FUNCTIONAL PLANT BREEDING JOURNAL
Scientific Journal. ISSN 2595-9433 - D.O.I. http://dx.doi.org/10.35418/2526-4117/v7a05
Volume 7, Article n. 05, Jan/December - Received: 18/11/2024 - Accepted: 27/03/2025

BRS FC429: Common bean cultivar with upright plants, carioca beans, slow darkening, and resistance to Fusarium wilt

Helton Santos Pereira[1]*, Thiago Lívio Pessoa Oliveira de Souza[1], Marcelo Sfeir Aguiar[1], Luís Cláudio de Faria[1], Joaquim Geraldo Cáprio da Costa[1], Paula Pereira Torga[1], Saulo Muniz Martins[1], Mariana Cruzick de Souza Magaldi[1], Nilda Pessoa de Souza[1], Adriano Moreira Knupp[1], Tamillys Cientielly de Lellis Albernarz Luz[1], Leonardo Cunha Melo[1]

Abstract: BRS FC429 is a common bean cultivar with high commercial quality carioca beans, very light beige seed coat color, and slow darkening. It shows wide adaptability to different production regions, mean yield of 2,176 kg.ha^{-1}, high yield potential (6,000 kg.ha^{-1}), upright plants, moderate resistance to Fusarium wilt, and intermediate resistance to angular leaf spot and bacterial wilt.

Keywords: *Phaseolus vulgaris*, Fusarium wilt, bacterial wilt, angular leaf spot.

Introduction

In recent years, Brazil has ranked among the main worldwide producers (2.5 million tons annually) and consumers of common bean (*Phaseolus vulgaris*) (EMBRAPA, 2024) (FAO, 2024). Carioca stands out among the various commercial groups of common bean, as it is preferred by most Brazilian consumers and accounts for around 70% of the consumer market (Pereira et al., 2021).

The Brazilian market has become increasingly demanding regarding commercial quality of beans, especially in relation to bean color. Over the period from harvest to sale of the grain, the beige color of the seed coat darkens in carioca commercial group beans, lowering their commercial value; grain with lighter color has higher commercial value. This means that farmers must sell the product quickly, regardless of the market price.

In this respect, one of the most important demands has been the development of new cultivars with slow seed coat darkening, because that trait allows farmers greater flexibility when selling their product. Various studies have already described important aspects of genetic control of grain seed coat darkening (Junk-Knievel et al., 2008; Silva et al., 2008; Elsadr et al., 2011; Alvares et al., 2019; Rodrigues et al., 2019).

Different institutions have already developed several carioca grain cultivars with slow darkening, such as BRSMG Madrepérola (Carneiro et al., 2012), ANFC 09, TAA Dama, IAC

[1] *Embrapa Arroz e Feijão, Rod. GO-462, km 12, Santo Antônio de Goiás, GO, Brazil.*
* *Corresponding author: helton.pereira@embrapa.br*

2051 (Carbonell et al., 2021), BRS FC415 (Pereira et al., 2022), BRS FC423 (Pereira et al., 2023), and IPR Águia. However, these cultivars are still far fewer in number compared to those with normal darkening; moreover, they are agronomically inferior to the best cultivars that have normal grain darkening, especially in relation to plant architecture, resistance to lodging, and resistance to diseases caused by soil-borne pathogens.

BRS FC429 stands out for its wide adaptability to different production regions (Central, South Central, and Northeast), upright architecture, moderate resistance to lodging, and excellent commercial grain quality, especially for its beans with very light beige color and light brown streaks and slow darkening. In addition, it has moderate resistance to Fusarium wilt, which allows it to be used in older crop areas under center pivot irrigation, and intermediate resistance to angular leaf spot and bacterial wilt.

