CROP BREEDING AND APPLIED BIOTECHNOLOGY

CULTIVAR RELEASE

BRS FP403: high-yielding black-seeded common bean cultivar with superior grain quality and moderate resistance to fusarium wilt

Crop Breeding and Applied Biotechnology
19: 240-244, 2019
Brazilian Society of Plant Breeding.
Printed in Brazil
http://dx.doi.org/10.1590/1984-70332019v19n2c34

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Abstract: *BRS FP403 is a common bean cultivar from the black bean market class with high grain yield and yield potential, high commercial and cooking quality, and moderate resistance to fusarium wilt (Fusarium oxysporum f. sp. phaseoli) and root rot diseases (Fusarium solani f. sp. phaseoli and Rhizoctonia solani).*

Keywords: *Phaseolus vulgaris, plant breeding, disease resistance, yield potential.*

INTRODUCTION

According to Faria et al. (2014), the mean gains in grain yield obtained by the Embrapa (*Empresa Brasileira de Pesquisa Agropecuária*) common bean breeding program is around 1.1% for the black bean market class. Recommendations for regions and for growing season-specific cultivars have been a challenge, due to low use of certified seed. This low use of certified seed leads to low seed demand and, consequently, a low level of production, which has failed to generate a satisfactory income for the seed industry (Melo et al. 2017). For that reason, a strategy commonly used for developing new common bean cultivars is to select superior elite genotypes with broad adaptation and yield stability (Pereira et al. 2013, Melo et al. 2017).

Special attention should be given to meeting the distinct requirements of common bean market classes Brazil. Approximately 20% of beans consumed by Brazilians come from the black bean class, and consumption is highest in the states of Rio de Janeiro, Espírito Santo, Paraná, Santa Catarina, and Rio Grande do Sul (Pereira et al. 2012). With the aim of developing new cultivars to meet this demand, Embrapa has established diverse cooperative agreements with the main common bean breeding programs in Brazil and the world. These partnerships provide a wide network for improvement of the common bean crop in Brazil, generating technical benefits for Brazilian growers and food security for consumers.

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Received: 18 December 2018
Accepted: 12 February 2019

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BREEDING METHODS

The black-seeded common bean cultivar BRS FP403 was derived from a multiple cross involving five parents (POT 51, ICA PIJAO, XAN 170, BAC 16 and XAN 91), carried out in 1993 at the International Center for Tropical Agriculture (CIAT – *Centro Internacional de Agricultura Tropical*, Cali, Colombia). In 1994, the F_1 generation resulting from this cross was sown in the field. In 1995, the F_2 generation was advanced, with selection of individual plants for upright plant architecture and rust resistance. In 1996, progenies from the $F_{2:3}$ generation were also grown in the field as single rows and evaluated for upright plant architecture and resistance to anthracnose and rust. The superior $F_{2:3}$ progenies were selected, harvested in bulk, and sent to *Embrapa Arroz e Feijão* (Santo Antônio de Goiás, GO, Brazil). In 1997, the $F_{2:3}$ progenies were grown in the field in the winter growing season in Santo Antonio de Goiás and evaluated and selected for upright plant architecture and resistance to common bacterial blight. Superior progenies were harvested in bulk and then evaluated for commercial grain quality. Selected progenies were evaluated in the field again in the $F_{2:5}$ generation during the 1998 winter growing season in Santo Antonio de Goiás, and in the high-performing progenies, individual plants were selected for upright architecture and grain yield. As of this breeding stage, the selected $F_{2:5:6}$ progenies were considered as lines. In 1999, also in Santo Antônio de Goiás, during the winter growing season, these lines were evaluated and selected once more for upright plant architecture and grain yield. In the dry growing season of 2000 in Ponta Grossa (PR, Brazil), the lines were also evaluated and selected for upright plant architecture, grain yield, and resistance to anthracnose, rust, and common bacterial blight. During the next three winter growing seasons (in 2000, 2001, and 2002) in Santo Antônio de Goiás, the lines were also evaluated and selected for upright plant architecture and grain yield. After all these evaluation cycles, the superior line CNFP 10794 was selected.

