5	3.0	mod alligator hide
MSY156-2	404	452	90	10	90	0	0	1.079	1.0	0	10	0	0	0.0	1.5	3.0	bright skin, attractive round tuber profile
MSZ062-10	445	491	91	9	91	0	0	1.087	1.0	0	60	0	0	0.0	1.5	1.0	darker netted skin
MSZ096-3	731	787	93	6	93	0	1	1.081	1.5	0	10	0	0	1.5	1.5	5.0	some flatter tubers
MSZ120-4	530	587	90	10	90	0	0	1.086	1.0	0	20	0	0	0.0	1.0	4.5	bright skin
MSZ219-1	396	416	96	3	94	2	1	1.079	1.0	0	30	0	0	0.0	1.5	2.5	darker netted skin
MSZ219-13	553	587	94	6	94	0	0	1.081	1.0	0	10	0	0	0.0	1.0	2.5	mod alligator hide
MSZ219-14	435	476	91	8	91	0	1	1.075	1.0	0	20	0	0	0.5	1.5	4.0	
MSZ219-46	459	489	94	6	93	1	0	1.076	1.5	0	30	0	0	0.0	1.0	3.0	
MSZ222-19	528	598	88	10	88	0	2	1.087	1.5	0	0	0	0	0.0	1.0	2.0	misshapen POs
MSZ242-13	417	471	88	8	87	1	4	1.096	1.0	0	0	0	0	0.0	1.0	2.0	mod skinning, GC in POs
MSZ242-7	368	405	91	8	91	0	1	1.092	1.0	0	20	0	0	0.0	1.5	2.5	misshapen POs
MSZ242-9	462	519	89	10	89	0	1	1.094	1.0	0	0	0	0	1.0	1.5	3.0	misshapen POs
MSZ248-10	346	385	90	9	90	0	1	1.079	1.0	0	0	0	0	1.5	1.5	1.5	
Niagara (NY152)	478	533	90	9	90	0	1	1.076	1.0	0	0	0	0	0.0	1.0	2.0	
NY162	422	483	87	8	87	0	5	1.077	1.0	0	0	0	0	0.0	1.0	1.5	misshapen POs
Snowden	**494**	**540**	**91**	**8**	**90**	**1**	**1**	**1.085**	**1.0**	**0**	**0**	**0**	**0**	**2.0**	**1.5**	**2.5**	
W9968-5	470	540	87	13	87	0	0	1.083	1.5	0	0	0	0	1.5	1.0	3.0	mod alligator hide
MEAN	**396**	**460**	**85**	**14**	**85**	**0**	**1**	**1.081**	**1.1**	**0**	**13**	**0**	**0**	**0.5**	**1.5**	**2.5**	

[1]SIZE
Bs: < 1 7/8"
As: 1 7/8" - 3 1/4"
OV: > 3 1/4"
PO: POs

[2]SPECIFIC GRAVITY
Data not replicated

[3]OUT OF THE FIELD CHIP COLOR SCORE
(SNAC Scale)
Ratings: 1 - 5
1: Excellent
5: Poor
Data collected by Techmark, Inc.

[4]RAW TUBER QUALITY
(percent of tubers out of 10)
HH: Hollow Heart
VD: Vascular Discoloration
IBS: Internal Brown Spot
BC: Brown Center

[5]COMMON SCAB RATING
0.0: Complete absence of surface or pitted lesions
1.0: Presence of surface lesions
2.0: Pitted lesions on tubers, though coverage is low
3.0: Pitted lesions common on tubers
4.0: Pitted lesions severe on tubers
5.0: More than 50% of tuber surface area covered in pitted lesions

[6]VINE VIGOR RATING

[7]VINE MATURITY RATING

FIELD DATA

Date: 5/30/18
Rating 1-5
1: Slow emergence
5: Early emergence (vigorous vines, some flowering)

Date: 8/20/18
Rating 1-5
1: Early (vines completely dead)
5: Late (vigorous vines, some flowering)

Planting date	4/27/18
Vine Kill Date	9/5/18
Harvest Date	10/12/18
Days (planting to vine kill)	131
Days (planting to harvest)	168
GDD_{40} MAWN Station	Entrican
GDD_{40} (planting to vine kill)	3567
Seed Spacing	10"
Row Width	34"
Harvest Length	23'

Results: 2018-2019 Chip Processing Box Bin Highlights

Petoskey (MSV030-4)

This Michigan State University variety has been evaluated in the Box Bin trial for four years. At harvest, the specific gravity was 1.078, below the trial average of 1.081. The US#1 yield was 352 cwt/A, slightly below average for the trial (Table 5). Petoskey was chemically immature mature at harvest, with the sucrose rating increasing from 0.699 to 0.854 between the two pre-harvest panels on August 13th and August 37th. This variety exhibited earlier maturity and scab tolerance. It had excellent out of the field chip quality, with a 1.0 chip score. At the first sample date on 10/10/18 the sucrose (X10) began to decrease, and continued to do so until late February, after which it began to rise until bin unloading on 6/17/19. Glucose concentrations were somewhat variable, with 0.004% at the first sample, which fluctuated between October and November before remaining at 0.002 for most of December to February. Between March and the end of storage in early June both glucose and sucrose concentrations increased. The box bin had a target temperature of 54ºF, and the bin was cooled to the target by early November. It stayed between 53.2ºF and 54ºF though May, before increasing slightly to 54.8ºF in June. There was no undesirable color reported during the whole storage season. Internal color was also good, with a high of 21.3% at bin unloading. In all but the first and last sample, total defects were less than 20%. Petoskey has continued potential for commercialization in Michigan due to chip quality in long term storage, higher specific gravity, and good internal quality. This variety will be in the 2019 National SNAC variety trial and the 2019-2020 Bulk Bin Trial.

Figure 1. Petoskey chip samples at the last acceptable processing date, 5/20/19 (left) and at last sample date, 6/3/19 (right).

Winterset (CO02321-4W)

This Colorado State University variety was named and released as Winterset in 2017. It has above average specific gravity, good chip color, and excellent internal quality. In 2018 it had a below average US #1 yield of 292 cwt/A compared to the trial average of 396 cwt/A. This variety does tend to have a smaller tuber size profile with more B sized tubers. It had early to mid-season maturity in 2018. Winterset was physiologically and chemically mature at harvest as sucrose decreased between the first and second pre-harvest sample from 0.484 to 0.400. Glucose remained consistent at 0.001 at both readings. During initial bin cooling between loading and November the sucrose concentration (X10) initially rose but then decreased. It fluctuated during the winter with a general positive trend, concluding with 1.785% (x10) at bin unloading. Glucose concentrations were more stable over the season, with slight fluctuations between 0.002 and 0.004 after bin cooling, but the final glucose concentration at bin unloading was 0.008. Bin cooling for this and all other varieties is described in the Petoskey variety description, as all box bin are stored together. Chip quality was excellent during storage, with internal color and undesirable color occurring at the last sample. Total defects were initially higher, between 19% and 25% from bin loading until January, but gradually decreased. At bin unloading, total defects were 62%, suggesting storage potential until May at 54ºF This variety will further evaluated in the 2019-2020 Box Bin trial with bi-weekly, instead of monthly samples, as it demonstrates long-term storage potential with minimal chip defects until June.