Breeding methods used

CNFC 16495 originated from the cross between the lines CNFC 8075 and LM202206076, which has slow grain darkening, followed by a backcross with LM202206076; both crosses were carried out at Embrapa Arroz e Feijão (Embrapa Rice and Bean) in Santo Antônio de Goiás, GO, Brazil, in 2004. Also in 2004, the F_1 generation of the population was sown in a screened enclosure. In 2005, in the rainy crop season in Ponta Grossa, the F_2 generation was evaluated and harvested in bulk, with selection based on resistance to diseases (anthracnose, rust, and common bacterial blight), plant architecture, lodging, seed coat color, darkening, and bean grain size and yield. In 2006, in the winter crop season, the F_3 generation was sown in the field and harvested in bulk in Santo Antônio de Goiás, with selection based on plant architecture, lodging, seed coat color, darkening, and bean grain size and yield. In 2007, in turn, in the dry crop season in Ponta Grossa, the F_4 generation was sown in bulk and selection was based on resistance to diseases (anthracnose, angular leaf spot, and bacterial wilt), plant architecture, lodging, seed coat color, darkening, and bean grain size and yield. In the 2007 rainy season, the F_5 generation was sown in Ponta Grossa, PR, and harvested in bulk, with selection based on resistance to diseases (anthracnose, rust, and common bacterial blight), plant architecture, lodging, seed coat color, darkening, and bean grain size and yield. In the 2008 winter crop season in Santo Antônio de Goiás, the F_6 generation was evaluated and individual plants were selected to obtain the lines, based on plant architecture, lodging, seed coat color, darkening, and bean grain size and yield.

In 2009, in the dry crop season in Ponta Grossa, the lines in the $F_{6:7}$ generation were sown in individual rows, and selection was carried out based on resistance to diseases (anthracnose, angular leaf spot, and bacterial wilt), plant architecture, lodging, seed coat color, darkening, and bean grain size and yield. In 2009, in the rainy crop season, the lines in the $F_{6:8}$ generation were sown in individual rows in Ponta Grossa, and selection was based on resistance to diseases (anthracnose, rust, and common bacterial blight), plant architecture, lodging, seed coat color, darkening, and bean grain size and yield. In 2010, in the winter crop season in Santo Antônio de Goiás, the lines in the $F_{6:9}$ generation were evaluated and selected for plant architecture, lodging, seed coat color, darkening, and bean grain size and yield, selecting the line that received the name CNFC 16495. As of this step, evaluation in experiments with replications in multiple environments began.

In 2012, the CNFC 16495 line was evaluated in the grain quality progeny trial made up of 81 treatments, consisting of 79 new lines and two check cultivars (BRS Estilo and BRSMG Madrepérola). A randomized block experimental design was used with three replications and plots of two 4-meter rows. The trials were set up in two environments: Ponta Grossa in the dry seasons and Santo Antônio de Goiás in the winter season. In these experiments, it was possible to evaluate grain yield, 100-seed weight, plant growth cycle, plant architecture, resistance to lodging, and resistance to diseases (anthracnose, angular leaf spot, common bacterial blight, and bacterial wilt). Combined analysis of these data led to selection of the line CNFC 16495 for participation in the preliminary experiment.

In 2013, the CNFC 16495 line was evaluated in the preliminary carioca grain quality experiment composed of 35 treatments, consisting of 32 new lines and three check cultivars (BRS Estilo, BRSMG Madrepérola, and BRS Ametista). A randomized block experimental design was used with three replications and plots of two or three 3-meter rows. The experiments were conducted in three environments: Santo Antônio de Goiás (GO) (two experiments) in the winter season, and Ponta Grossa (PR) in the rainy season. In these experiments, it was possible to evaluate grain yield, no. 12 sieve (4.5 mm) yield, seed coat color, darkening, shape, uniformity and 100-seed weight, plant cycle, plant architecture, resistance to lodging, and resistance to diseases (anthracnose, common bacterial blight, angular leaf spot, Fusarium wilt, and bacterial wilt). Combined analysis of the data obtained in the preliminary experiment, together with the data obtained in the progeny test experiment, led to selection of the CNFC 16495 line for participation in the intermediate experiment, based on the results from five environments.

