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CULTIVAR

Pinto Bean Cultivars Blackfoot, Nez Perce, and Twin Falls

Shree P. Singh,* Phillip N. Miklas, Mark A. Brick, Howard F. Schwartz, Carlos A. Urrea, Henry Terán, Carlos Centeno, Barry Ogg, Kristen Otto, and Alvaro Soler

Abstract

Pinto bean (*Phaseolus vulgaris* L.) cultivars 'Blackfoot' (Reg. No. CV-316, PI 680632), 'Nez Perce' (Reg. No. CV-317, PI 680633), and 'Twin Falls' (Reg. No. CV-318, PI 680634) were developed at the University of Idaho, Kimberly Research and Extension Center in collaboration with researchers in Colorado, Nebraska, and Washington. Blackfoot and Nez Perce are sister cultivars derived from the same bulk population, UIP35 (USPT-CBB-1/3/'Othello'/'UI 906'//'Topaz'/'Buster'). Twin Falls was selected from the bulk population UIP40 (USPT-CBB-1/3/CO12650/USPT-ANT-1//Othello/ABL15). The F_8 of both population bulks and checks were yield tested in the Western Regional Bean Trial in 2014 and 2015 and in the Cooperative Dry Bean Nursery in 2015. The three cultivars were yield tested in Idaho in 2015. They were also yield tested across nine production environments in Colorado, Idaho, Nebraska, and Washington in 2016. Blackfoot, Nez Perce, and Twin Falls are the first indeterminate erect Type II growth habit pinto bean cultivars resistant to *Bean common mosaic virus* (an aphid-vectored potyvirus) and bean rust developed at University of Idaho. Blackfoot has a compact Type IIA growth habit and produces little or no vine (i.e., elongated terminal axis with intertwined internodes that help the plant climb when provided support). In contrast, Nez Perce is tall and produces medium to long vines, with a Type IIB growth habit. Blackfoot has a mean maturity of 85 d and Nez Perce 95 d in southern Idaho. Twin Falls is a full-season cultivar (≥100 d) and relatively tall, with very small or no vines for climbing. The three cultivars have relatively smaller seed (<35 g 100^{-1} seeds) than early-maturity pinto 'Othello' (≥35 g 100^{-1} seeds) in the Pacific Northwest.

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Pinto bean (*Phaseolus vulgaris* L.) is the most important market class of bean in North America (Singh et al., 2007; Terán et al., 2009; USDA National Agricultural Statistics Service, 2015). Pinto bean production in the United States during 2015 was ~430,000 t, with a market value of $280 million (https://www.nass.usda.gov/Statistics_by_State/Idaho/). Bean growers in Idaho, the Pacific Northwest, and elsewhere in the United States desire cultivars with early maturity (≤85 d) and resistance to *Bean common mosaic virus* (BCMV, a seed-borne aphid-vectored potyvirus) and bean rust [caused by *Uromyces appendiculatus* (Pers.:Pers.) Unger]. They also desire an indeterminate erect growth habit (i.e., Type II; Singh, 1982) to facilitate mechanical direct cut field harvest. Currently available early-maturity pinto bean cultivars such as 'Common Pinto' (Singh, 2003), 'Othello' (Burke et al., 1995), and 'Topaz' in the Pacific Northwest have an undesirable indeterminate prostrate semi-climbing Type III growth habit (Singh, 1982) and are susceptible to diseases such as BCMV and/or bean rust. Cultivars with early maturity, erect Type II growth habit, and resistance to BCMV and bean rust are not currently available in Idaho, the Pacific Northwest, and the rest of the United States. Consequently, the objective of this research was to develop BCMV- and rust-resistant pinto bean cultivars with erect Type II growth habit and a range of harvest maturities.

Methods

Pinto bean cultivars Blackfoot and Nez Perce were derived from the population UIP35 with the pedigree USPT-CBB-1/3/Othello/'UI906'//Topaz/'Buster'. USPT-CBB-1 is an indeterminate semi-upright pinto bean germplasm release from the USDA-ARS, Prosser, WA (Miklas et al., 2001). It has moderate

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Abbreviations: BCMNV, *Bean common mosaic necrosis virus*; BCMV, *Bean common mosaic virus*; CDBN, Cooperative Dry Bean Nursery; KREC, Kimberly Research and Extension Center; QTL, quantitative trait locus; WRBT, Western Regional Bean Trial.