After this stage, CNFP 10794 was evaluated in field trials with replicates for grain yield and other important traits, e.g., disease resistance and plant architecture. In 2003, CNFP 10794 was evaluated together with 59 other common bean elite lines and four control cultivars (Diamante Negro, FTS Soberano, BRS Valente, and BRS Campeiro) in preliminary field trials with a randomized block design, three replicates, and plots consisting of two 4.0-m rows. These trials were conducted in four environments: Santo Antônio de Goiás in the winter growing season; Ponta Grossa in the rainy and dry growing seasons; and Lavras (MG, Brazil) in the winter growing season.

In 2005, CNFP 10794 was evaluated in the intermediate field trials with 17 other elite lines and five control cultivars (BRS Valente, BRS Grafite, IPR Uirapuru, Diamante Negro, and FTS Soberano) in a randomized block design with three replicates and plots of four 4.0-m rows, in six environments: Santo Antônio de Goiás in the winter growing season, Ponta Grossa in the rainy and dry growing seasons, Lavras in the dry growing season, Uberlândia (MG, Brazil) in the winter growing season, and Passo Fundo (RS, Brazil) in the rainy growing season. The combined analysis of data for grain yield and other important agronomic traits (plant architecture, lodging resistance, and disease resistance/tolerance) qualified the common bean elite line CNFP 10794 for advancement to the final field trials, the Value for Cultivation and Use Trials (VCU Trials).

In 2006, seeds of CNFP 10794 were multiplied to support the VCU trials. All final field trials were carried out in a randomized block design with three replicates and four 4.0-m rows, using the growing techniques recommended for the different environments and cropping systems. The two middle rows of each plot were harvested and the grain was evaluated for yield, percentage of commercial grain (sieve yield), 100 seed weight, cooking time, and protein content.

In 2007, 2008, 2010, 2011, 2012, 2013, 2014, and 2015, the common bean elite line CNFP 10794 was evaluated in 215 VCU trials in different growing regions (Pereira et al. 2009) and along with different control cultivars. In Region I (states of RS, SC, PR, MS, and SP) and Region II (states of ES, RJ, GO/DF, MG, MT, TO, BA, and MA), the control cultivars were BRS Esteio, BRS Supremo, BRS Campeiro, and IPR Uirapuru, and in Region III (states of SE, AL, PE, PB, CE, RN, and PI), the control cultivars were BRS Esteio, BRS Supremo, and IPR Uirapuru.

Grain yield was corrected to 13% moisture and measured in kg ha^{-1}. Sieve yield was determined in grain samples of 300 g per plot using sieves with oblong holes (4.25 mm width), according to Melo et al. (2017). From the seeds retained in the sieve, a new 100 seed sample was taken to determine 100 seed weight. In the final field trials, samples were taken from each plot with best results (highest mean yield and lowest coefficient of variation) to analyze cooking time and protein content. Analysis of cooking time were accomplished as described by Melo et al. (2017), according to the

methodology adapted from Proctor and Watts (1987). The protein content was analyzed in bean meal (beans ground in a ball mill), according to the micro-Kjeldahl method.

In addition, the following agronomic traits were evaluated: lodging resistance, plant architecture, and resistance to diseases (common bacterial blight, bacterial wilt, angular leaf spot, anthracnose, rust, fusarium wilt, root rot diseases, *Bean common mosaic virus* and *Bean golden mosaic virus*). For evaluations of all these traits, rating scales were used as described by Melo (2009), ranging from 1 (best performance) to 9 (worst performance).