In 2016, the CNFC 16495 line was evaluated in the intermediate carioca experiment made up of 52 treatments: 45 new lines and seven check cultivars (BRS FC402, BRS Estilo, BRS Notável, BRSMG Madrepérola, Pérola, ANFC09, and IPR Bem-te-vi). A randomized block experimental design was used with three replications and plots of two or three 3-meter rows. The experiments were conducted in eleven environments: Santo Antônio de Goiás (GO) (two experiments), Anápolis (GO), Lavras (MG), Uberlândia (MG), and Sete Lagoas (MG) in the winter season; Ponta Grossa (PR) in the rainy and dry seasons; Paripiranga (BA) in the rainy season; and Brasília (DF) in the winter and rainy seasons. In these experiments, it was possible to evaluate grain yield, no. 12 sieve (4.5 mm) yield, seed coat color, darkening, shape, uniformity, and 100-seed weight. The following evaluations were also made: plant cycle, plant architecture, resistance to lodging, and resistance to diseases (anthracnose, angular leaf spot, common bacterial blight, bacterial wilt, and Fusarium wilt).

Combined analysis of the data from the progeny, preliminary, and intermediate trial experiments led to selection of the CNFC 16495 line for the Value for Cultivation and Use (VCU) experiment, based on evaluation of 16 environments. In 2017, in the winter season in Santo Antônio de Goiás, seeds were multiplied to obtain enough to prepare the VCU experiments.

In 2018 and 2019, the CNFC 16495 line was evaluated in 66 experiments with 22 treatments, consisting of 15 new lines with a normal growth cycle and six check cultivars: BRS FC402, BRS Estilo, Pérola, BRSMG Uai, IPR Campos Gerais, and ANFC09. A randomized block experimental design was used with three replications and plot of four 4-meter rows, using the technologies recommended for the different environments and growing systems.

In these experiments, the following grain-related traits were evaluated: yield, no. 12 sieve (4.5 mm) yield, 100-seed weight, seed coat color, darkening, cooking time, and iron, zinc, and protein concentration. A scoring scale ranging from 1 (totally favorable phenotype) to 9 (totally unfavorable phenotype) (Melo, 2009) was used to evaluate plant architecture, resistance to lodging, and resistance to the following 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*), bean common mosaic virus (BCMV), and bean golden mosaic virus (BGMV).

Grain yield was expressed in $kg.ha^{-1}$ and adjusted to 13% moisture. Sieve yield was measured as follows: a 300-g sample was taken from each plot; the sample was then passed through a sieve with oblong openings of 4.5 mm width; the seeds retained on the sieve were weighed; and the weight of the seeds retained on the sieve was divided by the initial weight of the sample. From the seeds retained on the sieve, a new sample of 100 seeds was taken for weighing to determine 100-seed weight. A Mattson cooker was used to determine cooking time. Protein concentration was analyzed by determining nitrogen concentration using the micro-Kjeldahl method. Analyses of iron and zinc concentration were carried out using acid digestion of organic matter according to the flame atomic absorption spectrophotometry technique.

Of the 66 experiments set up, 59 were harvested and achieved the standards of experimental quality required to be considered for the cultivar registration process in regard to yield data. These 59 VCU experiments 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, and Minas Gerais) in the rainy, dry, and winter seasons; and in Region III (Pernambuco, Sergipe, and Alagoas) in the rainy season.

Grain yield and yield potential

In the VCU experiments, the cultivar BRS FC429 (CNFC 16495) had a mean yield of 2,176 $kg.ha^{-1}$, which was lower than the yields of the cultivars ANFC09 (2,347 $kg.ha^{-1}$) and BRS Estilo (2,292 $kg.ha^{-1}$) (Table 1). This also occurred in Region I (South Central) (2,565 $kg.ha^{-1}$) and in Region III (Northeast) (955 $kg.ha^{-1}$). In Region II (Central), BRS FC429 had a mean yield (2,206 $kg.ha^{-1}$) similar to that of the two check cultivars.

Table 1. Grain yield ($kg.ha^{-1}$) of cv. BRS FC429 compared to the mean of two check cultivars (ANFC09 and BRS Estilo) in the Value for Cultivation and Use (VCU) trials, according to the recommended growing region and sowing time, from 2018 to 2019.

