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REGISTRATION

Cultivar

Registration of 'AuSable' navy bean

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Abstract

'AuSable' (Reg. no. CV-358, PI 705150) navy bean (*Phaseolus vulgaris* L.), developed by Michigan State University AgBioResearch was released in 2023 as an early-mid season, disease-resistant, upright, short-vine bean cultivar with excellent dry down. AuSable was developed with the pedigree breeding method to the F_4 generation followed by pure line selection for disease, agronomic, and quality traits. In 6 years of field trials, AuSable yielded 3073 kg ha^{-1}, flowered in 46 days, and matured in 95 days on average. Plants averaged 45 cm in height, with a lodging resistance score of 1.7 and seed size of 22 g 100 seed^{-1}. AuSable combines high yield potential with early midseason maturity in a navy bean seed type. AuSable has outyielded 'Merlin' by 17% across 6 years and matured 3 days earlier. It exhibits uniform dry down equivalent to 'Vigilant' and is well adapted to the intensively managed, narrow row, direct-harvested production systems where beans are typically grown in Michigan and the Upper Midwest. AuSable possesses resistance to *Bean common mosaic virus*, is resistant to anthracnose races 7 and 73, has shown moderate tolerance to white mold, and was as tolerant to post emergence damping off caused by *Rhizoctonia solani* as other navy beans. It is susceptible to common bacterial blight. The seed size of AuSable (22 g 100 seed^{-1}) is most similar to 'Valiant' and slightly smaller than 'Liberty' (23 g 100 seed^{-1}). Seed of AuSable meets industry standards for packaging and canning quality in the navy bean seed class.

1 | INTRODUCTION

Navy bean (*Phaseolus vulgaris* L.) has historically played a crucial role in the Saginaw Valley region of Michigan, known for producing high quality beans exported worldwide through the Great Lakes shipping trade (Kelly, 2000). However, recent releases of navy bean cultivars have sacrificed traditional early maturity and uniform dry down in an effort to increase yield (Vandemark et al., 2014). As a result, current cultivars tend to retain foliage or the stems stay green at maturity, posing challenges during harvest. To address this, producers resort to chemical desiccants which aid in uniformly eliminating leaf retention and green stems.

While effective, this practice has prompted processors to express apprehensions about the heightened chemical usage just before harvest, potentially affecting public perception of beans as a healthy food and diminishing the sustainability narrative of bean as a low-input, environmentally friendly crop. In response to these challenges, 'AuSable', developed

Abbreviations: BCMNV, *Bean common mosaic necrosis virus*; BCMV, *Bean common mosaic virus*; CBB, common bacterial blight; MRC, Montcalm Research Center; MSU, Michigan State University; SVREC, Saginaw Valley Research and Extension Center.

by Michigan State University (MSU) AgBioResearch and released in 2023, offers a solution with its efficient, uniform dry down and an upright plant type that eliminates the need for desiccation, thereby enhancing the ease and timeliness of harvest. The early-to-midseason maturity of AuSable provides planting flexibility and ensures a more timely harvest, as well as an opportunity to producers in more northern areas to expand navy bean production. Earlier maturity also is attractive to winter wheat (*Triticum aestivum*) growers seeking to maximize yield by ensuring timely planting of the wheat crop that typically follows dry bean in the Saginaw Valley agricultural system. Furthermore, AuSable presents an opportunity to expand navy bean production beyond the current region, as US navy bean production has remained steady ranging from 13.0% to 14.2% of the total dry bean production in the last 4 years (2019–2022) largely due to competition from other bean classes limiting expansion (NASS, 2023).

AuSable navy bean (Reg. no. CV-358, PI 705150) characteristics position it as a high-yielding, early-mid season, disease-resistant, upright short-vine bean cultivar, contributing to the revitalization and expansion of navy bean production into northern Michigan.

Core Ideas

- AuSable is a high yielding navy bean.
- AuSable exhibits early to midseason maturity.
- AuSable is ideally suitable for direct harvest.
- AuSable has excellent dry down in absence of desiccants.
- AuSable exhibits an overall good disease resistance package.

