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CULTIVAR DESCRIPTION

AAC Expedition pinto dry bean

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Abstract: AAC Expedition is a high yielding pinto dry bean (*Phaseolus vulgaris* L.) cultivar with a semi-upright, indeterminate bush (Type IIb) growth habit, large seed size, low percentage of hard seed and bright seed coat colour. Improved seed quality traits especially bright seed coat colour and low percentage of hard seeds after soaking, and high yield potential of AAC Expedition will make it a preferred pinto bean cultivar for commercial production. AAC Expedition developed by Agriculture and Agri-Food Canada (AAFC) Research and Development Centre, Lethbridge, AB, is well suited for commercial production under irrigation in Alberta and Saskatchewan.

Key words: AAC Expedition, high yield, large seed size, bright seed coat colour, pinto bean

Introduction

Pinto bean is the largest market class of dry bean grown on the prairies. A constraint to pinto bean seed quality is the gradual darkening of seed coat colour during postharvest storage (Junk-Knievel et al. 2007; 2008; Elsadr et al. 2011). AAC Expedition, a high yielding pinto bean with a bright seed coat colour and large seed size, was developed by Agriculture and Agri-Food Canada (AAFC), Lethbridge Research and Development Centre, Lethbridge, AB. It was tested as W08-025 in early generation nurseries (F_2 to F_5), and as L13PS389 in the yield trials starting in the F_6 generation. L13PS389 was grown in the Short Season Wide Row Irrigated Dry Bean Cooperative Registration Trial in Alberta and Saskatchewan from 2015 to 2017, and was registered as AAC Expedition on 29 June 2018 (Registration no. 8581), by the Variety Registration Office, Canadian Food Inspection Agency, Ottawa, ON.

Pedigree and Breeding Method

AAC Expedition was derived from the cross W06-121/Island made at the AAFC Lethbridge Research and Development Centre in 2008. W06-121 was a F_1 hybrid of the cross Maverick/CDC WM-1 made in 2006. Maverick, a pinto bean cultivar with an indeterminate prostrate growth habit (Grafton et al. 1997), was used as a parent for its high yield potential and seed quality (size and shape). CDC WM-1, is also a pinto bean cultivar like CDC WM-2 (Bett et al. 2014), but exhibits a determinate bush growth habit, and was used as a parent for its bright seed coat colour and colour retention traits. CDC WM-1 and CDC WM-2 are considered as “slow darkening” pinto bean as the seeds retain their bright seed coat colour for two years after harvest or longer compared to that of regular pinto bean where the seed coat usually darken after harvest depending on the storage conditions (Junk-Knievel et al. 2007). Island pinto bean was developed at AAFC Lethbridge (Mündel et al. 2008), and is the dominant cultivar currently grown under irrigation in Alberta. It was selected as a parent for its early maturity, indeterminate bush growth habit, high yield and seed quality (size and shape). The cross was designed to improve the seed coat colour of Island pinto bean while maintaining high yield potential, indeterminate bush growth habit and early maturity.

AAC Expedition was developed by pedigree breeding. Five F_1 plants of the cross were grown in a greenhouse at Lethbridge in fall 2008, and the F_2 seeds from the increase were split between the two F_2 nurseries grown at Lethbridge (49°41'N, 112°46'W, elevation 910 m) and Vauxhall (50°10'N, 112°07'W, elevation 760 m), AB in 2009. Single-plant selections were made based on indeterminate bush (Type IIb) growth habit (Brick and Johnson, 2004), early maturity, yield potential (number and distribution of pods on the plant) and slow darkening pinto bean seed traits (size, shape and bright colour). In total, eight plants were selected from the F_2 nurseries

grown at both locations. The F_3 plants were grown at Lethbridge and Vauxhall in 2010, but single-plant selections were made only at Vauxhall. Lethbridge experienced below average temperature (1.1°C below 30-year average temperature of 15°C from May to September, ECCC 2018) and above average precipitation (172% of 30-year average accumulation of 253 mm from May to September, ECCC 2018) during the growing season in 2010, and therefore, the F_3 nursery was lost due to waterlogging. However, seeds from a plant selected in Vauxhall were planted in the F_4 nursery at both locations in 2011, and four plants were selected from the two nurseries.