Region	Season	BRS FC429	ANFC09	BRS Estilo	Number of environments
I	Rainy	3,010 b	3,186 a	3,201 a	15
	Dry	1,730 b	2,091 a	2,014 a	8
	Overall	2,565 b	2,805 a	2,788 a	23
II	Rainy	1,947 c	2,407 a	2,126 b	11
	Dry	1,626 a	1,764 a	1,591 a	3
	Winter	2,534 a	2,280 b	2,319 b	14
	Overall	2,206 a	2,275 a	2,165 a	28
III	Rainy	955 b	1,285 a	1,306 a	8
Overall	**-**	**2,176 c**	**2,347 a**	**2,292 b**	**59**

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

The maximum productivity in VCU experiments, obtained from the average of the three VCU experiments in which this cultivar presented the highest yield, was 3,920 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, even higher yields can be achieved, since there is no disease control in VCU experiments. The expected average yield in a crop with a good technological level and good environmental conditions of BRS FC431 is 4,000 kg.ha^{-1}. The productive potential, in optimal conditions, is 6,000 kg.ha^{-1}.

Commercial and nutritional seed quality

Regarding the grain technological and industrial quality traits, the BRS FC429 cultivar has a no. 12 sieve (4.5 mm) yield of 75%, meeting market requirements, though this is slightly lower than that of the cultivars ANFC09 and BRS Estilo (Table 2). BRS FC429 has a mean 100-seed weight of 24 grams, slightly lower than that of the two check cultivars. The beans are carioca type (cream-colored with brown streaks), without shine, with a circular to elliptical shape, and medium thickness. In relation to grain appearance, BRS FC429 has slow darkening grain, very light beige seed coat color and light brown streaks, similar to the beans of the cultivars ANFC09 and BRS FC415. However, the beans of BRS FC429 are quite uniform in color and do not turn grayish, in contrast with what occurs with most cultivars that have slow darkening, such as BRS FC415 and ANFC09, under some environmental conditions. The BRS FC429 beans are slightly more elongated than those of the check cultivars.

Mean cooking time of BRS FC429 is 35 minutes, longer than that of the ANFC09 and BRS Estilo cultivars (Table 2). With grain protein concentration of 19%, BRS FC429 was similar to the ANFC09 cultivar and higher than the BRS Estilo cultivar. Furthermore, BRS FC429 had a grain iron concentration of 61 mg.kg^{-1}, similar to that of ANFC09 and higher than that of BRS Estilo. The zinc concentration of 35 mg.kg^{-1} was similar to that of BRS Estilo and lower than that of ANFC09.

Table 2. Comparison of grain traits of the common bean cultivar BRS FC429 with the check cultivars ANFC09 and BRS Estilo.

Cultivar	CT (minutes)	PC (%)	FeC (mg kg^{-1})	ZnC (mg kg^{-1})	SY (%)	W100 (g)	COLOR	Color uniformity	DARK
BRS FC429	35 b	19 a	61 a	35 b	75 c	24 c	very light beige	uniform	slow
ANFC09	29 a	20 a	62 a	37 a	89 a	26 a	very light beige	medium	slow
BRS Estilo	26 a	17 b	51 b	35 b	78 b	25 b	very light beige	uniform	normal

CT – cooking time; PC – protein content; FeC – iron content; ZnC – zinc content; SY – sieved grain yield (< 4.5 mm); W100 – 100-seed weight; COLOR – predominant color; DARK – darkening. Mean scores followed by the same letter in columns do not differ statistically from each other according to the Scott-Knott test at 5% probability.

Other traits

In field experiments, BRS FC429 proved to have resistance to bean common mosaic virus and rust, moderate resistance to Fusarium wilt, and intermediate resistance to bacterial wilt and angular leaf spot (Table 3). However, it proved to be susceptible to bean golden mosaic virus, anthracnose, and common bacterial blight.

BRS FC429 has a normal plant growth cycle (from 85 to 94 days from emergence to physiological maturity), similar to that of the check cultivars (Table 3). The plants are bush type, with an indeterminate type II growth habit. Regarding plant architecture, BRS FC429 is upright and has moderate resistance to lodging, and it is suitable for mechanical harvest, including direct harvest. Its flowers are white, and at physiological maturity and harvest, the pods are yellowish.

Table 3. Agronomic traits and disease resistance traits of the cultivar BRS FC429 compared with the carioca grain cultivars ANFC09 and BRS Estilo.