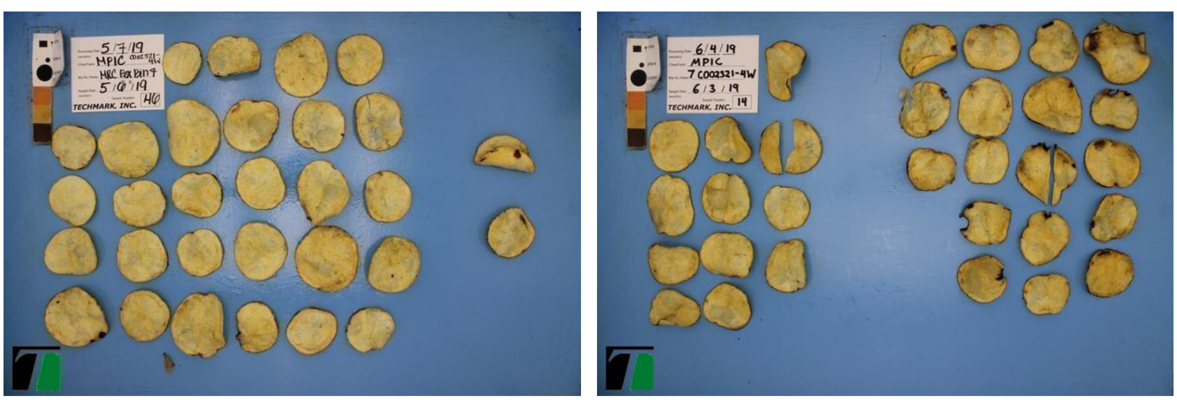

Figure 2. Winterset (CO02321-4W) chip quality on last acceptable sample date, 5/6/19 (left) and last storage sample, 6/3/19 (right).

NY162

This Cornell University variety had a highest US#1 and total yield in the 2018 box bin trial. The US#1 yield was 422 cwt/A and total yield was 483 cwt/A, compared to the trial average of 396 cwt/A and 460 cwt/A, respectively. NY162 had slightly more A-size potatoes than average, and a specific gravity below the trial average at 1.077. It had excellent internal quality, a good off the farm chip score, and early season maturity in 2018. It was chemically immature at harvest, with sucrose concentrations increasing from 0.372 to 0.510 between the first and second pre-harvest panel. The pre-harvest glucose levels were stable at 0.002 at both sample dates. The sucrose concentration (X10) began to decrease in mid-November and rose again in early March. The highest sucrose concentration occurred at the final sample at 1.079 (x10) at the final sample. Glucose concentrations were initially higher, especially between late October and early December, measuring between 0.014 and 0.024 during this time. By January, the concentrations had lowered to between 0.003 and 0.005 for the duration of storage. There were a few samples with undesirable color, split between early storage and the last few samples. Correspondingly, there were higher incidences of internal color and total defects early in storage. Chip quality was the best in March and April, suggesting re-conditioning occurred in storage. Defects were highest in the second to last sample on 5/20/19, with 62.2% total defects.

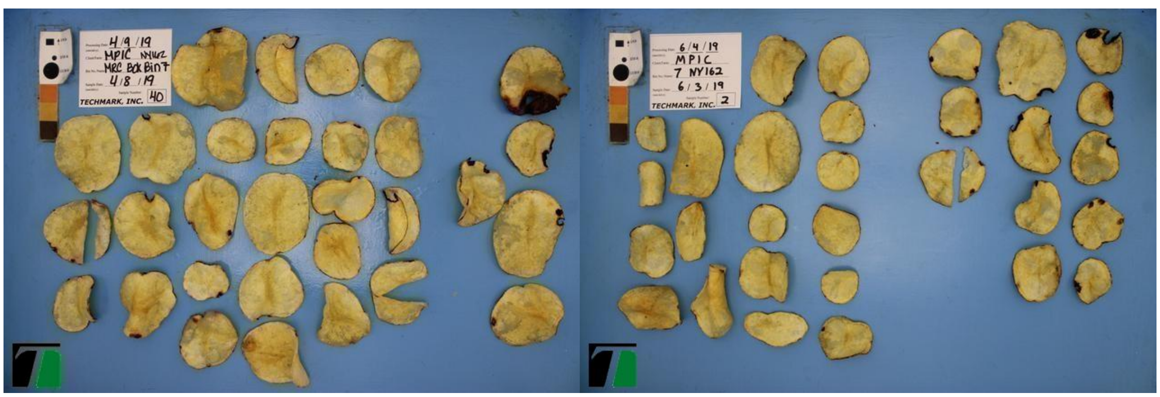

Figure 3. NY162 chip quality on last acceptable sample date, 4/8/19 (left) and last storage sample, 6/3/19 (right).

MSZ219-14

This variety is the sibling of the MSU selection MSZ219-13. In 2018 it had an above than average yield, 435 cwt/A US#1 tubers, more than the trial average of 396 cwt/A US#1 tubers. It had a specific gravity of 1.075, slightly lower than the trial average of 1.081. Off the farm chip color was average, and was scored at 1.0 compared to the 1.1 average for the trial. 20% vascular discoloration was observed in 2018, along with a vigorous vine and mid-season maturity. While the glucose level remained the same between the two pre-harvest panels, the sucrose increased slightly from 0.449 to 0.553, indicating chemical immaturity. This variety also went into storage earlier than some other box bin varieties and had an initial temperature of 72.4ºF, although the temperature was cooled to 53.2ºF by the second sample date. Sucrose concentrations remained high, above 0.389 (X10) in all samples. Glucose concentrations were also higher, between 0.005 and 0.012 from October to December, and rose again in March after a slight mid-season decline for a final concentration of 0.018 (X10). All samples excluding one had some internal color, with a high of 34% in early November and 39.6% at the last sample. Total chip defects were initially high, but generally decreased at each sample date between November and March. They rose again in the last two samples, ending with 44.6% defects. Bruise defects, combined with darker chip color, resulted in marginal chip samples. The last sample occurred on April 4th. This variety reconditions well in storage and has good chip quality until March. It will be evaluated again in the 2019 box bin trial.