2 | METHODS

2.1 | Pedigree

AuSable was developed from the single cross of N13120/PR0806-81. The MSU breeding line N13120 was derived from the single cross: N08003/N05324 that exhibited upright architecture, good yield performance, and exceptionally efficient dry down in combination with early season maturity. N08003 possessed exceptional early maturity and an efficient upright plant, whereas N05324 was a full season navy with large seed and excellent plant architecture. PR0806-81, derived from the single cross PR0301-181/BelMiDak RMR 10, was a small, white-seeded, multiple disease resistant germplasm line with resistance to *Bean common mosaic necrosis virus* (BCMNV), *Bean golden yellow mosaic virus* (BGYMV), and bean rust [caused by *Uromyces appendiculatus* (Pers.: Pers) Unger] developed for the humid tropical Caribbean and Central American regions by Jim Beaver at University of Puerto Rico (Beaver et al., 2015). The primary objective of the cross was to broaden the genetic base of current Michigan navy bean by combining desirable agronomic traits from N13120 with the multiple disease resistance traits of PR0806-81.

2.2 | Breeding line development

The hybridization of N13120/PR0806-81 was performed on the East Lansing campus of MSU during the winter of 2015. The F_1 plants (16A0103) were grown and selfed in the greenhouse during the spring of 2016 and no selection was practiced in this generation. Single plant selection no. 6 was made in F_2 nursery (16L102) at the Saginaw Valley Research and Extension Center (SVREC), Frankenmuth, MI, during summer of 2016 based on agronomic and navy bean seed traits. Traits selected included: upright type II growth habit, short vine development, lodging resistance, mid-season maturity, and uniform dry down. Seed color and size traits were selected as acceptable commercial navy bean seed class. A single $F_{2:3}$ progeny row (16-17T13) was grown and mass selected for seed and agronomic traits at Isabela, Puerto Rico. Selected traits included upright short vine, lodging resistance, good pod load, navy bean seed size and color, and freedom from diseases. Remnant seed was rub-inoculated (Kelly, 1997) for reaction to the *NL3* strain of BCMNV and anthracnose races 7 and 73 [caused by *Colletotrichum lindemuthianum* (Sacc. et Magnus) Lams.-Scrib] in the greenhouse at MSU, and only seed of resistant individuals was returned from Puerto Rico. Single plant selection no. 3 was made in the $F_{2:4}$ progeny row (17T1006) at Frankenmuth, MI, in summer 2017 for upright architecture, lodging resistance, acceptable pod load and placement, uniform mid-season maturity, and commercial navy bean seed traits. All future selections are F_4-derived as the line was mass selected in later generations. A single $F_{4:5}$ progeny row (17-18T440) was grown and mass selected at Isabela, Puerto Rico on the basis of agronomic and seed traits, similar to those described in the F_4 generation. Remnant seed was confirmed to be resistant to BCMNV, strain *NL3* in the greenhouse in East Lansing.

2.3 | Breeding line evaluation

An $F_{4:6}$ breeding line coded 16N103-06-03 entered replicated yield trials at Frankenmuth, MI, with the permanent code number N18103. The line was advanced based on yield performance, upright plant growth habit with resistance to lodging, earlier maturity with exceptional dry down, and acceptable canning quality. Canning tests were conducted based on established protocols (Hosfield & Uebersax, 1980; Wang et al., 2021). Based on superior yield performance and similar seed and canning quality as other current navy

bean cultivars, N18103 was entered into advanced yield trials in 2019 at SVREC and into the Dry Bean Performance Trials. Over 6 years (2018–2023) of testing, breeding line N18103 was advanced from F_7 to F_{11} generation and yield tested at 24 environments in mid-Michigan. Canning tests were conducted on seed produced at most Michigan locations. White mold [caused by *Sclerotinia sclerotiorum* (Lib.) de Bary] and common bacterial blight (CBB) [caused by *Xanthomonas axonopodis* pv. p*haseoli* (Smith) Dye] ratings were collected when field conditions were conducive to uniform natural infection. Inoculated *R. solani* root rot trials were also conducted at the East Lansing, MI, Plant Pathology Farm in 2022 following protocols described by Jacobs et al. (2019).

2.4 | Plot technique

Yield trials at SVREC were conducted as a four-replicate α-lattice and all performance trial locations were conducted using a four-replicate randomized complete block design in four-row plots. Plots were 6.1 m long with rows spaced 50 cm apart for all trials. Prior to harvest, plot length was trimmed to 4.5 m and the center two rows were direct harvested with a Wintersteiger Classic plot combine equipped with a Harvestmaster H2 system to record plot weight and moisture data. Samples were collected for canning quality, and yield data were adjusted to 18% moisture prior to analysis.

