



Manistee, a new Round-White Early to Mid-Season Maturing Potato Variety with Excellent Long-Term Storage Potential

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Received: 17 July 2025 / Accepted: 17 September 2025 / Published online: 22 October 2025
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Abstract

Manistee is a round white chip-processing potato (*Solanum tuberosum*) variety developed for long-term storage. Evaluated as MSL292-A, Manistee is a selection from a cross between Snowden and the chip-processing breeding line MSH098-2. The tubers of Manistee are compressed, round with shallow eyes and early to mid-season maturity. Field testing and on-farm trials show that this variety has high yield potential with specific gravity comparable to Snowden and similar to better tolerance to blackspot bruise. Manistee was formally released in 2013 and has demonstrated reliable and excellent long-term storage chip-processing quality up to eight months post-harvest which extends the chip-processing storage season beyond Snowden. Furthermore, preliminary studies with Manistee, Snowden, Lamoka and Pike tuber disks demonstrated that Manistee started the wound healing process faster than Lamoka and Pike and slightly faster than Snowden which supports observations of stable and reliable commercial storage of the tubers for chip-processing.

Keywords Potato cultivar · *Solanum tuberosum* · Chip-processing

Introduction

Manistee is a round white chip-processing potato (*Solanum tuberosum*) variety developed at Michigan State University for long-term storage. Evaluated as MSL292-A, Manistee is a selection from a cross between Snowden and the chip-processing breeding line MSH098-2 made in 1999 (Fig. 1). The maternal parent Snowden is an industry standard chip-processing cultivar. Snowden originates from the University of Wisconsin breeding program and is the result of a cross between the cultivars Lenape (B5141-6) and Wischip (Wisconsin Seed Potato Certification 2019). The paternal parent MSH098-2 is a chip-processing breeding line with excellent resistance to black spot bruise. MSH098-2 is the progeny of a cross between MSC127-3 an advance breeding line with excellent chip quality, and bulk pollen from a number of elite chip-processing breeding lines and cultivars.

The seedling generation that Manistee was selected from was grown in 1999 at MSU in East Lansing Michigan. Single hill plots were planted in 2000 at MSU and initial selections were made by visual assessment for tuber shape and appearance. Bulk selections were made during the single hill stage, and in year 2, a single hill selection was chosen and designated MSL292-A. This was followed by three years of selection and seed multiplication at the MSU Lake City Research Center (LCRC) in Lake City, Michigan. Clonal selection at LCRC evaluated tuber type, size, and set; vine maturity; reducing sugars and suitability for mechanical harvest. Replicated agronomic trials were conducted at the MSU Montcalm Research Center (MRC) in Lakeview, Michigan and ran concurrently with on-farm trials between 2008 and 2012. Resistance to common scab (*Streptomyces scabies*) was also evaluated in replicated disease trial between 2007 and 2012. Manistee was trialled in national SNAC trials in CA, FL, ID, ME, MI, MO, NC, ND, OR, PA, and WI for yield, specific gravity, internal defects, and chip processing quality between 2010 and 2013.

Manistee was formally released in 2013 as an early to mid-season maturing variety with excellent chip-processing quality out of long-term storage. The name Manistee was

