CROP BREEDING AND APPLIED BIOTECHNOLOGY

CULTIVAR RELEASE

BRS FC104 – Super-early carioca seeded common bean cultivar with high yield potential

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Abstract: *BRS FC104 is a carioca seeded common bean cultivar with super-early maturity (mean of 65 days; emergence to physiological maturity) and disease resistance superior to other early maturity carioca seeded cultivars. Is is recommended for growing in 21 Brazilian states and has high yield potential (3792 kg ha^{-1}), a mean yield of 2186 kg ha^{-1}, and 6.9% higher mean of the relative yield compared to the control cultivars.*

Keywords*: Phaseolus vulgaris, plant breeding, early crop cycle.*

INTRODUCTION

Brazil is one of the largest worldwide producers and consumers of dry bean or common bean (FAO 2018), which constitutes a food traditionally present in the Brazilian diet. Given the crop relevance, the Brazil common bean breeding programs have been conducted mainly by research institutions, which have been able to supply the market with new cultivars, associating desirable traits with disease resistance, early maturity, better plant architecture, and higher yield potential. In a period of 22 years, crop yield increased from 737 kg ha^{-1} (in 1994) to 1,441 kg ha^{-1} (in 2016) (http://www.cnpaf.embrapa.br/socioeconomia/index.htm). Genetic improvement has strongly contributed to this advance, through development of higher yielding cultivars (Faria et al. 2013). In common-bean breeding programs, various traits are considered, with the aim of increasing the chance of adoption of these new cultivars. Although bean grain yield is the trait of greatest economic importance, this phenotype must be associated with other traits that meet the demands of the whole production chain. Some traits are developed to meet regional demands, but early maturity, plant architecture, and bean grain size and color are important in all regions (Melo et al. 2010). Early maturity allows savings on water and power in irrigated systems, greater flexibility in management of production systems, use of shorter sowing periods to advance or delay the traditional sowing time currently spent for normal maturity cultivars, harvest outside the peak bean grain supply period, and avoidance of pests and diseases and drought periods (Pereira et. al. 2012).

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For the carioca (beige seed coat with brown stripes) market class, there are as yet few cultivars with this early maturity trait, such as Carioca Precoce, BRS 9435 Cometa (Faria et al. 2008), BRS Notável (Pereira et al. 2012), IPR Colibri, IPR Curió, IAC Imperador (Chiorato et al. 2012), and TAA Gol. Nevertheless, these cultivars are classified as semi-early (75 to 84 days) or early (65 to 74 days), but none of them is considered super-early (<65 days). Early cultivars have a greater impact on production systems by significantly reducing production costs and time for return on capital investment. Thus, super-early cultivars can contribute to flexibilization of the common bean production system through making it possible to advance or delay sowing within the different crop periods. Growing in shorter periods allows greater efficiency in soil use, with the possibility of better use of the crop year within the conditions in Brazil of multiple crop seasons in a single crop year.

CULTIVAR DEVELOPMENT

BRS FC104 derived from a cross between the lines CNFE 8009 and VC5 carried out in 2006 at Embrapa Arroz e Feijão, in Santo Antônio de Goiás, GO, Brazil. In 2006, the F_1 generation of the population was sown and advanced at the greenhouse in the winter crop season. In 2007, in the winter crop season, the F_2 generation was sown in the field in Santo Antônio de Goiás, in bulk, with selection for early maturity, plant architecture, and grain yield. In the dry season 2008, the F_3 generation was advanced in the field in Ponta Grossa, PR, in bulk, with selection for early maturity, reaction to anthracnose, grain yield, and reaction to rust and common bacterial blight. Also, in 2008, in the rainy season, the F_4 generation was sown, in bulk, in Ponta Grossa, and once more, selection was made for early maturity, grain yield, and reaction to common bacterial blight, anthracnose and rust. In 2009, the F_5 generation was sown in Santo Antônio de Goiás, in the winter crop season, and individual plants were selected based on early maturity and plant architecture.

