

Registration of 'Red Cedar' Dark Red Kidney Bean

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Abstract

'Red Cedar' dark red kidney bean (*Phaseolus vulgaris* L.) (Reg. No. CV-323, PI 685023), developed by Michigan State University AgBioResearch, was released in 2017 as an upright, full-season cultivar that possesses acceptable canning quality and tolerance to common bacterial blight (CBB) and root rots. Red Cedar was developed using pedigree breeding method to the F₄ generation followed by pure line selection for disease, agronomic, and quality traits. In 6 yr of field trials, Red Cedar yielded 3250 kg ha⁻¹, flowered in 40 d, and matured in 101 d on average. Plants averaged 48 cm in height, with a lodging resistance score of 1.8 and seed weight of 55.8 g 100 seed⁻¹. Red Cedar is resistant to race 73 of anthracnose, is partially resistant to local isolates of CBB, is sensitive to strain NL 3 of *Bean common mosaic necrosis virus*, and is susceptible to bean rust race 22:2. Red Cedar produces seed that meets industry standards for dry seed packaging and was rated satisfactory in overall canned bean quality in the dark red kidney bean seed class.

'Red Cedar' dark red kidney bean (*Phaseolus vulgaris* L.) (Reg. No. CV-323, PI 685023), developed by the Michigan State University (MSU) AgBioResearch, was released in 2017 as an upright determinate, full-season cultivar with enhanced yield potential. Dark red kidney bean is a specialty production class in the United States, contributing 5% to the total edible bean production (USDA–NASS, 2017). Production is largely concentrated in Minnesota and Wisconsin, with minor production in six other states, including Michigan, where it has local economic impact (USDA–NASS, 2017). Potential yields are lower in this class despite higher overall yield gains compared with other market classes (Vandemark et al., 2014). Genetic gains have been limited due to the narrow genetic base of dark red kidney bean cultivars driven largely by consumer demand for excellent canning quality. Dark red kidney bean production has declined dramatically in Michigan (USDA–ERS, 2017), due in large part to the low yield potential and an increased susceptibility to foliar bacterial and root rot pathogens. These pathogens limit the production of the current cultivar Red Hawk (PI 596630), released by Kelly et al. (1998), which is the industry standard for canning quality. A detailed description of the importance of kidney beans, their origins, acreage in the United States, and the serious pathogens that limit production is available in Osorno et al. (2017). The recently released 'Talon' (PI 674157) dark red kidney and 'Rosie' (PI 674156) light red kidney (Osorno et al., 2017) cultivars show considerable promise as they combine disease resistance with improved performance in very acceptable seed types. To sustain and expand the industry in Michigan, a new high-yielding, disease-resistant dark red kidney bean is needed that will meet the needs of local producers and the quality standards of the industry.

Methods

Red Cedar, tested as MSU dark red kidney bean breeding line K11306, was developed from a single cross made in fall

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Abbreviations: BCMNV, *Bean common mosaic necrosis virus*; CBB, common bacterial blight; MRF, Montcalm Research Farm; MSU, Michigan State University.

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2006 between a light red kidney bean line, K06621, from MSU breeding program with a dark red kidney line, USDK-CBB-15, released by the USDA-ARS program at Prosser, WA (Miklas et al., 2006). USDK-CBB-15 combines resistance to common bacterial blight (CBB) [caused by *Xanthomonas axonopodis* pv. *phaseoli* (Smith) Dye] with the desirable agronomic and canning quality characteristics of Red Hawk (Kelly et al., 1998). The MSU breeding line K06621 was an upright determinate light red kidney bean derived from the cross of two light red kidney bean breeding lines, K01635/K02601. K02601 (Chinook RRR) was a selection resistant to *Fusarium* root rot (caused by *Fusarium solani* f. sp. *phaseoli*) from the cultivar Chinook 2000 (PI 604227) (Kelly et al., 1999). K01635 was derived from cross of 'Beluga' (PI 604229) white kidney with an F₂ selection out of a cross with 'California Early Light Red Kidney'.

The purpose of the current cross was to transfer root rot resistance from the light red kidney class into a dark red kidney bean while retaining the CBB resistance and quality traits of the dark red kidney seed type.

