FUNCTIONAL PLANT BREEDING JOURNAL

Scientific Journal. ISSN 2595-9433
Volume 5, Article n. 2, Jan/December
D.O.I. http://dx.doi.org/10.35418/2526-4117/v5a2
Received: 07/23/2022 - Accepted: 10/14/2022

BRS FS313: JALO TYPE COMMON BEAN CULTIVAR WITH LARGE BEANS AND HIGH YIELD

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Abstract: BRS FS313 is a common bean cultivar with high yield (3,200 kg.ha^{-1}), jalo type bean grain, and greater 100-seed weight (50 g). It has a semi-early cycle, semi-upright plant architecture, and resistance to anthracnose and to root rots. BRS FS313 is recommended for the Central and South-Central regions of Brazil.

Keywords: *Phaseolus vulgaris*, anthracnose, root rots, 100-seed weight

Introduction

In recent years, Brazil has occupied one of the leading positions in production and consumption of common bean / dry edible bean (*Phaseolus vulgaris*). This legume is considered to have considerable economic and social importance, constituting an important source of protein in the Brazilian diet. Currently, planted area of the common bean crop in Brazil is 1.7 million hectares, with production of 2.5 million metric tons of grain and mean yield of 1,520 kg/ha^{-1} (Embrapa Arroz e Feijão, 2021).

Among the diverse commercial groups of common bean, *carioca* (cream-colored seed coat with brown streaks) and black beans are preferred by the vast majority of Brazilian consumers and represent 70% and 15% of the consumer market, respectively (Pereira et al., 2021). However, there are other commercial groups consumed to a more limited extent, and they are alternative sources, placing a differentiated product of greater commercial value on the domestic market. Among them are "*roxinho*" (small grain, rounded, purple, and 100-seed weight from 20 to 25 g); "*rosinha*" (small grain, elliptical, pinkish, and 100-seed weight from 20 to 25 g); "vermelho" (small grain, elliptical, red, and 100-seed weight from 20 to 25 g); "*mulatinho*" (small grain, elliptical, cream-colored, and 100-seed weight from 20 to 25 g); "*rajado*" (medium-sized grain, elongated reniform, cream-colored with reddish streaks, and 100-seed weight from 35 to 45 g); and "*jalo*" (medium-sized grain, elongated reniform, yellowish, and 100-seed weight from 35 to 45 g).

Over the years, breeding programs have placed less importance on these groups, and as a result, few cultivars are available.

Embrapa Arroz e Feijão has sought to recommend new cultivars of special grain types with high yield potential, better resistance to diseases, and adaptation to mechanized harvest so that farmers can offer consumers differentiated products of better quality and, consequently, improve return on their investment in the crop (Pereira et al., 2021). In recent years, new cultivars of some of the commercial groups mentioned have been recommended, such as BRS Agreste (Melo et al., 2008), IAC Centauro (Carbonell et al., 2008), and BRS FS307 with mulatinho grain (Faria et al., 2020); BRS Vereda (Faria et al., 2004), IAC Galante (Carbonell et al., 2008), and BRS FS212 with rosinha grain; BRS Pitanga (Rava et al., 2005) and BRS FS318 with roxinho grain; BRSMG Marte with red grain; IAC Harmonia (Chiorato et al., 2008), BRSMG Realce (Melo et al. 2014), and BRS FS311 with rajado grain (Aguiar, et al, 2021); and BRSMG União (Ramalho et al. 2012) with jalo grain.

Nevertheless, it is still important to make new cultivars available to the production sector. In this respect, the cultivar BRS FS313 stands out in relation to cultivars on the market, due to high yield, greater 100-seed weight, and resistance to anthracnose and root rot.