In 2010, progenies in the $F_{5:6}$ generation were sown in Ponta Grossa in the dry crop season, in which selection was made based on early maturity, grain yield, and reaction to angular leaf spot and anthracnose. In the winter crop season, also in 2010, these progenies were also evaluated in Santo Antônio de Goiás for early maturity and grain yield. From this step on, the selected progenies were considered as lines and the line CNFC 15874 was advanced to be evaluated in trials with replicates, in which grain yield and other traits of importance were evaluated, such as reaction to diseases and plant architecture.

In 2011, the line CNFC 15874 was evaluated in the Intermediate Trial (IT) with other 21 elite lines and six control cultivars in randomized blocks with three replicates and plots of two 4-meter rows carried out in nine environments: Santo Antônio de Goiás, in the dry and winter crop seasons; Sete Lagoas (MG) and Uberlândia (MG), in the winter season; Ponta Grossa, in the rainy and dry seasons; Lavras (MG) in the dry season; and Paripiranga (BA) and Carira (SE), in the rainy season. The combined analyses of the data on bean grain yield, 100-seed weight, sieve yield, bean grain appearance, reaction to diseases (anthracnose, angular leaf spot, common bacterial blight, bacterial wilt and fusarium wilt), early maturity, plant architecture, and tolerance to lodging allowed the CNFC 15874 line to be advanced to be evaluated in the trials of Value for Cultivation and Use (Valor de Cultivo e Uso - VCU) trials.

In 2012, multiplication was made to obtain sufficient seeds to prepare the VCU trials. During 2013 to 2015, the CNFC 15874 line was evaluated in 72 trials with three controls (Carioca Precoce, IPR Colibri, and BRS Notável) in a randomized block experimental design with three replicates and plots of four 4-m rows, using the technologies recommended for the different environments and cropping systems.

Bean grain yield was measured in kg ha^{-1} and corrected to 13% moisture. The percentage of bean grains with commercial size was measured in 300 g samples taken from each plot, which were sieved in a sieve with oblong holes of 4.25 mm width. The seeds retained in the sieve were weighed, and this weight was divided by the initial weight of the sample, thus obtaining the percentage of seeds with commercial size. From the seeds retained in the sieve, a new sample of 100 seeds was removed for weighing and to obtain the 100-seed weight. In some trials, samples were removed to perform analyses of protein content and of. For cooking time, the bean grains were soaked in distilled water at the proportion of 1:4 (w/v) at room temperature. At 16 hours, the water was eliminated and the bean grains were placed in a Mattson cooker. Cooking time was determined beginning at the time the water boiled to the time at which the rods of the cooker penetrated 50% + 1 of the bean grains. This method was adapted from Proctor and Watts (1987). The analyses of protein content were made based on bean grain meal, according to the micro-Kjeldahl method.

Other important agronomic traits evaluated were: tolerance to lodging; plant architecture; and reaction to diseases, including angular leaf spot (*Pseudocercospora griseola*), anthracnose (*Colletotrichum lindemutianum*), rust (*Uromyces appendiculatus*), fusarium wilt (*Fusarium oxysporum* f. sp. *phaseoli*), common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli* and *Xanthomonas fuscans pv. fuscans*), bacterial wilt (*Curtobacterium flaccumfaciens* pv. *flaccumfaciens*), *Bean common mosaic virus* (BCMV), and *Bean golden mosaic virus* (BGMV). These evaluations were made using evaluation scales for disease severity, described by Melo (2009), which ranged from 1 (absence of symptoms and signs of pathogens) to 9 (100% disease severity or plant death).

BEAN GRAIN YIELD AND YIELD POTENTIAL

A total of 72 VCU trials were carried out from 2013 to 2015 in the rainy season in Alagoas, Sergipe, Bahia, Pernambuco, and Rio Grande do Sul; in the dry season in Mato Grosso do Sul; in the winter season in Espírito Santo; in the rainy and dry seasons in Santa Catarina and Paraná; and in the rainy, dry, and winter seasons in Goiás, Distrito Federal, and Mato Grosso. The cultivar BRS FC104 (CNFC 15874) exhibited 6.9% superiority in grain yield compared to the mean value of the IPR Colibri. Considering each one of the three regions of recommendation for common bean cultivars (Pereira et al. 2009), the superiority registered was 5.4% in Region 1 (São Paulo, Mato Grosso do Sul, Paraná, Santa Catariana, and Rio Grande do Sul); 6.9% in Region 2 (Mato Grosso, Goiás/Distrito Federal, Minas Gerais, Rio de Janeiro, Espírito Santo, Bahia, Tocantins, and Maranhão); and 7.4% in Region 3 (Sergipe, Alagoas, Pernambuco, Paraíba, Rio Grande do Norte, Ceará, and Piauí).

