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BRS FP327: Early black common bean cultivar with high yield and upright plant architecture

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Abstract: BRS FP327 is a black common bean cultivar known for its high yield, particularly in the Central-South region, excellent commercial grain quality, erect plant architecture, and lodging resistance. Additional highlights include resistance to anthracnose and fusarium wilt and intermediate resistance to root rot.

Keywords: *Phaseolus vulgaris*, erect growth habit, short cycle.

Introduction

Brazil stands out as the world's largest producer and consumer of common beans, with an estimated per capita consumption of 17 kg per year (Silva, 2019). Due to its short growth cycle, common beans can be cultivated in three distinct growing seasons in Brazil, ensuring a steady supply to the national market (CONAB, 2024). There is demand for various commercial groups of common beans, including *carioca*, black, striped, purple, pink, *mulatinho*, and *jalo* beans (Vieira et al., 2006). These groups are visually distinguishable by seed coat color, the presence or absence of stripes, and grain size. The preferred bean type varies across Brazilian regions, a factor that should be considered in any analysis of the crop (Souza and Wander, 2014). Nationwide, consumer preference primarily favors the *carioca* and black groups, which account for 70% and 15% of Brazil's production, respectively. Consequently, breeding programs in Brazil focus their efforts on these two bean types (Pereira et al., 2019).

In recent years, Embrapa has released several black bean cultivars with standard growth cycles, e.g., BRS Esteio, one of the most widely planted black bean cultivars in the

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last decade (Pereira et al., 2013), and BRS FP403, known for its high yield and new large-grain standard (Souza et al., 2019). However, with regard to early-cycle black bean cultivars, Embrapa's last release was BRS Campeiro, introduced 20 years ago (Carneiro et al., 2004). The demand for early-cycle black bean cultivars continues to grow, particularly in southern Brazil, where second season crops in cold-climate regions require early maturation to avoid losses due to frost during the pod-filling stage (R8).

In response to this demand, Embrapa developed BRS FP327, a new early-cycle black bean cultivar characterized by high yield, excellent commercial grain quality, and upright plant architecture with high resistance to lodging. BRS FP327 also offers resistance to anthracnose and fusarium wilt, along with intermediate resistance to root rot diseases.

Breeding methods employed

Line CNFP 17466 originated from a double cross between the F_1 generations of crosses between lines LM203200683/LM203200702 and LM203200692/LM203200702, conducted at Embrapa Rice and Beans (Embrapa Arroz e Feijão) in Santo Antônio de Goiás (GO, Brazil) in 2006. Also in 2006, the F_1 generation of the population was sown in a screened environment. In 2007, during the rainy season, the F_2 generation population was sown in the field in Ponta Grossa (PR, Brazil) and bulk harvested. Selection focused on early maturity, disease resistance (anthracnose and common bacterial blight), plant architecture, lodging resistance, seed color, size, and yield. In 2008, the F_3 generation was evaluated and bulk harvested in Santo Antônio de Goiás (GO, Brazil) with selection criteria including early maturity, plant architecture, lodging resistance, color, size, and yield.

During the rainy season of 2009, the F_4 generation was sown in Ponta Grossa (PR, Brazil) and bulk harvested, with selections based on early maturity, disease resistance (anthracnose and common bacterial blight), plant architecture, lodging resistance, color, size, and yield. In 2010, the F_5 generation was evaluated in Santo Antônio de Goiás (GO, Brazil) with individual plants selected for early maturity, plant architecture, lodging resistance, color, size, and yield.