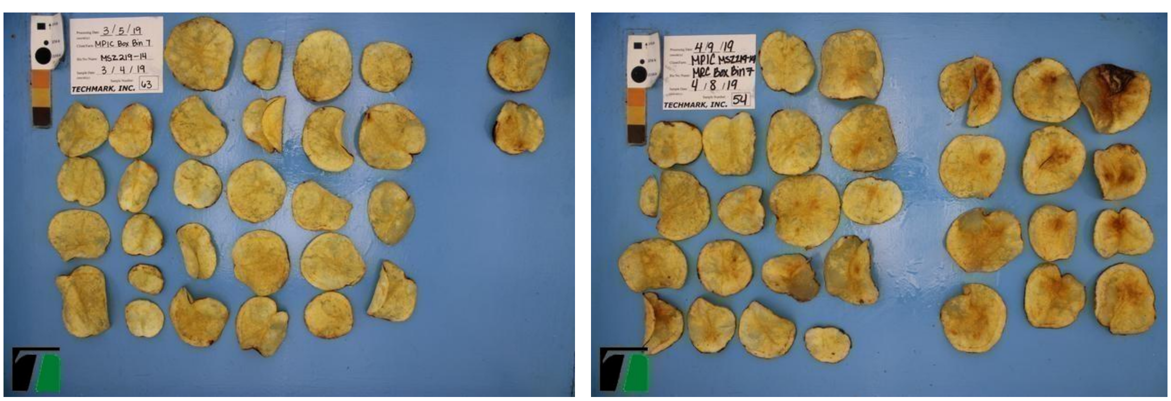

Figure 4. MSZ219-14 chip quality on last acceptable sample date, 3/4/19 (left) and last storage sample, 4/8/19 (right).

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Snowden

This variety was included as a commercial standard for the 2018-2019 Box Bin Trial. The yield was above average at 494 cwt/A US#1 with an above average specific gravity of 1.085. It had no internal defects and a common scab score of 2.0, higher than the trial average of 0.5 (Table 2). Consistent glucose and decreasing sucrose concentrations in the pre-harvest panel indicate chemical maturity at harvest. In early October, this variety was unloaded into storage and analyzed for sucrose and glucose concentrations. The bin temperature was initially very high, over 70F, but was cooled to 52.3F by the second sample date. Sucrose concentrations followed a U-shaped trend in storage, decreasing from bin loading to a low of 0.475 (X10) in early February. Concentrations then increased until the last sample date of April 8th, with a concentration of 1.030 (X10). Glucose concentrations fluctuated between 0.002 and 0.005, until they began increasing in the last two storage samples, ending at 0.021. Chip color was good until late March with minimal internal and undesirable color. The last sample, taken in early April, had 23.4% total defects. Sampling was discontinued after this date due to poor chip quality.

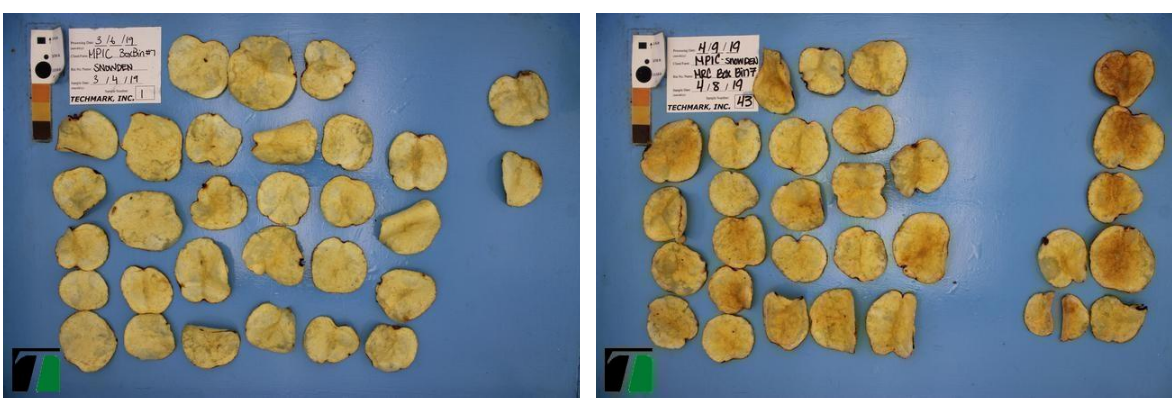

Figure 6. Snowden chip quality on last acceptable sample date, 3/4/19 (left) and last storage sample 4/8/19 (right).

II. 2018 - 2019 Bulk Bin (500 cwt. Bin) Report

(Chris Long, Trina Zavislan, Damen Kurzer, and Brian Sackett)

Overview and Objectives

The goals of the MPIC Storage and Handling Committee for the 2018-2019 bulk bin storage season were: 1. To further refine optimal storage profiles for Hodag and MSV030-4, and 2. To study the effects of two different storage temperatures on Lady Liberty and Mackinaw, and 3. To study the effects of harvest date (early vs. late) on Manistee storage.

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 54ºF, which in most cases is warmer 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 tubers might physiologically age. Bulk bins 1 through 6 were gassed with CIPC on October 10th, bins 7 and 9 were gassed with CIPC on November 7th, and bin 8 was gassed with CIPC on October 15th.

Bulk bin assignments are below:

1 and 2: Lady Liberty (Sackett Potatoes)

3 and 4: Mackinaw (Sackett Potatoes)

5: Hodag (Crooks Farms)

6: MSV030-4 (Walther Farms)

7: Box Bins

8: Early Manistee (Lennard Ag. Co.)

9: Late Manistee (Lennard Ag. Co.)

We began sugar monitoring the day tubers were loaded into storage and sampled tubers on a two-week 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 allows us to take samples 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.

We evaluated the pressure bruise samples 3 to 5 days after the bin was unloaded. We randomly selected a set of 25 tubers from each bag and visually inspected for pressure bruising. By removing the tuber skin with a knife, we evaluated the discoloration for each flat spot. A visual rating established presence or absence of flesh color (blackening of flesh). We calculated percent weight loss in each tuber sample as it was removed from the storage.

Lady Liberty Storage Trial (Bin 1 and 2)

Lady Liberty, a promising variety from the Cornell University, has commercialization potential in Michigan due to excellent chip quality, resistance to common scab, PVY and stem-end defect tolerance, smaller uniform tuber size profile, and long-term cold storage potential. The purpose of this bulk bin experiment was to evaluate glucose and sucrose reaction during pile cooling to 46ºF and 44ºF in bins 1 and 2, respectively. Cooling from initial pulp temperature to suberization temperature (68.8ºF to 56ºF) was achieved by direct cooling, and the bun was further cooled to 50ºF at a rate of either 0.4ºF per day or 0.6ºF per day. After reaching 50ºF, later cooling occurred at a rate of 0.2ºF per day until the temperature reached 46ºF or 44ºF. This strategy and cooling rate is used in all bulk bins, which are cooled from field temperature to suberization temperature, to 50ºF, to the target storage temperature.

We filled Bin 1 with Lady Liberty on September 25th. The seed was planted in Mecosta, MI on May 18th and vine killed on September 7th (112 DAP, GDD_{40} 3295). This planting was harvested on September 24th, 129 days after planting. The pulp temperature for tubers at the time of bin loading was 68.3ºF. Bin 1 was gassed with CIPC on October 10th. It was unloaded on July 1st and shipped to Utz Quality Foods, Hanover, PA.

Results

Bulk Bin 1, Lady Liberty (GDD_{40} 3295, 46ºF)

Chip quality out of the field was very good with 2.6% total defects reported on the first sample date, September 25th. Defects are reported by Techmark, Inc, and are determined using slices cut from stem to bud end. On this date, sucrose and glucose concentrations were 1.161 percent (X10) and 0.002 percent respectively with a pulp temperature of 68.8ºF.

