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# BRS FC414: COMMON BEAN CULTIVAR WITH HIGH YIELD AND COMMERCIAL QUALITY, RECOMMENDED FOR GROWING UNDER CENTER PIVOT IRRIGATION

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**Abstract:** BRS FC414 is a common bean cultivar with high commercial quality carioca bean grain and resistance to Fusarium wilt. It is widely adapted to different production regions, high yielding, and adapted to mechanical harvest. BRS FC414 is an option for growing light-colored carioca commercial group bean under central pivot irrigation conditions.

**Keywords:** *Phaseolus vulgaris*, Fusarium wilt, winter crop season.

## Introduction

Brazil is among the main worldwide producers and consumers of common bean (*Phaseolus vulgaris* L.) (FAO, 2022). According to Melo et al. (2017), this crop has high socioeconomic value in Brazil as it is part of production systems that include small, medium, and large producers, spread across a large part of Brazilian territory. Among those responsible for ensuring this high common bean production in Brazil are plant breeding programs.

In Brazil, these programs are conducted by public and private research institutions that have been able to supply the continuous demand for new cultivars (Pereira et al., 2021). Embrapa is the only Brazilian plant breeding program with a nationwide mission, and its grain yield gains are around 0.72% a year for the carioca commercial group (Faria et al., 2013) and 1.1% for the black bean commercial group (Faria et al., 2014).

In the development of new common bean cultivars in Brazil, the main strategy adopted is selection of genotypes that have wide adaptation, thus allowing recommendation of cultivars that maintain their competitiveness under the most diverse growing conditions and production systems. Embrapa has consolidated partnerships with the main institutions that research common bean in Brazil and in the world, at different levels of involvement.

The Common Bean Breeding Program of Embrapa in its 45 years of existence has released approximately 75 cultivars, with 12 grain types, for all common bean production regions in Brazil and for various consumer markets throughout the world. Of these 75 cultivars, 28 were before the cultivar protection law decreed in 1997, and 47 after this law, that is, 63% of the cultivars.

New cultivars need to have differentiated combinations of traits so that they can serve niche markets that the cultivars available on the market are not adapted to (Pereira et al., 2022). Characteristics such as upright plant architecture and resistance to Fusarium wilt have become traits in great demand and highly valued by growers. According to Melo et al. (2022), good plant architecture allows mechanical harvest with a low rate of field loss and low occurrence of diseases, due to greater aeration of the crop, as well as better commercial grain quality, since there is lower moisture in the pods at the time of harvest.

Although advances have already been obtained for this trait, it is necessary to obtain even more upright cultivars than those currently on the market or cultivars that combine this trait with another in a combination not yet available on the market. The combination of upright architecture, resistance to Fusarium, and a carioca bean grain with a white seed coat background has not yet been available on the common bean market and constitutes a competitive advantage for new cultivars.

# Breeding methods used

BRS FC414 arose from a cross between the cultivars BRS Horizonte and Magnífico made at Embrapa Rice and Beans in Santo Antônio de Goiás (GO) in 2004. Also in 2004, the $F_1$generation of the population was sown in screened enclosures. In 2005, in the dry crop season, the population in the $F_2$generation was sown in the field and harvested in bulk in Ponta Grossa (PR), with selection for seed coat color and grain size, plant architecture, and resistance to diseases (anthracnose, angular leaf spot, bacterial wilt, and rust). In the rainy season /2005, the population in the $F_3$generation was sown in Ponta Grossa and harvest was carried out in bulk, with selection based on reaction to diseases (anthracnose and common bacterial blight), plant architecture, and grain color and size.

In 2006, in Santo Antônio de Goiás, the $F_4$ generation was evaluated and harvested in bulk, with selection based on plant architecture, grain color and size, and grain yield. In the dry season/2007 in Ponta Grossa, the $F_5$ generation was evaluated and harvested in bulk, with selection for grain color and size, plant architecture, and resistance to diseases (anthracnose, angular leaf spot, bacterial wilt, and rust). Also in 2007, in the rainy season, in Ponta Grossa, the $F_6$generation was evaluated, and individual plants were selected based on reaction to diseases (anthracnose and common bacterial blight), plant architecture, and grain type and size in order to obtain lines.

