

IPR CELEIRO: Common bean cultivar moderately resistant to bean golden mosaic virus

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Abstract: *IPR Celeiro is a common bean (Phaseolus vulgaris L.) cultivar with a carioca-type seed and moderate resistance to Bean Golden Mosaic Virus (BGMV). IPR Celeiro has a normal life cycle and an upright architecture. This cultivar was released for the purpose of integrating its use with disease management systems in the cultivation areas affected by this virus.*

Keywords: *Phaseolus vulgaris L., Bean Golden Mosaic, resistance.*

INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) cultivation area in Brazil has ranged between 3 and 4 million hectares in the last two decades (Moraes and Menelau 2017, CONAB 2018). Approximately 50% of that area has been cultivated in the dry, fall-winter seasons, a period that extends from December to June, depending on the region (Moraes and Menelau 2017, CONAB 2018). Due to bean golden mosaic disease, caused by the *Bean Golden Mosaic Virus* (BGMV), bean yields in Brazil decreased significantly during the 1970s and 1980s, during which the dry season yields were the most affected. During the dry season, the losses caused by BGMV can reach as high as 100% (Bianchini 1999). In the state of Paraná, average yields reached a maximum of 967 kg ha⁻¹ in 1972, decreasing to 387 kg ha⁻¹ in 1986, and in Brazil, average yields decreased from 683 kg ha⁻¹ in 1971 to 387 kg ha⁻¹ in 1987 (Llanillo and Guerreiro 1989, CONAB 2018). The reduction in productivity was the result of edaphic factors, climatic fluctuations and biotic factors (i.e., pests and pathogens). However, since the 1970s, the largest decreases in yield have coincided with the highest incidences of BGMV in common bean cultivation areas (Wendland et al. 2016). Productivity gradually increased at the beginning of the 1990s (SEAB/DERAL 2017) due to the use of new technologies, mainly more-productive cultivars, appropriate sowing dates adjusted for each growing area and soil improvements.

Measures to control bean golden mosaic virus, such as chemical control of whitefly (*Bemisia tabaci* (Gennadius)), the vector of the virus, and adjusted seeding dates, may reduce the incidence of BGMV. The date of sowing should be made earlier or delayed according to the incidence of whitefly and climatic conditions in each growing area. Seeding time should avoid coinciding with exposure to the highest populations of whitefly, and the end of the crop cycle should not coincide with low temperatures or frost (Bianchini 2010).

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The use of resistant cultivars in an integrated disease management system is a valuable option for the efficient control of BGMV (Bianchini et al. 2005). Several research institutions in Brazil have focused on the search for resistant or moderately resistant common bean lines developed through conventional breeding (Bianchini 1999, Juliati et al. 2005, Coutinho et al. 2016), induced mutation (Tulmann Neto et al. 1993) or transgenic techniques (Carvalho et al. 2015, Souza et al. 2016). Some of these lines were commercially released, but due to undesirable agronomic or commercial characteristics, they were not accepted in the market. Some cultivars of the carioca group with resistance to golden mosaic had difficulties gaining commercial acceptance due to their seed appearance. For example, the seed coat of some cultivars had an orange corona (e.g., cv. Iapar 57 and cv. Iapar 72). In the 1980s, the common bean cultivar Ônix was released (Faria et al. 2016). It is a black bean with moderate tolerance to the disease; however, it had no real impact, mostly owing to its plant architecture type (Faria et al. 2016). Another aspect that was considered was the reduced competitiveness in relation to other cultivars, caused by lower yields or susceptibility to other pathogens occurring in the bean-growing regions. This study reports on the characteristics of the common bean cultivar IPR Celeiro, recently developed by the Agronomic Institute of the State of Paraná (IAPAR), with moderate resistance to BGMV. This characteristic combined with its upright architecture, good productivity and commercial seed quality led to registration in the National Register of Cultivars (RNC). IPR Celeiro was released for the purpose of integrating its use with BGMV management in the crop systems of the affected growing areas.