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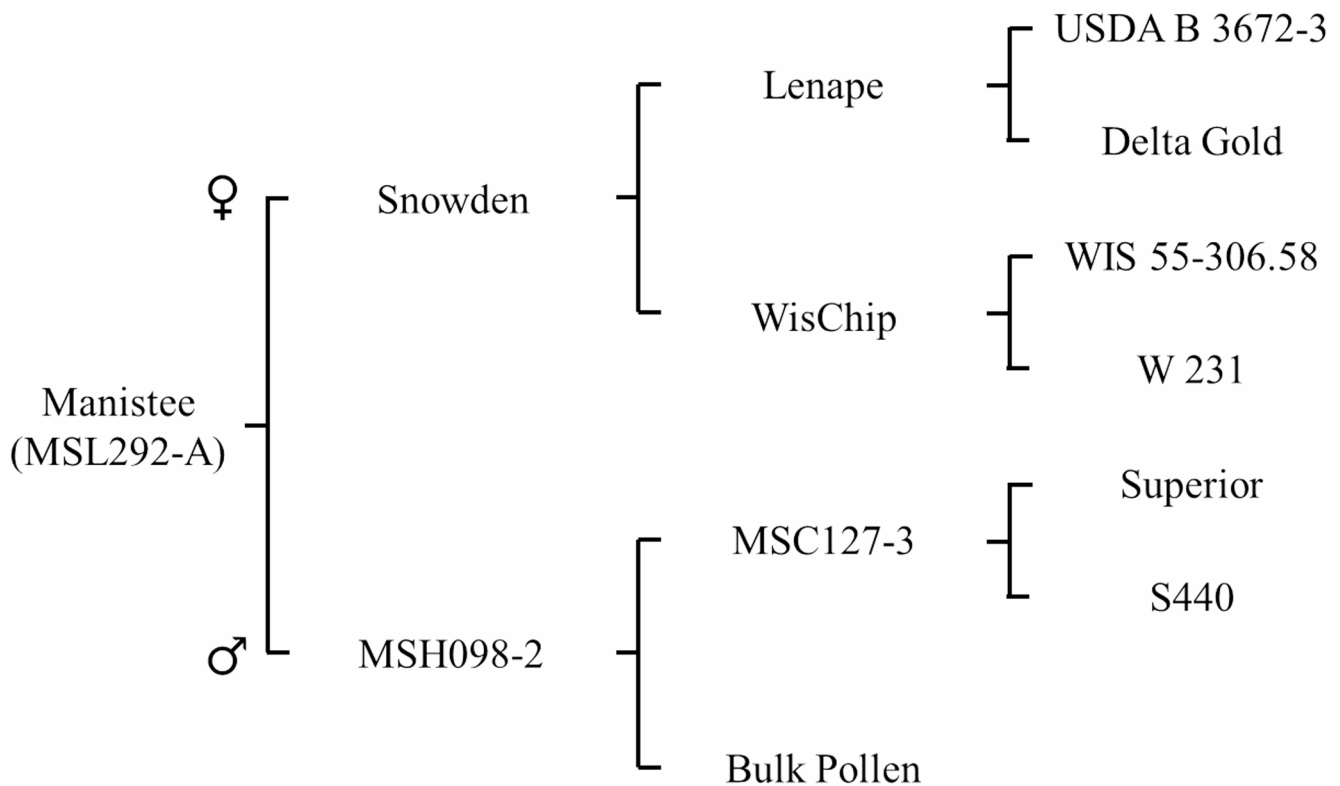


Fig. 1 Pedigree of Manistee (MSL292-A)

selected as a reference to Manistee county and the Manistee-Huron National Forest area near the LCRC where the initial development of this potato variety began.

Cultivar Description

Morphological characteristics of Manistee are shown in Figure 2.

Plants

Vines of Manistee are semi-erect with a balance of visible stems and foliage, with a medium maturity that is earlier than Snowden. Leaves are dark green (Royal Horticultural Society Color Chart value 137 A) with an open silhouette. Terminal leaflets are medium ovate with acuminate tips and obtuse to cordate bases with a slight waviness at the margins. Each leaf has an average of 4 pairs of narrowly ovate primary leaflets with acuminate tips and cordate bases, showing very little variation. Secondary and tertiary leaflet pairs range from 3 to 7 per leaf with an average of 6. Petioles are absent of any anthocyanin coloration and stipules are medium in size. Stems are weakly winged with weak anthocyanin coloration.

Flowers

Manistee produces a moderate number (10 to 17 with an average of 14) of inflorescence per plant under field conditions in Michigan. Corollas are pentagonal and bicolored with the interior surface color being 1:1 violet-white (RHS Color Chart value N82D and 155 A) and the outer surface of the corolla being white (RHS Color Chart value 155 A). The calyx bears no anthocyanin coloration. The anthers are dark yellow (RHS Color Chart value 14 A) and arranged in a narrow cone producing some pollen. The stigma is light green (RHS Color Chart value 146B) and capitate. Manistee is both male and female fertile under greenhouse conditions, with no berry production in the field.