GRAIN YIELD AND YIELD POTENTIAL

In 215 VCU Trials carried out in 2007, 2008, 2010, 2011, 2012, 2013, 2014, and 2015 in the rainy growing season in Sergipe, Alagoas, Pernambuco, and Bahia; in the winter growing season in Tocantins and Rio de Janeiro; in the rainy and dry growing seasons in Espírito Santo, Mato Grosso do Sul, Rio Grande do Sul, Santa Catarina, and Paraná; and in the rainy, dry, and winter growing seasons in Goiás/Distrito Federal, Mato Grosso, and São Paulo, the cultivar BRS FP403 (CNFP 10794) had a 12.3% higher grain yield than the mean of the four control cultivars (BRS Esteio, BRS Supremo, BRS Campeiro, and IPR Uirapuru). The mean superiority of the relative performance of BRS FP403 in the three main cultivar recommendation regions for common bean (Pereira et al. 2009) was 14.4% in 85 environments of Region I, 10.6% in 107 environments of Region II, and 12.6% in 23 environments of Region III (Table 1).

The yield potential of BRS FP403, estimated from the mean of the five best yield test results of this cultivar, was 4724 kg ha^{-1}. The overall mean yield of BRS FP403 was 2483 kg ha^{-1}, compared to 2245 kg ha^{-1} for the control cultivars. BRS FP403 exceeded the yield of the control cultivars by 16.5% and 11.5% in the rainy and dry growing seasons, respectively, in Region 1 for official recommendation of common bean cultivars. In Region 2, BRS FP403 achieved a 6.7% higher overall mean yield and up to a 15.5% higher mean yield in the dry season. In Region 3, the superiority was 12.6% in the rainy growing season. This indicates that BRS FP403 is a broadly adapted cultivar that can be grown advantageously in the main common bean Brazilian producing areas (Table 1).

Based on its agronomic performance, BRS FP403 was registered as suitable for growing in the rainy, dry, and winter growing seasons in the states of Mato Grosso, Goiás/Distrito Federal, Minas Gerais, Bahia, Espírito Santo, and Rio de Janeiro; in the rainy and dry seasons in Mato Grosso do Sul, Paraná, Santa Catarina, Rio Grande do Sul, and São Paulo; in the winter season in Tocantins; and in the rainy season in Maranhão, Sergipe, Alagoas, Pernambuco, Rio Grande do Norte, Piauí, Ceará, and Paraíba.

ADDITIONAL IMPORTANT AGRONOMIC TRAITS

Regarding grain quality traits, BRS FP403 exhibited large grain size, regular and standard cooking time, and good protein content and sieve yield (Table 2). In final field trials without fungicide application, BRS FP403 achieved 81% sieve yield, and the mean 100 seed weight was 26 g, higher than that of the control cultivars BRS Esteio (23 g) and BRS

Table 1. Mean grain yield of the common bean cultivar BRS FP403 compared to the mean of the control cultivars in final field trials conducted in different Brazilian growing regions from 2007 to 2015

Growing region	Growing season	BRS FP403 (kg ha^{-1})	Mean yield of control cultivars (kg ha^{-1})	Mean of the relative yield (%)	Number of environments
I[a]	Rainy	2784 a[d]	2468 b	116.5	50
	Dry	2339 a	2128 b	111.5	35
	Overall	2601 a	2328 b	114.4	85
II[b]	Rainy	2285 a	2175 a	106.7	36
	Dry	1893 a	1672 b	115.5	20
	Winter	2595 a	2339 b	111.5	51
	Overall	2360 a	2159 b	110.6	107
III[c]	Rainy	2621 a	2344 b	112.6	23
Overall	–	2483 a	2245 b	112.3	215

[a] Region I: RS, SC, PR, MS, and SP; control cultivars: BRS Esteio, BRS Supremo, BRS Campeiro, and IPR Uirapuru. [b] Region II: ES, RJ, GO/DF, MG, MT, TO, BA, and MA; control cultivars: BRS Esteio, BRS Supremo, BRS Campeiro, and IPR Uirapuru. [c] Region III: SE, AL, PE, PB, CE, RN, and PI; control cultivars: BRS Esteio, BRS Supremo, and IPR Uirapuru. [d] Means followed by the same letter in the table lines are not significantly different according to the Scott–Knott method at 10% probability.