Breeding methods

The cultivar IPR Celeiro was developed by conventional breeding at IAPAR in 1988, and its cross-code was HMD881 [((Porrillo Sintetico x MD821) x RM8454-8-4-cm) x Carnaval]. The parents were the black common bean cultivar Porrillo Sintetico and the cultivar Carnaval, which has a cream-colored seed coat with purple spots. Both cultivars were susceptible to BGMV. However, they showed desirable agronomic characteristics, mainly lower losses in yield caused by BGMV when compared with other susceptible genotypes. The line MD821 is a black common bean genotype with moderate BGMV resistance that was released as cultivar IAPAR 65 (Bianchini 1999). The line RM8454-8-cm, a carioca seed type with moderate BGMV resistance, originated from a cross between lines (MD632 x BAC32), the same cross as the cultivar IAPAR 57 (Bianchini 1999). The progenies were advanced by the single pod descendent (SPD) population up to the F_3 generation. From the F_3 generation, individual plants were selected, and their progenies were advanced by the genealogic method and mass selection up to the F_{11} generation. From the F_{11} generation, under field conditions with naturally occurring BGMV infection, several promising lines with mild symptoms or no apparent symptoms were selected for possible resistance to BGMV. In the F_{11} generation, the line 615/sg99 was selected, as it showed promising resistance to BGMV, but it lacked commercial quality seed. Through further selection within this line, the generations were advanced through the SPD method. The line 2442/04 with the carioca seed type was selected, but it had poor commercial seed quality. Within this line, the line MD1092 was further selected, combining resistance to BGMV with the commercial quality of the carioca seed type and a high yield potential.

The line MD1092 was included in yield trials in 2009, in yield tests of Value for Cultivation and Use (VCU) in 2010, and in the dry and fall-winter growing season for six years at six locations in the state of Paraná. The results from the fall-winter season of 2012, 2013 and 2015 were used for registration in Brazil. The environments in Paraná state (Brazil) evaluated were a) 2012: Londrina, Santana do Itararé, Cambará and Umuarama; b) 2013: Londrina, Cambará, Umuarama, Santana do Itararé and Jaguapitã; c) 2014: There were no results, the experiments were lost due to climatic problems in some localities and logistical operational difficulties; d) 2015: Londrina, Santana do Itararé, Umuarama and Palotina. The VCU test was conducted according to the standards of the Ministry of Agriculture, Livestock and Food Supply (MAPA 2019a). The VCU used a randomized complete block design with four replicates. The experimental plots consisted of four rows of five meters in length with row spacings of 0.5 m and a seed density of 12 to 15 seeds per linear meter. The two central rows of each plot were harvested. The VCU trials are prerequisites for registering a cultivar in the RNC/MAPA. The purpose of the RNC is to prequalify cultivars and species for the production and marketing of seeds and seedlings in Brazil (MAPA 2019b). The bean cultivars IPR Juriti, IPR Tangará, BRS Pérola and IPR Eldorado were the control cultivars (carioca seed type). The data were subjected to analysis of variance for each environment, and the means were grouped by the Scott-Knott test at $P = 0.05$ (Scott and Knott 1974).

The line MD 1092's (later IPR Celeiro) reactions to BGMV infection were evaluated in field experiments (VCU tests) and under greenhouse conditions. Symptom severity (SD) was evaluated on a 1 to 9 scale (1 = symptomless plant, 9 = severe mosaic or severe malformation affecting more than 75% of the leaf area and the plant size with witches' broom symptom) (Bianchini 1999). The field experiments followed the same design described in the VCU test, and inoculation occurred through natural BGMV infection. Table 1 shows the means of severity of the mosaic symptoms and deformations caused by BGMV in seven VCU experiments. The greenhouse experiment was evaluated once in a completely randomized design with ten repetitions, each plot consisting of one plant per pot. Infectious whiteflies (*Bemisia tabaci*) were used for the inoculation with more than 100 insects per plant during the plant's life cycle.