Progeny-row yield was added to the selection criteria in the F_5 yield trial, which was conducted in 2012 as a Modified Augmented Design (MAD type 2) (Lin and Poushinsky 1985). Four lines (three selected from Vauxhall and one from Lethbridge) were included in the F_5 yield trial grown at Lethbridge. The row length of the single-row plots was 5 m with 60 cm spacing between rows. A selection, VW08-025-1-6-1-3 from the F_5 yield trial was tested as L13PS389 in the wide row (60 cm row spacing) Preliminary (F_6) Yield Trial with two replications at Fairfield Research Farm (near Lethbridge) and Vauxhall in 2013. L13PS389 was tested in both the wide row and narrow row (23 cm row spacing) Advanced (F_7) Yield Trials with four replications at the above two locations in 2014. Based on seed yield and quality, lodging resistance, early maturity and indeterminate bush growth habit, L13PS389 was advanced to the Short Season Wide Row Irrigated Dry Bean Cooperative Registration Yield Trial from 2015 to 2017. The Cooperative Registration Yield Trial was grown at four locations (Fairfield Research Farm (5 km east of AAFC Lethbridge Research and Development Centre), Vauxhall and Bow Island, AB ($49^{\circ}52'\text{N}$, $111^{\circ}22'\text{W}$, elevation 795 m) and Outlook, SK ($51^{\circ}30'\text{N}$, $107^{\circ}03'\text{W}$, elevation 538 m)) in 2015, and five locations (Bow Island, Vauxhall, Cranford ($49^{\circ}48'\text{N}$, $112^{\circ}18'\text{W}$, elevation 824

m), Lethbridge (on-station) and Fairfield Research Farm) in 2016 and 2017 with four replications per location. The Cooperative Registration Yield Trial at Vauxhall was lost due to hail in early-June in 2015, waterlogging from above-average precipitation in August in 2016 (151% of 30-year average accumulation of 37 mm for August, ECCC 2018), and heat and drought stress from above-average temperatures (2°C above 30-year average of 15.8°C, ECCC 2018) and below-average precipitation (63% of 30-year average accumulation of 66 mm, ECCC 2018) in July and August in 2017. Also, seed yield data from the Cooperative Registration Yield Trial at Cranford in 2017 were not included in the statistical analysis due to a high CV (> 20%). In the Preliminary, Advanced and Cooperative Registration Yield Trials, plots consisted of four rows with a row length of 5 m, and the experimental design was a lattice. Island was used as a check cultivar in both the early generation nurseries and in the yield trials.

Performance

Agronomic traits

In the Short Season Wide Row Irrigated Dry Bean Cooperative Registration Yield Trial grown at 10 station-years between 2015 and 2017, the seed yield of AAC Expedition (experimental line L13PS389) was similar to the check cultivar Island (Table 1). AAC Expedition had an average maturity of 97 d over the 11 station-years, which was four days later maturing than the check cultivar Island (Table 1). However, days to maturity of AAC Expedition was the same as AC Black Diamond (i.e., 97 d over the 11 station-years between 2015 and 2017), a commercial cultivar currently grown in southern Alberta, and therefore, is within the acceptable range for dry bean production. The average 100-seed weight of AAC Expedition over the 11 station-years was 3 g higher than Island. Large seed size in the pinto bean market class is

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preferred in Mexico, an important market for Canadian pinto bean seeds as a premium price is associated with large, bright seeds. At maturity, AAC Expedition had slightly poorer lodging resistance compared to Island (Table 1). Plant growth habit and flower colour were assessed at flowering and Lethbridge location only. AAC Expedition has an indeterminate bush (Type IIb) growth habit (Brick and Johnson, 2004) with long vines, similar to Island. AAC Expedition has a white standard and wing petals, similar to Island.