Cultivar	Cycle	ARCH	LOD	AN	CBB	RU	ALS	BCMV	BGMV	FW	BW
BRS FC429	N	Upright	MR	S	S	R	I	R	S	MR	I
ANFC09	N	Semi-prostrate	I	I	S	R	I	R	S	S	S
BRS Estilo	N	Upright	MR	I	S	R	S	R	S	S	S

ARCH – plant architecture; LOD – lodging; AN – anthracnose; CBB – common bacterial blight; RU – rust; ALS – angular leaf spot; BCMV – bean common mosaic virus; BGMV – bean golden mosaic virus; FW – Fusarium wilt; BW – bacterial wilt; N – normal cycle; R – resistant; MR – moderately resistant; I – intermediate; S – susceptible.

Seed production

BRS FC429 was registered in 2024 under no. 56587, and the documents to apply for cultivar protection have been submitted to the Brazilian Ministry of Agriculture (Ministério da Agricultura, Pecuária e Abastecimento - MAPA). Genetic seed production will be the responsibility of Embrapa, and production to meet demand from grain growers will be carried out exclusively by 11 seed production companies (Sementes JHS, Sementes Marambaia, Sementes Aliança, BJ Sementes, Sementes Orient, Sementes Campolina, Shancap Sementes, Di Solo sementes, Sementes Lagoa Bonita, Menarin Sementes, and Cooprossel), who have signed a public-private partnership contract for development of new common bean cultivars with specific adaptation to a particular region, biome, sowing season, climate condition, or production system.

Conclusions

BRS FC429 stands out for its wide adaptability to different production regions (Central, South Central, and Northeast), upright plant architecture, moderate resistance to lodging, and excellent commercial grain quality. It has very light beige seed coat color with light brown streaks, slow darkening, and high grain uniformity. Additionally, it has moderate resistance to Fusarium wilt, which means it can be used in older center pivot irrigation crop areas, and it has intermediate resistance to angular leaf spot and bacterial wilt.

Based on its performance, BRS FC429 was registered under the no. 56587, for the following growing seasons and regions: rainy and dry seasons in Region I (Mato Grosso do Sul, Paraná, Santa Catarina, São Paulo, and Rio Grande do Sul); rainy, dry, and winter seasons in Region II (Goiás, Distrito Federal, Minas Gerais, Mato Grosso, Tocantins, Rio de Janeiro, and Espírito Santo); rainy and winter seasons in Bahia and Maranhão; and the rainy season in Region III (Sergipe, Alagoas, Pernambuco, Rio Grande do Norte, Piauí, Ceará, and Paraíba).

Acknowledgments

Our thanks to the other Embrapa units and to the partner institutions in cultivar evaluation, especially Embrapa Arroz e Feijão; Secretaria de Inovação e Negócios da Embrapa; Embrapa Tabuleiros Costeiros; Embrapa Agropecuária Oeste; Embrapa Milho e Sorgo; Embrapa Soja; Embrapa Cerrados; Embrapa Semi-Árido; Empresa de Pesquisa Agropecuária e Extensão Rural de Mato Grosso; Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural; Emater Alagoas; Emater Goiás; Fundação de Ensino Superior de Rio Verde; Universidade Federal de Lavras; Universidade Federal de Uberlândia; Universidade Estadual de Montes Claros; and Universidade Estadual Paulista – Ilha Solteira.

References

ALVARES, R.C.; STONEHOUSE, R.; SOUZA, T.L.P.O.; MELO, P.G.S.; MIKLAS, P. N.; BETT, K.E.; MELO, L.C.; RODRIGUES, L.A.; SOUZA, L.L.; PEREIRA, H.S. 2019. Generation and validation of genetic markers for the selection of carioca dry bean genotypes with the slow-darkening seed coat trait. **Euphytica**, 215, 1-11. *http://dx.doi.org/10.1007/s10681-019-2461-y*.