Reactions to anthracnose were evaluated in the laboratory against pathotypes 65, 89 and 95 of *Colletotrichum lindemuthianum* (Sacc & Magn.) Lams.-Scrib, according to the methodology described by Rava et al. (1993). Reactions of the cultivar to angular leaf spot [*Pseudocercospora griseola* (Sacc.) Crous & U. Braun], fusarium wilt [*Fusarium oxysporum* f. sp. *phaseoli* Kendrick and Snyder (Fop)], bacterial wilt [*Curtobacterium flaccumfaciens* pv. *flaccumfaciens* (Hedges) Collins & Jones] and common bacterial blight [*Xanthomonas axonopodis* pv. *phaseoli* (Smith 1897) Vauterin, Hoste, Kerster & Swings 1995] were rated according to the scale described by Schoonhoven and Pastor-Corrales (1987). The disease scale ranged from 1.0 to 9.0, and scores of 1.0 to 3.0 were considered resistant, 4.0 to 6.0 were considered intermediate and 7.0 to 9.0 were considered susceptible (Schoonhoven and Pastor-Corrales 1987). The reactions to the fungal and bacterial diseases were carried out field evaluations in the plots of VCU trials.

Disease response

The IPR Celeiro cultivar showed partial type resistance to BGMV and was classified as moderately resistant. BGMV-susceptible plants in some of the control cultivars expressed intermediate to severe mosaic symptoms (yellow spotting) with mild deformations of the leaves, and intermediate leaf curling with mild mosaic symptoms. In seven VCU trials conducted in the state of Paraná, the cultivar IPR Celeiro showed an average score for BGMV symptoms of 2.7, which was significantly lower than the scores for the susceptible cultivars IPR Juriti, IPR Tangará and Pérola (Table 1). The cultivar IPR Celeiro was included in the group with the lowest incidence of disease in 85.7% of the field evaluations (Table 1). Under greenhouse conditions, IPR Celeiro showed lower scores for leaf-curling and plant stunting at 15 and 45 days after emergence (Table 2). The lowest score for mosaic symptoms was observed in IPR Celeiro at 15 days after emergence. The intermediate score for mosaic symptoms at 45 days after emergence (Table 2) was the reason that IPR Celeiro was classified as moderately resistant to BGMV rather than resistant.

IPR Celeiro was also resistant to bean common mosaic virus (BCMV) based on the results of laboratory tests (Drijfhout et al. 1978). IPR Celeiro was susceptible to pathotype 65 and moderately resistant to pathotypes 89 and 95 of *Colletotrichum lindemuthianum*, the causal agent of anthracnose. In the field, the cultivar was susceptible to angular leaf spot, fusarium wilt, and bacterial wilt and had intermediate resistance to common bacterial blight.

Table 1. Clustering of means of severity values of the bean golden mosaic symptoms and deformations of IPR Celeiro and control cultivars evaluated in seven Value for Cultivation and Use (VCU) field experiments and frequency in class "a" (minor severity), individually analyzed (by location and year)

Cultivar	Location*/Year							Frequency		
	ST/11	ST/12	JA/12	LD/12	ST/15	PL/15	LD/15	Mean	N	%
IPR Celeiro	1.3 a**	2.8 a	4.0 a	5.3 b	1.3 a	1.8 a	1.0 a	2.7	6	85.7
IPR Eldorado	1.6 a	2.3 a	3.7 a	3.4 a	1.0 a	1.5 a	1.0 a	2.1	7	100
IPR Juriti	6.5 b	7.2 d	6.7 b	8.0 c	4.5 b	5.0 b	6.8 c	6.4	0	0
IPR Tangará	--	5.1 b	7.0 b	8.0 c	4.5 b	7.0 c	7.8 d	6.6	0	0
BRS Pérola	6.0 b	6.3 c	7.0 b	8.0 c	4.3 b	5.3 b	5.0 b	6.0	0	0
General Mean	2.33	4.20	4.88	5.34	1.64	2.78	2.13			
CV (%)	36.8	11.7	18.7	21.8	38.1	33.3	26.8			
Number of treatments	16	20	20	20	16	16	16			