Tubers

Tuber skin is buff in color (RHC Color Chart value 164B) with a netted texture. Tuber shape is round to compressed with a medium thickness. The average tuber weight under irrigated conditions in Michigan is 154.4 g with an average length of 5.3 cm (SD=0.48) and an average tuber width of 7.3 cm (SD=0.66). Tubers have 8.5 eyes on average with a range of 5

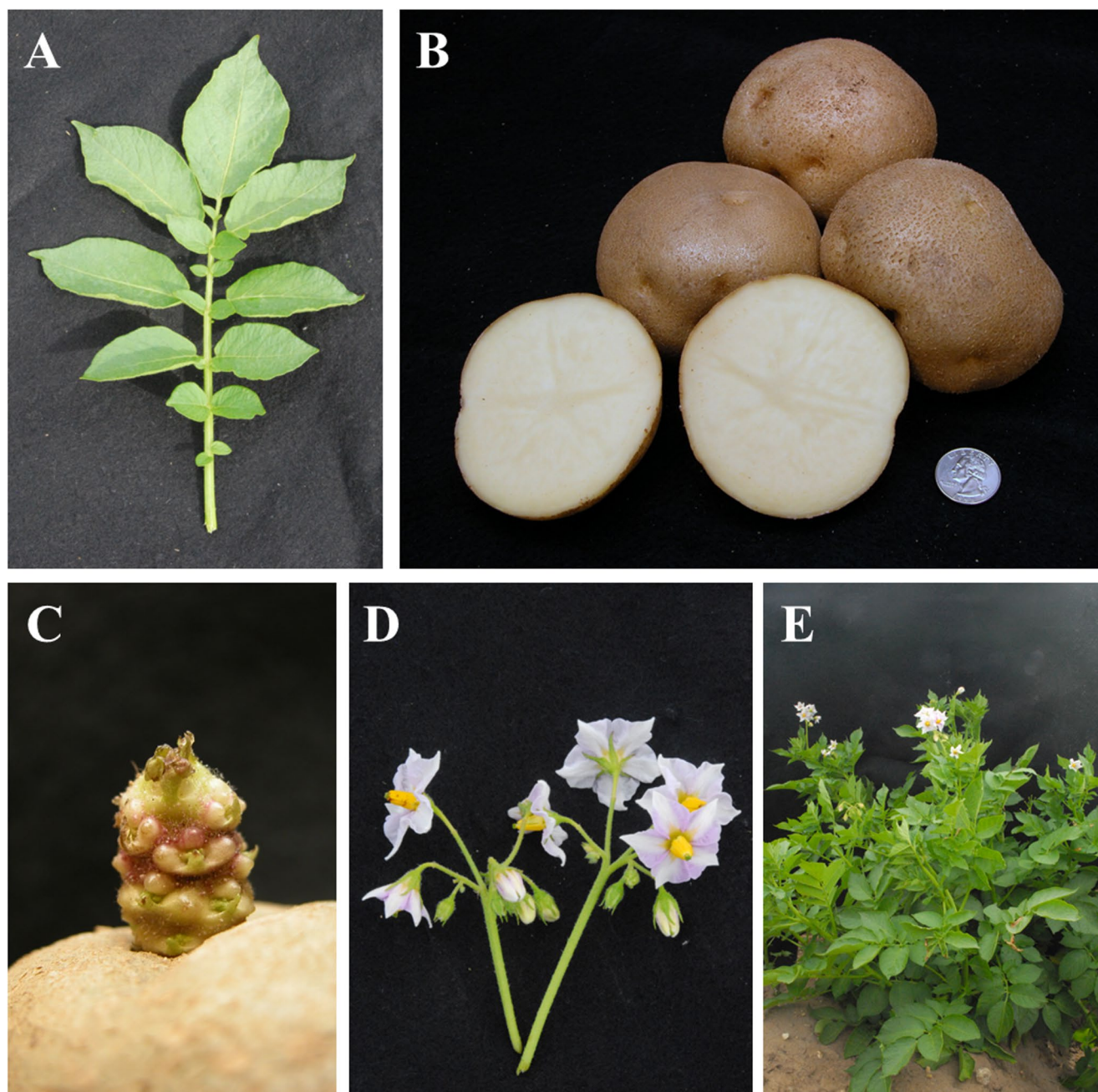


Fig. 2 Morphological characteristics of Manistee. A. Leaf, B. tubers and tuber flesh, C. light sprout, D. inflorescence, E. plant

to 11 and a predominately apical distribution and an absence of eyebrows. Flesh color is white (RHC Color Chart value 11D).

