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BRS FP426: A black common bean cultivar with excellent yield and commercial quality and high resistance to Fusarium wilt

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Abstract: BRS FP426 stood out for its high yield in the South-Central region (2,324 kg.ha^{-1}) and the excellent commercial quality of its grain (color, uniformity, 100-seed weight, and sieve yield). BRS FP426 has upright plant architecture and resistance to lodging; moreover, it has high resistance to Fusarium wilt, moderate resistance to anthracnose, and intermediate resistance to angular leaf spot.

Keywords: *Phaseolus vulgaris*, yield, *Fusarium* wilt, anthracnose, angular leaf spot.

Introduction

Common bean is recognized for its considerable economic and social importance, and it constitutes an important source of protein in the diet of the Brazilian population. Brazil has been among the world's largest producers and consumers of common bean, producing 2.3 million tons on 1.5 million hectares annually (Embrapa, 2024).

Around 20% of common bean consumed in Brazil is of the black bean type, with consumption varying according to the region and the Brazilian states. It is consumed in greater amount in the South region, in Rio de Janeiro, and in Espírito Santo (Pereira et al., 2021a). Brazil commonly imports black beans from other countries, such as Argentina and China, in years when domestic production is not able to supply the internal consumer market.

One of the strategies Embrapa has implemented over the past few years to decrease or end these imports is recommending new cultivars with high yield potential, greater disease resistance, and upright plant architecture so that farmers can achieve better yields with the crop.

In this regard, in recent years, Embrapa has released some black bean cultivars, such as BRS Esteio, which has high yield potential, high commercial grain quality (100-seed weight, appearance, and sieve yield), and moderate resistance to anthracnose (Pereira et al., 2013); BRS FP403, which has high yield and high commercial grain quality, with higher 100-seed weight in relation to BRS Esteio,

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and moderate resistance to Fusarium wilt and root rots (*Fusarium solani* f. sp. *phaseoli* and *Rhizoctonia. solani)* (Souza et al., 2019); and more recently, BRS FP417, which stands out for combining resistance to various diseases – excellent levels of resistance to anthracnose and to Fusarium wilt and intermediate resistance to common bacterial blight and to bacterial wilt (Aguiar et al., 2023). However, none of the cultivars cited above combine high resistance to Fusarium wilt with excellent yield for the South-Central region, the area with the largest production of black beans in Brazil.

For that reason, BRS FP426 was developed as a new cultivar that has high yield, excellent commercial grain quality (color, uniformity, 100-seed weight, and sieve yield), upright architecture, and high resistance to lodging. Additionally, the cultivar stands out for its high resistance to Fusarium wilt, moderate resistance to anthracnose, and intermediate resistance to angular leaf spot. This cultivar should help reduce the use of agricultural pesticides and, consequently, decrease impact on the environment and on human health, contributing to increase the sustainability of agricultural production.

Breeding methods used

CNFP 19248 arose from a cross between the cultivars BRS Esplendor and BRS Expedito, carried out at Embrapa Arroz e Feijão (Embrapa Rice and Bean) in Santo Antônio de Goiás, GO, in 2010. That cross was part of a block of crosses organized in a complete diallel arrangement among eight black bean lines/cultivars with different levels of resistance to Fusarium wilt, resulting in 28 populations. In the same year, the F_1 generation of these populations was sown in a screened enclosure. In 2011, in the winter crop season, the populations in the F_2 generation were sown in the field in Santo Antônio de Goiás, GO, and harvested in bulk.

The F_3, F_4, and F_5 generations of this population were evaluated together with the other 27 populations in experiments with replications in 2012, 2013, and 2014, always in an area highly infested with *Fusarium oxysporum* f. sp. *phaseoli*, the causal agent of Fusarium wilt, in Santo Antônio de Goiás. The experiments were conducted in a randomized block design with three replications and plots consisting of two 4-m rows. Reaction to Fusarium wilt, 100-seed weight, and grain yield were evaluated. A sample of each population was used to advance generations and to set up the next experiment, up to the F_5 generation.