The overall mean yield of BRS FC104 was 2,186 kg ha^{-1}, compared to 2,100 kg ha^{-1} for the control cultivar IPR Colibri. Considering the data for each region of recommendation, BRS FC104 exhibited 14.4% superiority over the IPR Colibri in the rainy season and 1.3% superiority in the dry season in Region 1. Thus, it showed greater adaptation to growing in the rainy crop season. In Region 2, BRS FC104 exhibited superiority of 12.6, 2.8, and 8.6% in the rainy, dry, and winter crop seasons, respectively (Table 1). In Region 3, in which common bean is grown only in the rainy season, superiority was 7.4%, indicating that the super-early cultivar BRS FC104 has broad adaptability and therefore can be grown in the main common bean production regions in Brazil.

The yield potential of BRS FC104, obtained from the mean of the five trials in which this cultivar exhibited the highest yields, was 3,792 kg ha^{-1}. This estimate shows that even though the cultivar has a super-early cycle, it has high genetic potential for grain yield, and that if the environment is favorable and there are good growing conditions, high yields can be achieved. This trait provides BRS FC104 with one of the best conversion rates of photoassimilates into bean grain weight developed by breeding programs, with a yield of 60 kg for each day of the cycle of this cultivar. The values found for a cultivar of normal cycle of high yield potential in excellent growing conditions is around 50 kg day^{-1} of the cycle.

Based on its performance, BRS FC104 was registered for the rainy, dry, and winter crop seasons in the states of Goiás, Distrito Federal, Mato Grosso, Espírito Santo, Rio de Janeiro, and Bahia; for the rainy and dry crop seasons in the states of Mato Grosso do Sul, Paraná, Santa Catarina, São Paulo, and Rio Grande do Sul; for the winter crop season

Table 1. Mean grain yield of the common bean cultivar BRS FC104 compared to the mean of control cultivar (IPR Colibri) in the final field trials (Value for Cultivation and Use trials), by region of recommendation and crop season in the period from 2013 to 2015

Region	Season	BRS FC104 (kg ha^{-1})	IPR Colibri (kg ha^{-1})	Mean of the relative IPR Colibri yields (%)	Number of environments
	Rainy	2331.8 a*	2102.3 b	114.4	6
I	Dry	1585.6 a	1594.2 a	101.3	13
	Overall	1821.3 a	1754.6 a	105.4	19
	Rainy	2401.5 a	2247.6 b	112.6	11
II	Dry	1438.2 a	1310.4 a	102.8	5
	Winter	2382.4 a	2267.4 b	108.6	26
	Overall	2275.0 a	2185.3 b	106.9	42
III	Rainy	2474.6 a	2372.1 a	107.4	11
Overall	-	2185.8a	2100.2b	106.9	72

Region I: RS, SC, PR, MS and SP; Region II: ES, RJ, GO, DF, MG, MT, TO, BA and MA; Region III: SE, AL, PE, PB, CE, RN and PI. *Means followed by the same letter in the table columns are not significantly different according to the Tukey test at 5% probability.

Table 2. Agronomic traits and reaction to diseases of the cultivar BRS FC104 compared to the control cultivars IPR Colibri and Carioca Precoce

Cultivar	Cycle	ARCH	SW	SY	AN	CBB	RS	ALS	BCMV	BGMV	FW	BW
BRS FC104	SE	SP	I	I	MS	MS	MR	S	R	S	S	MS
IPR Colibri	EM	SP	S	L	S	S	MS	S	R	S	S	S
Carioca Precoce	EM	SP	S	L	S	S	MS	S	R	S	S	S

ARCH – Plant architecture; SW - 100-seed weight: I: Intermediary**,** S: Small; SY - Sieve yield: I: intermediary, L: low; AN - Anthracnose; CBB – Common bacterial blight; RS - Rust; ALS – Angular leaf spot; BCMV – Bean common mosaic virus; BGMV – Bean golden mosaic virus; FW – Fusarium wilt; BW – Bacterial wilt; EM – Early maturity; SE – Super-early maturity; R - Resistant (score 1); MR – Moderately resistant (scores 2 and 3); MS – Moderately susceptible (scores 4 to 6) S - Susceptible (scores 7 to 9).

in Tocantins, and for the rainy crop season in the states of Maranhão, Sergipe, Alagoas, Pernambuco, Rio Grande do Norte, Ceára Piauí, and Paraíba.