In 2008, in the winter season, the progenies in the $F_{6:7}$generation were sown in Santo Antônio de Goiás in individual rows, and selection was made based on plant architecture, grain color and size, and grain yield. In 2009, in the dry season in Ponta Grossa, the $F_{6:8}$ lines were evaluated and selected for grain color and size, plant architecture, and resistance to diseases (anthracnose, angular leaf spot, bacterial wilt, and rust), selecting the line that received the name CNFC 15839. As of this point, the step of evaluation in experiments with replications in multiple environments began.

In 2010, the CNFC 15839 line was evaluated in the progeny test trial, composed of 170 treatments, consisting of 163 new lines and seven check cultivars (BRS Estilo, BRS Cometa, Pérola, BRS Pontal, IAC Alvorada, BRSMG Majestoso, and IPR Juriti). A randomized block experimental design was used with three replications and plots consisting of two 4-m rows. The trials were set up in two environments: Ponta Grossa in the dry season and Santo Antônio de Goiás in the winter season. In these trials, it was possible to evaluate grain yield, plant architecture, resistance to lodging, and reaction to diseases (anthracnose, angular leaf spot, and common bacterial blight). Combined analysis of these data led to selection of the CNFC 15839 line for participation in the preliminary trial.

In 2011, the CNFC 15839 line was evaluated in the preliminary carioca trial, composed of 68 treatments, consisting of 63 new lines and 5 check cultivars (BRS Estilo, BRS Cometa, Pérola, BRS Notável, and IAC Alvorada). A randomized block experimental design was used with three replications and plots of two 4-m rows. The trials were conducted in six environments: Santo Antônio de Goiás (GO), in the winter season; Ponta Grossa (PR) and Carira (SE), in the rainy season; and Ponta Grossa, Lavras (MG), and Santo Antônio de Goiás in the dry season. In these trials, grain yield, cycle, plant architecture, resistance to lodging, and reaction to diseases (anthracnose, common bacterial blight, angular leaf spot, and bacterial wilt) were evaluated. Joint analysis of the data obtained in the preliminary trial, together with the data obtained in the progeny test trial, led to selection of the CNFC 15839 line for participation in the intermediate trial.

In 2013, the CNFC 15839 line was evaluated in the intermediate carioca trial composed of 38 treatments, consisting of 32 new lines and six check cultivars (BRS Cometa, BRS Estilo, BRS Notável, BRS Ametista, IPR 139, and Pérola). A randomized block experimental design was used with three replications and plots of two 4-m rows. The trials were conducted in eleven environments: Santo Antônio de Goiás (GO), in the winter season (three trials); Ponta Grossa (PR), in the rainy and dry seasons; Carira (SE) and Paripiranga (BA), in the rainy season; and Brasília (DF), Lavras (MG), Uberlândia (MG), and Sete Lagoas (MG), in the winter season. In these trials, it was possible to evaluate yield, sieve yield, grain appearance, and 100-seed weight. In addition, evaluation was made of cycle, plant architecture, resistance to lodging, and reaction to diseases (anthracnose, angular leaf spot, common bacterial blight, bacterial wilt, and Fusarium wilt).

Joint analysis of the data of the progeny test and preliminary and intermediate trials led to selection of the CNFC 15839 line for the Value for Cultivation and Use (Valor de Cultivo e Uso - VCU) trial, based on evaluation of 20 environments. In 2015, in the winter season in Santo Antônio de Goiás, seeds were multiplied to obtain a sufficient number for preparation of the VCU trials.

In 2016 and 2017, the CNFC 15839 line was evaluated in 86 trials composed of 20 treatments, consisting of 15 new lines with normal cycle and five check cultivars: BRS FC402, BRS Estilo, Pérola, IPR Bem-te-vi, and ANFC09. 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 growing systems.

In those experiments, it was possible to evaluate the following aspects related to the grain: yield, yield in sieve 12 (4.5mm), 100-seed weight, seed coat color, darkening, cooking time, and iron, zinc, and protein concentration. The following evaluations were also made on a scoring scale ranging from 1 (totally favorable phenotype) to 9 (totally unfavorable phenotype) (Melo, 2009): plant architecture, resistance to lodging, and reaction to 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*), root rots (*Fusarium solani, Rizoctônia solani*), bean common mosaic virus (BCMV), and bean golden mosaic virus (BGMV).