resistance to common blight {caused by *Xanthomonas campestris* pv. *phaseoli* Smith (Dye) [synonym: *X. axonopodis* pv. *phaseoli* (Smith) Vauterin et al.] and *X. campestris* pv. *phaseoli* var. *fuscans* (Burkholder) Starr & Burkholder (synonym: *X. fuscans* subsp. *fuscans* sp. nov.)}, the *I* gene for resistance to BCMV, and *Ur-3* and *Ur-6* genes for resistance to bean rust. Pinto cultivar Othello (Burke et al., 1995) has early maturity (~ 85 d), resistance to several pathogens including some strains of BCMV (including NY-15; Singh et al., 2008), *Beet curly top virus* (a leafhopper-vectored curtovirus), *Bean dwarf mosaic virus* (a whitefly-transmitted begomovirus), and Fusarium root rot [caused by *Fusarium solani* (Martius) Appel and Wr. f. sp. *phaseoli* (Burk.) Snyd. and Hans.] (Burke et al., 1995; Seo et al., 2007). Othello has a Type III growth habit (Singh, 1982) and is highly susceptible to bean rust and other major diseases of common bean (Singh et al., 2008; Terán et al., 2009). UI 906 is an early-maturity small-seeded (<25 g 100^{-1} seeds) black bean cultivar with the *I* gene for resistance to BCMV released by the University of Idaho (Dean, 2000). Topaz is an early-maturity BCMV- and bean rust-susceptible pinto cultivar with a Type III growth habit. It was developed by the Rogers Brother Seed Company, Nampa, ID. Buster pinto bean has late maturity (≥100 d), Type II growth habit, and resistance to BCMV and bean rust. It was developed by Seminis Vegetable Seeds, Filer, ID in the 1990s. USPT-CBB-1, Othello, and Buster were resistant to soil iron and zinc deficiencies in field trials conducted at Kimberly, ID (unpublished data). One hundred and eighty-six F_1 seeds were produced for the cross UIP35 in winter 2005–2006.

Twin Falls was selected from the multiple-parent population UIP40 with the pedigree USPT-CBB-1/3/CO12650/USPT-ANT-1//Othello/ABL15. Pinto CO12650 is a breeding line from Colorado State University, Fort Collins. It has Type II growth habit and medium maturity (90–95 d). USPT-ANT-1 is a late-season (~100 d) germplasm release with Type III growth habit and resistance to anthracnose [caused by *Colletotrichum lindemuthianum* (Sacc. and Magn.) Lams.-Scrib.] (Miklas et al., 2003b). Anthracnose resistance in USPT-ANT-1 is controlled by the *Co-4*^{2} gene. Breeding line ABL15 has Type II growth habit with resistance to BCMV and soil iron and zinc deficiency. It was developed at the Kimberly Research and Extension Center (KREC), University of Idaho, in 2003 (unpublished data). Ninety-six F_1 seeds were produced to form the initial UIP40 population during winter 2005–2006.

The F_1 seeds of UIP35 and UIP40 were sown in a field that was deficient in iron and zinc at Kimberly (Westermann et al., 2011) in 2006. Tall plants with Type II growth habit (Singh, 1982) and high pod load that were resistant to soil iron and zinc deficiency were harvested in fall 2006. Nine $F_{1:2}$ seeds harvested from each F_1 plant were grown in the greenhouse at the KREC and inoculated with the US-6 strain of BCMV in winter 2006–2007. Symptomless (i.e., putative resistant) F_2 plants were harvested in bulk to form $F_{1:3}$ families, which were planted in the same iron- and zinc-deficient field at Kimberly in 2007. Seeds from all plants within each $F_{1:3}$ family that were resistant to soil iron and zinc deficiency and had Type II growth habit, early maturity (≤90 d), and desirable seed characteristics (large size, rhomboid shape, and bright cream color with pinto pattern) were bulked to form an $F_{1:4}$. In addition, an overall bulk composite for each population was made by taking 25 $F_{1:4}$ seeds from each harvested $F_{1:3}$ family (i.e., a population bulk UIP35 for USPT-CBB-1/3/Othello/UI 906//Topaz/Buster and population bulk UIP40 for USPT-CBB-1/3/CO12650/USPT-ANT-1//Othello/ABL15). The UIP35 and UIP40 population bulks were advanced to F_8 in the field at the KREC in the subsequent years without selection for any trait. In addition, nine seeds from each selected $F_{1:4}$ family were grown in the greenhouse and inoculated with the US-6 strain of BCMV in 2008–2009. Each resistant plant was harvested separately, and again the $F_{4:5}$ plants were screened for BCMV resistance in 2010–2011. All BCMV-resistant $F_{4:5}$ plants within a family were harvested and bulked. The $F_{4:6}$ families were grown in the iron- and zinc-deficient field at Kimberly in 2012. Seeds from all harvested plants within each selected $F_{4:6}$ family were bulked to form 175 $F_{4:7}$ families from the two populations. Subsequently, they were evaluated in a nonreplicated adaptation (observation) nursery under optimum field-growing conditions and moderate drought stress at Kimberly, ID, Fort Collins, CO, Scottsbluff, NE, and Othello and Roza (a purgatory plot characterized by nutrient and water stress), WA, in 2013. Pinto Othello was used as a check at all locations. Visual evaluations for plant type, pod load, and maturity were made at all locations. Evaluation for the response to a mixture of locally occurring uncharacterized (i.e., not challenged against a set of differential common bean to determine specific pathogen race composition) races of *U. appendiculatus* also was made in the greenhouse and field at Fort Collins.