Lady Liberty was slightly physiologically and chemically immature at bin loading as indicated by a stable glucose concentration between two pre-harvest panels, as well as an increase in sucrose between loading and mid-November to a high of 1.041 percent (X10). During this time period, glucose levels also increased once from 0.002 to 0.003 in late October. After November, sucrose levels Decreased through early April, reaching a low of 0.467 (X10). Once the bin reached the target temperature of 48ºF in early January fluctuated between 0.001 and 0.004, and stayed at this concentration through bin unloading on July 1st. During storage, internal color was excellent with no undesirable color for the duration of storage. There was also no undesirable color observed, excluding the last sample at bin unloading, with 3.1% undesirable color. Total defects were low overall, with twelve storage samples that has chip defects. The highest total defect was 13.6% in mid-June. All other samples had total defects lower than 10%.

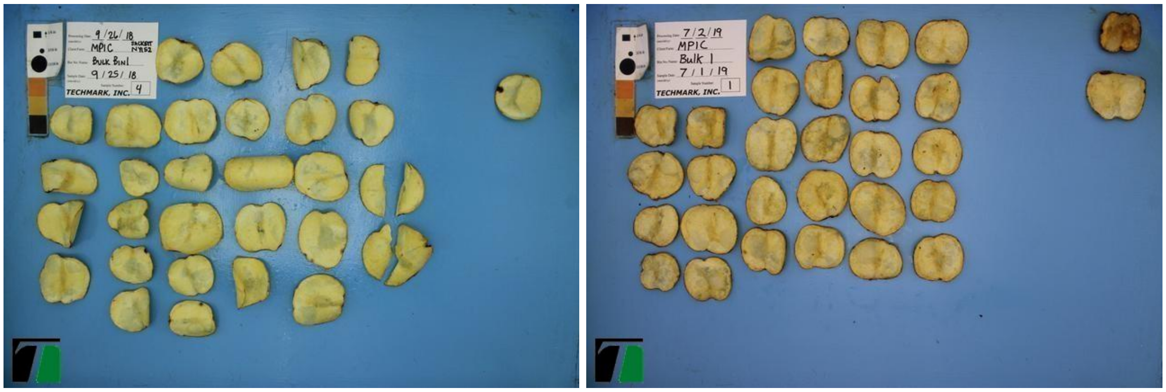

Figure 7. Bulk bin 1 out of the field chip sample on 9/25/18 and final chip sample on 7/1/19.

On July 1st the Bin was unloaded (Figure 8) and the potatoes were processed by Utz Quality Foods, Hanover PA, on July 2nd. The processor noted a very small tuber size profile, along with some pitted scab and pressure bruise. A very small amount of hollow heart was observed. Chip quality was good, with 1% internal defects and 4% external defects. There were no greening or stem end defects (Figure 9). The Hunter Agtron score was 69.1. The processor noted that the fryer operator had to adjust the slice thickness and dwell time (time spent cooking in oil) to reduce chip blistering (Figure 10). Chip blistering was even more pronounced when Lady Liberty was kettle cooked. Due to small tuber size, the chips were very small and remained flat after cooking. This is a known issue in Lady Liberty chip quality, which is otherwise excellent. At bin unloading, the average weight loss of tubers was 6.8%. 13.6% of tubers had bruising with color, while 63.6% had bruising with no color and 24.4% had no bruising (Table 6). Lady Liberty continues to be a promising variety with commercialization potential in Michigan. It will be further evaluated in the 2019 to 2020 storage season in the box bin trial.

Figure 8. Lady Liberty potatoes at bin unloading on 7/1/19.

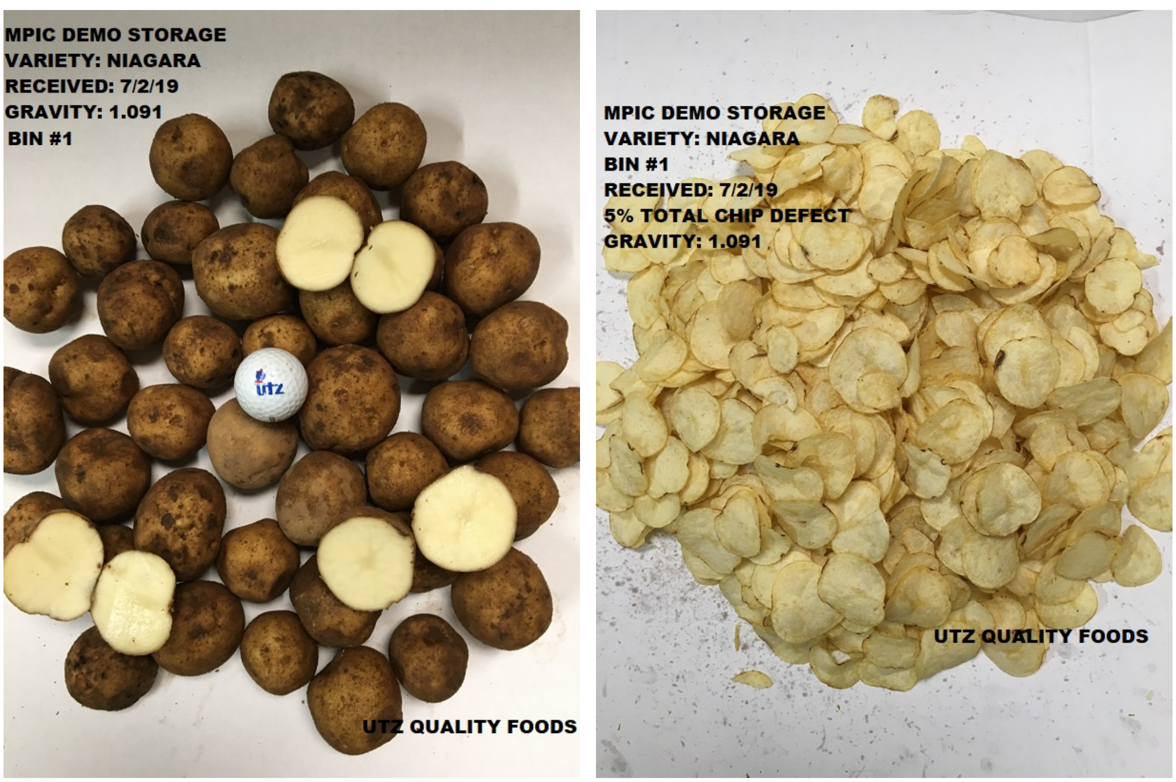

Figure 9. Lady Liberty whole and chipped tubers at Utz Quality Foods, 7/2/19.

Figure 10. Lady Liberty chip blistering visible at Utz Quality Foods, 7/2/19.

Bulk Bin 2, Lady Liberty (GDD_{40} 3295, 44ºF)

Chip quality out of the field was very good with 5.6% total defects reported on the first sample date, September 25th. Defects are reported by Techmark, Inc, and are determined using slices cut from stem to bud end. On this date, sucrose and glucose concentrations were 1.081 percent (X10) and 0.002 percent respectively with a pulp temperature of 67.3ºF.