In 2011, during the dry season in Ponta Grossa (PR, Brazil) the $F_{5:6}$ lines were evaluated and selected for early maturity, plant architecture, lodging resistance, disease resistance (anthracnose, angular leaf spot, curtobacterium wilt, and rust), seed color, size, and yield. During the rainy season of 2011 in Ponta Grossa (PR, Brazil) the $F_{5:7}$ lines were evaluated and selected for early maturity, disease resistance (anthracnose and common bacterial blight), plant architecture, lodging resistance, color, size, and yield. In the winter of 2012, $F_{5:8}$ progenies were sown in individual rows in Santo Antônio de Goiás (GO, Brazil) and selected for early maturity, plant architecture, lodging resistance, color, size, and yield. Similarly, in the winter of 2013, $F_{5:9}$ progenies were sown in individual rows in Santo Antônio de Goiás (GO, Brazil), and selections focused on early maturity, plant architecture, lodging resistance, color, size, and yield. The line selected from this process was designated CNFP 17466. Following this selection, CNFP 17466 underwent evaluation in replicated experiments across multiple environments.

In 2014, line CNFP 17466 was evaluated in the early black progeny test, which included 39 treatments: 35 new lines and four control varieties (BRS Esteio, BRS Esplendor, BRS Campeiro, and IPR Uirapuru). The experiment followed a randomized block design with three replications and plots of two four-meter rows. Tests were conducted across four environments: Ponta Grossa (PR, Brazil) during the dry and rainy seasons; and Santo Antônio de Goiás (GO, Brazil) during the winter in two different areas. These trials assessed the growth cycle, plant architecture, lodging resistance, disease response (anthracnose, angular leaf spot, common bacterial blight, and fusarium wilt), grain color, sieve yield (4.25 mm), 100-seed weight, and grain yield. The joint analysis of these data allowed CNFP 17466 to be selected for the early black preliminary trial.

In 2016, line CNFP 17466 was evaluated in the early black preliminary trial, consisting of 28 treatments: 24 lines and four controls (BRS Esteio, BRS Esplendor, BRS Campeiro, and IPR Uirapuru). The experiment employed a randomized block design with three replications and plots of two four-meter rows. Trials took place in seven environments: Brasília (DF, Brazil) during the winter and rainy seasons; Uberlândia (MG, Brazil); and Santo Antônio de Goiás (GO, Brazil) in two areas during the winter; and Ponta Grossa (PR, Brazil) during the rainy and dry seasons. This trial allowed for the evaluation of growth cycle, plant architecture, lodging resistance, disease response (anthracnose, angular leaf spot, common bacterial blight, curtobacterium wilt, fusarium wilt, and root rot), grain color, sieve yield (4.25 mm), 100-seed weight, and grain yield. The combined analysis of the data from the early black preliminary trial, along with data from the early black progeny test, enabled CNFP 17466 to be selected for the early black intermediate trial.

In 2018, line CNFP 17466 was assessed in the early black intermediate trial, which included 15 treatments: 11 lines and four controls (BRS Esteio, BRS Esplendor, BRS Campeiro, and IPR Uirapuru). The experiment followed a randomized block design with three replications and plots of three three-meter rows. Trials were conducted across nine environments: Santo Antônio de Goiás (GO, Brazil) in the winter in two areas; Ponta Grossa (PR, Brazil) during the rainy and dry seasons; Brasília (DF, Brazil) during the rainy and winter seasons; Anápolis (GO, Brazil); Sete Lagoas (MG, Brazil); and Macaé (RJ, Brazil), during the winter. This trial evaluated productivity, sieve yield (4.25 mm), color, shape, uniformity, and 100-seed weight. Additionally, it assessed growth cycle, plant architecture, lodging resistance, and disease response (anthracnose, angular leaf spot, common bacterial blight, curtobacterium wilt, and fusarium wilt).

The combined analysis of data from the early black progeny, preliminary, and intermediate trials enabled the CNFP 17466 line to be selected for the Cultivation and Use Value (VCU) experiment, based on evaluations across 20 environments. In 2019, seed multiplication was carried out in Santo Antônio de Goiás (GO, Brazil) during the winter season to obtain a sufficient quantity for the VCU trials.

In 2020 and 2021, the CNFP 17466 line was evaluated in 42 trials with 14 treatments, comprising 11 black-seeded lines with varying growth cycles, from semi-early (75 to 84 days) to early (65 to 74 days), and three control varieties: BRS Campeiro and IAC Veloz, both with semi-early cycles, and IPR Uirapuru with a standard cycle. The experiments used a randomized block design with three replications and plots of four four-meter rows, applying recommended technologies for different environments and cultivation systems.