On the basis of all observations, 10 to 15 plants were harvested from each selected $F_{4:7}$ family at Kimberly in 2014. Subsequently, a total of 110 $F_{7:8}$ plant-to-progeny rows from each population were grown and bulk harvested each at Blenheim, New Zealand, Juana Diaz, Puerto Rico, and Los Andes, Chile, in winter 2014–2015. Selection for post-harvest seed coat color darkening and seed size and shape was conducted before planting and after harvest. Seeds from 72 selected $F_{7:9}$ breeding lines derived from UIP35 population and 48 breeding lines from UIP40 population were multiplied at Kimberly in summer 2015. In addition, a single-row plot of each $F_{7:9}$ breeding line was grown in the same field under a moderate water stress at Kimberly and under bean rust pressure at Fort Collins to evaluate drought tolerance and resistance to bean rust, respectively. At Kimberly, data were recorded for growth habit, number of days to maturity, seed yield, and seed characteristics including size, shape, color, and post-harvest seed coat color darkening.

Seeds from three early-maturity (<90 d to maturity) $F_{7:9}$ breeding lines derived from the same $F_{4:7}$ family with good seed characteristics, Type II growth habit, and resistance to BCMV and bean rust were taken from the UIP35 population and bulked to form the cultivar Blackfoot. Similarly, Nez Perce was formed by combining four $F_{7:9}$ breeding lines derived from another $F_{4:7}$ family with 90- to <100-d maturity from population UIP35 that had good seed characteristics, Type II growth habit, and resistance to BCMV and bean rust. The cultivar Twin Falls is a bulk of four $F_{7:9}$ breeding lines all from the same $F_{4:7}$ family from the UIP40 population selected for Type II growth habit, full-season maturity (~100 d), and resistance to BCMV and bean rust.

Before bulking, the breeding lines for each of the three cultivars were screened to ensure they were uniform for their response to BCMV or *Bean common mosaic necrosis virus* (BCMNV, an aphid-vectored potyvirus) in the greenhouse in Colorado (BCMNV strain NL-3), Idaho (BCMV strain NY-15), Nebraska (BCMNV strain NL-3), and Washington (BCMNV strain NL-3) and tested for the response to bean rust in the field at Fort Collins in 2016. All breeding lines were also tested for the presence or absence of the sequence characterized amplified region (SCAR) markers linked with the BCMV/BCMNV (*I*, *bc-1²*, and *bc-3* alleles) and bean rust (*Ur-3*) at Prosser in 2016. Similarly, they were tested for the presence or absence of the common blight resistance quantitative trait loci (QTLs), SU91 on chromosome 8 (Pedraza et al., 1997) and SAP6 on chromosome 10 (Miklas et al., 2003a) at Prosser. The response to ARX8AC and Xcp25 strains of *X. campestris* pv. *phaseoli* was determined in the greenhouse in Idaho in 2016.

The F_8 bulks of UIP35 and UIP40 along with other breeding lines and checks from the public bean breeding programs in Colorado, Idaho, Nebraska, and Washington were evaluated in the Western Regional Bean Trial (WRBT) in 2014 and 2015. They were also tested in the Cooperative Dry Bean Nursery (CDBN) in the United States and Canada in 2015. In the WRBT and CDBN, data were recorded for growth habit, days to maturity, seed yield, and 100-seed weight, among other traits. The three cultivars and checks were also tested for seed yield in Idaho in 2015 and across nine stressed and nonstressed production conditions in Colorado, Idaho, Nebraska, and Washington in 2016. All quantitative data were analyzed using the SAS (v. 9.1) PROC GLM statistical package (SAS Institute, 2004).