Sucrose levels initially fell in storage until early November, but then increased and remained higher through early February, after which they generally decreased until closer to bin unloading in June. Glucose levels remained largely stable, between 0.002 and 0.004 for the duration of storage. The target temperature of 44ºF was reached in early February, and was maintained until early June. Similar to Bin 1, Bin 2 had good chip quality for most of storage. There was only one incidence of undesirable color towards the end of storage, 3.6%. Internal color was also good, with only two samples exhibiting browning. Total defects were somewhat variable, with 32.6% in early October as the highest percent defects. All other samples had less than 13% total defects (Figure 12).

Bin 2 was unloaded on July 1st and was processed at Utz on July 2nd (Figure 11). As in Bin 1, Utz noted that the size profile was very small. The fryer operator also adjusted the slice thickness and dwell time to minimize chip blistering. The processor comments on chip quality were identical to those of Bin 1.There was 1% internal defects and 2% external defects. The Hunter Agron score was 69.5 (Figure 13).

At bin unloading, the average tuber weight loss was 6%. 12.9% of tubers were bruised with color, while 78.7% were bruised with no color and 8.4% had no bruising (Table 6).

Figure 11. Lady Liberty potatoes at bin unloading on 7/1/19.

Figure 12. Bulk Bin 2 out of the field chip sample on 9/25/18 and final chip sample on 7/1/19.

Figure 13. Whole and chipped Lady Liberty potatoes from Bin 2 at Utz Quality Foods, 7/2/19.

Table 6. 2018-2019 PRESSURE BRUISE DATA
Bulk Bin #1 and #2 Lady Liberty (Mecosta, MI)

Location[1]	Average Weight Loss (%)	Average Number of External Pressure Bruises Per Tuber[2]				Average % of Total Tuber Number		
		0	1	2	3+	Without Bruise	Bruised (No Color)	Bruised with Color[3]
14' Bin 1	6.1	7.0	11.0	4.3	2.7	28.0	64.0	8.0
8' Bin 1	8.4	7.7	8.0	6.7	2.0	30.7	60.0	14.0
3' Bin 1	6.0	3.7	7.3	8.7	5.7	14.7	66.7	18.7
OVERALL AVERAGES	**6.8**					**24.4**	**63.6**	**13.6**
14’ Bin 2	5.8	3.7	8.0	8.3	4.7	14.7	78.7	6.7
8’ Bin 3	discarded	1.3	4.3	9.0	10.3	5.3	80.0	14.7
3’ Bin 3	6.1	1.3	4.0	9.0	11.0	5.3	77.3	17.3
OVERALL AVERAGES	**6.0**					**8.4**	**78.7**	**12.9**

[1] Feet above the bin floor.
[2] A Sample of 25 tubers randomly selected. Each tuber was first evaluated for the number of visual pressure bruises 0, 1, 2, 3+.
[3] A cut slice was removed just below the skin of each bruised area. If any flesh was darkened, it was scored as a tuber "with color".

Loaded	9/25/18 (both)	Pulp Temp. (at Filling)	68.3ºF (1) 69.4ºF (2)		
Unloaded	7/1/19 (both)	Target Storage Temp.	46ºF (1) 44ºF (2)	End Temp.	55.2ºF (1) 53.2ºF (2)

Mackinaw Storage Trial (Bins 3 and 4)

This Michigan State University variety had commercialization potential in Michigan due to PVY and Late Blight resistance and common scab tolerance. It produces a high percentage of A-sized tubers and has a high specific gravity, as well as long-term chip quality in storage. These two bulk bins were filled with potatoes grown by Sackett Potatoes in Mecosta, MI. The potatoes in both bins were planted on May 18th and vines were killed on September 7th (112 DAP, GDD_{40} 3037). Harvest occurred on September 25th, 130 days after planting. At harvest the pulp temperature was 69.4ºF. The tubers were in good condition at bin loading, with 83% bruise free tubers. Mackinaw was slightly physiologically and chemically immature at bin loading as indicated by a decreasing glucose concentration and increasing sucrose concentration between two pre-harvest panels. The bins were loaded on September 25th and treated with CIPC on October 10th. These bins were designed to study chip quality and potato storability under two different storage protocols.

Results

Bulk Bin 3, Mackinaw (GDD_{40} 3037, 48ºF)

This bin was cooled to the target temperature of 48ºF by mid-December. Initially, the bin was going to be cooled to 46ºF, but concerns over chip quality at this lower temperature based on initial chip defects dictated a slightly higher target temperature. The tubers were in good condition at bin loading, with 80% bruise free tubers. The initial bin temperature was 65.8ºF at the first chip sample, and the bin was cooled to the target temperature of 48ºF by late December. This was maintained until early June, when the temperature was increased to 52.8ºF at the final chip sample date of July 1st. Mackinaw had a high initial sucrose (x10) concentration for the first few months of storage. Concentrations were at or above 1.000% (x10) through late January, but decreased gradually through June. In the last month of sampling, the concentration rose again. Glucose concentrations were also somewhat elevated, fluctuating between 0.002 and 0.004 for the duration of storage. Mackinaw had good internal quality, with only one sampling displaying 3.8% undesirable color. Four chip samples displayed internal color. In all but two samples, there were at least some total defects, with a high of 40.3% in December. Bruising was the most common defect observed during storage sampling (Figure 14).

Bin 3 was unloaded on July 1st and processed by Utz Quality Foods on July 2nd (Figure 15). At unloading, the average tuber weight loss was 15.2%. 27.6% of tubers had no bruising, 61.3% had bruising with no color, and 11.1% were bruised with color (Table 7). The processor noted an average tuber size profile, and good internal quality. Some pressure bruise defects were visible, and the specific gravity was 1.096. There were 3% defects, 1% internal and 2% external. The internal defect score was due to slight stem end browning. The Hunter Agtron score was 70.7. Overall, the processor noted excellent finished chip quality, but the fryer operator had to adjust slice thickness and dwell time to maintain chip quality (Figure 16).

Figure 14. Bulk Bin 3 out of the field chip sample on 9/25/18 and last chip sample on 7/1/19.

Figure 15. Bulk Bin 3 unloading on 7/1/19.

Figure 16. Whole and chipped tubers from Bulk Bin 3 at Utz Quality Foods on 7/2/19.

Bulk Bin 4, Mackinaw (GDD$_{40}$ 3037, 50ºF)

This bulk bin was initially cooled to 50ºF, and further cooling to 44ºF was initially planned. However, elevated sucrose and concerns over chip defects dictated maintaining the bin at 50ºF for the duration of storage. This bin reached the target temperature by late

November, and remained at or near the target until bin unloading. Sucrose levels were high at the beginning of storage, and remained over 1.000% (x10) until it began to decrease in January. Concentrations rose in June, rising to 1.107% (x10) at the last sample. Glucose concentrations were more stable, between 0.001% and 0.003% for most of storage. There was no incidence of internal color, and six samples with internal color, all below 10%. Total defects were variable, with higher chip defects through December, with evidence of reconditioning at improved chip quality later in storage. The last chip sample was collected on July 1st, 2019 (Figure 17).