Light Sprouts

Light sprouts are ovoid in shape with a medium number of root initials and an intermediate habit. Sprout bases have weak pubescence and are green in color in addition to medium anthocyanin coloration. The tips of light sprouts have a medium amount of pubescence with weak anthocyanin coloration and green in color.

Characteristics

Agronomic Performance

Yield and specific gravity of Manistee were comparable to the reference check cultivar Snowden, with fewer internal defects in replicated trials from 2008 to 2012 at the MRC in Lakeview, Michigan (Table 1). In the same trials, Manistee also exhibited earlier maturity than Snowden. Trial plots were 7 m in length with three replicates. Field spacing

Table 1 Agronomic performance trials at the Michigan State University Montcalm Research Center, Lakeview, Michigan

Entry	Yield (mt ha ⁻¹)		Percent of Total ¹			As	OV	PO	Gravity	Chip Score ²	Tuber Quality (%) ³			Maturity ⁴
	US#1	Total	US#1	Bs	HH						IBS	BC		
2012 (10 May – 17 September; 131 d)														
Manistee	39	45	87	13	82	6	0	0	1.077	1.0	0	0	0	1.1
Snowden	31	43	73	27	72	0	0	0	1.080	1.0	0	0	0	1.4
HSD _{0.05}	NS	NS							NS					
2011 (9 May – 20 September; 134 d)														
Manistee	39	46	84	16	78	6	0	0	1.082	1.0	0	0	0	1.8
Snowden	31	39	80	19	79	1	1	1	1.080	1.5	3	0	0	2.5
HSD _{0.05}	NS	NS							0.006					
2010 (4 May – 21 September; 140 d)														
Manistee	51	59	86	14	83	3	0	0	1.079	1.0	3	0	0	1.2
Snowden	55	62	90	10	80	10	1	1	1.079	1.0	8	0	0	2.1
HSD _{0.05}	NS	NS							NS					
2009 (5 May – 17 September; 135 d)														
Manistee	19	28	67	33	67	0	0	0	1.084	1.0	0	0	0	1.1
Snowden	21	31	68	31	67	0	1	1	1.086	1.0	3	0	0	2.0
LSD _{0.05}	NS	NS							NS					
2008 (8 May – 24 September; 140 d)														
Manistee	37	43	86	14	83	3	1	1	1.084	1.5	0	0	0	2.8
Snowden	43	47	91	9	84	7	0	0	1.088	1.5	3	0	0	3.5
LSD _{0.05}	NS	NS							0.004					
Mean (2008–2012)														
Manistee	37	44	82	18	79	4	0	0	1.081	1.1	1	0	0	1.6
Snowden	36	44	80	19	76	4	1	1	1.083	1.2	3	0	0	2.3
HSD _{0.05}	NS	NS							NS					

¹Size Distribution: B: < 5.1 cm.; A: 5.1–8.3 cm.; OV: > 8.3 cm.; PO: Pickouts²Snack Food Association Chip Score Ratings 1–5; 1 = Excellent; 5 = Poor; ≥ 2.5 = Unacceptable³Tuber Quality: HH: Hollow Heart, VD: Vascular Discoloration; IBS: Internal Brown Spot; BC: Brown Center. Percent of 40 oversize (> 8.3 cm) tubers cut⁴Vine maturity taken typically at late August. 1 = Early (vines completely dead), 5 = Late (flowering)Mean comparisons were made using Fisher's LSD or Tukey's HSD ($\alpha = 0.05$)

between plants was 30 cm with 86 cm spacing between rows. Total nitrogen fertilization during the season was 244 kg/ha. The Montcalm site is a McBride sandy loam soil with supplemental overhead irrigation.

Manistee's performance in on-farm grower trials in Michigan between 2008 and 2012 was similar to observations in research trials (Table 2). Yield, specific gravity, and tuber size distributions were not significantly different between Snowden and Manistee; although on average Manistee typically had fewer internal defects, specifically hollow heart (Table 2). Out of the field chip scores were also similar between Manistee and Snowden in these trials. On-farm trials are conducted on private commercial farms throughout the state of Michigan, using each farm's respective management practices. On-farm plots are unreplicated single observation plots and are harvested and graded to collect agronomic performance data.