2.5 | Statistical analysis

Results were compiled from all trials and an analysis of variance was conducted for each measured trait in each trial. All statistical analyses were performed using ANOVA for each measured trait in each trial using Genovix software (Agronomix Software, 2021). All trials at SVREC and the Montcalm Research Center (MRC) were arranged in α-lattice design with four replicates (complete blocks) and a variable number of incomplete blocks (Iblock) within replicates, depending on the number of entries (Patterson & Williams, 1976). A mixed model was used in which genotypes were considered fixed effects and replicates and Iblock were random. Fisher's protected least significant difference ($p \leq 0.05$) was used to compare entry means in trials that had significant F-tests for entries. Individual *t*-tests were used to separate mean yields between entries grown at the same locations.

3 | CHARACTERISTICS

3.1 | Yield performance

AuSable has been tested for 6 years (2018–2023) over 24 locations in cooperation with colleagues in Michigan. The combined yield data comparisons with other navy bean cultivars are shown in (Table 1). Over 24 locations, AuSable yielded 3073 kg ha^{-1} which was equivalent to the average test means of 3137 kg ha^{-1} ($p \leq 0.38$). It significantly outyielded the older navy cultivar 'Merlin' (PVP 201100392; 17%) and was not significantly different than the yields of 'Vigilant' (PVP 201200164; 2%, $p \leq 0.57$) and 'Alpena' (Kelly et al., 2015; 4%, $p \leq 0.64$). Average yield was 6% less than 'Medalist' (PVP 200700330; $p \leq 0.32$), 7% less than 'Valiant' ($p \leq 0.25$), and significantly less than full season cultivars 'HMS Bounty' (11%) and 'Liberty' (18%), thus underscoring the relationship between yield and longer season maturity. Yield ranged from a high of 4215 kg ha^{-1} under irrigated growing conditions at MRC in 2020 to a low of 2074 kg ha^{-1} under excessive rainfall that led to water damage at Tuscola, MI, in 2023.

3.2 | Agronomic traits

AuSable exhibits the Type-IIa upright, indeterminate short-vine growth habit combined with good resistance to lodging (1.7 on scale 1 to 5) (Table 2.). AuSable is not as erect as Vigilant, but generally more upright than other navy cultivars tested, although no significant differences were observed. Plants averaged 45 cm in height similar to the other navy cultivars. Only Vigilant (52 cm) was significantly taller. AuSable is an early to mid-season bean, flowering in 46 days and maturing in 95 days after planting (Table 2). The range in maturity is from 83 to 102 days depending on the environment. The earliest maturity was observed under abnormally hot dry conditions in 2021, and the latest during 2023 when the harvest period was abnormally wet and cold. Maturity was not significantly different than the other mid-season cultivar Vigilant but was significantly earlier than the other cultivars: Valiant (2 days), Merlin, Medalist and Alpena (3 days), HMS Bounty (6 days), and Liberty (7 days). AuSable has demonstrated the same earlier maturity and uniform dry down as Vigilant which are attractive to growers desiring a shorter season cultivar. Grower motivation for a shorter growing season bean is driven by crop rotation constraints, the need to reduce the use of chemical desiccants to enhance sustainability, or by the growing number of organic producers. AuSable has a high agronomic acceptance rating (4.5) similar to the other cultivars due to its upright habit, resistance to lodging, uniform dry down, and favorable high pod placement in the plant canopy.

3.3 | Seed quality traits

AuSable has a larger navy bean seed averaging 22.1 g 100 seed^{-1} (Table 2) and seed size ranged from 20.5 to 23.7 g 100 seed^{-1} over years and locations. The seed is significantly

TABLE 1 Yield comparison of AuSable navy bean with seven other navy bean cultivars grown for 6 years (2018–2023) at 24 environments in Michigan.