Bin 4 was unloaded on July 1st, and potatoes were shipped to Utz Quality Foods for processing (Figure 18). At bin unloading, the average tuber weight loss was 6.6%. 62.2% of tubers were bruised with no color, 27.1% were bruise free, and 10.7 were bruised with color (Table 7). The processor noted an average size profile, good internal quality, and minor pressure bruise defect. There were 2% total defects, 1% internal and 1% external. The Hunter Agron score was 70.1, and the specific gravity was 1.091. The sample had excellent chip quality, and the samples displayed slight stem end defect and internal discoloration (Figure 19).

Figure 17. Bulk Bin 4 out of the field chip sample on 9/25/18 and last chip sample on 7/1/19.

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Figure 18. Unloading Bulk Bin 4 on 7/1/19.

Figure 19. Whole and chipped tubers from Bulk Bin 4 at Utz Quality Foods on 7/2/19.

Table 7. 2018-2019 PRESSURE BRUISE DATA Bulk Bin #3 and #4 Mackinaw (Mecosta, MI)								
Location[1]	Average Weight Loss (%)	Average Number of External Pressure Bruises Per Tuber[2]				Average % of Total Tuber Number		
		0	1	2	3+	Without Bruise	Bruised (No Color)	Bruised with Color[3]
14' Bin 3	6.9	7.7	10.7	4.7	2.0	30.7	60.0	9.3
8' Bin 3	34.0	8.0	9.3	5.7	2.0	32.0	57.3	10.7
3' Bin 3	4.7	5.0	9.7	7.0	3.3	20.0	66.7	13.3
OVERALL AVERAGES	**15.2**					**27.6**	**61.3**	**11.1**
14’ Bin 4	6.5	11.7	7.7	4.0	1.3	46.7	45.3	8.0
8’ Bin 4	7.4	4.7	8.0	9.0	3.3	18.7	65.3	16.0
3’ Bin 4	6.0	4.0	11.7	5.7	3.7	16.0	76.0	8.0
OVERALL AVERAGES	**6.6**					**27.1**	**62.2**	**10.7**

1 Feet above the bin floor.
2 A Sample of 25 tubers randomly selected. Each tuber was first evaluated for the number of visual pressure bruises 0, 1, 2, 3+.
3 A cut slice was removed just below the skin of each bruised area. If any flesh was darkened, it was scored as a tuber "with color".

Loaded	9/25/18(both)	Pulp Temp. (at Filling)	69.4ºF (both)		
Unloaded	7/1/19 (both)	Target Storage Temp.	48.0ºF (3) 50.0ºF (4)	End Temp.	52.8ºF (3) 70.8ºF (4)

Hodag Storage Trial (Bin 5)

This University of Wisconsin variety was evaluated as W5955-1. It has an above average specific gravity, tolerance to common scab, and good chip color out of storage. This Bulk Bin was filled with potatoes grown at Crooks Farms. The potatoes were planted on April 30th, and bine killed September 6th (129 DAP, 3578 GDD_{40}). Harvest occurred on September 24th, 147 days after planting. At bin loading the pulp temperature was 57.7ºF. The tubers were in good condition at harvest with 93% bruise free tubers. No pre-harvest panels were taken for this variety. Bin 5 was loaded on September 24th and was treated with CIPC on October 10th. This bin study was designed to establish a storage protocol and target temperatures based on sucrose and glucose responses to lower temperatures.

Results

Bulk Bin 5, Hodag (GDD_{40} 3578, 47ºF)

The temperature in Bulk Bin 5 was gradually cooled from field temperature to 48ºF in early December with fresh air forced through the pile. At this time, the Storage and Handling committee chose to lower the temperature further to 47ºF by late December. This bin was maintained at this lower temperature through bin unloading. The sucrose concentration initially fluctuated in a generally upward trend, but began to decrease in February through the end of storage. The glucose concentration was largely stable, between 0.002 and 0.005%. No samples had undesirable color, and six samples had undesirable color, all below 6%. Total defects were more variable, with seven samples having no internal defects, and the other ten samples with defects at or less than 11%. The last sample was chipped on May 20th (Figure 20).

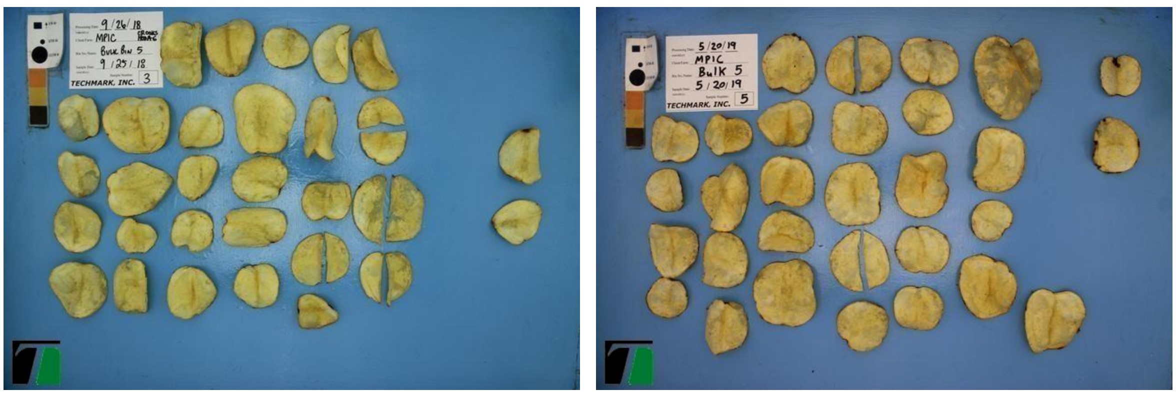

Figure 20. Bulk bin 5 first chip sample on 9/25/18, and last chip sample on 5/20/19

On May 20th, the bin was unloaded and the potatoes were shipped to Herr Foods, Inc., Pennsylvania for processing on May 21st. At unloading, the average tuber weight loss was 5.5%. 39.1% of tubers were bruise free, 56.0% were bruised with no color, and 4.9% were bruised with color (Table 8). The Hunter Agron score was 49.2. There were 19.4% total defects, mainly internal color. The size profile was inconsistent. Overall, the chip quality was good for Hodag after almost eight months (Figure 21).

Figure 21. Hodag potatoes and chips at Herr Foods on May 21st.

Table 8. 2018-2019 PRESSURE BRUISE DATA Bulk Bin #5 Hodag (Edmore, MI)								
Location[1]	Average Weight Loss (%)	Average Number of External Pressure Bruises Per Tuber[2]				Average % of Total Tuber Number		
		0	1	2	3+	Without Bruise	Bruised (No Color)	Bruised with Color[3]
14' Bin 4	6.2	13.0	9.3	3.0	0.0	52.0	46.7	1.3
8' Bin 4	4.7	10.3	7.3	5.7	1.7	41.3	53.3	5.3
3' Bin 4	5.5	6.0	7.7	8.7	1.7	24.0	68.0	8.0
OVERALL AVERAGES	**5.5**					**39.1**	**56.0**	**4.9**

[1]Feet above the bin floor.
[2]A Sample of 25 tubers randomly selected. Each tuber was first evaluated for the number of visual pressure bruises 0, 1, 2, 3+.
[3]A cut slice was removed just below the skin of each bruised area. If any flesh was darkened, it was scored as a tuber "with color".