Performance of Pinto UIP35 and UIP40 Bulks in Regional and National Nurseries

Maturity

The mean number of days to maturity for UIP35 was 91 d in 2014 and 96 d in 2015 in the WRBT (Table 1). The respective values for UIP40 were 96 and 102 d. Othello had a mean maturity of 85 d in both years. In the CDBN in 2015, the mean maturity for UIP35, UIP40, and Othello were 94, 98, and 86 d, respectively (Table 1; P.N. Miklas, unpublished data, 2015). Pinto 'Centennial' (M.A. Brick, unpublished data, 2015) had a mean of 98 d and 'Eldorado' (Kelly et al., 2012) had 99 d.

Seed Yield and Seed Weight

Mean seed yield of UIP35 in the WRBT across the four states (Colorado, Idaho, Nebraska, and Washington) was 2836 kg ha^{-1} and that of UIP40 was 2570 kg ha^{-1} compared with 2210 kg ha^{-1} for the check cultivar Othello in 2014 (Table 1). However, the three values were not significantly different ($P > 0.05$). The respective seed yields for the three pinto beans in the WRBT in 2015 were 3275, 3120, and 2575 kg ha^{-1}. Thus, Othello yielded less ($P < 0.05$) than UIP35 and UIP40. In the CDBN across 10 locations in the United States and Canada in 2015, UIP35 had mean seed yield of 2975 kg ha^{-1}, UIP40 had 2825 kg ha^{-1}, and Othello had 2525 kg ha^{-1} (Table 1). Although UIP35 had significantly higher yield than Othello, yields of UIP35, UIP40, and check cultivars Centennial and Eldorado were not significantly different.

Mean seed weight of UIP35, UIP40, and Othello were 32, 33, and 33 g 100 seed^{-1}, respectively, in the WRBT in 2014 (Table 1). The respective values were 33, 32, and 34 g 100 seed^{-1} in the WRBT in 2015. Mean seed weight of UIP35 and UIP40 were 31 and 32 g 100 seed^{-1} compared with 37 g 100 seed^{-1} for Othello across 10 locations in the CDBN in the United States and Canada in 2015 (Table 1). Check cultivars Centennial and Eldorado had mean seed weight of 39 g 100 seed^{-1}.

Disease Resistance

UIP35 and UIP40 were resistant to a mixture of uncharacterized races of *U. appendiculatus* in the greenhouse and field at Fort Collins and in the field at Beltsville, MD, in the CDBN in 2015 (Table 2; P. Miklas, unpublished data, 2015). In contrast, Othello and Eldorado were highly susceptible to bean rust. Similarly, UIP35 and UIP40 were resistant to the BCMV strain

Table 1. Mean number of days to maturity, 100 seed weight, and seed yield for pinto bean UIP35, UIP40, Othello, Centennial, and Eldorado evaluated in regional and/or national nurseries.

Identification	Maturity		100 seed weight		Seed yield	
	2014	2015	2014	2015	2014	2015
	d		g		kg ha^{-1}	
WRBT†						
UIP35 bulk	91	96	32	33	2836	3275
UIP40 bulk	96	102	33	32	2570	3120
Othello	85	85	33	34	2210	2575
LSD ($P \leq 0.05$)	4	5	3	3	650	585
CV (%)	3	3	5	6	15	12
CDBN‡						
UIP35 bulk		94		31		2975
UIP40 bulk		98		32		2825
Othello		86		37		2525
Centennial		98		39		3105
Eldorado		99		39		2955
LSD ($P \leq 0.05$)		5		5		445
CV (%)§		5		14		20

† WRBT = Western Regional Bean Trial, conducted in Colorado, Idaho, Nebraska, and Washington in 2014 and 2015.

‡ CDBN = Cooperative Dry Bean Nursery, evaluated across 10 states/provinces in the United States and Canada in 2015.

§ LSD and CV values were determined using all genotypes tested in the respective trial.

Table 2. Response of pinto bean UIP35 bulk, UIP40 bulk, Othello, Centennial, Eldorado, Blackfoot, Nez Perce, and Twin Falls to *Bean common mosaic virus* (BCMV) in the greenhouse at Kimberly, ID; to *Bean common mosaic necrosis virus* (BCMNV) in the greenhouse at Fort Collins, CO, Scottsbluff, NE, and Prosser, WA; and to bean rust in the greenhouse and/or field at Fort Collins, CO.

Cultivar	BCMV (US-6)	BCMNV (NL-3)	Bean rust† Greenhouse	Bean rust† Field
			1–6	1–6
Population bulk				
UIP35	Resistant	–	–	1
UIP40	Resistant	–	–	1
Checks	(NY-15)			
Othello	Resistant	–	–	6
Centennial	Resistant	–	–	1
Eldorado	Resistant	–	–	6
New cultivars				
Blackfoot	Resistant	Tn‡	1	1
Nez Perce	Resistant	Tn	1	1
Twin Falls	Resistant	Mosaic or mild mosaic	1	1

† Bean rust scored on a 1-to-6 scale, where 1–2 = resistant, 3–4 = intermediate, and 5–6 = susceptible response.