F₁ plants (07A-0830) were grown and selfed in the greenhouse at East Lansing, MI, during spring 2007 with no selection. Six single-plant selections were made on the basis of agronomic and bean seed traits in an F₂ population (07L-0961) grown at the Montcalm Research Farm (MRF), Entrican, MI, in 2007, and selection 5 was advanced. The traits selected included an upright type-I growth habit, lodging resistance, midseason maturity and uniform dry-down. Seed size and seed appearance traits acceptable as commercial dark red kidney bean were also selected. In 2008, single plant selection no. 2 was made in the F_{2,3} progeny row (08T-6492) at MRF for upright architecture, lodging resistance, acceptable pod load and placement, uniform midseason maturity, and commercial dark red kidney bean seed traits. In 2009, single plant selection no. 2 was made in the F_{3,4} progeny row (09T-4357) at MRF for determinate habit, lodging resistance, acceptable pod load and placement, uniform midseason maturity, and commercial dark red kidney bean seed traits. All future selections are F₄-derived as the line was mass selected in later generations. A single F_{4,5} progeny row (9-10T-4298) was grown at Isabela, PR, during winter 2009, but the crop was lost due to flooding at harvest. In 2010, another single F_{4,5} progeny row (10T-5633) was grown and selected on the basis of agronomic and seed traits, similar to those previously described at MRF using seed from 2009 season. An F_{4,6} breeding line (07K830-05-02-02) entered replicated yield trials at MRF in 2011 with the permanent accession code number K11306. Remnant seed was confirmed to be sensitive to *Bean common mosaic necrosis virus* strain NL-3 in the greenhouse in East Lansing. In addition, routine greenhouse screening was conducted with anthracnose [caused by *Colletotrichum lindemuthianum* (Sacc. et Magnus) Lams.-Scrib] race 73 and rust race 22:2 [caused by *Uromyces appendiculatus* (Pers.:Pers.)]. Screening against local isolates of CBB was conducted in the field when disease was observed. Screening for white mold [caused by *Sclerotinia sclerotiorum* (Lib.) de Bary] was conducted in naturally infected plots grown under sprinkler irrigation at MRF and rated as described by Miklas et al. (2013). During 6 yr of testing (2012–2016), Red Cedar was advanced from the F₇ to the F₁₂ generation and yield tested at 13 site-years in mid-Michigan and Ontario. Canning tests were conducted in the food science department at MSU

on seed produced at most of the Michigan locations from 2011 to 2016 following protocols described by Hosfield and Uebertax (1980). To assess canning quality, a team of 10 to 15 trained panelists subjectively rated Red Cedar as being acceptable in canned bean color and in appearance, on a 1-to-5 scale, where 5 is excellent and 3 is average (neither acceptable nor unacceptable). This evaluation is based on whole bean integrity (no splitting or clumping), uniformity of size (uniform water uptake), retention of red color, and clear brine (no starch extrusion into canning liquid). Texture following canning was measured using Kramer Shear Press on 100 g of rinsed and drained canned samples using a standard shear-compression cell of a Kramer Shear Press (Food Technology Corp.). A colorimeter, Hunter Labscan XE (Hunter Associate Laboratory, Inc.), was used for extracting color parameters from washed-drained canned beans. For analysis, three measurements of color/lightness were extracted: $L^*a^*b^*$ or CIELAB color channels, with L^* the lightness component that goes from 0 (dark red kidney) to 100 (white), and parameters a^* (from green to red), and b^* (from blue to yellow) varying from -120 to +120. An analysis of variance was conducted for each measured trait in each trial. Fisher's protected LSD ($p \leq 0.05$) was used to compare entry means in trials that had significant F -tests for lines. Individual t tests were used to separate mean yields between entries grown at the same locations. A source of breeder seed of Red Cedar was produced in Twin Falls, ID, in 2016.

Characteristics

Red Cedar was tested for 6 yr (2011–2016) over 13 locations by MSU in cooperation with colleagues in Michigan and Ontario (Table 1). Over 13 site-years, Red Cedar yielded 3250 kg ha⁻¹, with yield ranging from a high of 4435 kg ha⁻¹ in MRF in 2014 to a low of 2150 kg ha⁻¹ under severe root rot pressure in Montcalm, MI, in 2015. In 11 trials, Red Cedar significantly outyielded the cultivars Red Hawk (6%), and 'Montcalm' (PI 549870) (16%), and the test mean by 6% over 6 yr. In 4 yr of testing, Red Cedar significantly outyielded Talon by 10% over 10 locations. Under high management and irrigated conditions, Red Cedar has produced competitive yields in excess of 4 t ha⁻¹ and appears well adapted to this production system used for kidney bean production in Michigan. Under nonirrigated conditions, yields of Red Cedar have ranged from 2240 to 3315 kg ha⁻¹ in Gratiot, MI.