Esplendor (21 g), indicating the high commercial value of the grain. For that reason, it is expected that BRS FP403 will have grain quality parameters higher than those observed in the present study when grown in commercial fields with disease control through fungicide application. The mean cooking time of BRS FP403 was 32.5 min., similar to that of BRS Esteio (32.0 min.) and lower than that of BRS Esplendor (35.5 min.). The mean grain protein content of BRS FP403 (22.0%) was practically identical to that of the control cultivar BRS Esplendor (22.1%) and higher than that of BRS Esteio (20.3%) (Table 2).

Based on screening through artificial inoculation, BRS FP403 is resistant to BCMV. In field trials, it showed moderate resistant to rust, fusarium wilt, and root rot diseases. However, it was susceptible to anthracnose, angular leaf spot, common bacterial blight, bacterial wilt, and BGMV (Table 3).

BRS FP403 has plants with upright plant architecture and indeterminate growth habit (Type II), presenting a normal cycle (85-95 days from seedling emergence to physiological seed maturity) similar to that of BRS Esteio and BRS Esplendor (Table 3). This new Embrapa black-seeded common bean cultivar is moderately resistant to lodging and can be used for mechanical direct harvest.

Compared to BRS Esteio (Pereira et al. 2013), the most promising and modern black-seeded common bean cultivar released by Embrapa, BRS FP403 has higher grain yield and yield potential, resistance to fusarium wilt and root rot diseases, but the same commercial and bean cooking quality as BRS Esteio, with a larger bean grain size. For that reason, BRS FP403 is expected to be adopted as a new technical solution for common bean growers throughout Brazil, but especially in the South of Brazil, traditionally the predominant area for production of black beans. The introduction of BRS FP403 will also affect grower options for the winter growing season in Central Brazil since it is moderately resistant to fusarium wilt and root rot diseases. This new cultivar should allow growing of black-seeded beans under a center pivot irrigation system, which is very common in Central Brazil. When this type of irrigation system is intensively used without correct soil and crop management practices, it has limitations for growing the current black-seeded cultivars. These cultivars are susceptible to fusarium wilt and root rot diseases and, therefore, their yield is also greatly impaired in this situation.

BRS FP403 was registered as a new black-seeded common bean cultivar in the *Registro Nacional de Cultivares* – RNC (National Cultivar Registration Service) of the *Ministério da Agricultura, Pecuária e Abastecimento* – MAPA (Brazilian Ministry of Agriculture) on May 12, 2017, under number 36170. The cultivar protection process is proceeding in the *Serviço Nacional de Proteção de Cultivares* – SNPC (National Cultivar Protection Service), MAPA (Process No. 21806.000220/2016-11). Embrapa is in charge of basic seed production.

Table 2. Grain traits of the common bean cultivar BRS FP403 compared to the control cultivars BRS Esteio and BRS Esplendor in final field trials conducted in Brazil

Cultivar	**Cooking time** (minutes)	**Protein content** (%)	**100 seed weight** (g)[a]	**Sieve yield** (%)[a]
BRS FP403	32.5 a[b]	22.0 a	26 a	81 a
BRS Esteio	32.0 a	20.3 b	23 b	82 a
BRS Esplendor	35.5 b	22.1 a	21 b	66 b

[a] Estimates obtained in field trials without chemical control of diseases and using a sieve with mesh no. 11 (4.25 mm).

[b] Means followed by the same letter in the table columns are not significantly different according to the Scott–Knott method at 10% probability.