‡ Tn = top necrosis of plants caused by the BCMNV strain NL-3.

US-6 in the greenhouse at Kimberly when tested from 2006 to 2011.

Characteristics

Growth Habit

Blackfoot, Nez Perce, and Twin Falls have a Type II growth habit (Singh, 1982) (Table 3). Blackfoot has a compact growth habit, whereas Twin Falls is relatively tall. Both produce a Type IIA growth habit with short or no vines (Singh, 1982). In contrast, Nez Perce produces medium to long vines, with a Type IIB growth habit (Singh, 1982). In the western United States as well as elsewhere in North America, Type II growth habit cultivars of the common bean races Durango and Mesoamerica (Singh et al., 1991) are sought to facilitate direct harvest and to reduce contact of pods with the soil surface. Thus, Type II cultivars have reduced production costs and dependence on farm labor and energy (Kelly, 2001). Furthermore, high humidity in the midwestern United States favors foliar diseases such as white mold [caused by *Sclerotinia sclerotiorum* (Lib.) de Bary], anthracnose, bean rust, and common blight. In such environments, cultivars with a Type II growth habit are more likely to express disease avoidance due to their open erect plant canopy (Kelly, 2001; Miklas et al., 2013) than Type III cultivars such as pinto Othello and Topaz.

Table 3. Mean seed yield, 100 seed weight, and number of days to maturity for pinto bean cultivars Blackfoot, Nez Perce, and Twin Falls along with checks evaluated in the field at Kimberly, ID, in 2015.

Cultivar	Growth habit†	Seed yield	100 seed weight	Maturity
		— kg ha^{-1} —	— g —	— d —
Blackfoot	IIA	1970	32	86
Nez Perce	IIB	2660	33	94
Twin Falls	IIA	3490	32	108
Othello	III	2645	37	85
Centennial	IIB	2455	37	97
Eldorado	IIB	2750	38	95
LSD ($P \leq 0.05$)		645	3	3
CV (%)		16	8	9

† Growth habit IIA = indeterminate erect Type II with no vine; IIB = indeterminate erect Type II with medium to long length vine; and III = indeterminate prostrate Type III with small to medium length vine.

Maturity

Blackfoot, Nez Perce, and Twin Falls will provide growers diverse options for harvest maturity. The cultivar Othello (85 d) and Blackfoot (86 d) have early maturity, Nez Perce (94 d) has medium maturity, and Twin Falls has full-season maturity (108 d) at Kimberly (Table 3). These cultivars compare to the current cultivars Centennial at 97 d and Eldorado at 95 d. Differences in maturity may also occur among pinto bean cultivars due to the environment. In 2016, both Blackfoot and Othello matured in 87 d and Nez Perce, Twin Falls, and Centennial in 95 d at Kimberly (data not shown). At Scottsbluff, NE, Blackfoot matured at 85 d, Othello at 86 d, Nez Perce at 98 d, Twin Falls at 99 d, and Centennial at 103 d. However, differences in maturity among these cultivars in Colorado and Washington were not large across environments in 2016.

In southern Idaho, the northwestern and northern United States, and southwestern Canada, early- to medium-maturity common bean cultivars are relatively less risky because they can be planted from mid-May to early June and harvested at the end of August or early September to avoid freezing temperatures that may occur in early fall. Furthermore, early-maturity cultivars may require reduced frequency and amount of irrigation water to facilitate early harvest. However, the major weakness of early-maturity cultivars in southern Idaho and other western US states is that they are often lower yielding compared with medium-season (e.g., Centennial and Nez Perce) and full-season (e.g., Twin Falls) cultivars (Table 3). Seed yield can be reduced approximately 12 kg ha^{-1} by each day of earliness at Cali, Colombia, as well as at Davis, CA (White and Singh, 1991; White et al., 1992).

