

## Common bean genotypes for agronomic and market-related traits in VCU trials

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**ABSTRACT:** Value for Cultivation and Use (VCU) trials are undertaken when evaluating improved common bean (*Phaseolus vulgaris* L.) lines, and knowledge of agronomic and market-related traits and disease reaction is instrumental in making cultivar recommendations. This study evaluates the yield, cooking time, grain color and reaction to anthracnose (*Colletotrichum lindemuthianum*), Fusarium wilt (*Fusarium oxysporum* f. sp. *phaseoli*) and Curtobacterium wilt (*Curtobacterium flaccumfaciens* pv. *flaccumfaciens*) of 25 common bean genotypes derived from the main common bean breeding programs in Brazil. Seventeen VCU trials were carried out in the rainy season, dry season and winter season from 2009 to 2011 in the state of São Paulo. Analyses of grain color and cooking time were initiated 60 days after harvest, and disease reaction analyses were performed in the laboratory under controlled conditions. In terms of yield, no genotype superior to the controls was observed for any of the seasons under consideration. Grains from the dry season exhibited better color, while the rainy season led to the shortest cooking times. The following genotypes BRS Esteio, BRS Esplendor and IAC Imperador were resistant to anthracnose, Fusarium wilt and Curtobacterium wilt and, in general, genotypes with lighter-colored grains were more susceptible to anthracnose and Fusarium wilt.

**Keywords:** *Phaseolus vulgaris*, Fusarium wilt, Curtobacterium wilt, anthracnose, selection

### Introduction

Value for Cultivation and Use (VCU) trials in the common bean Genetic Breeding Program of the Agronomic Institute (IAC) were undertaken in the state of São Paulo, Brazil, in an evaluation of improved common bean lines in keeping with standards established by the Brazilian Ministry of Agriculture, Livestock and Food (Ministério da Agricultura, Pecuária e Abastecimento - MAPA).

Consumers of common bean take nutritional, industrial and commercial traits into consideration, and the most important traits are grain size, seed coat color, mechanical damage and cooking time (Peña-Valdivia et al., 2011). Cooking time should be considered by common bean breeding programs since cooking is required for consumption of these grains. It also contributes to characterization of the sensory properties of color, taste and texture, which consumers consider appealing (Wang et al., 2003; Shimelis and Rakshit, 2005).

Together with grain traits, it is just as important to identify common bean genotypes that exhibit genetic resistance or tolerance to the main diseases that can afflict the crop. Anthracnose (*Colletotrichum lindemuthianum*) is considered to be one of the main diseases that attacks the part of the plant that is above ground. This pathogen exhibits high pathogenic variability, and, in the state of São Paulo, nine races causing significant damage to commercial crops have already been identified (Carbonell et al., 1999). Fusarium wilt, caused by the fungus *Fusarium oxysporum* f. sp. *phaseoli* is among the most important soil diseases that affect common bean. Seven physiological races of *Fusarium oxysporum* distributed in different regions of the world have been described, with

indications that, in Brazil, there is a predominance of race 2 (Alves-Santos et al., 2002a). As regards bacterial diseases, Curtobacterium wilt of the common bean (*Curtobacterium flaccumfaciens* pv. *flaccumfaciens*) is a relatively new disease, that is found throughout the main producing regions of the world (Hsieh et al., 2004) and is becoming increasingly significant in Brazil.

This study aimed to evaluate the yield of 25 common bean genotypes sown in 17 environments in the state of São Paulo, to determine the cooking time and grain color of the genotypes in different crop seasons, and to evaluate the reaction of the genotypes to physiological races 31, 65 and 81 of *Colletotrichum lindemuthianum*, to the mixture of races I and II of *Fusarium oxysporum*, and to an isolate of *Curtobacterium flaccumfaciens*.

