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BRS Sublime - Common bean cultivar with carioca grain, resistance to angular leaf spot and high nutritional quality

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Abstract: *BRS Sublime is a common bean cultivar with carioca grains, high nutritional grain quality, and high yield potential (4667 kg ha^{-1}). It has a normal cycle, upright growth, low loss rates in the mechanical harvest, and is recommended for planting in 19 Brazilian states, in the three main common bean cultivation regions. It is the first cultivar developed in the world with angular leaf spot resistance.*

Key words*: Phaseolus vulgaris, Pseudocercospora griseola, breeding.*

INTRODUCTION

Brazil is the world's largest producer of common bean (*Phaseolus vulgaris* L.), which is a staple food and protein source of the traditional diet in Brazil. Consumers are demanding about the region-specific grain color and type and with regard to the cooking quality. About 70% of all consumed common bean belong to the carioca grain group, which is produced mainly in the states of the South, Southeast and Midwest regions of the country. In the agricultural year 2014, including all three growing seasons, 2.7 million tons of common bean were produced on an area of 1.9 million hectares, i.e., a national mean yield of 1.389 kg ha^{-1} (Embrapa Arroz e Feijão 2016).

The occurrence of angular leaf spot caused by *Pseudocercospora griseola* increased considerably in the last two decades and under favorable conditions for the pathogen, yields can drop by 80% (Wendland et al. 2016). Thus, host genetic resistance is undoubtedly the most efficient, economical and least risky method for producers, consumers and the environment. The development of new cultivars resistant to *P. griseola* is hampered by the pathogenic variability of this fungus. For this reason, it is recommended to select or use genotypes with the highest degrees of horizontal and partial resistance.

The common bean breeding program of Embrapa and partners focuses on the development of cultivars that are more disease-resistant, with high

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productive potential and upright growth, allowing direct mechanical harvesting with a low loss rate (Melo et al. 2010). The yield gains obtained with common bean breeding by Embrapa are of the order of 0.72% per year for carioca bean (Faria et al. 2013) and of 1.1% per year for black bean grain (Faria et al. 2014). From 1984 to 2015, Embrapa and partners launched 55 cultivars with different grain types (annual average of 1.8 cultivars), 32 of which were released after the cultivar protection law.

Disease resistance can be qualitative/monogenic or quantitative/polygenic. Qualitative/monogenic or race-specific resistance is controlled by genes that are somehow involved in pathogen recognition, triggering disease control. This resistance type is mediated by main effect genes, only effective for certain pathogen races, and often not very durable in comparison with quantitative resistance. The latter, on the other hand, is polygenic, controlled by genes that act after pathogen recognition by the plant, but is effective against a broad spectrum of races, although the symptoms are not eliminated. Quantitative resistance is conferred by several genes of minor or secondary effect, but which together result in a broader and more stable resistance. This increases the buffer capacity of this resistance, able to resist genetic changes in the pathogen population. The effects of the two resistance types in disease epidemiology can be summarized as follows: qualitative resistance reduces the initial pathogen inoculum, whereas quantitative resistance mainly slows down the disease progression rate (Camargo 2011).