Disease Resistance

AAC Expedition was assessed for partial field resistance (i.e., avoidance) to white mould, caused by *Sclerotinia sclerotiorum* (Lib.) de Bary, in an inoculated and irrigated disease nursery at AAFC-Lethbridge (49°41'N, 112°46'W, elevation 910 m) (Balasubramanian et al. 2014). White mould incidence and severity of AAC Expedition were similar to that of the check cultivar Island (Table 1). Seedling resistance to race 73 and 105 of *Colletotrichum lindemuthianum* (Sacc. & Magnus) Briosi & Cav., the causal agent of anthracnose was assessed in a greenhouse at AAFC-Morden (49°11'N, 98°05'W, elevation 298 m) (Balardin et al. 1997; Dongfang et al. 2008). AAC Expedition and Island were resistant to both races of anthracnose (data not shown). Based on visual observations in the field in southern Alberta, under natural inoculation conditions, both AAC Expedition and Island were susceptible to common bacterial blight, caused by *Xanthomonas axonopodis* pv. *phaseoli* (Smith) Vauterin et al. (Vauterin et al. 1995); syn. *X. campestris* pv. *phaseoli* (E.F. Smith) Dye.

Seed quality

Consumer preferences for dry bean seed quality vary by market class and end-use. Pinto bean seeds are primarily sold on the basis of visual seed quality traits including seed size, shape, colour and lustre. Therefore, post-harvest darkening of the seed coat is a significant problem in pinto (Junk-Knievel et al. 2008; Elsadr et al. 2011), carioca and cranberry bean, with consumers preferring seeds with a lighter seed coat colour (i.e., higher L^* value, please see below) in these market classes. Seeds of AAC Expedition and Island pinto bean harvested from four replications of the Cooperative Registration Yield Trial grown at four locations in 2017 (i.e., Bow Island, Cranford, Lethbridge on-station and Fairfield Research Farm) were subjected to cooking and canning quality assessments in the Bean Pilot Plant at AAFC-Lethbridge. In addition to the 100-seed weight which was determined as part of the agronomic traits (Table 1), the dry seed was assessed for L^* (light-dark, with higher values for lightness), a^* (red-green, with positive value for redness and negative values for greenness), and b^* (yellow-blue, with positive value for yellowness and negative values for blueness) attributes of colour using a CR-410 Chromameter (Konica Minolta Sensing Americas, Inc., Ramsey, NJ, USA). Seeds of AAC Expedition had a higher L^* and lower a^* compared to Island, indicating a bright base colour (i.e., primary seed coat colour) and a light colour of specks (i.e., secondary colour) on the seed coat (Table 2).

For the cooking quality, 200 seeds per replication per location were soaked in deionised water at room temperature (21°C) for 16 h and cooked for 20 min at 95°C. The percentage of hard seed and partially hydrated seed were determined after soaking and after cooking. Hydration coefficients after soaking and after cooking were determined as seed weight after soaking or after cooking / weight of dry seed. AAC Expedition had approximately one-tenth of the hard seeds observed in Island (Table 3). The percentage hard seed observed in Island in 2017 was higher than hard seeds observed in 2015 which was 14.4%. Based on the cooking quality assessment of

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several pinto bean experimental lines and cultivars in the Bean Pilot Plant over the years, the slow darkening pinto bean cultivars such as CDC WM-2, AAC Explorer and AAC Expedition consistently have low percentage hard seed. Percentage of partially hydrated seed before cooking was similar in both AAC Expedition (15%) and Island (6%). It is however, important to note hard seeds and partially hydrated seeds were not observed after cooking in either cultivar. After soaking, seeds of AAC Expedition doubled in weight (hydration coefficient = 2.1). Island was lower at 1.7, probably due to the presence of hard seeds. After cooking, both cultivars had similar hydration coefficient (2.6 vs. 2.4).