After evaluation of the F_5 generation, individual and combined analyses of variance were carried out, allowing selection of the populations BRS Esplendor/BRS Expedito and BRS Expedito/CNFP15867. At the same time, 58 individual plants from each population were harvested and stored in the F_5 generation, which gave rise to the lines, including CNFP 19248.

The CNFP 19248 line was evaluated in a line-testing experiment for resistance to Fusarium wilt in black bean composed of 121 treatments: 116 lines and five check cultivars (BRS FP403, BRS Esplendor, and BRS Expedito, resistant to Fusarium wilt; and BRS Esteio and BRS Supremo, susceptible). An 11 × 11 triple lattice design was used, with plots of two 3-m rows. The experiments were carried out over two years (2015 and 2016) in the same pathogen-infested area in the winter crop season. In these experiments, it was possible to evaluate reaction to Fusarium wilt, yield, and 100-seed weight. Combined analysis of these data led to selection of the CNFP 19248 line for participation in the advanced experiment.

In 2017 and 2018, the CNFP 19248 line was evaluated in the advanced experiment for resistance to Fusarium wilt in black beans; this experiment consisted

of 35 treatments: 31 lines and four check cultivars (BRS FP403, BRS Esplendor, BRS Esteio, and BRS Supremo). A randomized block experimental design was used, with three replications and plots of three 3-m rows. The trials were conducted in seven environments: Santo Antônio de Goiás, GO, in the 2017 winter season, in two areas, one of which was infested with the pathogen; Tangará da Serra, MT, and Brasília, DF, in the 2017 winter season; Ponta Grossa, PR, in the 2017 rainy season and 2018 dry season; and Paripiranga, BA, in the 2017 rainy season. In these experiments, it was possible to evaluate reaction to diseases (Fusarium wilt, anthracnose, angular leaf spot, common bacterial blight, and bacterial wilt), growth cycle, plant architecture, resistance to lodging, yield, 100-seed weight, and grain appearance.

Combined analysis of the data of the experiments of line-testing and advanced testing for resistance to Fusarium wilt in black beans led to selection of the line CNFP 19248 for the Value for Cultivation and Use (VCU) experiment, based on evaluation of nine environments. In 2019, in the winter crop season in Santo Antônio de Goiás, GO, plants were multiplied to obtain enough seeds to prepare the VCU experiments.

In 2020 and 2021, the CNFP 19248 line was evaluated in 42 experiments consisting of 14 treatments: 11 lines with black grain and normal cycle, and three check cultivars: BRS Esteio, BRS FP403, and IPR Uirapuru. A randomized block experimental design was used with three replications and plots of four 4-m rows, using the technologies recommended for the different environments and crop systems.

In these experiments, it was possible to evaluate the following grain-related aspects: yield, sieve yield (sieve 11 – 4.25 mm), 100-seed weight, color, uniformity, shape, cooking time, and concentrations of iron, zinc, and protein. Additionally, evaluations were conducted using a scoring scale ranging from 1 (completely favorable phenotype) to 9 (completely unfavorable phenotype) (Melo, 2009) for plant architecture, resistance to lodging, and reaction to the following diseases: common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli*), bacterial wilt (Curtobacterium flaccumfaciens pv. *flaccumfaciens*), angular leaf spot (*Pseudocercospora griseola*), anthracnose (*Colletotrichum lindemutianum*), rust (*Uromyces appendiculatus*), Fusarium wilt (*Fusarium oxysporum* f. sp. *phaseoli*), bean common mosaic virus (BCMV) and bean golden mosaic virus (BGMV).

Grain yield was adjusted to 13% moisture and expressed in kg ha^{-1}. Sieve yield was determined by removing a 300-g sample from each plot, which was then passed through a sieve with oblong openings of 4.25 mm thickness. The seeds retained on the sieve were weighed and divided by the initial weight of the sample. From the seeds retained on the sieve, a new 100-seed sample was taken for weighing to determine 100-seed weight. A Mattson cooker was used to determine cooking time. Protein concentration was analyzed by determining nitrogen content using the micro-Kjeldahl method. Iron and zinc concentrations were analyzed through acid digestion of organic matter using the flame atomic absorption spectrophotometry technique.