Loaded	9/24/18	Pulp Temp. (at Filling)	57.7ºF		
Unloaded	5/20/19	Target Storage Temp.	47.0ºF	End Temp.	47.4ºF

Petoskey Storage Trial (Bin 6)

Petoskey, evaluated as MSV030-4 is a Michigan State University variety. It has an above average specific gravity, common scab tolerance, and good raw internal quality and chip color. This variety was planted at Walther Farms on April 27th and vine killed on August 31st (126 DAP, GDD_{40} 3511). Potatoes were harvested on September 14th, 140 DAP. Only one pre-harvest sample was taken on August 20th. The sucrose rating was 0.555 with 0.002% glucose. Tuber quality was good at bin loading with 90% bruise free tubers and the pulp temperature was 64.4ºF. Bin 6 was gassed with CIPC on October 10th. The purpose of this bin study was to refine the storage profile, and lower the bin temperature while still achieving acceptable glucose and sucrose concentrations, thereby maintaining chip quality.

Results

Bulk Bin 6, Petoskey (GDD_{40} 3511, 48ºF)

This variety was cooled to the target temperature of 48ºF by mid-December, and was maintained at this temperature until the last sample on May 6th, when the temperature rose to 50.4ºF. Sucrose concentrations rose from bin loading until December, fluctuated until late March, and then rose until the end of the storage season. Glucose concentrations were more stable, but gradually increased after late March, similarly to sucrose. There were two samples with undesirable color, both after April. There was limited internal color, ten chip samples had none while eight samples had 15% or less internal color. Total defects were variable, with a higher percentage of defects at the beginning and end of storage, with the best chip quality in January and February.

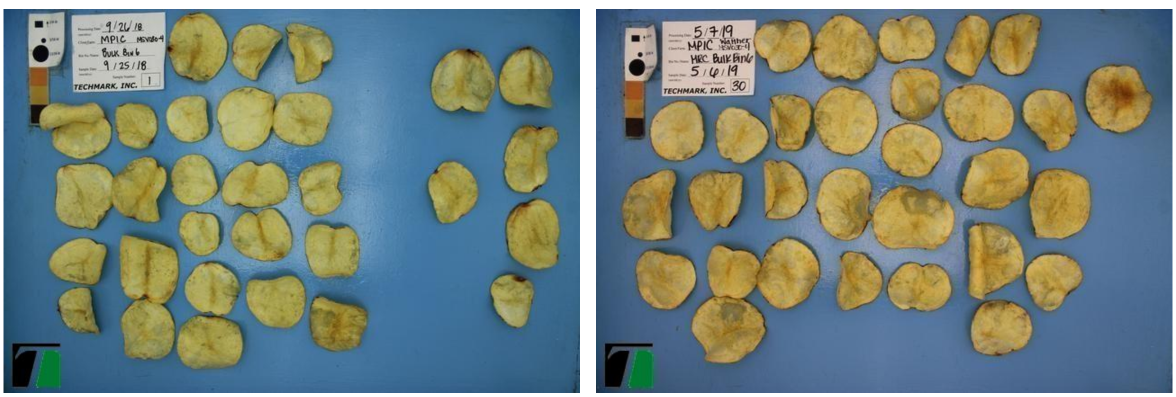

Figure 22. Bulk bin 6 initial chip sample on 9/25/18 and final chip sample on 5/6/19.

At the beginning of storage, Petoskey was scheduled to ship in June, but declining chip quality dictated an earlier shipping date. Bin 6 was unloaded on May 6th and shipped to Better Made Snack Foods in Detroit, Michigan where it was processed on May 7th. It has a specific gravity of 1.088 at a Hunter Agrtron score of 63.1. There were 3.6% total defects, 1.8% internal defects and 1.8% external defects (Figure 23). At Unloading, the average tuber weight loss was 5.6%. 41.8% of tubers had no pressure bruise, 44% had bruising with no color, and 14.2% had bruising with color (Table 6).

The Potato Outreach Program received a chip sample from Bulk Bin 6 chips processed at Better Made and sorted the chips by defect type. 83% of tubers were acceptable, there were 6% external defects, 5% internal defects, and 6% stem end defect (Figure 24).

Figure 23. Petoskey tubers and chips at Better Made Snack Foods on May 7th.

Figure 24. Petoskey chips sorted by defect type.

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Table 6. 2018-2019 PRESSURE BRUISE DATA Bulk Bin #6 Petoskey (Walther Farms)								
Location[1]	Average Weight Loss (%)	Average Number of External Pressure Bruises Per Tuber[2]				Average % of Total Tuber Number		
		0	1	2	3+	Without Bruise	Bruised (No Color)	Bruised with Color[3]
14'	7.4	10.7	9.3	5.0	0.0	42.7	37.3	20.0
8'	5.1	10.3	12.0	2.7	3.0	41.3	44.0	14.7
3'	4.5	10.3	12.7	2.0	0.0	41.3	50.7	8.0
OVERALL AVERAGES	**5.6**					**41.8**	**44.0**	**14.2**

1 Feet above the bin floor.
2 A Sample of 25 tubers randomly selected. Each tuber was first evaluated for the number of visual pressure bruises 0, 1, 2, 3+.
3 A cut slice was removed just below the skin of each bruised area. If any flesh was darkened, it was scored as a tuber "with color".

Loaded	9/24/18	Pulp Temp. (at Filling)	64.4ºF		
Unloaded	5/6/19	Target Storage Temp.	48.0ºF	End Temp.	50.4ºF

Manistee Storage Trial (Bins 8 and 9)

Manistee is a Michigan State University variety with good chip color and raw internal quality, and good tuber storability. These bins were filled with early planted (Bin 8) and late planted (Bin 9) Manistee to determine if early planted Manistee can store for a long as later planted Manistee while maintaining chip quality. Bin 8 tubers were planted at Lennard Ag. Co. on April 26th. It was vine killed on August 27th (124 DAP, GDD_{40} 3657). Two pre-harvest panels were taken on August 15th and August 22nd. The glucose concentration was stable between samples, and the sucrose decreased between samples, indicating chemical maturity. The potatoes were harvested on September 14 and had a pulp temperature of 77.4ºF. The tubers had some damage at harvest and were 67% bruise free. This bin was gassed with CIPC on October 15th.

The Manistee tubers for Bulk Bin 9 were also grown by Lennard Ag. Co., and were planted on June 7th. The plants were vine killed on October 1st (117 DAP, GDD_{40} 3602) and were harvested on October 16th (132 DAP). At loading on October 17th the pulp temperature was 45.8ºF with 88% bruise free tubers. One pre-harvest panel was taken on September 17th. This bin was gassed with CIPC on November 7th.