For the canning quality assessment, moisture content of seed was determined using a GAC2500-INTL Moisture Tester (Dickey-john, Auburn, IL), and 90 g of seed on a moisture-free basis were soaked in deionised water at room temperature (21°C) for 16 h and blanched for 3 min at 93°C in deionised water. The hydration coefficient was determined after soaking and blanching as seed weight after soaking or blanching / weight of dry seed. Blanched seeds were transferred to 398 ml cans and filled with a 1% (w/v) iodized table salt solution prepared using deionised water. Cans were processed at 121°C for 20 min at 4 rpm using a 2402 Multimode R&D Retort (Allpax Products, LLC, Covington, LA, USA), and cooled in cold running water for 20 min at 4 rpm. Cans were stored for two weeks prior to opening for assessment. Matting (clumping) of seeds was assessed on a 1 to 4 scale, where 1 = none, 2 = trace, 3 = slight, and 4 = moderate. Seeds were assessed for appearance (broken and split seed, and free seed coat), and the appearance was assessed using a 1 to 4 scale, where 1 = excellent, 2 = good, 3 = acceptable, and 4 = poor. The can content was weighed, and the drained weight of bean seed was determined after washing in tap water on an 8-mesh screen (Tyler series) positioned at a 15° angle. Percentage drained weight was determined as (weight of bean seed / weight of can contents)

*100. The texture (kg force) was determined by placing 100 g of washed drained bean in to a standard shear compression cell (CS-1) of Texture Measurement System - Touch (TMS-Touch, Food Technology Corp., Sterling, VA, USA) and shearing them using a load cell of 255 kg-force at a rate of 0.83 cm sec⁻¹. The colour of processed (canned) seed was assessed using a CR-410 Chromameter.

AAC Expedition had a higher hydration coefficient after soaking and blanching compared to Island (Table 3). A hydration coefficient of 2.0 or higher is generally preferred by processors as it reduces the amount of bean seeds required to fill a can. After blanching, seeds of both AAC Expedition and Island more than doubled in seed weight. Seeds of AAC Expedition showed moderate matting in cans compared to Island, and the appearance of processed seeds of AAC Expedition was rated poor compared to Island as the seeds were damaged during canning and subsequent washing of seeds for the determination of drained weight. The seeds of AAC Expedition from 2017 were rated slightly poorer for matting and appearance after canning compared to Island, but pinto bean seeds are primarily consumed as cooked, mashed bean. Drained weight of AAC Expedition was lower than that of Island, but was > 60% indicating more than 60% of the can content was pinto bean seed. The texture or firmness of AAC Expedition was 36% lower than that of Island which was probably due to the presence of broken and split seeds during canning. After canning, seeds of AAC Expedition had a higher L* and lower a* compared to Island, indicating bright or light seed colour (Table 2).

Development, Maintenance and Distribution of Pedigreed Seed

The breeder seed production of AAC Expedition was started in 2015. Two hundred pods were randomly selected from plants grown in a seed increase nursery at Vauxhall. The pods were

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hand-threshed individually and seeds (F_9) with the size, shape and bright seed coat colour appropriate for a slow darkening pinto bean were selected. The seeds were grown in the greenhouse at Lethbridge in the winter of 2016 and the plants were harvested individually. After examining the seed (F_{10}), 36 progeny-rows were planted at Twin Falls, Idaho in the summer of 2016. The seeds from 36 progeny-rows were bulked and this F_{11} seed formed the first breeder seed. Breeder seed of AAC Expedition will be maintained by the AAFC Lethbridge Research and Development Centre, Lethbridge, AB. AAC Expedition was released on an exclusive basis for seed production and marketing to Viterra Inc. (2802 -5th Avenue North, Lethbridge, AB, T1H 0P1), where pedigreed seed may be purchased.

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References

Balardin, R.S., Jarosz, A.M., and Kelly, J.D. 1997. Virulence and molecular diversity in *Colletotrichum lindemuthianum* from South, Central and North America. *Phytopathology* **87**: 1184–1191. doi:10.1094/PHYTO.1997.87.12.1184. PMID:18945016.

Balasubramanian, P. M., Conner, R. L., McLaren, D. L., Chatterton, S. and Hou, A. 2014. Partial resistance to white mould in dry bean. *Can. J. Plant Sci.* **94**: 683–691. doi:10.4141/cjps2013-312.