These experiments assessed grain traits such as yield, sieve yield (4.25 mm), 100-seed weight, color, uniformity, shape, cooking time, and concentrations of iron, zinc, and protein. Additional assessments included plant architecture, lodging resistance, and disease resistance, using a scale from 1 (completely favorable phenotype) to 9 (completely unfavorable phenotype) (Melo, 2009). Diseases evaluated included common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli*), curtobacterium wilt (*Curtobacterium flaccumfaciens* pv. *flaccumfaciens*), angular leaf spot (*Pseudocercospora griseola*), anthracnose (*Colletotrichum lindemutianum*), rust (*Uromyces appendiculatus*), fusarium wilt (*Fusarium oxysporum* f. sp. *phaseoli*), root rots (*Fusarium solani* and *Rhizoctonia solani*), common bean mosaic virus (CBMV), and bean golden mosaic virus (BGMV).

Grain yield was measured in kg ha^{-1}, adjusted to 13% grain moisture. Sieve yield was determined by taking a 300g sample from each plot, sieving it through an oblong 4.25 mm sieve, weighing the retained seeds, and dividing this weight by the initial sample weight. A new 100-seed sample was then taken from the retained seeds for weight measurement. Cooking time was determined using the Mattson cooker. Protein concentration was analyzed by nitrogen content using the micro-Kjeldahl method. Iron and zinc concentrations were measured via acid digestion of organic matter, using flame atomic absorption spectrophotometry.

Results and Discussion

Of the 42 experiments installed, 38 were successfully harvested and met the necessary experimental quality standards to be considered in the cultivar registration process, specifically regarding yield data. These 38 VCU experiments were conducted in Region I (Santa Catarina, Paraná, São Paulo, and Mato Grosso do Sul) during the rainy and dry seasons, and in Region II (Goiás, Federal District, Mato Grosso, Espírito Santo, and Minas Gerais) during the rainy, dry, and winter seasons. In these trials, the BRS FP327 cultivar showed an average yield of 2,492 kg ha^{-1}, which is 5.4% higher than BRS Campeiro (2,365 kg ha^{-1}) and 26.2% higher than IAC Veloz (1,974 kg ha^{-1}) (Table 1). This increase was also observed separately in each region. In Region I (Central-South), the average yield was 2,394 kg ha^{-1}, with 7.5% and 32.4% increases over BRS Campeiro and IAC Veloz, respectively. In the Central Region, the average yield was 2,578 kg ha^{-1}, with a 3.7% increase over BRS Campeiro (2,486 kg ha^{-1}) and 21.5% over IAC Veloz (2,122 kg ha^{-1}).

Table 1. Grain yield (kg ha^{-1}) of cv BRS FP327 compared to the mean of two controls (BRS Campeiro and IAC Veloz) in the Value for Cultivation and Use (VCU) trials, according to the recommended cultivation region and sowing time, from 2020 to 2021.

Region	Season	BRS FP327	BRS Campeiro	IAC Veloz	Number of environments
I	Rainy	2,811 a	2,756 a	2,170 b	7
	Dry	2,070 a	1,817 a	1,525 c	9
	Overall	2,394 a	2,228 b	1,807 c	16
II	Rainy	2,751 a	2,623 a	1,860 b	6
	Dry	2,281 a	1,760 b	1,874 b	3
	Winter	2,563 a	2,637 a	2,379 b	9
	Overall	2,578 a	2,486 b	2,122 c	18
Overall	**-**	**2,492 a**	**2,365 b**	**1,974 c**	**34**

Region I - MS, PR, SP; Region II - MG, GO, DF, MT, RJ. Mean scores followed by a common letter in rows do not differ statistically according to the Scott-Knott method at 5% probability.