ORIGIN AND DEVELOPMENT OF THE CULTIVAR

BRS Sublime was derived from the hybridization between the lines EMP 250 / 4 / A 769 /// A 429 / XAN 252 // V 8025 / PINTO UI 114, in 1990, at the International Center for Tropical Agriculture (CIAT), Cali, Colombia. From there, Embrapa received the population in the F_4 generation, and all subsequent selection cycles were carried out at Embrapa Arroz e Feijão, in Santo Antônio de Goiás - GO. In 1995, the F_4 population was sown and angular leaf spot resistant plants were selected to constitute the F_5 population. Selection for grains according to the commercial standard of carioca beans was also performed. In 1996, in the F_5 generation, individual plants were selected for anthracnose, angular leaf spot and rust resistance. In 1997, the $F_{5:6}$ families were selected for rust resistance and upright plant architecture. In 1998, selection addressed families in the $F_{5:7}$ generation and plants within the families were selected for resistance to common bacterial blight, upright plant architecture, grain yield and carioca grain market standards. In 2000, $F_{5:8}$ lines were selected, based on yield and upright plant architecture, and line LM 200203999 was selected. In 2001, this line was evaluated in the Preliminary Test of Lines, along with 109 other lines and 4 controls (IAC Tybatã, Iapar 81, FT Magnífico, Pérola). These tests were conducted at four sites: Santo Antônio de Goiás - GO and Seropédica - RJ, in the winter; Ponta Grossa - PR, in the rainy; and Lavras, MG, in the dry growing season. In 2003, the line was evaluated in the Intermediate Trial with 24 other lines and 5 controls (BRS Horizonte, Iapar 81, FT Magnífico, Pérola, and IAC Tybatã), in 7 environments: Santo Antônio de Goiás - GO, and Simão Dias - SE, in the rainy season; Ponta Grossa - PR, in the rainy and dry seasons; Lavras - MG, and Seropédica - RJ, in the winter; and Sete Lagoas - MG, in the dry growing season. The combined analysis of grain yield data and other agronomic traits indicated line LM 200203999 (previously labelled CNFC 10429), for further evaluation in VCU tests. From 2005 to 2012, it was evaluated in 333 tests, with the control cultivars Pérola, Iapar 81, BRS Pontal, BRS 9435 Cometa, BRS Estilo, IAC Alvorada, IAC Carioca, IPR Tangará, SCS Guará, and IPR Juriti. The agronomic traits earliness, lodging tolerance and plant architecture were assessed on a score scale proposed by Melo (2009). In addition, BRS Sublime and the controls Pérola and BRS Estilo were evaluated for their reaction to common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli* and *Xanthomonas fuscans pv. fuscans*); bacterial wilt (*Curtobacterium flaccumfaciens* pv *flaccumfaciens*); angular leaf spot (*Pseudocercospora griseola*); anthracnose (*Colletotrichum lindemutianum*); Fusarium wilt (*Fusarium oxysporum* f. sp. *phaseoli*) and to Bean Common Mosaic Virus (BCMV). The disease reactions were tested under artificial inoculation, in a greenhouse and under natural conditions of field infestation (except for BCMV). The reactions of BRS Sublime to rust (*Uromyces appendiculatus*) and golden mosaic (BGMV) were evaluated under natural field conditions. These evaluations were based on scales of disease severity and incidence, described by Paula Júnior and Wendland (2012), ranging from 1 (no symptoms) to 9 (100% disease severity and presence of dead plants).

Grain yield was measured in kg ha^{-1} and corrected to 13% grain moisture. The sieved grain yield was measured by taking samples of 300 g grain per plot and sieving them through 4.25-mm-mesh (sieve 11) to determine the percentage of seeds with commercial size and the 100-seed weight. To determine the cooking time, the beans were soaked in distilled

water at room temperature, at a water:grain ratio of 1:4 (w/v). After 16 hours, the water was removed and the grains were placed in a Mattson cooker. The cooking time was determined from the boiling point of the water, until the moment when the needles of the Mattson cooker penetrated 50% +1 of the grains, according to a methodology adapted from Proctor and Watts (1987). The protein content was analyzed by the methodology of Dumas in an elemental analyzer (Perkin-Elmer 2400 Series II CHNS/O Elemental Analyzer with AD-6 Ultra Microbalance), according to Bremner (1996). To determine the grain contents of iron and zinc, single samples were analyzed by acid digestion of the organic matter (in a 2:1 nitro-perchloric mixture), by flame atomic-absorption spectrophotometry, adapted from the Association of Official Analytical Chemists (1995).

GRAIN YIELD AND YIELD POTENTIAL

From 2005 to 2012, line CNFC 10429 was evaluated in 333 VCU tests in the growing seasons: rainy and dry, in Mato Grosso do Sul-PR, Santa Catarina-RS; rainy in the states of Espírito Santo, Sergipe, Alagoas and Pernambuco; dry in Bahia; winter in Rio de Janeiro; and rainy, dry and winter in.the federal units São Paulo, Goiás, Distrito Federal, and Mato Grosso.

Line CNFC 10429 stood out with a 2.1% higher grain yield than the controls, in the mean of all evaluated environments. The yield potential was 4667 kg ha^{-1} (mean of the five environments with highest yields) and the mean yield was 2116 kg ha^{-1}, in the 333 test environments (Table 1). With regard to the three regions of cultivation recommendation of common bean cultivars (Pereira et al. 2010), the line performed 1.8% better than the control cultivars in Region 1 (São Paulo, Mato Grosso do Sul, Paraná, Santa Catarina, and Rio Grande do Sul); 11.4% higher in Region 2 (Mato Grosso,

Table 1. Mean grain yield (kg ha^{-1}) of cultivar BRS Sublime compared to that of the controls Pérola and BRS Estilo in tests of value for cultivation and use (VCU), from 2005 to 2012, for each region of cultivation recommendation and growing season