### Materials and Methods

A total of 25 common bean genotypes were evaluated, with 13 genotypes from the Agronomic Institute (IAC), five from the Brazilian Agricultural Research Corporation - EMBRAPA, two from the Agricultural Research and Rural Extension of Santa Catarina - EPAGRI, two from the Federal University of Lavras - UFLA and three from the Paraná Agronomic Institute - IAPAR (Table 1). The 2009/2010/2011 VCU trials consisted of 17 experiments conducted in the state of São Paulo in the following locations, crop seasons, and years: Capão Bonito (24°0' S; 48°20' W) and Mococa (21°28' S; 47°0' W) in the rainy season of 2009; Avaré (23°6' S; 48°56' W), Mococa and Tatuí (23°21' S; 47°51' W) in the dry season of 2010; Andradina (20°53' S; 51°23' W), Espírito Santo do Pinhal (22°10' S; 46°45' W) and Votuporanga (20°25' S; 49°58' W) in the winter season of 2010; Av-

Table 1 – Comparison of mean values for grain yield of 25 common bean genotypes in the 2009 and 2010 rainy crop seasons, 2010 and 2011 dry crop seasons and the 2010 and 2011 winter crop seasons in environments in the state of São Paulo, and for reaction to the pathogens of anthracnose (*Colletotrichum lindemuthianum*), Fusarium wilt (*Fusarium oxysporum*) and Curtobacterium wilt (*Curtobacterium flaccumfaciens*).

Common Bean Cultivars and Lines	Yield in Crop Seasons <sup>1</sup>			Joint analysis	Reaction to Physiological Races of <i>C. lindemuthianum</i> <sup>2</sup>			Reaction to <i>Fusarium oxysporum</i> <sup>3</sup>	Reaction to <i>Curtobacterium flaccumfaciens</i> <sup>3</sup>
	Rainy	Dry	Winter		Race31	Race65	Race 81	Mixture of Races I and II	IAC Isolate
	kg ha <sup>-1</sup>								
IAC Alvorada (IAC Carioca)	1929	2172	2471	2191	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>R</b>
BRS Pérola (Embrapa Carioca)	<b>2149</b>	<b>2374</b>	<b>2638</b>	<b>2387</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>MR</b>	<b>S</b>
IAC Diplomata (IAC Preto)	2042	2141	2228	2137	<b>R</b>	<b>R</b>	<b>R</b>	<b>MR</b>	<b>S</b>
IAC Una (IAC Preto)	<b>2277</b>	<b>2344</b>	<b>2369</b>	<b>2330</b>	<b>R</b>	<b>R</b>	<b>R</b>	<b>MR</b>	<b>S</b>
Gen C2-1-6-1 (IAC Carioca)	2141	2611	2421	2391	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>MR</b>
Gen C2-1-6-1-1 (IAC Carioca)	2506	2353	2631	2497	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>
Gen C2-3-1-1-2 (IAC Carioca)	2183	2448	2527	2386	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>
Gen C4-5-4-1-2 (IAC Carioca)	1529	1830	2308	1889	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>R</b>
Gen C4-8-1-1 (IAC Carioca)	1968	2048	2549	2188	<b>R</b>	<b>R</b>	<b>R</b>	<b>S</b>	<b>R</b>
CHC 97-29 (Epagri Carioca)	2618	2147	2456	2407	<b>S</b>	<b>S</b>	<b>S</b>	<b>R</b>	<b>MR</b>
CHP 98-59 (Epagri Preto)	2041	2370	2542	2318	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>	<b>S</b>
BRS Esteio (Embrapa Preto)	2451	2578	2619	2549	<b>R</b>	<b>R</b>	<b>R</b>	<b>R</b>	<b>MR</b>
BRS Cometa (Embrapa Carioca)	1961	2078	2374	2138	<b>R</b>	<b>R</b>	<b>S</b>	<b>S</b>	<b>S</b>
IPR Eldorado (IAPAR Carioca)	2140	2191	2411	2247	<b>S</b>	<b>S</b>	<b>S</b>	<b>R</b>	<b>S</b>
BRS Esplendor (Embrapa Preto)	2242	2498	2611	2450	<b>R</b>	<b>R</b>	<b>R</b>	<b>R</b>	<b>R</b>
BRS Estilo (Embrapa Carioca)	2225	2291	2458	2325	<b>R</b>	<b>R</b>	<b>R</b>	<b>S</b>	<b>MR</b>
LP 0403 (IAPAR Carioca)	2385	2636	2523	2515	<b>R</b>	<b>R</b>	<b>S</b>	<b>R</b>	<b>MR</b>
L P 0577(IAPAR Carioca)	2017	2428	2452	2299	<b>S</b>	<b>S</b>	<b>S</b>	<b>R</b>	<b>R</b>
MAIL-22 (UFLA Carioca)	1921	2277	2279	2159	<b>S</b>	<b>R</b>	<b>S</b>	<b>MR</b>	<b>S</b>
IAC Imperador (IAC Carioca)	2355	2480	2521	2452	<b>R</b>	<b>R</b>	<b>R</b>	<b>R</b>	<b>R</b>
Gen P5-4-4-1 (IAC Carioca)	1735	2122	2557	2138	<b>R</b>	<b>R</b>	<b>R</b>	<b>S</b>	<b>S</b>
Gen Pr11-3-5-1 (IAC Carioca)	2178	2358	2525	2354	<b>R</b>	<b>R</b>	<b>R</b>	<b>R</b>	<b>S</b>
Gen Pr11-6-4-1-2 (IAC Preto)	1689	1938	2488	2038	<b>R</b>	<b>R</b>	<b>R</b>	<b>S</b>	<b>MR</b>
Gen Pr14-2-3-2 (IAC Preto)	1914	2258	2535	2236	<b>R</b>	<b>R</b>	<b>R</b>	<b>MR</b>	<b>S</b>
RP-2 (UFLA Carioca)	2396	2186	2404	2329	<b>S</b>	<b>R</b>	<b>S</b>	<b>S</b>	<b>S</b>
<sup>4</sup> Mean	<b>2111 C</b>	<b>2268 B</b>	<b>2476 A</b>	<b>2294</b>	---	---	---	---	---
CV (%)	<b>21.56</b>	<b>18.96</b>	<b>16.74</b>	<b>17.19</b>	---	---	---	---	---
DMS kg ha <sup>-1</sup>	<b>632</b>	<b>468</b>	<b>355</b>	<b>235</b>	---	---	---	---	---