* Locations of evaluation: ST: Santana do Itararé/PR, JA: Jaguapitã/PR, LD: Londrina/PR, PL: Palotina/PR. ** Mean values followed by the same letter in the column were grouped in same class by the Scott-Knott test at the 5% probability level. Note: Severity values were evaluated on a 1 to 9 scale (1 = symptomless plant, 9 = dead plant).

Agronomic characteristics

IPR Celeiro has a normal life cycle, requiring 37 - 42 days from seedling emergence to flower and approximately 87 days from seedling to physiological seed maturity. The plants have an upright architecture and indeterminate growth habit (Type II), which facilitates cultivation and mechanical harvesting. The flowers are white, and the pods are yellow at physiological maturity. The seeds belong in the carioca market class, which is the preferred market class in Brazil, and have an opaque and light beige seed coat and light brown stripes and an average 1000-seed weight of 240 g. The mean cooking times of IPR Celeiro measured by Mattson bean cooker (Proctor and Watts 1987) were 16.5 minutes and 27.5 minutes in the dry season and fall-winter, respectively. The protein content was determined by the micro-Kjeldahl method (AOAC 1980). The mean protein content was 20.8% and 22.4% in the dry season and fall-winter, respectively.

Table 2. Severity score of mosaic symptoms (M) and leaf-curling and plant stunting (LC-Pst) in the IPR Celeiro and susceptible cultivars under greenhouse conditions, infected with BGMV by the vector *Bemisia tabaci** at 15 and 45 days after emergence (DAE) at Londrina, PR, 2015

Cultivar	M		LC-Pst	
	15 DAE	45 DAE	15 DAE	45 DAE
IPR Celeiro	2.0 A a**	5.4 B b	2.3 A d	3.1 B a
IPR Juriti	3.7 A b	4.5 B a	4.9 A c	5.0 A b
RJ-Rosa***	5.8 A c	7.1 B a	3.8 A b	5.8 B c
IPR Tangará	3.6 A b	4.2 A b	7.1 A d	7.5 A d
General Mean	4.5		4.9	
CV (%)	28.1		29.3	

* Population density > 100 insects per plant; 47 treatments (genotypes) were used. ** Mean values followed by the same lowercase letter in the column or by capital letter in the row do not differ significantly by the Scott-Knott test at the 5% probability level. *** "RJ-Rosa" is a line originating from the natural cross between BRS Radiante and IPR Garça. RJ-Rosa is a control that is susceptible to mosaic (M) and moderately susceptible to LC-Pst. Note: The severity score is based on a scale from 1 (plant without symptom) to 9 (dead plant).

Table 3. Mean grain yield (kg ha⁻¹) of the cultivar IPR Celeiro and controls IPR Eldorado, IPR Juriti, IPR Tangará and Pérola, in 13 Value for Cultivation and Use (VCU) experiments, tested during three years in the fall/winter season