Year	Location	AuSable	Merlin	Medalist	Vigilant	Valiant	HMS Bounty	Liberty	Alpena	Trial Mean	$LSD_{0.05}$	CV
		kg ha^{-1}										%
2018	SVREC 8101	3677[a]	3710	3116	3733				3979	3699	392	8.9
2019	SVREC 9101	2802	2119	2533	2197				2544	2320	280	10.1
2020	SVREC 2001	3744	3217	3105	3038	3856			3127	3609	370	8.7
2020	MRC 2019	4215	2970							3934	471	8.9
2021	SVREC 2104	3082	2724	2253		2970	2847		2847	3127	359	6.8
2021	Bay, MI	3464	2959	3307	2858	3206	3318	3497		3228	560	14.7
2021	Huron, MI	3508	2735	3262	3318	2735	3251	3251		3195	650	11.9
2021	Sanilac, MI	3598	3026	3150	3497	3307	4114	4091		3262	583	15.0
2021	Tuscola, MI	3811	3116	3744	3340	3419	3542	3946		3598	527	12.4
2021	MRC 2117	2242	2287						1244	2107	426	14.9
2022	SVREC 2205	2085					2500	2500	3038	2926	426	9.0
2022	Huron 2224	3295					3139	2982	2444	3139	628	11.9
2022	Bay, MI	3340	2802	3968	3621	3004	3665	4080		3363	527	13.2
2022	Huron, MI	2701	2634	3004	3329	2645	3486	3542		2881	986	15.6
2022	Sanilac, MI	3307	2253	4237	2959	4203	4237	5156		3195	773	26.6
2022	Tuscola, MI	3038	2197	3172	3329	3564	3206	3408		3015	426	21.6
2023	SVREC 2301	2500					2432	2847	2600	2813	314	9.6
2023	SVREC 2303	2500					2309	3183	1984	2679	392	10.7
2023	Huron 2323	3026					3105	3632	4013	3363	482	8.3
2023	Bay, MI	3777		4102	3587	3968	5022	4607		3733	673	15.3
2023	Huron, MI	3038		4181	3139	4226	3688	3789		3508	740	17.8
2023	Sanilac, MI	2354		3912	2432	3643	3564	3374		3172	314	14.1
2023	Tuscola, MI	2074		3262	2847	3060	3621	3464		2612	1031	19.5
2023	MRC 2318	2567					2376	2567		2813	616	16.3
Overall	means (24)	3073								3137		

(Continues)

TABLE 1 (Continued)

Year	Location	AuSable	Merlin	Medalist	Vigilant	Valiant	HMS Bounty	Liberty	Alpena	Trial Mean	$LSD_{0.05}$	CV
14 common	Environments	3323	2768									
16 common	Environments	3207		3394								
15 common	environments	3215			3148							
14 common	environments	3203				3415						
19 common	environments	3003					3338					
18 common	environments	2999						3551				
10 common	environments	2895							2782			
t test	$P \geq 0.05$ =		0.0001	0.32	0.57	0.25	0.02	0.00	0.62	0.38		
Yield Percentage		100	83	106	98	107	111	118	96	102		

Abbreviations: CV, coefficient of variation; MRC, Montcalm Research Center; SVREC, Saginaw Valley Research and Extension Center.

[a]Yield data adjusted to 18% seed moisture content.

larger in size than several cultivars, equivalent to Valiant (21.7 g 100 seed^{-1}) and significantly smaller compared to Liberty (23.3 g 100 seed^{-1}). AuSable has a typical bright white navy bean dry seed color.

In canning trials, AuSable has been subjectively rated by a team of panelists as being above average in cooking quality. This evaluation is based upon whole bean integrity (no splitting or clumping), uniformity of size (uniform water uptake), and clear brine (no starch extrusion into canning liquid). AuSable rated 3.6 on a scale of 1 to 5 where 5 is best and 3 is mid-scale (neither acceptable nor unacceptable). No significant differences were observed within the commercial navy beans evaluated.

3.4 | Disease traits

AuSable possesses the single dominant hypersensitive *I* gene which conditions resistance to seed-borne BCMV but is sensitive to the temperature-insensitive, necrosis-inducing strains of BCMNV like *NL3* and *NL8* (Table 3). AuSable exhibits similar reactions to the other navy bean cultivars to several different pathogens. AuSable was susceptible to CBB but resistant to anthracnose races 7 and 73. AuSable exhibited moderate susceptibility (66%) to white mold which was similar when compared to the other navy bean cultivars (Table 3) in mold trials designed to encourage disease development. Only HMS Bounty (45%) had significantly less infection, and Alpena (81%) exhibited significantly more infection. Fungicides are routinely applied to manage white mold in navy beans grown under intensive narrow row production systems. This data represents an average of 2 years of irrigated trials at MRC, and 3 years of on-farm trials in Huron County, MI, where white mold routinely impacts bean production. AuSable appears to tolerate root rot caused by *Rhizoctonia solani* (AG2-2) as well as other navy cultivars under natural field conditions. Data presented in Table 3 is an average % damping off following emergence collected in an inoculated trial under center pivot irrigation during 2022. Rhizoctonia infection has been an increasing problem in Michigan bean production in recent years.