<sup>1</sup>Values in bold print correspond to the best standard cultivar of comparison by the Dunnett test (5 %) for the corresponding commercial group (IAC Alvorada and BRS Pérola for the carioca group and IAC Una and IAC Diplomata for the black group); <sup>2</sup>Resistance/susceptibility reaction to the pathogen evaluated (R – Resistant; S – Susceptible); <sup>3</sup>Resistance/susceptibility reaction to the pathogen evaluated (R – Resistant; MR – Moderately Resistant; S – Susceptible); <sup>4</sup>Mean values followed by the same letter do not differ (Skott-Knott test,  $p < 0.05$ ).

aré, Capão Bonito and Mococa in the rainy season of 2010; Avaré, Capão Bonito and Mococa in the dry season of 2011; and Colina (20°42' S; 48°32' W), Ribeirão Preto (21°10' S; 47°49' W) and Votuporanga in the winter season of 2011. The experiments sown in the winter season received supplemental irrigation.

A randomized block experimental design was used according to the MAPA standards for VCU trials, with three replications. Plots consisted of four 4m length rows, spaced at 0.50 m, with 10 to 12 viable plants per meter, the useful area of the plot being the two center rows.

Evaluations pertaining to cooking time (CT) and grain color were carried out 60 days after harvest as described by Perina et al. (2014). For this purpose, the grains were classified in a size 13 sieve (13/64") with

oblong holes. This classification aimed to standardize grain size and make sample exhibit grains with a pattern as required by the packaging industry. Grains visually perceived as grains damaged by insects or mechanically damaged were removed. Mean cooking time (CT) was determined through the use of three replications with 25 grains per replication, obtained from a 30 g sample for each genotype. These uniform grains were soaked in distilled water for 16 h at room temperature. After this period, the 25 grains were individually placed in the orifices at the base of the Mattson cooker, and the device was placed in a beaker containing 1000 mL of boiling distilled water. Cooking time, measured in the Mattson cooker, was interrupted on the fall of the thirteenth rod out of a total of 25 (Proctor and Watts, 1987).

Evaluation of seed coat color was performed with a manual colorimeter, model CR-410. Quantification of the L\* (luminosity) parameter followed the CIE 1976 (L\*a\*b\*) color scale system, in which the parameter L\* represents the luminosity scale from 0 to 100 (Ribeiro et al., 2008). The standard illuminant D65 was used (corresponding to daylight, including ultraviolet light) and 2° standard observer. This value was presented in the form of a Unit of Measurement (u.m.) of the parameter. Ribeiro et al. (2008) affirm that carioca (beige with brown stripes) genotypes with L\* greater than 55 and black genotypes with L\* less than 22 have greater market value; however, they state that these values are empirical and subjective.