Seed Yield and Seed Weight

Twin Falls had the highest yield and Blackfoot the lowest yield at Kimberly in 2015 (Table 3). In addition, there were no significant differences among seed yields of Nez Perce, Othello, Centennial, and Eldorado. Nez Perce had higher yield than

Blackfoot under nonstress condition at Othello, WA, in 2016 (Table 4). There were no seed yield differences among the three new pinto bean cultivars and checks Othello and Centennial under drought stress at the same location. However, Blackfoot, Nez Perce, and Othello yielded significantly higher than the susceptible check pinto 'Stampede' (Osorno et al., 2010) under drought stress (396 kg ha^{-1}) in the same trial (P.N. Miklas, unpublished data, 2016). Blackfoot was the lowest yielding and Nez Perce had the highest yield in a purgatory plot characterized by drought stress and nutrient deficiency at Roza, WA (Table 4). In the same trial, the three new pinto bean cultivars and Othello outyielded the susceptible check pinto 'Chase' (Coyne et al., 1994), which yielded 952 kg ha^{-1} (P.N. Miklas, unpublished data, 2016). Blackfoot had the highest yield in a nitrogen-deficient field at Paterson, WA (Table 4). It significantly outyielded Twin Falls and susceptible check pinto 'UI 196' (Dean, 2000) with yield of 1858 kg ha^{-1}. However, Blackfoot did not have significantly higher yield than Othello. There were no significant differences among the three cultivars and checks under nonstress and drought stress at Fort Collins in 2016 (Table 4). Twin Falls had higher yield than all other cultivars under both nonstress and drought stress at Scottsbluff in 2016 (Table 4). In Idaho, Nez Perce had higher yield than Othello and Twin Falls in a field that had been under continuous beans for the past 66 yr (Table 4).

Blackfoot, Nez Perce, and Twin Falls had lower 100-seed weight than Othello, Centennial, and Eldorado at Kimberly in 2015 (Table 3). Similar results were observed across Colorado, Idaho, Nebraska, and Washington in 2016 (data not shown). Pinto and other market classes of beans with higher seed weight or larger seed size are preferred in the domestic and international trade and often may bring a premium price.

Disease Resistance

Blackfoot, Nez Perce, and Twin Falls are resistant to the NY-15 strain of BCMV based on a greenhouse test in Idaho (Table 2). However, when Twin Falls was inoculated with the NL-3 strain of BCMNV in the greenhouse in Nebraska, it produced mosaic symptoms. In a similar greenhouse test in Washington, the NL-3 inoculated plants of Twin Falls exhibited milder mosaic symptoms. The discrepancy could be due to the greenhouse environment, inoculation method, the plant growth stage when inoculations were made, and/or the pathogen response evaluated. In contrast, Blackfoot and Nez Perce exhibited a top-necrotic and black root response in Colorado, Nebraska, and Washington, which indicates the presence of the dominant *I* gene for resistance to all strains of BCMV and a necrotic response to BCMNV strains such as NL-3 (Drijfhout et al., 1978). Molecular marker assays confirmed the presence of the *I* gene (Bello et al., 2014) in Blackfoot and Nez Perce. Twin Falls lacked dominant *I* gene allele and recessive *bc-1*^{2} (Miklas et al., 2000) and *bc-3* (Hart and Griffiths, 2013) alleles. Given that Twin Falls exhibited mosaic symptoms when inoculated with NL-3 strain and no symptoms with US-6 strain, it lacks the recessive *bc-1*^{2} and *bc-3* alleles; thus, most likely it may possess the recessive *bc-2* allele, which will be susceptible to NL-3 and develop mosaic symptoms in its presence (Drijfhout et al., 1978).

Blackfoot, Nez Perce, and Twin Falls were resistant to a mixture of uncharacterized races of *U. appendiculatus* in field and greenhouse trials at Fort Collins in 2015 (Table 2). Furthermore, their response was similar in the field at Fort Collins in 2016 (data not shown). Based on these observations and the presence of an indel-marker linked to the resistant allele *Ur-3* (M.A. Pastor-Corrales, USDA-ARS, personal communication, 2016), all three cultivars carry the *Ur-3* allele for resistance to bean rust. In contrast, as noted above (also see Table 2), Othello and Eldorado were susceptible to bean rust. None of the three new pinto bean cultivars carry the common blight resistance QTL SU91 or SAP6, and they were susceptible when challenged by the ARX8AC and Xcp25 strains of *X. campestris* pv. *phaseoli* in the greenhouse in Idaho in 2016 (data not shown).

Tolerance to Abiotic Stresses

The initial selections from the F_1 to F_6 for resistance to soil iron and zinc deficiency were made in an iron- and zinc-deficient field at Kimberly (Westermann et al., 2011) between 2006 and 2012. Pinto Othello, UIP35, UIP40, and approximately 175 $F_{4:6}$ families derived from the latter two were resistant to severe soil iron and zinc deficiency and manganese toxicity in 2012 (data not shown). Because Blackfoot, Nez Perce, and Twin Falls were derived from the above $F_{4:6}$ families, they may be resistant to soil iron and zinc deficiency and manganese toxicity. Thus, based on the above discussions, it may be worthwhile to further test the three new pinto bean cultivars along with known susceptible and tolerant checks under nonstress, in nitrogen-, iron-, and/or zinc-deficient soils, and under drought stress across contrasting production conditions to ascertain their resistance/tolerance to these abiotic stresses.