Of the 42 experiments set up, 38 were harvested and met the standards of experimental quality necessary to be considered in the cultivar registration process in relation to yield data. These 38 VCU experiments were conducted in Region I (Santa Catarina, Paraná, São Paulo, and Mato Grosso do Sul) in the rainy and dry crop seasons, and in Region II (Goiás, Distrito Federal, Mato Grosso, Espírito Santo, and Minas Gerais) in the rainy, dry, and winter crop seasons.

Grain yield and yield potential

The BRS FP426 cultivar had mean yield of 2,501 kg.ha^{-1}, which was 3.3%, 3.8%, and 7.2% higher than the yields of BRS Esteio, BRS FP403, and IPR Uirapuru, respectively (Table 1).

Table 1. Grain yield (kg ha^{-1}) of the BRS FP426 cultivar compared to the mean of the three check cultivars (BRS Esteio, BRS FP403, and IPR Uirapuru) in the Value for Cultivation and Use (VCU) experiments, according to regions for recommendation of cultivars and crop seasons in 2020 and 2021.

Region	Season	BRS FP426	BRS Esteio	BRS FP403	IPR Uirapuru	Number of environments
I	Rainy	2,986 a	2,363 b	2,498 b	2,483 b	8
	Dry	1,843 a	1,982 a	1,866 a	1,730 a	11
	Mean	2,324 a	2,142 b	2,132 b	2,047 b	19
II	Rainy	3,036 a	2,577 b	2,809 a	2,636 b	6
	Dry	2,612 a	2,664 a	2,569 a	2,672 a	5
	Winter	2,449 b	2,820 a	2,664 b	2,577 b	8
	Mean	2,677 a	2,702 a	2,685 a	2,620 a	19
Overall mean	**-**	**2,501 a**	**2,422 b**	**2,408 b**	**2,334 c**	**38**

Region I - SC, PR, and SP; Region II – MG, ES, GO, DF, MT, and RJ; Region III – SE and AL. Mean values followed by the same letter in the rows do not differ statistically from each other according to the Scott-Knott test at 5% probability.

In Region I (South-Central), the mean yield was 2,324 kg.ha^{-1}, exceeding the mean of the check cultivars by 8.5% (BRS Esteio), 9.0% (BRS FP403), and 13.5% (IPR Uirapuru). In Region II (Central), mean yield was 2,677 kg.ha^{-1}, similar to that of the three check cultivars.

The maximum productivity in VCU experiments, obtained from the average of the four VCU experiments in which this cultivar presented the highest yield, was 4,190 kg ha-1. This estimate shows that the cultivar has high genetic potential and that if the environment is favorable and there are good growing conditions, even higher yields can be achieved, since there is no disease control in VCU experiments. The expected average yield in a crop with a good technological level and good environmental conditions of BRS FP426 is 5,200 kg ha-1. The productive potential, in optimal conditions, is 6,700 kg ha-1.

Grain quality

In relation to technological and industrial quality traits of the grain, the BRS FP426 cultivar has high no. 11 sieve yield (82%), similar to that of the BRS Esteio and BRS FP403 cultivars and higher than that of IPR Uirapuru (Table 2).

Table 2. Traits of grain from the BRS FP426 cultivar compared to the check cultivars BRS Esteio, BRS FP403, and IPR Uirapuru.

Cultivar	CT (minutes)	PC (%)	FeC (mg kg^{1})	ZnC (mg kg^{1})	SY(%)	100SW(g)
BRS FP426	32 a	22 a	48 a	33 a	82 a	27 a
BRS Esteio	33 a	21 a	51 a	31 a	85 a	23 c
BRS FP403	31 a	23 a	52 a	33 a	85 a	25 b
IPR Uirapuru	30 a	20 a	49 a	30 a	78 b	22 d

CT – cooking time; PC – protein concentration; FeC – iron concentration; ZnC – zinc concentration; SY – sieve yield (sieve 11 - 4.25 mm); 100SW – 100-seed weight. Mean values followed by the same letter in the rows do not differ statistically from each other according to the Scott-Knott test at 5% probability.