The data obtained were subjected to individual analyses of variance for each environment so as to evaluate experimental precision, rejecting experiments that had coefficients of variation above 25 % for grain yield. The data were then subjected to joint analyses of variance of the group of environments for each crop season and a joint analysis of the three crop seasons. To obtain yield and cooking time, the mean values of the genotypes were compared to the following controls: IAC Alvorada and BRS Pérola (carioca commercial group) and IAC Diplomata and IAC Una (black commercial group) by the Dunnett test ( $p < 0.05$ ), and the differences of mean values between crop seasons were analyzed by the Scott-Knott test ( $p < 0.05$ ). For grain color, the mean values of the L\* parameter of the genotypes were compared using the Scott-Knott test ( $p < 0.05$ ) by means of the GENES program (Cruz, 2013).

For inoculation of the pathogens that cause anthracnose, Fusarium wilt and Curtobacterium wilt, isolates that came from the Plant Health Center of the Agronomic Institute (IAC) were used. For inoculation with anthracnose (*C. lindemuthianum*), six seedlings for each genotype, with two replications, were used, sown in a box with vermiculite. Isolates of physiological races 31, 65 and 81 of *C. lindemuthianum* were sprayed on the genotypes separately by race with a conidium suspension at a concentration of  $10^6$  conidia mL<sup>-1</sup>. The seedlings were then stored in a room in temperature conditions of around 23 °C, 90 % humidity and controlled luminosity with a 12-hour photoperiod. Evaluation of symptoms in the seedlings with regard to infection response was made 7 to 10 days after inoculation, using a scale 1-9, 1 being resistant and without symptoms to 9 being susceptible and dead.

For inoculation of *Fusarium oxysporum* f. sp. *phaseoli*, the experimental design consisted of three pots for each genotype containing two inoculated seedlings per pot. For spore transfer to the pots, the plants were immersed in a suspension of spores at a concentration of  $10^6$  conidia mL<sup>-1</sup> for 10 min and then planted in pots containing a sterilized mixture of soil and sand. Evaluation of symptoms was made 30 days after inoculation, adopting a scoring scale from 1 to 3 for plants to be classified as resistant (R), 4 to 5 as moderately resistant (MR)

and 6 and above as susceptible (S) plants. For inoculation of the pathogen, a mixture of isolates of races I (American) and II (Brazilian) was used, as already described by Alves-Santos et al. (2002b).

Inoculation of *Curtobacterium flaccumfaciens* pv. *flaccumfaciens* was performed through punctures in the stem between the cotyledonary leaves with an entomological needle previously moistened in bacterial colonies. The experimental design consisted of three pots for each genotype, each pot containing two inoculated plants. Disease symptoms were evaluated 30 d after inoculation, attributing scores which ranged from 0 to 9, according to Souza et al. (2006). As per this scale, the genotypes that obtained an average score lower than 2.33 were considered resistant (R), genotypes with an average score from 2.34 to 4.0 were considered moderately resistant (MR), and above this score, genotypes were considered susceptible (S).

## Results and Discussion

None of the crop seasons exhibited genotypes superior to the corresponding standards (Dunnett test,  $p < 0.05$ ) (Table 1). In the combination of the three crop seasons of 2009/2010/2011, although no genotype with a yield higher ( $p < 0.05$ ) than that of the best control was identified, it is noted that the genotypes had a performance similar to that of the respective standard cultivars and are considered sufficient for recommending new common bean cultivars for the agricultural sector.

The rainy season produced the lowest mean yield (2111 kg ha<sup>-1</sup>) when compared to the other crop seasons, i.e., the dry (2268 kg ha<sup>-1</sup>) and winter (2476 kg ha<sup>-1</sup>) seasons. The lower yield observed for the rainy season in this study may be explained by the occurrence of a strong infestation of silver leaf whitefly (*Bemisia tabacci*), where the experiment in Mococa showed a mean yield of 940 kg ha<sup>-1</sup> and the Capão Bonito experiment did not go beyond 1500 kg ha<sup>-1</sup>.