In national SNAC trials, Manistee yield and specific gravity were comparable to Snowden over four years of trials from 2010–2013 in most locations (Table 3). North Carolina was the only location where Manistee had both reduced yields and specific gravity compared to Snowden. California and North Dakota also had reduced yields but higher specific gravity than Snowden.

Storage Chip-Processing

The agronomic performance of Manistee was similar to Snowden other than earlier maturity and fewer internal defects. Manistee consistently had better chip quality than Snowden in short and long-term storage trials conducted at the Michigan Potato Industry Commission Research Demonstration Storage in Lakeview, Michigan between 2009 and 2012 (Table 4). Chip scores for Manistee were excellent quality and more consistent than Snowden in short-term storage. In long-term storage, Manistee retained excellent chip-processing quality for at least eight months over all three storage trials (Table 4). The first testing date took place one-month post-harvest. For the duration of these trials, storage was maintained at a target temperature of 10° C and fry temperature for chips was 171° C.

Blackspot Bruise

Manistee exhibited better tolerance to blackspot bruise than Snowden over five years of evaluation (Table 5). Manistee had a higher percentage of bruise free tubers and fewer spots per tuber over all five years. However, these differences were not statistically significant based on means comparisons using Tukey's Honestly Significant

Table 2 Agronomic performance of Manistee from Michigan On-Farm trials

Table 2 Agronomic performance of Manistee from Michigan On-Farm trials													
Entry	N ¹	Yield (mt ha ⁻¹)		Percent of Total ²					Specific Gravity	Chip Score ³	Tuber Quality (%) ⁴		
		US#1	Total	US#1	Bs	As	OV	PO			HH	IBS	BC
Manistee													
2012	6	52	57	91	8	85	6	1	1.069	1.2	0	20	0
2011	4	59	65	91	9	71	5	1	1.073	1.0	1	1	0
2010	5	55	60	93	7	87	6	0	1.074	1.1	2	2	0
2009	4	64	67	95	5	86	9	0	1.079	1.1	0	4	3
2008	3	59	62	95	5	89	6	0	1.077	1.0	0	0	0
Mean		58	62	93	7	84	6	0	1.074	1.1	1	5	1
Snowden													
2012	6	54	62	85	15	81	5	0	1.072	1.0	0	7	0
2011	4	61	67	90	9	85	6	1	1.075	1.0	18	13	0
2010	5	57	61	90	8	84	6	2	1.076	1.3	21	0	0
2009	4	68	73	93	7	88	5	1	1.081	1.1	3	0	0
2008	3	55	61	91	9	88	3	0	1.078	1.0	0	3	0
Mean		59	65	90	10	85	5	1	1.076	1.1	8	5	0
Overall On-Farm Mean													
Manistee	22	58	62	93	7	84	6	0	1.074	1.1	1	5	1
Snowden	22	59	65	90	10	85	5	1	1.076	1.1	8	5	0
HSD _{0.05}		NS	NS						NS				

¹N Number of On-Farm locations contributing to annual mean

²Size Distribution: B: < 5.1 cm, A: 5.1–8.3 cm, OV: >8.3 cm, PO: Pickouts

³Snack Food Association Chip Score; 1=Excellent; 5=Poor; ≥ 2.5=Unacceptable

⁴Tuber Quality: HH: Hollow Heart, VD: Vascular Discoloration; IBS: Internal Brown Spot; BC: Brown Center. Percent of 40 oversize (>8.3 cm) tubers cut

Mean comparisons were made using Tukey's HSD ($\alpha=0.05$)