Year	Sites	Control cultivars				IPR Celeiro	CV (%)	Fcal.
		IPR Eldorado	IPR Juriti	IPR Tangará	Pérola			
2012	Cambará	1463 A d	1635 A b	1370 A d	1913 A b	1442 A c	24.0	6.8**
	Londrina	1353 A d	900 B c	584 B e	585 B d	713 B e	16.9	12.0**
	Santana do Itararé	910 A e	432 B d	461 B e	508 B d	848 A e	17.1	29.7**
	Umuarama	1424 A d	1193 A c	1805 A c	1494 A c	1587 A c	24.6	2.7*
Mean (year 2012)		1287	1040	1055	1125	1148	-	-
2013	Cambará	356 B f	1608 A b	1272 A d	1401 A c	1139 A d	21.5	7.2**
	Jaguapitã	383 B f	1233 A c	1241 A d	1595 A c	1549 A c	19.4	10.9**
	Londrina	1555 A d	857 B c	577 B e	964 B d	1541 A c	14.1	53**
	Santana do Itararé	2276 A b	1988 A a	1823 A c	1892 A b	1505 B c	19.3	4.1**
Umuarama		416 D f	1697 B b	1135 C d	2362 A a	1322 A c	16.7	24.9**
Mean (year 2013)		997	1476	1209	1643	1411	-	-
2015	Londrina	1858 B c	1066 D c	1092 D d	1557 C c	2447 A b	18.8	5.2**
	Palotina	968 A e	344 B d	547 B e	735 B d	1199 A d	14.0	2.4*
	Santana do Itararé	2811 A a	2142 B a	2236 B b	2553 A a	2595 A b	13.3	1.8ns
	Umuarama	3065 A a	2213 B a	2820 A a	2839 A a	2995 A a	20.0	14.7**
Mean (year 2014)		2175	1441	1673	1921	2309	-	-
General mean		1449	1331	1305	1569	1606	-	-
Rmtest (%)*		102.5	94.2	92.3	111.0	113.6	-	-

CV: coefficient of environmental variation; Fcal: F calculated in the analysis of variance; **/* significant to 1%, 5% by F test, respectively; ns: not significant. Averages followed by the same uppercase letter in the row or lowercase in the column belong to the same statistically homogeneous grouping. Scott-Knott test ($P < 0.05$). * Rmtest = [(Mean of genotype) / (Mean of the control cultivars)] x 100.

Grain yield

The yield trial was evaluated in 13 environments (combination of locale and year) at six locations (Cambará, Londrina, Santana do Itararé, Umuarama, Palotina and Jaguapitã) in the state of Paraná (Table 3). The analysis of individual variance showed a significant effect of genotype on yield effect for all environments except for Santana do Itararé in the fall-winter season/2015. These results indicate that the yields differed among the genotypes. The coefficients of variation estimated were less than 24%, below 25%, which is the acceptable value established by the Register National of Cultivars of the Ministry of Agriculture, Livestock and Food Supply (MAPA 2019a). From the performance analysis of the IPR Celeiro cultivar in VCU trials, it could be verified that the maximum yield of this cultivar was 2995 kg ha⁻¹ at Umuarama in the fall-winter season/2015. The IPR Celeiro average yields for the three years, 2012 (four environments), 2013 (five environments) and 2015 (four environments), were 1148 kg ha⁻¹, 1411 kg ha⁻¹ and 2309 kg ha⁻¹, respectively. The results of the joint analysis of variance showed that the effects of environments, genotypes and genotype-environmental (G x E) interaction were significant ($P < 0.05$). Due to the interaction G x E, the Scott-Knott (1974) grouping test was performed both between genotypes within each environment and between environments in each genotype. It was verified that in ten of thirteen environments analyzed, the cultivar IPR Celeiro was classified in the group with higher average yields that were significantly different from the other classes in ten environments. The yields of IPR Celeiro averaged 13.6% more than the overall mean of testers (Table 3).

Basic seed production

The genetic and basic seeds were produced by IAPAR. Other categories of commercial seeds were produced in partnership with seed companies. The list of seed producer partners is available at the website www.iapar.br or can be obtained by email: comercial@iapar.br.

Registration and protection

The common bean cultivar IPR Celeiro was registered in the National Register of Cultivars (RNC) of the Brazilian Ministry of Agriculture, Livestock and Supply (MAPA) under the number 35438 and is protected by the National Variety Protection Service (SNPC) certificate Nr 21806.000004, starting on 05/10/2017.

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