For the dry season, the genotypes that stood out were the BRS Esteio cultivar, with a black seed coat and a mean yield of 2578 kg ha<sup>-1</sup>, the carioca seed coat line Gen C2-1-6-1, with a mean yield of 2611 kg ha<sup>-1</sup>, and LP 0403, with a mean yield of 2636 kg ha<sup>-1</sup>.

The winter season was that which showed the greatest yield values, with a mean of 2476 kg ha<sup>-1</sup>. It also showed the least yield difference among the genotypes. The genotypes that stood out in the winter season were the standard control cultivar of the carioca group, BRS Pérola, and the Gen C2-1-6-1-1, BRS Esteio and BRS Esplendor genotypes of the black group.

When data from joint analysis work are considered, the performance of the LP 0403, Gen C2-1-6-1-1 lines and the IAC Imperador cultivar changes. The IAC Imperador cultivar, which was not mentioned as standing out among the crop seasons, was in 4<sup>th</sup> place when considering only the joint analysis mean yield in reference to the 17 experiments performed. It exhibited

a mean yield of 2452 kg ha<sup>-1</sup>. This result arises from stability of production because, to obtain fourth place, small changes had to occur in the yield values during the crop periods from 2009 to 2011. A similar result was obtained for the BRS Esplendor cultivar, with a mean yield of 2450 kg ha<sup>-1</sup> and in 5<sup>th</sup> place in joint analysis. These cultivars stand out from the others because the identification of more stable and adapted cultivars, in addition to more productive ones, has been an alternative widely used by common bean breeding programs in various regions in Brazil (Carbonell et al., 2004; Torga et al., 2013) that allow for more reliable recommendations.

The IAC Imperador and BRS Esplendor cultivars stood out by showing resistance to the three physiological races of *Colletotrichum lindemuthianum*, which cause anthracnose, to the mixture of the two races of *Fusarium oxysporum* (race 1 and race 2), which causes Fusarium wilt, and to the isolate of *Curtobacterium flaccumfaciens*, which causes Curtobacterium wilt (Table 1).

Race 81 of *Colletotrichum lindemuthianum* was identified by the common bean genetic breeding program of IAC as the race of pathogen of greatest importance because of its aggressiveness and because it is the most frequently recurring race in the state of São Paulo, and other Brazilian states. When the genotypes of Table 1 are compared, most were susceptible to race 81 and resistant to races 31 and 65. This result may be explained by the fact that selection processes in the past were directed to obtaining genotypes resistant to race 65 of anthracnose, which was described as the most widespread in Brazil in the 1990s (Carbonell et al., 1999). The cultivars IAC Diplomata, IAC Una, BRS Estilo, BRS Esplendor, BRS Esteio, and IAC Imperador and the lines Gen C4-8-1-1, Gen P5-4-4-1, Gen Pr11-3-5-1, Gen Pr 11-6-4-1-2 and Gen Pr14-2-3-2 stand out for resistance to anthracnose as they are resistant to all three races of the pathogen.

The lack of genotypes superior to the standard controls of the carioca group in terms of yield is noteworthy, mainly because the control for comparison of the carioca seed coat was the BRS Pérola cultivar, introduced in 1998 by EMBRAPA. The absence of genetic gain is normally indicated as a consequence of the narrowing of the genetic base and the use of related parents in breeding programs, which restricts the variability available for carrying out selection (McCouch, 2005). Thus, the inability to obtain genotypes superior to the controls for grain yield could be explained by pointing to restrictions in the genetic base of the breeding programs in Brazil. But, in practice, this does not occur, as identified by Perseguini et al. (2011), who analyzed the genetic base of 60 genotypes of carioca seed coat, including the main cultivars developed in Brazil, and proved that the genetic base of the common bean breeding programs in Brazil is not narrow.

An explanation for this absence of yield superiority of the new cultivars in relation to the controls could be the fact that inclusion of selection for agronomic and technological traits of the grains required by the con-

sumer market reduces genetic progress in common bean yield. Considering the genetic breeding program carried out by the Agronomic Institute (IAC) Chiorato et al. (2010) studied the genetic progress of the program from 1989 to 2007 and found that as of 1998 there were decreases in the genetic progress of the program due to selections aimed at increasing the size of the grains, shorter cooking time and resistance to darkening. The gains in technological quality of grains in this period are seen through a reduction in cooking time (Table 2) and lighter-colored grains (Table 3) of the current lines when compared to the control, BRS Pérola, introduced in 1998. Another result that may also be related to the lack of superiority of some genotypes in relation to the controls would be the experimental precision of the trials, which did not allow for small differences from the standards to be detected.