Table 3 Four year yield averages for Manistee in multistate SNAC trials

Entry	Loc ¹	Yield (mt ha ⁻¹)		Percent of Total ²					Specific
		US#1	Total	US#1	Bs	As	OV	PO	Gravity
Manistee	CA	23	28	82	16	85	-	9	1.094
Snowden	CA	41	48	85	14	85	3	-	1.092
Manistee	FL	33	43	77	14	79	4	9	1.072
Snowden	FL	40	48	84	10	82	8	5	1.073
Manistee	ID	38	54	72	26	68	5	2	1.088
Snowden	ID	43	57	75	24	68	7	2	1.092
Manistee	ME	36	41	87	9	81	10	5	1.084
Snowden	ME	36	40	88	6	83	12	7	1.087
Manistee	MI	48	53	90	10	83	7	-	1.068
Snowden	MI	48	57	85	15	79	6	-	1.072
Manistee	MO	37	43	84	16	84	-	-	1.082
Snowden	MO	37	42	87	13	87	-	-	1.081
Manistee	NC	28	36	78	12	77	2	11	1.076
Snowden	NC	33	41	78	22	77	1	1	1.081
Manistee	ND³	27	32	80	22	62	12	-	1.089
Snowden	ND ³	32	41	80	21	60	14	-	1.088
Manistee	OR³	80	96	83	7	83	13	4	1.077
Snowden	OR ³	84	104	82	6	82	12	4	1.080
Manistee	PA	32	39	83	11	82	7	13	1.079
Snowden	PA	34	39	88	10	87	2	6	1.084
Manistee	WI	69	73	92	5	75	25	5	1.076
Snowden	WI	74	78	94	9	66	28	3	1.083
Manistee	Overall	41	48	83	14	78	9	7	1.079
Snowden	Overall	45	53	84	14	78	10	4	1.081
HSD _{0.05}		NS	NS						NS

¹Loc: Location of trials²Size Distribution: B: < 5.1 cm, A: 5.1–8.3 cm, OV: >8.3 cm, PO: Pickouts³Locations with only three years of trial dataMeans comparisons were made using Tukey's HSD ($\alpha=0.05$)**Table 4** Storage Chip-Processing results for Manistee and Snowden at the Michigan Potato Industry Commission C.F. Burt Cargill Demonstration Storage, Lakeview, MI

Line								
2011–2012	22/11/2011	21/12/2011	31/1/2012	28/2/2012	27/3/2012	20/4/2012	21/5/2012	6/6/2012
Manistee	1.0	1.0	1.0	1.0	1.5	1.0	1.5	1.5
Snowden	1.0	1.0	1.0	1.5	1.0	1.5	2.5	3.0
2010–2011	15/11/2010	14/12/2010	18/1/2011	22/2/2011	15/3/2011	12/4/2011	11/5/2011	8/6/2011
Manistee	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5
Snowden	1.5	1.0	1.0	1.5	1.5	2.0	3.0	-
2009–2010	10/11/2009	9/12/2009	5/1/2010	1/2/2010	1/3/2010	7/4/2010	10/5/2010	2/6/2010
Manistee	1.0	1.0	ND	1.0	2.0	-	1.0	1.5
Snowden	2.5	1.5	1.5	1.0	1.0	2.5	3.0	3.0

Sample dates: day/month/year

Snack Food Association Chip Score; 1 = Excellent; 5 = Poor; ≥ 2.5 = Unacceptable

Difference ($\alpha=0.05$). Blackspot bruise susceptibility was measured using a simulated bruise test consisting of four replicate composite samples of 25 A-sized tubers collected at harvest. After 12 h minimum of storage at 10 °C (50° F), samples were rotated 10 times in a six-sided plywood drum before being abrasive peeled and scored for bruising.

Wound Healing

Preliminary studies with Manistee and Lamoka tuber tissue disks (2 cm x 0.5 cm) demonstrated that Manistee initiated the wound healing process faster than Lamoka. This was based on resistance of the tissue undergoing

Table 5 Blackspot bruise susceptibility from simulated bruise tests

Entry	Year	Number of Spots per Tuber						Percent (%)	
		0	1	2	3	4	5+	Bruise	Average
Manistee	2012	10	7	5	2	1		40	1.1
Snowden		1	14	8	2			4	1.4
Manistee	2011	16	8	1				64	0.4
Snowden		11	7	5	1			46	0.8
Manistee	2010	8	5	9	3			32	1.3
Snowden		9	5	5	4		2	36	1.5
Manistee	2009	18	6		1			72	0.4
Snowden		10	9	6				40	0.8
Manistee	2008	20	5					80	0.2
Snowden		8	8	2	6	1		32	1.4
Manistee	Mean	12	5	4	2	1		48	0.6
Snowden		7	7	4	3	1	1	26	1.0
HSD _{0.05}								NS	NS