Breeding methods

BRS FS313 originated from the cross between the cultivar Jalo EEP558 and the line BAN30 carried out at Embrapa Arroz e Feijão in Santo Antônio de Goiás, GO, Brazil, in 2004. In the same year, the F_1 generation of the population was sown in a screened enclosure. In 2005, in the dry season, the population in the F_2 generation was sown in the field and harvested in bulk in Ponta Grossa (PR), with selection for grain color and size, plant architecture, and disease resistance (anthracnose, angular leaf spot, bacterial wilt, and rust). In the 2005 rainy season, the population in the $F_{3,}$ generation was sown in Ponta Grossa and harvested in bulk, with selection based on reaction to the 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 and grain color, size, and yield. In the 2007 dry season, in Ponta Grossa, the F_5 generation was evaluated and harvested in bulk, with selection for grain color and size, plant architecture, and disease resistance (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 crop 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 and grain color, size, and 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 disease resistance (anthracnose, angular leaf spot, bacterial wilt, and rust), selecting the line LMJ 209101479. As of this step, this line received the name CNFC 15592, and the step of evaluation in experiments with replications in multiple environments began.

In 2010, the line CNFJ 15592 was evaluated in the jalo progeny trial, composed of 13 treatments, consisting of 11 new lines and two check cultivars (Jalo Precoce and BRSMG União). A randomized block experimental design was used, with three replications and plots of two 4-m rows. The trials were conducted in two environments: Ponta Grossa, in the dry season and Santo Antônio de Goiás in the winter season. Grain yield, reaction to angular leaf spot, and plant cycle were evaluated in these trials. Combined analysis of these data led to selection of the line CNFJ 15592 for participation in the preliminary jalo trial.

In 2011, the line CNFJ 15592 was evaluated in the preliminary jalo trial, composed of nine

treatments, consisting of seven new lines and two check cultivars (BRSMG União and Jalo Precoce). 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 crop season and Ponta Grossa (PR) in the rainy and dry seasons. In these trials, grain yield, plant cycle, and reaction to bacterial wilt and to powdery mildew were evaluated. Combined analysis of the data obtained in the preliminary jalo trial together with the data obtained in the jalo progeny trial led to selection of the line CNFJ 15592 for participation in the intermediate trial.

In 2013, the line CNFJ 15592 was evaluated in the diverse intermediate trial, composed of 13 treatments, consisting of nine new lines (three of the jalo type and six of the rajado type) and four check cultivars (BRSMG União, Jalo Precoce, BRS Radiante, and BRSMG Realce). 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 crop season (three trials); Ponta Grossa, PR, in the rainy and dry crop seasons; and Brasília, DF, in the winter crop season. Yield and 100-seed weight were evaluated in these trials. In addition, plant cycle, plant architecture, resistance to lodging, and reaction to diseases (anthracnose, angular leaf spot, bacterial wilt, powdery mildew, and Fusarium wilt) were evaluated.

Combined analysis of the data from the jalo progeny, preliminary jalo, and diverse intermediate trials led to selection of the CNFJ 15592 line for the Value for Cultivation and Use (*Valor de Cultivo e Uso* - VCU) trial, based on evaluation of nine environments. In 2015, in the winter crop season in Santo Antônio de Goiás, seeds were multiplied to obtain sufficient seeds for preparation of the VCU trials.

In the years 2016 and 2017, the line CNFJ 15592 was evaluated in 40 trials composed of 15 treatments, consisting of 11 new lines (three of the jalo type and eight of the rajado type) and four check cultivars: BRSMG União, Jalo Precoce, BRS Radiante, and BRSMG Realce. 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 cropping systems.

In these trials, the following aspects related to the grain were evaluated: yield, 100-seed weight, appearance, cooking time, and protein content. In addition, a scoring scale ranging from 1 (totally favorable phenotype) to 9 (totally unfavorable phenotype) (Melo, 2009) was used to evaluate the following aspects: plant architecture, resistance to lodging, and reaction to diseases – anthracnose (*Colletotrichum lindemutianum*), common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli*), rust (*Uromyces appendiculatus*), angular leaf spot (*Pseudocercospora griseola*), common mosaic virus *(Bean common mosaic virus)* and golden mosaic virus *(Bean golden mosaic virus)*, Fusarium wilt (*Fusarium oxysporum* f. sp. *phaseoli*), and bacterial wilt (*Curtobacterium flaccumfaciens* pv. *Flaccumfaciens*).