Bett, K.E., Vandenberg, A., Banniza, S., Lu, Q., Barlow, B., and Ife, S. 2014. CDC WM-2 common bean. *Can. J. Plant Sci.* **94**: 469–471. doi:10.4141/cjps2013-313

Brick, M. A. and Johnson, J. J. 2004. Classification, development and varietal performance. Pages 7–13 in H. F. Schwartz, M. A. Brick, R. M. Harveson, and G. D. Franc, eds. Dry bean production and pest management. 2nd ed. Bulletin 562A. Colorado State University, University of Nebraska, Lincoln, NE, and University of Wyoming, Laramie, WY, USA.

Dongfang, Y., Conner, R. L., Yu, K., Balasubramanian, P., Penner, W. C. and Yager, L. M. 2008. Identification of anthracnose resistance genes in dry bean cultivars grown in Manitoba. *Can. J. Plant Sci.* **88**: 771–781. doi:10.4141/CJPS07145

Elsadr, H.T., Wright, L.C., Pauls, K.P., and Bett, K.E. 2011. Characterization of seed coat post harvest darkening in common bean (*Phaseolus vulgaris* L.). *Theor. Appl. Genet.* **123**: 1467–1472. doi:10.1007/s00122-011-1683-8.

Environment and Climate Change Canada (ECCC). 2018. Historical Data. [Online]. Available: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html [13 Nov. 2018]

Grafton, K.F., Venette, J.R., and Chang, K.C. 1997. Registration of Maverick pinto bean. *Crop Sci.* **37**: 1672–1672.

Junk-Knievel, D.C., Vandenberg, A., and Bett, K.E. 2007. An accelerated postharvest seed-coat darkening protocol for pinto beans grown across different environments. *Crop Sci.* **47**: 694–702. doi:10.2135/cropsci2006.05.0325.

Junk-Knievel, D.C., Vanderberg, A., and Bett, K.E. 2008. Slow darkening in pinto bean (*Phaseolus vulgaris* L.) seed coat is controlled by a single major gene. *Crop Sci.* **48**: 189–193. doi:10.2135/cropsci2007.04.0227.

Lin, C.S. and Poushinsky, G. 1985. A modified augmented design (type 2) for rectangular plots. *Can. J. Plant Sci.* **65**: 743–749. doi:10.4141/cjps85-094.

Mündel, H. -H., Kiehn, F. A., Huang, H. C., Conner, R. L. and Balasubramanian, P. 2008. Island pinto bean. *Can. J. Plant Sci.* **88**: 161–163. doi:10.4141/CJPS07044.

Vauterin, L., Hoste, B., Kersters, K. and Swings, J. 1995. Reclassification of *Xanthomonas*. *Internat. J. System. Bacteriol.* **45**: 472–489.

Table 1. Means of agronomic and disease traits of the pinto bean cultivar AAC Expedition and the check cultivar Island grown in Alberta and Saskatchewan from 2015 to 2017.

Cultivar	Yield (t ha ⁻¹)	Maturity (d)	Seed weight (g 100 seeds ⁻¹)	Lodging resistance ^a (1–5 scale)	Anthracnose ^b		White mould ^c	
					Race 73	Race 105	Incidence (%)	Severity (1–4)
AAC Expedition	4.14	97	40.7	3.4	R	R	33	1.7
Island	4.31	93	37.7	3.1	R	R	25	1.5
LSD _{0.05}	0.22	1	1.3	0.2	—	—	12	0.3
Station–years	10	11	11	11	3	3	3	3

Note: LSD, least significant difference. —, no value. LSD was calculated from a pooled error term of all entries common to the Short Season Wide Row Irrigated Dry Bean Cooperative Registration Trial from 2015 to 2017. Data were from four replications of trials grown at Bow Island and Fairfield Research Farm, Lethbridge (2015-2017), Outlook, SK (2015), and Cranford and Lethbridge on-station (2016-2017). Data from Cranford in 2016 were not included in the statistical analysis for yield due to CV > 20%.

^aLodging resistance was determined at maturity using a 1 to 5 scale, from 1 = upright plants, 3 = partially upright plants to 5 = plants lodged due to weak stem.

^bReactions against anthracnose races were assessed after artificial inoculation in a greenhouse. R, resistant; S, susceptible.