CROP CYCLE

Under adequate conditions of nutrition, lighting, temperature, and rainfall, BRS FC104 has a super-early cycle (mean of 65 days, from emergence to physiological maturity), shorter than that of the early cultivars IPR Colibri and Carioca Precoce (Table 2). Planning the crop growing period with BRS FC104 should always consider possible variations in the cycle arising from edaphic and climatic conditions foreseen for the period.

OTHER TRAITS

The cultivar had sieve yield of 84.4% (intermediary) and mean 100-seed weight of 25 g (intermediary), values superior to those of the control cultivars (Table 2), indicating that it is a cultivar with grain of high commercial value, considering the standard of the early maturity carioca bean cultivars.

The cultivar BRS FC104 was resistant to common mosaic virus (BCMV) under artificial inoculation. In the field trials, it proved to be moderately resistant to rust and moderately susceptible to anthracnose, common bacterial blight, and bacterial wilt. However, it shown to be susceptible to angular leaf spot, fusarium wilt, and golden mosaic virus (BGMV) (Table 2). Thus, BRS FC104 has greater disease resistance than the control cultivars; it is more resistant to anthracnose, common bacterial blight, rust, and bacterial wilt, and it has a similar reaction to angular leaf spot, common mosaic virus, and golden mosaic virus.

The plants of BRS FC104 have a semi-prostrate plant architecture, indeterminate growth habit (typo III), low tolerance to lodging, as in most early maturity cultivars. For this reason, preferentially, indirect mechanical harvest should be used. Its flowers are white and, at physiological maturity, the pods are reddish. At the time of harvest, the pods have a yellow color. Its grains have a light beige seed coat with light brown stripes that is not shiny, and they have a reniform oblong shape.

BRS FC104 stands out in relation to early maturity cultivars available on the market because it has a shorter cycle, higher bean grain yield, and greater resistance to anthracnose than other early maturity cultivars, with adequate commercial grain quality. Thus, the expectation is that BRS FC104 can be adopted as a new technological solution by common bean growers throughout Brazil, contributing in an efficient way to the sustainability of the common bean crop in Brazilian agribusiness. The biggest impact of adoption of this cultivar will likely be to increase operational flexibility in common bean production systems through making it possible to advance or delay the crop in different seasons and growing in a shorter period of time will allow greater efficiency in land use. In addition, it will allow greater probability of avoiding biotic and abiotic stresses, reduction in production costs through savings in water, electrical power, and crop inputs, and, finally, reduction in time of return on investment. It will allow harvest in periods with a small supply of the common bean grain.

Seed production

The cultivar BRS FC104 was registered on 6 March 2017 under number 36426 and granted provision protection on 22 June 2017 from the Ministry of Agriculture (Ministério da Agricultura, Pecuária e Abastecimento – MAPA). Production

of basic seeds will be under the responsibility of Embrapa and partners.

CONCLUSIONS

The carioca seeded common bean cultivar BRS FC104 has a super-early cycle, with high yield potential and disease resistance superior to that of other early carioca seeded cultivars currently available in the Brazilian market.

BRS FC104 is recommended for growing in the following states and crop seasons: rainy, dry, and winter crop seasons in Goiás, Distrito Federal, Mato Grosso, Espírito Santo, Rio de Janeiro, and Bahia; rainy and dry crop seasons in Mato Grosso do Sul, Paraná, Santa Catarina, São Paulo, and Rio Grande do Sul; only in the winter crop season in Tocantins; and only in the rainy crop season in Maranhão, Sergipe, Alagoas, Pernambuco, Rio Grande do Norte, Piauí, Ceará, and Paraíba.

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