Grain yield was measured in kg/ha and corrected to 13% grain moisture. For 100-seed weight, a random sample of 100 seeds removed from each plot was weighed. In the best trials (highest mean yields and lowest coefficient of variation), samples were removed to analyze cooking time and protein content. For cooking time, the common bean grain was soaked in distilled water at the proportion of 1:4 (w/v) at ambient temperature for 16 hours. The water was then eliminated and the beans were placed in a Mattson cooker. Cooking time was determined as of the point of boiling of the water up to the time at which the plungers of the Mattson cooker penetrated 50% + 1 bean grain. The methodology was adapted from Proctor and Watts (1987). Protein content was analyzed from grain meal (grain ground in a ball mill), determining the nitrogen content by the micro-Kjeldahl method.

Grain yield and yield potential

Of the 40 experiments set up, 30 were harvested and achieved the standards of experimental quality necessary to be considered in the cultivar registration process in relation to yield data. These 30 VCU experiments were conducted in Region I (Santa Catarina, Paraná, and São Paulo) in the rainy season and in Region II (Goiás, Distrito Federal, Mato Grosso, Espírito Santo, and Minas Gerais) in the rainy, dry, and winter seasons.

In relation to yield, the cultivar BRS FS313 (CNFJ 15592) exhibited overall mean yield of 2,203 kg ha^{-1}, exceeding the overall mean yield of the check cultivars Jalo Precoce (1,970 kg ha^{-1}) and BRSMG União (1,950 kg ha^{-1}) by 12.4% (Table 1).

In the rainy season for Region 1 (South Central), BRS FS313 exhibited mean yield (2,330 kg.ha^{-1}) higher than that of the check cultivars BRSMG União (2,024 kg.ha^{-1}) and Jalo Precoce (1,814 kg.ha^{-1}), superiority of 15.1% and 28.5%, respectively (Table 1). In region II (Central), no difference was observed between the mean yield of BRS FS313 (2,071 kg.ha^{-1}) compared to the mean yield of the check cultivars BRSMG União (1,882 kg.ha^{-1}) and Jalo Precoce (1,937 kg.ha^{-1}).

The yield potential of BRS FS313, obtained from the mean of the five experiments in which the cultivar had the highest yields, was 3,200 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.

Commercial and nutritional seed quality

In relation to the characteristics of technological and industrial quality of the grain, the cultivar BRS FS313 had a mean 100-seed weight of 50 grams, higher than that of the cultivars Jalo Precoce and BRSMG União; both of these check cultivars had a mean weight of 38 grams (Table 2). The grain has a yellowish color, characteristic of the jalo type, though with bean grain larger than the standard grain, with a short oblong reniform shape, and not shiny. Mean cooking time of BRS FS313 was approximately 39 minutes,

Table 1. Grain yield (kg ha^{-1}) of the cultivar BRS FS313 compared to the mean of the two check cultivars (BRSMG União and Jalo Precoce) in the Value for Cultivation and Use (VCU) experiments by recommendation region and sowing season in 2016 and 2017.

Region	Crop Season	BRS FS313	BRSMG União	Jalo Precoce	Number of environments
I	Rainy	2,330 a	2,024 b	1,814 b	9
II	Rainy	2,115a	1,987a	2,124a	8
	Dry	1,827a	1,654a	1,680a	3
	Winter	2,272a	2,004b	2,008b	10
	Mean	2,071a	1,882a	1,937a	21
Overall	**-**	**2,203 a**	**1,970 b**	**1,950 b**	**30**

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

Table 2. Characteristics of the grain of the cultivar BRS FS313 compared to the check cultivars BRSMG União and Jalo Precoce.

Cultivar	Cooking time (minutes)	Protein content (%)	100-seed weight (g)
BRS FS313	39 a	21 a	50 a
BRSMG União	44 a	22 a	38 b
Jalo Precoce	45 a	21 a	38 b

Mean values followed by the same letter in the row do not differ statistically from each other according to the Scott-Knott test at the 5% level of probability.