Evaluations of cooking time (CT) carried out for the genotypes (Table 2) in the rainy season indicated that the lines Gen C2-1-6-1, Gen C2-3-1-1-2 and LP04-03 lines and the BRS-Cometa cultivar were superior in relation to the control, IAC Alvorada, in shorter cooking time. With regard to the dry season, the Gen C2-1-6-1, Gen P5-4-4-1 and IAC Imperador lines showed CT lower than that of the control, BRS Pérola. In the winter season, the Gen P5-4-4-1 line stood out, with CT lower than that of the controls. Among the genotypes evaluated, the CT ranged from 26'51" to 32'10" for the combination of the three crop seasons. This variation is due to the genetic differences present in the genotypes, environmental influence and genotype by environment interaction (Dalla Corte et al., 2003; Perina et al., 2014). The results for CT indicated that the Gen C2-1-6-1, Gen C2-3-1-1-2, BRS Cometa, LP 0403, IAC Imperador, and Gen P5-4-4-1 genotypes stood out in relation to the standard control for the carioca group, and the Gen Pr11-6-4-1-2 line stood out among the genotypes in the black group.

The CT mean values reported for crop seasons showed differences (Table 2). The CT values for the rainy season were lower than those of the dry and winter seasons, as expected, since the rainy season is considered most favorable for differentiating genotypes that are superior in cooking time (Perina et al., 2014). Nevertheless, in the literature, lower values are found for cooking time in the dry season (Perina et al., 2014), indicating that cooking time may also be related to the quality of the grain at the time of harvest.

For colorimetry analyses (Table 3), differences ( $p < 0.05$ ) were found for the mean values of the crop seasons, and the aim was to find genotypes with light colored grain, the carioca grain being known as "milk type", and non-purplish grains for the black seed coat. Consumer acceptance of the bean grain takes the visual aspect into consideration since light-colored grains for the carioca seed coat are associated with being recently harvested and rapidly cooked and, for black seed coat grains, less of a light color is mainly associated with a thick broth after cooking. A higher value (54.39) for L\*



Table 2 – Comparison of mean values of cooking time (CT) of grains of 25 common bean genotypes grown in the 2009 and 2010 rainy sowing seasons, 2010 and 2011 dry sowing seasons and the 2010 and 2011 winter sowing seasons in environments in the state of São Paulo.

Common Bean Cultivars/Lines	CT (min) <sup>1</sup>			
	Rainy	Dry	Winter	Joint Analysis
Gen C2-1-6-1 (IAC Carioca)	22.58*	25.27*	33.39	27.08*
GenC2-1-6-1-1 (IAC Carioca)	25.46	32.15	31.17	29.59
GenC2-3-1-1-2 (IAC Carioca)	23.11*	26.35	34.57	28.01*
GenC4-5-4-1-2 (IAC Carioca)	26.51	28.18	40.35	32.08
GenC4-8-1-1 (IAC Carioca)	26.39	27.37	32.58	29.18
CHC 97-29 (Epagri Carioca)	27.21	33.15	32.25	31.27
CHP 98-59 (Epagri Preto)	28.18	29.15	34.34	30.56
BRS Esteio (Embrapa Preto)	24.01	31.36	31.51	29.36
BRS Cometa (Embrapa Carioca)	24.12*	26.21	35.19	28.51*
IPR Eldorado (IAPAR Carioca)	25.31	27.52	37.09	30.37
BRS Esplendor (Embrapa Preto)	29.00	31.24	36.05	32.10
BRS Estilo (Embrapa Carioca)	27.09	30.36	36.60	31.35
LP 0403 (IAPAR Carioca)	23.28*	30.24	31.27	28.26*
LP 0577 (IAPAR Carioca)	27.04	28.09	36.21	30.45
MAII-22 (UFLA Carioca)	26.37	27.10	39.02	31.23
IAC Imperador (IAC Carioca)	25.49	24.58*	34.01	28.03*
GenP5-4-4-1 (IAC Carioca)	26.12	25.17*	28.23*	26.51*
GenPr11-3-5-1 (IAC Carioca)	28.20	26.02	32.04	29.15
GenPr11-6-4-1-2 (IAC Preto)	25.18	29.12	29.01	28.17*
GenPr14-2-3-2 (IAC Preto)	27.39	30.02	33.39	30.27
RP-2 (UFLA Carioca)	29.12	27.56	37.22	31.30
IAC Alvorada(IAC Carioca)	<b>27.37</b>	30.36	<b>32.14</b>	<b>30.36</b>
BRS Pérola (Embrapa Carioca)	28.11	<b>28.16</b>	36.08	30.78
IAC Diplomata (IAC Preto)	24.11	<b>27.21</b>	33.15	<b>28.16</b>
IAC Una (IAC Preto)	<b>24.17</b>	29.33	<b>32.45</b>	28.65
Mean <sup>2</sup>	<b>26.15 A</b>	<b>29.30 B</b>	<b>34.38 C</b>	<b>29.49</b>
CV (%)	<b>3.20</b>	<b>3.99</b>	<b>4.01</b>	<b>5.48</b>
DMS kg ha <sup>-1</sup>	<b>2.30</b>	<b>2.75</b>	<b>2.23</b>	<b>1.32</b>