Table 3. Agronomic traits and disease resistance of the common bean cultivar BRS FP403 compared to the control cultivars BRS Esteio and BRS Esplendor in final field trials conducted in Brazil

Cultivar	**Crop cycle**[a]	**Plant architecture**	**Disease resistance**[b]								
			ANT	**CBB**	**RST**	**ALS**	**BCMV**	**BGMV**	**FWT**	**RRD**	**BWT**
BRS FP403	N	Upright	S	MS	MR	S	R	S	MR	MR	S
BRS Esteio	N	Upright	MR	S	MR	S	R	S	MS	MS	S
BRS Esplendor	N	Upright	MS	MR	MR	S	R	S	MR	S	S

[a] N – Normal cycle (85-95 days). [b] ANT – Anthracnose (*Colletotrichum lindemutianum*), CBB – Common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli* and *Xanthomonas fuscans* pv. *fuscans*), RST – Rust (*Uromyces appendiculatus*), ALS – Angular leaf spot (*Pseudocercospora griseola*), BCMV – *Bean common mosaic virus*, BGMV – *Bean golden mosaic virus*, FWT – Fusarium wilt (*Fusarium oxysporum* f. sp. *phaseoli*), RRD – Root rot diseases (*Fusarium solani* f. sp. *phaseoli* and *Rhizoctonia solani*), and BW – Bacterial wilt (*Curtobacterium flaccumfaciens* pv. *flaccumfaciens*); R – Resistant (score 1), MR – Moderately resistant (scores 2 and 3), MS – Moderately susceptible (scores 4 to 6), and S – Susceptible (scores 7 to 9).

CONCLUSIONS

The common bean cultivar BRS FP403 of the black bean class has a normal growing cycle (85-95 days), high grain yield and yield potential, high commercial and cooking quality, yield stability, and moderate resistance to fusarium wilt and root rot diseases. BRS FP403 is recommended for growing in the following states and growing seasons: rainy, dry, and winter seasons in the states of Mato Grosso, Goiás/Distrito Federal, Minas Gerais, Bahia, Espírito Santo, and Rio de Janeiro; rainy and dry seasons in Mato Grosso do Sul, Paraná, Santa Catarina, Rio Grande do Sul, and São Paulo; winter season in Tocantins; and rainy season in Maranhão, Sergipe, Alagoas, Pernambuco, Rio Grande do Norte, Piauí, Ceará, and Paraíba.

ACKNOWLEDGEMENTS

We are thankful to International Center for Tropical Agriculture (CIAT – *Centro Internacional de Agricultura Tropical*, Cali, Colombia) to provide the $F_{2:3}$ progeny bulks used in the development of the cv. BRS FP403. The following partner institutions contributed to the agronomic performance evaluation which results leading to the selection of the cv. BRS FP403: Embrapa Arroz e Feijão; Embrapa Cerrados; Embrapa Agropecuária Oeste; Embrapa Tabuleiros Costeiros; Embrapa Soja; Secretaria de Inovação e Negócios da Embrapa; Instituto Agronômico de Pernambucano (IPA); Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (Incaper); Agência Goiana de Assistência Técnica, Extensão Rural e Pesquisa Agropecuária (Emater–GO); Empresa Mato-Grossense de Pesquisa, Assistência e Extensão Rural (Empaer–MT); Empresa de Pesquisa Agropecuária do Estado do Rio de Janeiro (Pesagro); Fundação Estadual de Pesquisa Agropecuária (Fepagro–RS); Instituto Federal de Goiás (IFG, Urutaí–GO); Universidade Federal de Goiás (UFG, Goiânia–GO); Uni-Anhanguera; Universidade de Cruz Alta; Universidade Estadual Paulista; Universidade Federal do Mato Grosso do Sul; Universidade Estadual do Mato Grosso do Sul; Universidade Estadual do Centro-Oeste (Unicentro–PR); and Instituto Luterano de Ensino Superior (ILES/ULBRA, Itumbiara–GO). T.L.P.O.S., H.S.P., A.W., and L.C.M. are supported by the Brazilian Council for Scientific and Technological Development (CNPq – Conselho Nacional de Desenvolvimento Científico e Tecnológico).

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