Table 3. Agronomic characteristics and reaction to diseases of the cultivar BRS FS313 compared to the jalo check cultivars BRSMG União and Jalo Precoce.

Cultivar	Cycle	ARCH	AN	CBB	RU	AS	CM	GM	FOP	BW	ROT
BRS FS313	SE	Semi-upright	R	MS	MR	S	S	S	MR	S	R
BRSMG União	SE	Semi-upright	MS	MS	MR	S	NI	S	MR	S	MS
Jalo Precoce	E	Semi-upright	R	MR	MR	S	S	S	MR	S	MS

SE – Semi-early; E – Early; ARCH – Plant architecture; AN – Anthracnose; CBC – Common bacterial blight; RU – Rust; AS – Angular leaf spot; CM – Common mosaic; GM – Golden mosaic; FOP – Fusarium wilt; BW – Bacterial wilt; ROT – Root rots; SE – Semi-early; E – Early; R – Resistant; MR – Moderately resistant; MS – Moderately susceptible; S – Susceptible; NI – No information.

similar to that of the check cultivars. The percentage of protein in the grain of BRS FS313 (21.2%) was similar to that of the check cultivars.

Other traits

BRS FS313 has a semi-early cycle (of 75 to 84 days from emergence to physiological maturity), similar to that of the check cultivar BRSMG União. The plants are shrub type with a determinate growth habit. In relation to plant architecture, BRS FS313 is semi-upright and has intermediate resistance to lodging; it is adapted to mechanized harvest, including direct harvest. The flowers are white, and at physiological maturity and at the time of harvest, the pods are yellowish (Table 3).

Under artificial inoculation, the cultivar BRS FS313 is susceptible to the common mosaic virus. In field experiments, it proved to be resistant to anthracnose and root rots, moderately resistant to Fusarium wilt and rust, and moderately susceptible to common bacterial blight. However, it showed susceptibility to golden mosaic virus, bacterial wilt, and angular leaf spot (Table 3).

Seed production

BRS FS313 was registered on 5 Nov. 2020 under no. 45429 and protected on 26 Jul. 2021 under no. 20210284 with the Brazilian Ministry of Agriculture, Livestock and Food Supply. Production of basic seeds for making it available to seed producers will be under the responsibility of Embrapa and of partners selected through public notices of technical cooperation. Additional information can be obtained on the Embrapa page on Internet through the link *https://www.embrapa.br/busca-de-solucoes-tecnologicas*.

Conclusions

BRS FS313 is noteworthy for its high yield, higher 100-seed weight, and resistance to root rots in relation to cultivars of the jalo commercial group.Based on its performance, BRS FS313 was registered for Region I (South Central) for the rainy crop season in the states of Mato Grosso do Sul, Paraná, Santa Catarina, São Paulo, and Rio Grande do Sul; for Region II (Central) in the rainy, dry, and winter crop seasons in the states of Goiás, Mato Grosso, Distrito Federal, Tocantins, Rio de Janeiro, and Espírito Santo; and for Bahia and Maranhão in the rainy and winter crop seasons.

Acknowledgments

We thank partner institutions in evaluation of the cultivar: Embrapa Arroz e Feijão; Secretaria de Inovação e Negócios da Embrapa (SIN), Embrapa Agropecuária Oeste; Empresa Mato-grossense de Pesquisa Agropecuária e Extensão Rural (Empaer); Agência Goiana de Assistência Técnica, Extensão Rural e Pesquisa Agropecuária (Emater-GO); Universidade de Rio Verde (UniRV); Embrapa Cerrados; Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (Incaper); Universidade Federal de Goiás (UFG); Universidade Federal de Lavras (UFLA); Universidade Federal de Uberlândia (UFU); Universidade Estadual de Montes Claros (Unimontes); and Empresa de Pesquisa Agropecuária do Estado do Rio de Janeiro (Pesagro).

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