Table 4. Mean seed yield for pinto bean cultivars Blackfoot, Nez Perce, and Twin Falls along with checks evaluated at several locations in 2016.

Cultivar	Washington				Colorado		Nebraska		Idaho
	Roza	Paterson	Othello						
	PP†	Low N	NS	DS	NS	DS	NS	DS	CBC
	kg ha^{-1}								
Blackfoot	1561	2969	2873	1430	1944	1035	1222	706	1740
Nez Perce	2139	–	4577	1704	1791	1220	1865	1767	1965
Twin Falls	1929	2288	4478	1041	1516	1023	4470	3412	1170
Othello	1811	2475	3751	1766	1601	–	2390	1794	1485
Centennial	–	–	4454	923	1793	968	2268	1266	1575
LSD ($P \leq 0.05$)	381	590	840	890	ns	ns	946	552	352

† PP = purgatory plot characterized by drought stress and nutrient deficiency; N = nitrogen; NS = nonstress; DS = drought stress; and CBC = continual bean cropping conditions for the past 66 yr.

Area of Adaptation

Blackfoot, Nez Perce, and Twin Falls were developed with differing harvest maturity for common bean production regions of southern Idaho and the western United States. Because they possess resistance to rust imparted by the *Ur-3* gene, their adaptation zone may expand to the more humid and relatively warmer bean growing environments in the High Plains and the central regions of the United States and southern Canada, where that resistance is still effective against the pathogen.

Availability

Breeder and foundation seed of Blackfoot, Nez Perce, and Twin Falls will be maintained by the Idaho Foundation Seed Program under the direction of the Idaho Agricultural Experiment Station, University of Idaho, Moscow, ID 83844. Requests for seed can be made by emailing the Foundation Seed Program (seed@uidaho.edu). Seeds of the three cultivars have also been deposited with the National Plant Germplasm System, Fort Collins, CO, where they will be available 5 yr after registration and publication of this article. If Blackfoot, Nez Perce, and Twin Falls are used for research or contribute to germplasm enhancement and/or cultivar development, appropriate acknowledgment of the researchers and institutions responsible for their development is requested.

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References

Bello, M.H., S.M. Moghaddam, M. Massoudi, P. McClean, P.B. Cregan, and P.N. Miklas. 2014. Application of in silico bulked segregant analysis for rapid development of markers linked to *Bean common mosaic virus* resistance in common bean. BMC Genomics 15:903. doi:10.1186/1471-2164-15-903

Burke, D.W., M.J. Silbernagel, J.M. Kraft, and H.H. Koehler. 1995. Registration of Othello pinto bean. Crop Sci. 35:943.

Coyne, D.P., D.S. Nuland, D.T. Lindgren, and J.R. Steadman. 1994. 'Chase' pinto dry bean. HortScience 29:44–45.

Dean, L.L. 2000. History of bean research and development. In: S.P. Singh, editor, Common bean research, production, and utilization. Univ. of Idaho, Moscow, ID. p. 3–11.

Drijfhout, E., M.J. Silbernagel, and D.W. Burke. 1978. Differentiation of strains of bean common mosaic virus. Neth. J. Plant Pathol. 84:13–26. doi:10.1007/BF01978099

Hart, J.P., and P.D. Griffiths. 2013. A series of eIF4E alleles at the *Bc-3* locus are associated with recessive resistance to *Clover yellow vein virus* in common bean. Theor. Appl. Genet. 126:2849–2863. doi:10.1007/s00122-013-2176-8

Kelly, J.D. 2001. Remaking bean plant architecture for efficient production. Adv. Agron. 71:109–143. doi:10.1016/S0065-2113(01)71013-9

Kelly, J.D., W. Mkwaila, G.V. Varner, K.A. Cichy, and E.M. Wright. 2012. Registration of 'Eldorado' pinto bean. J. Plant Reg. 6:233–237. doi:10.3198/jpr2012.02.0140crc

Miklas, P.N., D.P. Coyne, K.F. Grafton, N. Mutlu, J. Reiser, D. Lindgren, and S.P. Singh. 2003a. A major QTL for common bacterial blight resistance derives from the common bean great northern landrace cultivar Montana No. 5. Euphytica 131:137–146. doi:10.1023/A:1023064814531