Region	Growing season	BRS Sublime	Mean of controls	Relative yield (%)	Number of environments
Region I		2226	2233	101.8	161
PR	rainy	2344	2352	97.1	34
	dry	2243	2068	112.6	22
SC	rainy	2602	2634	98.0	20
	dry	2068	1994	111.4	10
RS	rainy	1647	1865	88.0	11
	dry	1285	1324	98.6	6
MS	rainy	1985	2199	90.3	2
	dry	1932	1948	105.9	25
SP	rainy	2478	2635	96.2	16
	dry	2193	1963	111.7	9
	winter	3137	3220	101.4	6
Region II		2124	2012	111.4	131
ES	rainy	2466	2380	101.4	3
RJ	winter	1820	1819	99.0	8
	rainy	2073	1639	139.0	28
GO/DF	winter	2177	2312	94.4	25
	dry	1677	1460	129.6	16
	rainy	2052	1732	116.8	2
MT	dry	1422	1300	103.4	9
	winter	2676	2680	100.1	24
BA	rainy	1677	1460	129.6	18
Region III		2144	2154	102.8	39
SE	rainy	2604	2587	101.1	22
AL	rainy	1312	1236	113.1	5
PE	rainy	1647	1743	101.5	12
General mean		2116	2160	102.1	333

Region I - PR, SC, RS, MS and SP; Region II –ES, RJ, GO, DF, MT, BA; Region III – SE, AL, PE.

Goiás/Distrito Federal, Minas Gerais, Rio de Janeiro, Espírito Santo, Bahia, Tocantins, and Maranhão); and 2.8% higher in Region 3 (Sergipe, Alagoas, Pernambuco, Paraíba, Rio Grande do Norte, Ceará, and Piauí) (Table 1). Therefore, CNFC 10429 was selected for release as new cultivar, under the name BRS Sublime.

Compared to the controls, the data of BRS Sublime in the different, characteristic growing seasons of each region of cultivation recommendation showed a 6.08% lower grain yield in the rainy and a 8.04% higher yield in the dry season in Region 1. In the winter in Region1 (represented by the State of São Paulo only) or the State of São Paulo (Region 1), BRS Sublime was similar to the controls (+1.4%). Likewise, in Region 2, the grain yield of BRS Sublime was similar to that of the controls in the winter (-2.2%), but in contrast, preformed far better in both the dry (+16.5%) and the rainy season (+21.7%) (Table 1). In general, the performance of BRS Sublime differed more from the controls in the growing seasons with more favorable environmental conditions to the occurrence of angular leaf spot. This indicates that its resistance to the causal agent of this disease is a relevant factor for its recommendation as a new option of carioca grain cultivar for the common bean agribusiness.

TECHNOLOGICAL AND PROCESSING QUALITY OF THE GRAIN

With regard to the grain quality traits, cultivar BRS Sublime has high nutritional value, with regular grain color and size (Table 2). It also stands out for good cooking properties, with a mean cooking time of 27 minutes, which is shorter than that of BRS Estilo and similar to Pérola. Regarding the nutritional value, the protein percentage of BRS Sublime was 24.3%, also superior to BRS Estilo and similar to Pérola. The cultivar also has a higher potential for use in biofortification programs for iron and zinc (63.4 ppm Fe, 30.9 ppm Zn) than BRS Estilo (22.7% protein, 51.9 Ppm Fe, 28.7 ppm Zn) and Pérola (23.6% protein, 59.1 ppm Fe and 28.8 ppm Zn). The grain of BRS Sublime has the size, shape and color preferred by domestic consumers, with a mean 100-seed weight of 25 g (Table 2), similar to the cultivars Pérola and BRS Estilo, indicating the potentially high commercial value of this cultivar.

DISEASE REACTION

In the field, BRS Sublime has horizontal resistance to angular leaf spot and vertical resistance to ALS and common mosaic virus, aside from intermediate resistance to rust, bacterial wilt and anthracnose (Table 3). BRS Sublime is susceptible to Fusarium wilt, common bacterial blight, and golden mosaic virus. Under artificial inoculation in the greenhouse, it proved resistant to the pathotypes 65, 73, 81, 87, 91, and 457 of the fungus *C. lindemuthianum* (Wendland et al. 2012).