^cWhite mould incidence refers to the mean percentage of plants with symptoms in the inoculated disease nursery at Lethbridge from 2015 to 2017. White mould severity was assessed using a 1 to 4 scale, where 1 = healthy plants, 2 = plants have one infected branch or pod, 3 = plants have multiple infected branches or pods, and 4 = main stem is girdled or plants were dead.

Table 2. Means of seed coat colour attributes of the pinto bean cultivar AAC Expedition and the check cultivar Island grown at four locations in Alberta in 2017.

Cultivar	Dry seed colour ^a			Canned seed colour ^a		
	L*	a*	b*	L*	a*	b*
AAC Expedition	71.6	5.3	14.0	34.0	9.7	21.6
Island	64.1	8.0	15.2	29.3	11.7	19.8
LSD _{0.05}	2.5	1.1	2.6	2.6	0.8	2.5

Note: LSD, least significant difference. Data were from seeds harvested from four replications of the Short Season Wide Row Irrigated Dry Bean Cooperative Registration Trial grown in 2017 at Bow Island, Cranford, Lethbridge on-station and Fairfield Research Farm.

^aColour of dry bean seed: L*, a*, and b* attributes of colour were measured on dry and processed (canned) seed using a CR-410 Chromameter (Konica Minolta Sensing Americas, Inc., Ramsey, NJ, USA). L* indicates “light-dark” with higher values for lightness; a* indicates “red-green” with positive values for redness and negative values for greenness; and b* indicates “yellow-blue” with positive values for yellowness and negative values for blueness. One-hundred g of processed bean seed was used to determine colour after canning.

Table 3. Means of cooking and canning quality traits of the pinto bean cultivar AAC Expedition and the check cultivar Island grown at four locations in Alberta in 2017.

Cultivar	Cooking quality – Hard seed (%) ^a		Canning quality					
	Before cooking	After cooking	HCS ^b	HCB ^c	Drain weight (%) ^d	Matting (1–4) ^e	Appearance (1–4) ^f	Texture (kg force) ^g
AAC Expedition	5.4	0.0	2.2	2.4	62	4.0	4.0	25
Island	48.4	0.0	1.7	2.2	66	3.3	3.3	39
LSD _{0.05}	14.8	6.5	0.1	0.1	2	0.6	0.5	7

Note: LSD, least significant difference ($p > 0.05$). Data were from seeds harvested from four replications of the Short Season Wide Row Irrigated Dry Bean Cooperative Registration Trial grown in 2017 at Bow Island, Cranford, Lethbridge on-station and Fairfield Research Farm.

^aTwo hundred seeds per genotype per location were soaked in de-ionised water at room temperature for 16 h and cooked for 20 min at 95°C. Percentage hard seed was determined before and after cooking.

^bHydration coefficient after soaking (HCS): 90 g of pinto bean seed was soaked for 16 h in de-ionised water at room temperature (21°C). Hydration coefficient after soaking was determined as: seed weight after soaking / weight of dry seed.

^cHydration coefficient after blanching (HCB): Soaked seed was blanched for 3 min at 93°C. Hydration coefficient after blanching was determined as: seed weight after blanching / weight of dry seed.

^dDrain weight (%): Bean seeds were processed at 121°C for 20 min in brine using a 2402 Multimode R&D Retort (Allpax Products, LLC, Covington, LA). Can content was weighed and the weight of bean seed was determined after washing in tap water on a 8-mesh screen (Tyler series) positioned at a 15° angle. Percentage drain weight was determined as: (weight of bean seed / weight of can contents) * 100.

^eMatting (clumping) of seeds was assessed on a 1 to 4 scale, where 1 = none, 2 = trace, 3 = slight and 4 = moderate.

^fAppearance of seeds was assessed on a 1 to 4 scale, where 1 = excellent, 2 = good, 3 = acceptable, and 4 = unacceptable.

^gTexture (Firmness) (kg force 100 g seed⁻¹) was determined by placing 100 g of washed drained bean in to a standard shear compression cell (CS-1) of Texture Measurement System - Touch (TMS-Touch, Food Technology Corp., Sterling, VA) and shearing them using a load cell of 255 kg force at a rate of 0.83 cm sec⁻¹.