<sup>1</sup>Values in bold print correspond to the best standard cultivar of comparison by the Dunnett test (5 %) for the corresponding commercial group (IAC Alvorada and BRS Pérola for the carioca group and IAC Una and IAC Diplomata for the black group); <sup>2</sup>Mean values followed by the same letter do not differ (Skott-Knott test,  $p < 0.05$ ); \*Significant (Dunnett test,  $p < 0.05$ ).

was obtained in the dry season (Table 3), in comparison to the winter (51.72) and rainy (51.06) seasons, which did not differ ( $p < 0.05$ ) between themselves, thus showing that for the dry season, the seed coats of recently harvested grains were lighter-colored.

For the black seed coat grains, an L\* value less than 22 was not observed (Table 3). According to Ribeiro et al. (2008), an L\* value less than 22 has greater commercial value. The dry (23.81) and rainy (23.86) seasons, which did not differ between themselves, showed more satisfactory results than the winter season (24.15) (Table 3).

In the rainy season, the genotypes with carioca seed coat with greater L\* value, were higher than 53, which have greater commercial value, as suggested by Ribeiro et al. (2008), were Gen C2-3-1-1-2 (53.61) and Gen C2-1-6-1 (53.06). For the dry season, the genotypes with a lighter-colored carioca seed coat were Gen C2-1-6-1 (56.76), Gen C2-1-6-1-1 (56.71), Gen C4-5-4-1-2 (56.57), Gen C2-3-1-1-2 (56.36) and IAC Alvorada (55.77). It is noteworthy that in this season, only five genotypes did not show values greater than 53. In the winter season,

the genotypes Gen C4-5-4-1-2 (54.46), Gen C2-1-6-1-1 (54.28) and Gen C2-1-6-1 (54.14) had a carioca seed coat that stood out. The values found for the combination of the three seasons display the genotypes Gen C2-1-6-1 (54.65), Gen C2-1-6-1-1 (54.56), Gen C2-3-1-1-2 (54.15) and Gen C4-5-4-1-2 (53.67) as grains with a lighter-colored carioca seed coat (Table 3).

The genotypes with lighter-colored grains, such as the Gen C2-1-6-1, Gen C2-1-6-1-1, Gen C2-3-1-1-2, Gen C4-5-4-1-2 lines and the IAC Alvorada cultivar, were generally susceptible to anthracnose and to Fusarium wilt. Darkening in beans may be related to the presence of polyphenolic compounds (Beninger et al., 2005), and these compounds are directly connected with plant defense against pathogens (Islam et al., 2003). Selection directed to obtaining lighter-colored grains causes the phenolic compounds to be reduced in the plant, for these compounds are active in oxidation which accelerates grain darkening. With regard to yield, there is no interference because the Gen C2-1-6-1 and Gen C2-1-6-1-1 lines showed excellent yield numbers (Table 3).

Table 3 – Comparison of the mean values of grain colorimetric parameters (L\* value) of 25 common bean genotypes grown in the 2009 and 2010 rainy sowing seasons, 2010 and 2011 dry sowing seasons and the 2010 and 2011 winter sowing seasons in environments in the state of São Paulo.