Cultivar BRS Sublime has a high level of horizontal resistance (quantitative/polygenic) to angular leaf spot (Table 4). This fact gives this cultivar the feature of a more durable resistance to the disease and a high sensitivity of discriminating different pathotypes of angular leaf spot. Under artificial inoculation in the greenhouse, it proved also vertical resistant to the pathotypes 31-31, 63-15, 63-23, 63-39, 63-47 and 63-63 of the fungus *P. griseola* (Table 5). In ongoing studies of genetic mapping at Embrapa Arroz e Feijão, the effect of loci associated with resistance to angular leaf spot in BRS Sublime is being identified and quantified.

Table 2. Technological and processing grain quality and agronomic traits and disease reaction of common bean cultivar BRS Sublime and control cultivars

Cultivar	**Cooking time** (min.)		**Protein** (%)		**Iron** (ppm)		**Zinc** (ppm)		**100-seed weight** (g)*		
BRS Sublime	27.0		24.3		63.4		30.9		25		
BRS Estilo	30.9		22.7		51.9		28.7		25		
Pérola	27.8		23.6		59.1		28.8		26		
	Market group	**Cycle**	**Plant architecture**	**AN**	**CBB**	**RU**	**ALS**	**VMCF**	**BGMV**	**FW**	**BW**
BRS Sublime	Carioca	N	Upright	I	S	I	R	R	S	S	I
BRS Estilo	Carioca	N	Upright	I	S	I	S	R	S	S	S
Pérola	Carioca	N	Semi-upright	S	S	I	I	R	S	I	S

*Estimated in experiments without disease control, using mesh 11 (4.25 mm).

Anthracnose; CCB- common bacterial blight; RU-Rust; ALS-Angular leaf spot; BCMV-bean common mosaic virus; BGMV-bean golden bean mosaic virus; FW- Fusarium wilt; BW- bacterial wilt. N-normal cycle. R- Resistant (score 1.0 to 3.0); I- Intermediate (scores 3.1 to 4.0); S- Susceptible (scores 4.1 to 9).

Table 3. Severity of Angular Leaf Spot (ALS) of cultivar BRS Sublime compared to that of the controls BRS Estilo and Pérola in tests of value for cultivation and use (VCU), from 2009 to 2012, in 55 environments of cultivation recommendation and growing season. Severity of different races of ALS inoculated in the cultivar BRS Sublime and compared to that of the controls BRS Estilo and BRS Horizonte in tests of greenhouse control conditions. Temperature: 25-28 °C

Cultivar		**ALS**		
BRS Sublime		2.4 – R		
BRS Estilo		4.8 – S		
Pérola		4.2 – S		
Number of environments: 55				
Isolates *Pg*	**Patotype/Race**	**Cultivars**		
		BRS Sublime	**BRS Estilo**	**BRS Horizonte**
Pg 60.4	63-39	1	5	8
Pg 762	31-31	2	6	5
Pg 786	63-63	3	4	6
Pg 1219	63-47	1	2	3
Pg 525.4	63-23	2	2	3
Pg 738	63-15	1	3	5
Pg 1231	63-47	1	3	4
Pg 1236	63-63	1	2	3
General mean		1.5 - R	3.37 - I	4.62 - S

R - Resistant (score 1.0 to 3.0); I- Intermediate (scores 3.1 to 4.0); S- Susceptible (scores 4.1 to 9).

OTHER TRAITS

Cultivar BRS Sublime has an upright plant architecture (Table 3), an indeterminate growth habit (type II), and is suited for direct mechanical harvesting, which allows harvesting with a low loss index. It has a normal long cycle of 85 to 90 days, from emergence to physiological maturity (Table 3). The flowers are white and, at physiological maturity, the pods are reddish yellow. At harvest maturity, the pods turn sand yellow. The grains are light beige with light brown stripes, slightly flattened elliptical shape and not shiny.

SEED PRODUCTION

BRS Sublime was registered on October 30, 2013 (no. 31173), and protected on March 11, 2016 (certificate no. 20160051), by the Ministry of Agriculture, Livestock and Supply (MAPA). The institution Emater-GO will be in charge of basic seed production.

CONCLUSIONS

The common bean cultivar of the market group BRS Sublime has a normal cycle, upright and low loss in the direct mechanical harvest, high productive potential, high commercial and nutritional grain quality, apart from quantitative or polygenic resistance to angular leaf spot. BRS Sublime is recommended for common bean production systems in Region 1, in the rainy and dry growing seasons; in São Paulo, in the rainy, dry and winter growing seasons. In Region 2, in the rainy, dry and winter growing seasons. In Region 3, in the rainy growing season.

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