4 | AVAILABILITY

AuSable navy bean was released by MSU AgBioResearch, East Lansing, MI, and is available under license from MSU Technologies, with the option that AuSable may be sold for seed by name only under the Foundation and Certified seed classes. A royalty will be assessed on each 100-weight unit of Foundation and/or Certified seed sold. Breeder seed is maintained by MSU AgBioResearch under license with Michigan Crop Improvement

TABLE 2 Comparison of agronomic and quality characteristics of AuSable with seven navy bean cultivars over six years of testing (2018-2023) at 10 environments in Michigan.

Cultivars	Flower	Maturity	Height	Lodging[a]	Agronomic index[b]	100-seed weight	Visual appearance[c]
	——days——		cm	1–5	1–7	g	1-5
AuSable	46	95	44.5	1.7	4.5	22.1	3.6
Merlin	44	98	47.5	2.0	4.1	19.7	3.3
Medalist	44	98	47.6	2.0	4.3	20.1	3.6
Vigilant	44	95	51.9	1.1	4.8	21.0	3.9
Valiant	41	97	43.0	2.2	4.0	21.7	3.8
HMS Bounty	47	101	45.5	1.9	4.1	19.2	3.7
Liberty	47	102	44.1	2.1	4.2	23.3	4.0
Alpena	47	98	45.7	2.1	4.3	19.1	3.7
Mean	47.3	97.2	46.2	1.7	4.5	20.7	3.0
LSD (0.05)	1.6	1.7	5.0	0.7	0.9	0.9	0.5

[a]Lodging rated on a 1–5 scale, where 1 = all plants erect and 5 = all plants severely lodged.
[b]Agronomic Acceptance Index rated on a 1–7 scale, where 1 = worst and 7 = excellent.
[c]Visual appearance of canned bean on a 1–5 scale, where 1 = very undesirable and 5 = very desirable.

TABLE 3 Comparison of disease characteristics of AuSable with seven other navy bean cultivars.

Cultivars	BCMNV[a]	Anthracnose		CBB[b]	White mold[c]	Rhizoctonia[d]
	NL 3	Race 7	Race 73	Local isolate(s)	%	%
AuSable	R	R	R	S	65.6	4.25
Merlin	R	R	S	S	65.4	2.0
Medalist	R	R	S	S	65.3	7.5
Vigilant	R	ND	S	S	56.6	ND
Valiant	R	R	ND	S	71.0	7.25
HMS Bounty	R	R	S	S	44.7	6.75
Liberty	R	ND	S	S	62.6	5.75
Alpena	R	S	S	S	81.4	ND
Mean					69.8	7.8
LSD (0.05)					17.6	6.2

[a]BCMNV = *Bean common mosaic necrosis virus*; R = resistant, S = susceptible, ND = no data.
[b]Common bacterial blight (CBB) was evaluated under natural infection at Saginaw Valley Research and Extension Center in 2020 and 2022 on a 1–5 scale where 1 = resistant and 5 = severely infected. No significant differences were observed.
[c]White mold was evaluated at Montcalm Research Center in 2020, 2021, and 2023 under irrigation and in Huron on-farm trials in 2021–2023 on a 1–9 scale, where 1 = no diseased plants and 9 = 100% diseased plants.
[d]*R. solani* AG2-2 isolate Rs_14-17. Data reported from 2022 as % damping off following emergence in an inoculated field trial.

Association. Foundation seed will be maintained by the Michigan Crop Improvement Association. U.S. Plant Variety Protection for AuSable is anticipated. Seed of AuSable has been deposited with the National Plant Germplasm System, where it will be available on expiration of PVP, 20 years after the date of publication. Small quantities of AuSable seed for testing purposes can be obtained from the corresponding author during the period of PVP protection. Recipients of seed are asked to make appropriate recognition of the source of germplasm if it is used in the development of a new cultivar, germplasm, parental line, or genetic stock.

AUTHOR CONTRIBUTIONS

Francisco Gomez: Funding acquisition; investigation; project administration; resources; software; supervision; validation; writing—review and editing. **James D. Kelly**: Conceptualization; funding acquisition; investigation; project administration; resources; supervision; visualization; writing—review and editing. **Evan Wright**: Data curation; formal analysis; investigation; methodology; resources; validation; visualization; writing—original draft; writing—review and editing. **Halima Awale**: Investigation; methodology; resources; validation; writing—review and

editing. **Scott Bales**: Investigation; methodology; resources; supervision; validation; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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