Simulated blackspot bruise tests: Each 4-replicate composite sample of 25 A-size tubers were collected at harvest, held at 10 °C (50 °F) at least 12 h, and placed in a six-sided plywood drum and rotated ten times to produce simulated bruising. Samples were abrasive-peeled and scored

healing to digestion with cell wall degrading enzymes and infection by *Pectobacterium carotovorum* subsp. *carotovorum* (Pcc). After 3 and 6 days of healing, the upper layer of healing tissue was excised and treated with cell wall degrading enzymes (a mixture of pectinase and cellulase) to release wound healing tissues that were resistant to degradation as an indicator of the initial suberization process. At 3 days after wounding, Manistee produced 4.41 ± 1.36 mg/disk of cell wall degrading enzyme resistant material as compared to 1.98 ± 0.95 mg/disk for Lamoka. This response is likely the result of the initiation of closing layer formation. At 7 days, the amount of enzyme resistant tissue was 7.90 ± 1.67 mg/disk for Manistee and 5.97 ± 0.92 mg/disk for Lamoka. Using infection by Pcc as another means of evaluating wound healing, tubers disks were inoculated by applying 100 μ L of a 10^8 cfu/ml suspension of Pcc cells to the disk surface without further wounding. Preliminary results showed that at 3 days of healing, 36% of the Manistee disks could be infected by Pcc as compared to 89% the disks from Lamoka. After 6 days, 7% of the Manistee disks and 58% of the Lamoka disks were infected. In this study, Snowden responded similar to Manistee and Pike responded similar to Lamoka (Dmytryszn et al. 2022).

Total Glycoalkaloid (TGA) Analysis

Total glycoalkaloid (TGA) concentrations of solanine and chaconine in Manistee average 15.6 mg% (range 4.3–25.8) (mg/100 g of fresh weight), which is lower than the industry reference variety Snowden at 18.5 mg% (range 6.0–28.2) under the same trial conditions. Comparably, the reference variety Atlantic averaged 9.6 mg%

(range 4.0–14.2) from the same trials. Tubers were sampled at harvest from replicated agronomic field trials at the Montcalm Research Center (Lakeview, MI) over six years (2009, 2010, 2015, 2016, 2017, and 2019). For 2009 and 2010, tuber samples were sent to Dr. Brian Perkins at the University of Maine. For these TGA analyses, the extraction and rapid high-performance liquid chromatographic (HPLC) determination method was used (Carman et al. 1986). Solanine and chaconine levels for the remaining sample years were determined by LC/MS analysis at the MSU Research Technology Support Facility (East Lansing, MI) using a LC/MS/MS (tandem quadrupole) using a Waters TQ-D UPLC/MS/MS equipment. Manistee TGA content is below the industry threshold of 20 mg%.

Disease Resistance

Manistee is similar in susceptibility to common scab (*Streptomyces scabies*) as Atlantic and Snowden (Table 6). Over six years of evaluation from replicated plots in the MSU common scab disease nursery, Manistee's common scab disease resistance ratings (2.3–2.8) were largely equivalent to the susceptible checks Snowden (2.3–2.9) and Atlantic (2.4–3.0) (Table 6). Lower scores are considered more resistant (0 = no infection, < 2 = resistant, and 5 = highly susceptible). Producers should expect a similar incidence and severity of common scab in Manistee that can be expected from both Snowden and Atlantic.

Manistee wasn't formally tested for virus resistance or resistance to late or early blight and has no known resistance genes for these pathogens. While Manistee is not resistant

Table 6 Common Scab (*Streptomyces scabies*) Ratings from the Scab Disease Nursery at the Michigan State University Montcalm Research Center, Lakeview, MI and the Michigan State University Soils Farm, East Lansing, MI

LINE	2012		2011		2010		2009		2008		2007		Mean	
	Rating	Max	Rating	Max	Rating	Max	Rating	Max	Rating	Max	Rating	Max	Rating	Max
Manistee	2.5	3.0	2.8	3.5	2.5	3.0	2.3	3.0	2.8	3.0	2.3	3.0	2.5	3.5
Atlantic	2.8	3.5	3.0	3.5	2.9	3.0	2.7	3.0	2.4	3.0	2.4	3.0	2.7	3.5
Snowden	2.6	3.0	2.4	2.5	2.9	3.5	2.3	3.0	2.6	3.0	2.6	3.0	2.5	3.5
HSD _{0.05}	NS		NS		NS									
LSD _{0.05}							NS		NS		NS			

MSU Common Scab Disease Severity Rating Scale (0–5)

0: No scab lesions

1: Superficial or infrequent surface scab with 1–10% coverage with no pitting

2: Moderate surface scab 11–25% coverage with few, minor pits

3: Slight to average pits, with or without surface scab 26–50% surface coverage

4: Serious pitted scab, with 51–75% coverage

5: Severe pitted scab that may be accompanied by surface or raised lesions > 75%

Mean comparisons were done using Tukey's HSD (2010–2012) and Fisher's LSD (2007–2009) ($\alpha=0.05$)

to PVY, and shows typical PVY symptoms when infected, no unusual susceptibility to was observed during agronomic trials.