BRS FP426 had a mean 100-seed weight of 27 grams, higher than that of the check cultivars, including BRS FP403, which has the highest 100-seed weight among the cultivars available on the market. Its bean grain is black, matte, from circular

to elliptical shape, and of medium thickness. In relation to grain appearance, BRS FP426 had uniform black grain without purpling. Mean cooking time of BRS FP426 was 32 minutes, similar to that of the check cultivars. In relation to protein percentage, and grain iron and zinc concentration, BRS FP426 was also similar to the check cultivars.

Other traits

BRS FP426 had a normal growth cycle (from 85 to 94 days from emergence to physiological maturity), similar to that of the check cultivars. The plants are bush type, with an indeterminate type II growth habit. In relation to plant architecture, BRS FP426 is upright and has resistance to lodging and is thus adapted to mechanical harvest, including direct harvest. The flowers are purple, and at physiological maturity and at harvest, the pods are yellowish, with purple specks (Table 3).

In field experiments, BRS FP426 proved to be resistant to bean common mosaic virus and to Fusarium wilt. It was in fact more resistant than BRS FP403 and BRS FP417, which are considered standards of resistance to Fusarium wilt. Moreover, BRS FP426 had moderate resistance to rust and anthracnose and intermediate resistance to angular leaf spot, which is noteworthy, as most black bean cultivars are susceptible to angular leaf spot. However, BRS FP426 proved to be susceptible to bean golden mosaic virus, bacterial wilt, and common bacterial blight. In general, BRS FP426 stood out for its high resistance to fungal leaf diseases.

Table 3. Agronomic traits and reaction to diseases of the BRS FP426 cultivar compared to the check cultivars BRS Esteio, BRS FP403, and IPR Uirapuru.

Cultivar	Cycle	ARCH	LOD	AN	CBB	RU	ALS	BCMV	BGMV	FUS	BW	RR
BRS FP426	N	Upright	R	MR	S	MR	I	R	S	R	S	-
BRS Esteio	N	Semi-upr.	MR	MR	S	MR	S	R	S	S	S	MR
BRS FP403	N	Upright	R	S	S	MR	S	R	S	MR	S	R
IPR Uirapuru	N	Upright	R	S	S	MR	S	R	S	S	SS	S

N – normal cycle; ARCH – plant architecture; LOD – lodging; AN – anthracnose; CBB – common bacterial blight; RU – rust; ALS – angular leaf spot; BCMV – bean common mosaic virus; BGMV – bean golden mosaic virus; FUS – Fusarium wilt; BW – bacterial wilt; RR – root rots; R – resistant; MR – moderately resistant; I – intermediate; S – susceptible.

Seed production

BRS ELO FC426 was registered on 20 May 2024 under number 59974 in the Brazilian Ministry of Agriculture (Ministério da Agricultura, Pecuária e Abastecimento – MAPA) for growing in the rainy and dry season in Region I (Mato Grosso do Sul, Paraná, Santa Catarina, São Paulo, and Rio Grande do Sul) and in the rainy, dry, and winter seasons in Region II (Minas Gerais, Goiás, Distrito Federal, Mato Grosso, Tocantins, Maranhão, Bahia, Espírito Santo, and Rio de Janeiro). Cultivar protection was applied for in MAPA.

Production of basic seeds to make available to seed producers will be under the responsibility of Embrapa and of partners selected through public notices for technical cooperation. Additional information can be found on the Embrapa website through the link: *https://www.embrapa.br/busca-de-solucoes-tecnologicas*.

Conclusion

BRS FP426 stood out for its high yield, especially in the South-Central region (Region I), which is the region that most produces black beans. It has excellent commercial grain quality (color, uniformity, 100-seed weight, and sieve yield), upright plant architecture, and high resistance to lodging. It also stands out

for its high resistance to Fusarium wilt, moderate resistance to anthracnose, and intermediate resistance to angular leaf spot.

Based on its performance, BRS FP426 was registered for the rainy and dry seasons in Region I (Mato Grosso do Sul, Paraná, Santa Catarina, São Paulo, and Rio Grande do Sul) and rainy, dry, and winter seasons in Region II (Minas Gerais, Goiás, Distrito Federal, Mato Grosso, Tocantins, Maranhão, Bahia, Espírito Santo, Rio de Janeiro).

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