The maximum productivity in VCU experiments, obtained from the average of the three VCU experiments in which this cultivar presented the highest yield, was 3,876 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 FP327 is 5,000 kg ha-1. The productive potential, in optimal conditions, is 6,000 kg ha-1.

With regard to technological and industrial quality traits, the BRS FP327 cultivar has a high sieve 11 yield (4.25 mm) (80%), comparable to BRS Campeiro and IAC Veloz (Table 2). BRS FP327 has an average 100-seed weight of 25 grams, similar to BRS Campeiro and greater than IAC Veloz. The grains are black, matte, with a circular to elliptical shape and medium thickness. Visually, the grains are uniform black, with no purpling. The average cooking time for BRS FP327 is 30 minutes, similar to BRS Campeiro (Carneiro et al., 2004) and IAC Veloz (Chiorato et al., 2020). Protein, iron, and zinc content are also comparable to the control cultivars.

Table 2. Comparison of grain traits of common bean cultivar BRS FP327 with the controls BRS Campeiro and IAC Veloz.

Cultivar	CT (minutes)	PC (%)	FeC (mg kg^{-1})	ZnC (mg kg^{-1})	SY (%)	W100 (g)
BRS FP327	30 a	20 a	52 a	40 a	80 a	25 a
BRS Campeiro	30 a	21 a	53 a	42 a	79 a	24 a
IAC Veloz	32 a	20 a	49 a	39 a	78 a	22 b

CT - Cooking time; PC - Protein content; FeC - Iron Content; ZnC - Zinc Content; SY - Sieved grain yield (<4.25 mm); W100 - 100-seed weight. Mean scores followed by a common letter in columns do not differ statistically according to the Scott-Knott method at 5% probability.

In field trials, BRS FP327 showed resistance to common bean mosaic virus, moderate resistance to rust, anthracnose, and fusarium wilt, and intermediate resistance to root rots. However, it was susceptible to bean golden mosaic virus, angular leaf spot, curtobacterium wilt, and common bacterial blight. Generally, BRS FP327's resistance profile was similar to that of BRS Campeiro, showing higher resistance to anthracnose. Compared to IAC Veloz, BRS FP327 had a generally higher level of disease resistance (Table 3).

Table 3. Agronomic traits and disease reaction traits of cultivar BRS FP327, in comparison with the carioca grain cultivars BRS Campeiro and IAC Veloz.

Cultivar	Cycle	ARCH	LOD	AN	CBB	RU	ALS	BCMV	BGMV	FW	CUR	RR
BRS FP327	SP	Upright	R	MR	S	MR	S	R	S	MR	S	I
BRS Campeiro	SP	Upright	MR	I	S	MR	S	R	S	MR	S	I
IAC Veloz	SP	Upright	R	S	S	MR	S	-	S	I	S	-

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; FW - Fusarium wilt; CUR - Curtobacterium wilt; RR - Root rots; SP - Semi-early cycle; R - Resistant; MR - Moderately resistant; I - Intermediate; S - Susceptible.

BRS FP327 has a semi-early cycle (75 to 84 days from emergence to physiological maturity), similar to the control cultivars (Table 3). The plants are bushy with indeterminate growth type II. In terms of architecture, BRS FP327 is erect and resistant to lodging, making it suitable for mechanical, including direct, harvesting. The flowers are purple, and at physiological and harvest maturity, the pods turn yellow.

Key highlights of BRS FP327 include its

semi-early cycle, which has been highly demanded by black bean producers, particularly in Region I (Central South Brazil), the main production area for this type of bean. Additionally, BRS FP327 shows high yield, particularly in the Central South region, excellent commercial grain quality (color, uniformity, 100-seed weight, and sieve yield), erect architecture, and high resistance to lodging. Another notable feature is its resistance to anthracnose and fusarium wilt and intermediate resistance to root rots.

Based on its performance, BRS FP327 will be 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 for the rainy, dry, and winter seasons in Region II (Minas Gerais, Goiás, Federal District, Mato Grosso, Tocantins, Maranhão, Bahia, Espírito Santo, and Rio de Janeiro).

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