Grain yield was measured in kg $ha^{-1}$and corrected to 13% grain moisture. Sieve yield was measured in the following manner: a 300 g sample was removed from each plot; the sample was then passed through a sieve with oblong openings of 4.5 mm width; the seeds retained in the sieve were weighed; and the weight of the seeds retained in the sieve was divided by the initial weight of the sample. A new sample of 100 seeds was taken from the seeds retained in order to weight them and obtain 100-seed weight. A Mattson cooker was used for determination of cooking time. Protein concentration was analyzed through determination of nitrogen concentration by the micro-Kjeldahl method. Iron and zinc concentrations were analyzed by

acid digestion of organic matter according to the flame atomic absorption spectrometry technique.

## Grain yield and yield potential

Of the 86 trials set up, 60 were harvested and achieved the standards of experimental quality necessary to be considered in the cultivar registration process in relation to yield data. These 60 VCU trials were conducted in Region I (Santa Catarina, Paraná, São Paulo, and Mato Grosso do Sul) in the rainy and dry seasons, in Region II (Goiás, Distrito Federal, Mato Grosso, Espírito Santo, Minas Gerais, and Bahia) in the rainy, dry, and winter seasons, and in Region III (Sergipe, Alagoas, and Pernambuco) in the rainy season.

In these trials, the cultivar BRS FC414 (CNFC 15839) exhibited mean yield of 2229 kg.ha$^{-1}$, higher than BRS Estilo (2067 kg.ha$^{-1}$) and lower than Pérola (2267 kg.ha$^{-1}$), with 104.9% of mean performance relative to the mean of the check cultivars. In Region I, BRS FC414 also had yield lower than that of the check cultivar Pérola and higher than that of BRS Estilo, with performance relative to the mean of the check cultivars of 103.2%. In Regions II and III, the yield of BRS FC414 was similar to that of the check cultivar Pérola and higher than that of BRS Estilo, with 104.6% and 111.5% of performance relative to the mean, respectively (Table 1).

**Table 1.** Grain yield of cv BRS FC414 compared to the mean of two controls (BRS Estilo and Pérola) in the Value for Cultivation and Use (VCU) trials, according to the recommended growing region and sowing time, from 2016 to 2017.

| Region | Season | BRS FC414 (kg ha$^{-1}$) | BRS Estilo (kg ha$^{-1}$) | Pérola (kg ha$^{-1}$) | Number of environments |
|---|---|---|---|---|---|
| **I** | Rainy | 2,828 a | 2,731 a | 2,954 a | **16** |
| | Dry | 1,292 a | 841 b | 1,475 a | **5** |
| | Overall | 2,462 b | 2,280 c | 2,606 a | **21** |
| **II** | Rainy | 2,381 a | 2,314 b | 2,379 a | **11** |
| | Dry | 1,771 a | 1,382 b | 1,744 a | **6** |
| | Winter | 2,014 a | 1,982 a | 2,048 a | **16** |
| | Overall | 2,092 a | 1,984 b | 2,103 a | **33** |
| **III** | Rainy | 2,173 a | 1,824 b | 2,025 a | **7** |
| **Overall** | - | **2,229 b** | **2,067 c** | **2,267 a** | **61** |

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

The yield potential of BRS FC414, obtained from the mean of the five trials in which the cultivar had the highest yields, was 3,985 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, high yields can be achieved.

## Grain commercial and nutritional quality

In relation to grain technological and industrial quality traits, the cultivar BRS FC414 had excellent sieve yield (84%), better than that of the BRS Estilo and Pérola cultivars. BRS FC414 had a mean 100-seed weight of 27.4 grams, better than that of the BRS Estilo and Pérola cultivars, which are references in the market in relation to commercial quality of the grain (Pereira et al., 2022). The grain is carioca type (cream-colored seed coat with brown streaks), of elliptical shape, and without shine. In relation to grain appearance, BRS FC414 proved to be similar to BRS Estilo, with light cream-colored seed coat and light brown streaks. Mean cooking time of BRS FC414 was32 minutes, similar to that of the Pérola cultivar. In relation to grain protein percentage, the mean content of BRS FC414 (24,7%) was similar to that of Pérola and better than that of BRS Estilo. Furthermore, BRS FC414 had iron content (61.9 mgkg$^{-1}$) in the grain similar to that of the Pérola and BRS Estilo cultivars and zinc content (37.1 mgkg$^{-1}$) better than that of these cultivars (Table 2).