Vines of Manistee did not display any sensitivity to metribuzin at any point during the growing season, when applied at the recommended rates.

Manistee was issued plant variety protection (PVP) in the USA under #201400226 on 16 May 2015.

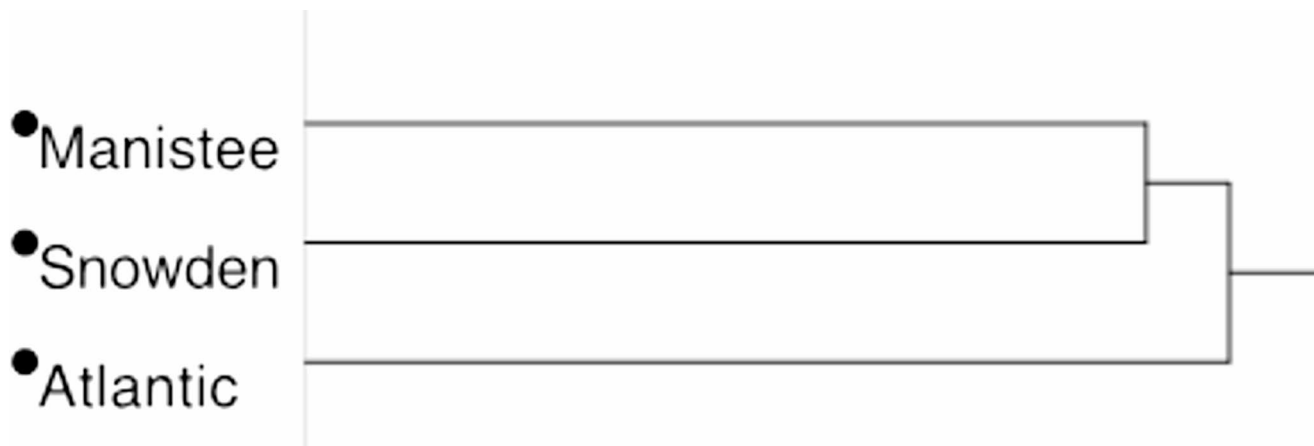
DNA Profile (SNP Genotyping)

DNA was isolated from Manistee to determine the SNP genotype DNA profile using the SolCAP Infinium 8303 Potato SNP Array. The SNP nucleotide calls for Manistee, Atlantic, and Snowden are available in the Supplemental Material Table S4 in Hirsch et al. (2013) (Fig. 3).

After filtering, 3,763 SNPs for 250 potato clones were presented in Hirsch et al. (2013). The SNPs were further filtered to remove no-calls for comparing Manistee with Atlantic and Snowden. Of the 3,085 filtered SNPs, Manistee differed from Atlantic by 1,968 SNPs (63.8%) and from Snowden by 1,633 SNPs (52.9%). The SNP genotype DNA profile is unique to Manistee.

Seed Availability

Virus-free tissue culture plantlets are maintained at the Michigan State University Potato Breeding and Genetics Program. Small amounts of seed for testing can be obtained from David Douches at Michigan (517-884-6946, douchesd@msu.edu). In addition, certified seed is currently being produced commercially.

**Fig. 3** Hierarchical cluster analysis of the cultivars Manistee, Snowden, and Atlantic using 3763 SNPs

Author Contributions Competing Interests: The authors have no competing interests to declare, relevant to the content of this article. All authors were involved in the selection and evaluation of the Manistee potato variety. William Behling, David Douches, Joseph Coombs and Ray Hammerschmidt contributed to the writing of the manuscript.

Funding The development and testing of Manistee was supported in part by the Michigan State University AgBioResearch, Michigan Potato Industry Commission, and the USDA Grant 2023-34141-410020 for Potato Breeding/Variety Development.

Data Availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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