Miklas, P.N., J.D. Kelly, and S.P. Singh. 2003b. Registration of anthracnose-resistant pinto bean germplasm line USPT-ANT-1. Crop Sci. 43:1889–1890. doi:10.2135/cropsci2003.1889

Miklas, P.N., R.C. Larsen, R. Riley, and J.D. Kelly. 2000. Potential marker-assisted selection for *bc-1*^{2} resistance to bean common mosaic potyvirus in common bean. Euphytica 116:211–219. doi:10.1023/A:1004006514814

Miklas, P.N., L.D. Porter, J.D. Kelly, and J.M. Myers. 2013. Characterization of white mold disease avoidance in common bean. Eur. J. Plant Pathol. 135:525–543. doi:10.1007/s10658-012-0153-8

Miklas, P.N., J.R. Smith, K.F. Grafton, D.P. Coyne, and M.A. Brick. 2001. Release of pinto and great northern bean germplasm lines USPT-CBB-1, USPT-CBB-2, USPT-CBB-3, and USGN-CBB-4 with erectness and resistance to common bacterial blight, rust, and mosaic. Annu. Rep. Bean Improv. Coop. 44:183–185.

Osorno, J., K.F. Grafton, G.A. Rojas-Cifuentes, R. Gelin, and A.J. Vander Wal. 2010. Release of 'Lariat' and 'Stampede' pinto beans. J. Plant Reg. 4:5–11. doi:10.3198/jpr2009.03.0143crc

Pedraza, F., G. Gallego, S.E. Beebe, and J. Tohme. 1997. Marcadores SCAR y RAPD para la resistencia a la bacteriosis común (CBB). In: S.P. Singh and O. Voysest, editors, Taller de mejoramiento de frijol para el Siglo XXI: Bases para una estrategia para América Latina. CIAT, Cali, Colombia. p. 130–134.

SAS Institute. 2004. SAS user's guide: Statistics. SAS Inst., Cary, NC.

Seo, Y.-S., J.-S. Jeon, M.R. Rojas, and R.L. Gilbertson. 2007. Characterization of a novel Toll/interleukin-1 receptor (TIR)-TIR gene differentially expressed in common bean (*Phaseolus vulgaris* cv. Othello) undergoing a defence response to the geminivirus *Bean dwarf mosaic virus*. Mol. Plant Pathol. 8:151–162. doi:10.1111/j.1364-3703.2007.00379.x

Singh, S.P. 1982. A key for identification of different growth habits of *Phaseolus vulgaris* L. Annu. Rep. Bean Improv. Coop. 25:92–95.

Singh, S.P. 2003. Early maturity among common bean landraces of the western United States. Annu. Rep. Bean Improv. Coop. 46:229–230.

Singh, S.P., P. Gepts, and D.G. Debouck. 1991. Races of common bean (*Phaseolus vulgaris*, Fabaceae). Econ. Bot. 45:379–396. doi:10.1007/BF02887079

Singh, S.P., H. Terán, M. Lema, M.F. Dennis, R. Hayes, and C. Robinson. 2008. Breeding for slow darkening high yielding broadly adapted dry bean pinto 'Kimberly' and 'Shoshone'. J. Plant Reg. 2:180–186. doi:10.3198/jpr2007.12.0708crc

Singh, S.P., H. Terán, M. Lema, D.M. Webster, C.A. Strausbaugh, P.N. Miklas, H.F. Schwartz, and M.A. Brick. 2007. Seventy-five years of breeding dry bean of the western USA. Crop Sci. 47:981–989. doi:10.2135/cropsci2006.05.0322

Terán, H., M. Lema, D. Webster, and S.P. Singh. 2009. 75 years of breeding pinto bean for resistance to diseases in the United States. Euphytica 167:341–351. doi:10.1007/s10681-009-9892-9

USDA National Agricultural Statistics Service. 2015. Idaho annual statistical bulletin. USDA National Agricultural Statistics Service, Northwest Regional Field Office. Boise, ID.

Westermann, D.T., H. Terán, C.G. Muñoz-Perea, and S.P. Singh. 2011. Nutrient uptake and utilization by common bean landraces and cultivars in seven stressed and non-stressed organic and conventional production systems. Can. J. Plant Sci. 91:1089–1099. doi:10.4141/cjps10114

White, J.W., and S.P. Singh. 1991. Sources and inheritance of earliness in tropically adapted indeterminate common bean. Euphytica 55:15–19. doi:10.1007/BF00022554

White, J.W., S.P. Singh, C. Pino, M.J. Ríos, and I. Buddenhagen. 1992. Effect of seed size and photoperiod response on crop growth and yield of common bean. Field Crops Res. 28:295–307. doi:10.1016/0378-4290(92)90015-2