Red Cedar exhibits a Type-I upright determinate (bush) growth habit combined with good resistance to lodging (1.8 on scale of 1 to 5, where 1 = erect and 5 = prostrate). Red Cedar resembles Montcalm and Talon in erectness and is less erect than Red Hawk. Plants average 48 cm in height, similar in height to the other dark red kidney cultivars (Table 2). Red Cedar is a full-season bean, flowering in 40 d and maturing 101 d after planting. The range in maturity is from 97 to 105 d depending on season and location. It matures 1 d later than Red Hawk, 1 d earlier than Talon, and 3 d earlier than Montcalm. Red Cedar has demonstrated the same uniform maturity and dry-down as Red Hawk. Red Cedar has a high agronomic acceptance rating (4.5) due to its upright habit, resistance to lodging, disease resistance and uniform dry-down at maturity.

Table 1. Yield comparisons of Red Cedar with three dark red kidney bean cultivars grown for 6 yr (2011–2016) at 13 locations in Michigan and Ontario.

Year	Location†	Red Cedar	Red Hawk	Montcalm	Talon	Mean	LSD _{0.05}	CV
2011	MRF 1221	3584	3506	3013		3416	728	13.1
2012	MRF 2219	3394	3382	3147		3058	627	15.0
2013	MRF 3216	2923	3024	2117	2509	3170	314	7.0
2014	MRF 4216	4435	3550	3203	3718	3629	414	8.5
2014	Gratiot. MI	3080	2800	2699	2990	2845	829	20.0
2014	Montcalm. MI	2699	2710	2150	2565	2318	459	13.8
2015	Gratiot. MI	3315	2632	2766	3013	3192	605	13.3
2015	Montcalm. MI	2150	1960	1837	1949	2274	963	31.8
2016	MRF 6208	4155	3842	3584	3797	3651	515	11.8
2016	MRF 6213	3282				3203	470	10.8
2016	Gratiot. MI	2240	2206	1949	2632	2587	448	12.1
2016	Montcalm. MI	3965	3987	3506	3741	3674	762	14.6
2016	Exeter. ON	3024			2397	2520	437	11.7
Overall	Mean (13)	3250	3055*	2725**	2931*	3041*		
t test	$p \geq 0.05$		0.04806	0.00008	0.02248	0.03731		
Yield	%	100	94	84	90	94		

* $p \leq 0.05$.

** $p \leq 0.01$.

† MRF = Montcalm Research Farm, Entrican, MI.

Table 2. Comparison of agronomic characteristics of Red Cedar with three dark red kidney bean cultivars over 6 yr (2011–2016) at six locations.

Cultivar	Flower	Maturity	Height	Lodging†	Agronomic index‡	100 seed weight
	d	d	cm	1–5	1–7	g
Red Cedar	40	101	48	1.8	4.5	55.8
Red Hawk	39	100	48	1.4	3.9	59.5
Montcalm	40	104	48	1.9	3.4	61.2
Talon	42	102	48	1.8	4.0	57.8
Mean	39	100	47	1.5	4.1	59.8
LSD _{0.05}	1.7	2.4	2.4	0.5	0.7	3.6

† Lodging score, where 1 = erect, 5 = prostrate.

‡ Agronomic acceptance index, where 1 = worst, 7 = excellent.

Red Cedar possesses the single dominant hypersensitive *I* gene, which conditions resistance to seed-borne *Bean common mosaic virus*, but it is sensitive to the temperature-insensitive-necrosis-inducing strains of *Bean common mosaic necrosis virus* like NL 3 and NL 8, which are known to occur in the Pacific Northwest. Over 3 yr of field testing, Red Cedar has exhibited moderate levels of resistance to CBB and was rated 1.4 (1–5 scale, where 1= resistant, 5=susceptible), whereas Red Hawk and Talon rated 3.0 and Montcalm 3.2 (Table 3). Red Cedar is resistant to anthracnose race 73 and susceptible to rust race 22:2, which is now prevalent in Michigan (Table 3). White mold incidence evaluated over 2 yr testing (2013–2014) at MRF was 49% compared with 20% for the white kidney cultivar Snowdon (PI 665013). Red Cedar appears to tolerate root rot disease(s) better than current dark red kidney cultivars. Surveys of Michigan dry bean root rots revealed a high abundance of *Fusarium solani* clade 2 isolates (Jacobs et al., 2016). Specifically, putative *F. brasiliense* was frequently recovered (Jacobs and Chilvers, unpublished data). In a trial inoculated with *F. brasiliense* in 2016, Red Cedar yielded 2520 kg ha⁻¹ across four replications compared with 2195 kg ha⁻¹ for the resistant cultivar Rosie. Plots inoculated with *Rhizoctonia solani* AG 2-2 were more severely damaged, with low percentage emergence the main cause of the reduced yields. Plots

inoculated with AG 2-2 yielded 1395 kg ha⁻¹, similar to Rosie at 1400 kg ha⁻¹. These yield data are not included in Table 1 as they were based on single 3-m rows.