**Table 2.** Grain traits of the common bean cultivar BRS FC414 compared to the check cultivars Pérola, BRS FC402, and BRS Estilo.

| Cultivar | CT (minutes) | PC (%) | FeC (mg kg$^{-1}$) | ZnC (mg kg$^{-1}$) | RP (%) | W100 (g) |
|---|---|---|---|---|---|---|
| **BRS FC414** | 32 b | 24.7 a | 61.9 a | 37.1 a | 83.9 a | 27.4 a |
| **BRS Estilo** | 26 a | 22.2 b | 54.6 a | 33.8 c | 82.1 b | 24.9 c |
| **BRS FC402** | 32 b | 24.8 a | 65.9 a | 36.7 b | 71.6 b | 22.2 d |
| **Pérola** | 32 b | 24.0 a | 61.6 a | 34.0 c | 79.9 c | 26.2 b |

CT – cooking time; PC –protein content; FeC –iron content; ZnC –zinc content; RP – sieve yield (>4.5 mm); W100 – 100-seed weight. Mean scores followed by the same letter in the columns do not differ statistically from each other according to the Scott-Knott method at 5% probability.

## Other traits

In field trials, BRS FC414 proved to be moderately resistant to Fusarium wilt and moderately susceptible to anthracnose. However, it proved to be susceptible to the golden mosaic virus, common bacterial blight, bacterial wilt, and angular leaf spot (Table 3). BRS FC414 has a normal cycle (from 85 to 94 days, from emergence to physiological maturity), similar to that of the check cultivars (Table 3). The plants are shrub type with an indeterminate type II growth habit. In relation to plant architecture, BRS FC414 is upright and has good resistance to lodging, and it is adapted to mechanical harvest, including direct harvest. Flowers are white and at physiological maturity and harvest, the pods are yellowish.

**Table 3**. Agronomic traits and disease reaction traits of the cultivar BRS FC414 in comparison with the carioca grain cultivars BRS Estilo, BRS FC402, and Pérola.

| Cultivar | Cycle | ARCH | AN | CBB | RU | ALS | CMV | GMV | FW | CUR | RR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **BRS FC414** | N | Upright | MS | S | MR | S | R | S | MR | S | MS |
| **BRS Estilo** | N | Upright | MS | S | MR | S | R | S | S | S | S |
| **BRS FC402** | N | Semi-prostrate | MR | MS | MR | S | R | S | MR | S | MR |
| **Pérola** | N | Semi-prostrate | S | S | MR | MS | R | S | MS | S | MS |

ARCH –plant architecture; AN –anthracnose; CBB –common bacterial blight; RU –rust; ALS –angular leaf spot; CMV –common mosaic virus; GMV –golden mosaic virus; FW – Fusarium wilt; CUR–bacterial wilt; RR –root rots; N –normal cycle; R –resistant; MR – moderately resistant; MS –moderately susceptible; S –susceptible

# Seed production

BRS FC414 was registered in September 2021 under number 46938 with the Brazilian Ministry of Agriculture (Ministério da Agricultura, Pecuária e Abastecimento – MAPA). Seed production will be the responsibility of Embrapa and production to meet the needs of growers will be carried out by partner seed production companies, selected through public notices of call for bids for technical cooperation.

# Conclusions

BRS FC414 stands out for excellent grain quality in regard to commercial aspects. In addition, it has upright plant architecture and moderate resistance to Fusarium wilt and root rots, which allows it to be used in growing areas under center pivot irrigation. Based on its performance, BRS FC414 will be registered for the rainy and dry crop seasons in Region I (Mato Grosso do Sul, Paraná, Santa Catarina, São Paulo, and Rio Grande do Sul), for the rainy, dry, and winter crop seasons in Region II (Goiás, Distrito Federal, Mato Grosso, Tocantins, Maranhão, Bahia, Espírito Santo, and Rio de Janeiro), and for the rainy season in Region III (Sergipe, Alagoas, Pernambuco, Rio Grande do Norte, Piauí, Ceará, and Paraíba).

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