Genotypes	Rainy	Dry	Winter	Joint analysis
	L*	L*	L*	L*
Gen C2-1-6-1 (IAC Carioca)	53.06 a <sup>1</sup>	56.76 a	54.14 a	54.65 a
Gen C2-1-6-1-1 (IAC Carioca)	52.71 a	56.71 a	54.28 a	54.56 a
Gen C2-3-1-1-2 (IAC Carioca)	53.61 a	56.36 a	52.49 b	54.15 a
Gen C4-5-4-1-2 (IAC Carioca)	50.01 b	56.57 a	54.46 a	53.67 a
IAC Imperador (IAC Carioca)	52.41 a	53.22 c	52.98 b	52.87 b
Gen P5-4-4-1 (IAC Carioca)	52.48 a	54.41 b	50.95 c	52.61 b
Gen Pr11-6-4-1-2 (IAC Carioca)	50.47 b	51.93 c	49.98 d	50.79 c
Gen C4-8-1-1 (IAC Carioca)	51.00 b	54.32 b	52.14 b	52.48 b
BRS Cometa (Embrapa Carioca)	50.19 b	52.21 c	48.71 d	50.36 c
BRS Estilo (Embrapa Carioca)	50.08 b	53.71 b	51.21 c	51.66 b
IPR Eldorado (IAPAR Carioca)	51.11 b	54.57 b	50.76 c	52.14 b
LP 0403 (IAPAR Carioca)	52.99 a	53.10 b	53.08 b	53.06 b
LP 0577 (IAPAR Carioca)	51.62 a	53.28 c	51.47 c	52.12 b
CHC97-29 (Epagri Carioca)	49.53 b	52.17 c	51.38 c	51.02 c
MAII-22 (UFLA Carioca)	48.59 b	52.91 c	50.07 d	50.52 c
RP-2 (UFLA Carioca)	50.68 b	54.46 b	50.96 c	52.03 b
<sup>2</sup> IAC Alvorada (IAC Carioca)	50.22 b	55.77 a	51.80 c	52.59 b
<sup>2</sup> BRS Pérola	48.33 b	52.72 c	50.19 d	50.41 c
<sup>1</sup> Mean Value	<b>51.06 B</b>	<b>54.39 A</b>	<b>51.72 B</b>	<b>52.39</b>
CV (%)	<b>7.83</b>	4.03	4.40	6.32
Gen Pr11-3-5-1 (IAC Preto)	24.08 a <sup>1</sup>	24.13 a	23.87 a	24.02 a
Gen Pr14-2-3-2 (IAC Preto)	23.60 a	23.25 b	23.83 a	23.56 b
BRS Esplendor (Embrapa Preto)	24.66 a	24.26 a	24.10 a	24.34 a
BRS Esteio (Embrapa Preto)	23.93 a	24.31 a	24.09 a	24.10 a
CHP98-59 (Epagri Preto)	23.65 a	23.69 b	24.51 a	23.94 a
<sup>2</sup> IAC Diplomata (IAC Preto)	23.94 a	23.64 b	24.07 a	23.88 a
<sup>2</sup> IAC Una (IAC Preto)	23.14 a	23.40 b	24.57 a	23.70 b
<sup>1</sup> Mean Value	<b>23.86 B</b>	<b>23.81 B</b>	<b>24.15 A</b>	<b>23.93</b>
CV (%)	<b>6.16</b>	2.97	3.65	4.58

L\* (unit of measure): Luminosity; <sup>1</sup>Mean values followed by the same small letter in the column do not differ (Scott-Knott test,  $p < 0.05$ ); <sup>2</sup>Values in bold print correspond to the standard cultivars.

## Conclusions

For the combination of the crop seasons from 2009 to 2011, no genotypes superior to the controls for grain yield were observed for the black and carioca seed coat groups. It was possible to the IAC Imperador and BRS Esplendor genotypes as being resistant to anthracnose, Fusarium wilt and Curtobacterium wilt. The dry crop season had lighter-colored grains, while the shortest cooking times were obtained in the rainy crop season. The genotypes with a lighter-colored seed coat, like Gen C2-1-6-1, Gen C2-1-6-1-1, Gen C2-3-1-1-2, Gen C4-5-4-1-2 and the IAC Alvorada cultivar, were more susceptible to anthracnose and to Fusarium wilt.

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