Red Cedar has a typical-sized dark red kidney bean seed averaging 55.8 g 100 seed⁻¹ (Table 2), and seed size ranged from 52 to 62 g 100 seed⁻¹ over years and locations. The seed is slightly smaller than Red Hawk (59.5 g), Montcalm (61.2 g), and Talon (57.8 g). In canning trials, Red Cedar was subjectively rated by a team of panelists as being average in processing quality. Red Cedar rated 3.3 on a scale of 1 to 5, where 5 is excellent and 3 is average (Table 4). Within the commercial dark red kidney bean class, Red Cedar was rated slightly below Red Hawk (3.8) and Montcalm (3.5) and better than Talon (2.8). Visual value scores ranged from low of 2.3 to high of 4.3 over 10 locations from 2012 to 2016. Data on *L*a*b**-color (*L**, lightness scale) of cooked beans showed that Red Cedar was equivalent to Talon (15.5) and darker in color compared with other cultivars. Data on *L*a*b**-color (*+a** is red scale) of canned beans showed that Red Cedar had a lower value (17.7) than other cultivars. Data on hydration ratios and drained weight ratios were similar among all four cultivars (Table 4). Texture of cooked beans showed Red Cedar to be intermediate at 47 kg 100 g⁻¹ compared with Red Hawk (40 kg), Montcalm (44 kg), and Talon (58 kg). Texture

Table 3. Comparison of disease characteristics of Red Cedar with three dark red kidney bean cultivars.

Cultivars	BCMV†	Anthracnose		Rust	Common bacterial blight
	NL 3	Race 7	Race 73	Race 22:2	Local isolates
Red Cedar	R‡	S	R	S	1–5§
Red Hawk	R	R	R	S	1.4
Montcalm	R	S	R	S	3.0
Talon	R	S	R	S	3.2
					3.0

† BCMNV = *Bean common mosaic necrosis virus*.

‡ R = resistant, S = susceptible.

§ 1=resistant, 5= susceptible.

Table 4. Comparison of canning quality characteristics of Red Cedar with three dark red kidney bean cultivars grown over 5 yr (2012–2016) at 10 locations.

Cultivars	Canned color $L^*a^*b^*$		Hydration ratio†	Drained weight ratio‡	Texture§	Visual appearance¶
	L^* scale#	a^* scale††				
Red Cedar	15.1	17.7	2.1	1.2	47	3.3
Red Hawk	17.9	19.4	2.1	1.2	40	3.8
Montcalm	20.9	19.8	2.2	1.2	44	3.5
Talon	15.5	18.2	2.1	1.2	58	2.8

† Hydration ratio: weight of soaked bean prior to canning/fresh weight of beans (equivalent to 90 g dry matter).

‡ Drained weight ratio: weight of cooked beans only/weight of soaked beans prior to canning.

§ Texture: force in kilograms required to compress 100 g of processed beans, measured using Kramer shear press.

¶ Visual appearance, where 1 = very undesirable, 5 = very desirable (10 locations).

L^* scale, 0 = dark, 100 = white.

†† a^* scale ranges from green –120 to red +120, determined using Hunter Lab color meter.

values below 30 kg 100 g⁻¹ are outside the acceptable range for processed dark red kidney beans (Hosfield and Uebersax, 1980). Red Cedar exhibits an overall satisfactory canning quality in the dark red kidney bean market class.

Availability

Red Cedar dark red kidney bean cultivar was released by MSU AgBioResearch, East Lansing, MI, and is available under license from MSU Technologies, with the option that Red Cedar may be sold for seed by name only under the foundation and certified seed classes. A royalty will be assessed on each hundred-weight unit of foundation seed sold. Breeder seed is maintained by MSU AgBioResearch under license with the Michigan Crop Improvement Association. Foundation seed will be maintained by the Michigan Crop Improvement Association. US Plant Variety Protection (PVP) for Red Cedar is anticipated. Seed of Red Cedar has been deposited with the USDA–ARS National Plant Germplasm System, where it will be available on expiration of PVP, 20 yr after the date of publication. Small quantities of Red Cedar seed for testing purposes can be obtained from the corresponding author during the period of PVP. 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.

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