Results

Bulk Bin 8, Early Manistee, (GDD$_{40}$ 3657, 48ºF)

Bulk Bin 8 had initially high sucrose levels, which fluctuated between samples but remained high until late February. Concentrations then decreased before rising at the last sample date. Glucose concentrations were also variable, rising to a high of 0.012% in late February, reflecting the earlier elevated sucrose concentrations. Chip quality was variable, with all samples having at least 5% total defects. The samples in late October and late January had the highest percent total defects, 31.6% and 39.2% respectively. There was also some internal color observed in all but three chip samples. There was almost no undesirable color, excluding one 2.1% in late February. The storage season began with a temperature of 57.0ºF that was dropped to 51.6ºF and then maintained in December due to defects and free sugar. The bin was later cooled by 4/10ºF to 50.0ºF and then by 2/10ºF to 48ºF. The target temperature was reached by January and maintained until late April. The last sample was taken on May 6th (Figure 25).

Figure 25. Bulk Bin 8 out of the field chip sample on 9/25/18, and last chip sample on 5/6/19.

Bulk bin 8 was unloaded on May 6th and processed by Better Made Snack Foods May 7th (Figure 26). At unloading, the tubers had an average of 7.7% weight loss. 60.9% of tubers had no bruising, 38.7% had bruising with no color, and 0.4% had bruising with color. The Hunter Agron score was 62.8, and the specific gravity was 1.080. There were 7.7% total chip defects. 5.1% of chips had internal sugars, 1.1% were green, 0.9% had internal defects, and 0.7% had external defects.

Figure 26. Early Manistee tubers and chipped potatoes at Better Made Snack Foods on May 7th.

The Potato Outreach Program evaluated the defects from potato chips produced at Better Made Snack Foods (Figure 27). There were 74% acceptable chips, 9% external defects, 7% internal defects, and 11% stem end defects.

Figure 27. Early Manistee chips are separated into acceptable (left side), external defects, internal defects, and stem end defects (right side) by the Potato Outreach Program.

Bulk Bin #9, Late Manistee, (GDD_{40} 3602, 50ºF)

Bulk bin 9 had a higher target temperature than Bin 8, and was stored at 50ºF from December through early May. Similar to Bin 8, there were concerns about chip defects and free sugar, so the target temperature was set at 50.0ºF to preserve chip quality. The storage temperature was increased to 55.4ºF prior to bin unloading (Figure 28). Compared to Bin 8, Bin 9 had lower sucrose levels, which generally decreased until early April. Sucrose concentrations rose slightly through the end of storage on July 1st. As in Bin 8, Late Manistee had elevated glucose concentrations, which rose to 0.011% in early January. This bin had higher total defects than Bin 8, with the most defects appearing earlier in storage. The second chip sample, taken November 5th, had 64.5% total defects. Total defects were lowest in April and May, suggesting chip reconditioning. Internal color followed a similar trend, with the most color appearing in earlier samples and the lowest percentage of internal color in April and May. Five chip samples had undesirable color.

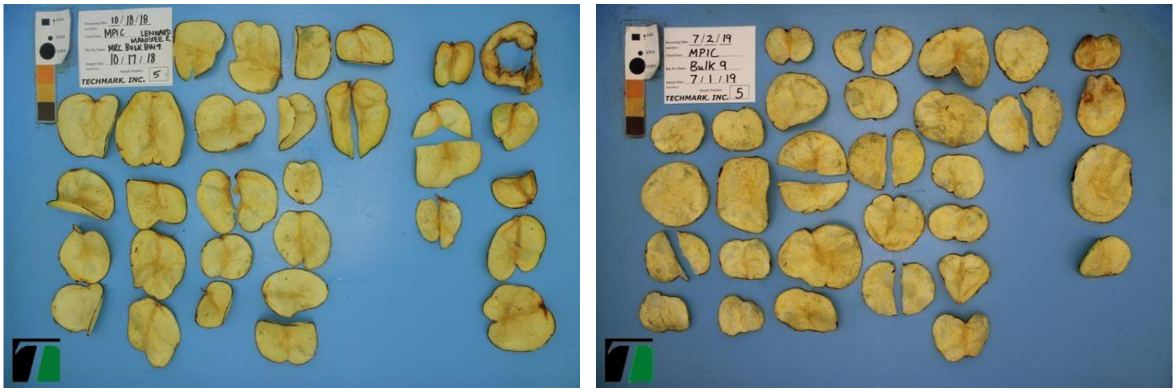

Figure 28. Bulk bin 9 out of the field chip sample on 10/17/18, and last chip sample on 7/1/19

Bulk bin 9 was unloaded on July 1st and processed by Better Made Snack Foods on July 2nd (Figure 29). At bin unloading, the average tuber weight loss was 7.8%. 30.7% of tubers had no bruising, 58.2% had bruising with no color, and 11.1% had bruising with color (Table 9). The specific gravity at processing was 1.085 and the Hunter Agtron score was 61.0. There were 11.5% total defects, 6.7% greening and 4.8% external defects (Figure 30).

Figure 29. Bin 9 unloading on July 1st.

Figure 30. Bin 9 Late Manistee tubers and chips at Better Made Snack Foods on July 2nd.

The Potato Outreach Program evaluated chip samples from Better Made Snack Foods and sorted them by defect type (Figure 31). There were 57% acceptable chips, 18% external defects, 12% internal defects, and 13% stem end defects.

Figure 31. Early Manistee chips are separated into acceptable (left side), external defects, internal defects, and stem end defects (right side) by the Potato Outreach Program.

Table 9. 2018-2019 PRESSURE BRUISE DATA Bulk Bin #8 and #9 Early and Late Manistee (Lennard Ag. Co.)								
Location[1]	Average Weight Loss (%)	Average Number of External Pressure Bruises Per Tuber[2]				Average % of Total Tuber Number		
		0	1	2	3+	Without Bruise	Bruised (No Color)	Bruised with Color[3]
14' Bin 8	7.4	18.0	7.0	0.0	0.0	72.0	28.0	0.0
8' Bin 8	9.0	14.0	10.0	1.0	0.0	56.0	44.0	0.0
3' Bin 8	6.7	13.7	10.7	0.7	0.0	54.7	44.0	1.3
OVERALL AVERAGES	**7.7**					**60.9**	**38.7**	**0.4**
14’ Bin 9	6.1	12.3	11.3	1.3	0.0	49.3	45.3	5.3
8’ Bin 9	7.6	8.7	10.7	4.7	1.0	34.7	54.7	10.7
3’ Bin 9	9.5	2.0	7.7	10.3	5.0	8.0	74.7	17.3
OVERALL AVERAGES	**7.8**					**30.7**	**58.2**	**11.1**

[1] Feet above the bin floor.
[2] A Sample of 25 tubers randomly selected. Each tuber was first evaluated for the number of visual pressure bruises 0, 1, 2, 3+.
[3] A cut slice was removed just below the skin of each bruised area. If any flesh was darkened, it was scored as a tuber "with color".

Loaded	9/14/18 (8) 10/17/18 (9)	Pulp Temp. (at Filling)	77.4ºF (8) 45.8 ºF (9)		
Unloaded	5/6/19 (8) 7/1/19 (9)	Target Storage Temp.	48.0ºF (8) 50.0ºF (9)	End Temp.	50.8ºF (8) 55.6ºF (9)