CARBONELL, S.A.M.; CHIORATO, A.F; BEZERRA, L.M.C.; GONÇALVES, J.G.R.; ROVARIS, S.R.S.; GONÇALVES, G.M.C.; PAULINO, J.F.C. 2021. IAC 2051: common bean cultivar of carioca type with slow seed coat darkening. Crop Breeding and Applied Biotechnology, 21: 1-4. *https://doi.org/10.1590/1984-70332021v21n2c37*

CARNEIRO, J.E.S.; ABREU, A.F.B.; RAMALHO, M.A.P.; PAULA JUNIOR, T.J.; DEL PELOSO, M.J.; MELO, L.C.; PEREIRA, H.S.; PEREIRA FILHO, I.A.; MARTINS, M.; VIEIRA, R.F.; MARTINS, F.A.D.; COELHO, M.A.O.; CARNEIRO, P.C.S.; MOREIRA, J.A.A.; SANTOS, J.B.; FARIA, L.C.; COSTA, J.G.C.; TEXEIRA, H. 2012. BRSMG Madrepérola: common bean cultivar with late-darkening carioca grain. **Crop Breeding and Applied Biotechnology**, 12: 281-284.

ELSADR, H.T.; WRIGHT, L.C.; PAULS, H.P.; BETT, K.E. 2011. Characterization of seed coat post-harvest darkening in common bean (*Phaseolus vulgaris* L.). **Theoretical and Applied Genetics**, 123: 1467-1472. *http://dx.doi.org/10.1007/s00122-011-1683-8*.

EMBRAPA. **Dados de conjuntura da produção de feijão comum (*Phaseolus vulgaris* L.) no Brasil: 1985 a 2023**. Retrieved from <*http://www.cnpaf.embrapa.br/socioeconomia/index.htm*>. Accessed on Jan. 28, 2024.

FAO. **Faostat**. Retrieved from <*http://faostat3.fao.org/browse/Q/QC/E*>. Accessed on Jan. 6, 2024.

JUNK-KNIEVEL, D.C.; VANDERBERG, A.; BETT, K.E. 2008. Slow darkening in pinto bean (*Phaseolus vulgaris* L.) seed coats is controlled by a single major gene. **Crop Science**, 48: 189-193. *http://dx.doi.org/10.2135/cropsci2007.04.0227*.

MELO, L.C. 2009. **Procedimentos para condução de ensaios de valor de cultivo e uso em feijoeiro-comum**. Santo Antônio de Goiás: Embrapa Arroz e Feijão. 104p. (Embrapa Arroz e Feijão. Documentos, 239).

PEREIRA, H.S.; DEL PELOSO, M.J.; SOUZA, T.L.P.O.; FARIA, L.C.; AGUIAR, M.S.; WENDLAND, A.; COSTA, J.G.C.; DÍAZ, J.L.C.; MAGALDI, M.C.S.; ABREU, A.F.B.; PEREIRA FILHO, I.A.; ALMEIDA, V.M.; MARTINS, M.; MELO, L.C. 2021. BRS FS305 - Common bean cultivar with calima bean for export. **Functional Plant Breeding Journal**, 3: 75-79. *http://dx.doi.org/10.35418/2526-4117/v3n1a8*.

PEREIRA, H.S.; SOUZA, T.L.P.O.; AGUIAR, M.S.; FARIA, L.C.; COSTA, J.G.C.; MAGALDI, M.C.S.; SOUZA, N.P.; KNUPP, A.M.; GUIMARÃES, C.M.; CARVALHO, H.W.L.; ALMEIDA, V.M.; MELO, L.C. 2022. BRS FC415 - Common bean cultivar with high yield, commercial quality, slow seed coat darkening, and resistance to soil pathogens. **Functional Plant Breeding Journal**, 4: 33-39. *http://dx.doi.org/10.35418/2526-4117/v4n2a4*.

PEREIRA, H.S.; SOUZA, T.L.P.O.; AGUIAR, M.S.; FARIA, L.C.; COSTA, J.G.C.; GUIMARÃES, C.M.; ALMEIDA, V.M.; MELO, L.C. 2024. BRS FC423 - Common bean cultivar with carioca grain type with slow darkening, high yield, and high resistance to anthracnose and root rots. **Functional Plant Breeding Journal**, 5: 1-7. *http://dx.doi.org/10.35418/2526-4117/v5a11*.

RODRIGUES, L.L.; RODRIGUES, L.A.; SOUZA, T.L.P.O.; MELO, L.C.; PEREIRA, H.S. 2019. Genetic control of seed coat darkening in common bean cultivars from three market classes. **Crop Science**, 59: 2046-2054. *http://dx.doi.org/10.2135/cropsci2019.03.0161*.

SILVA, G.S.; RAMALHO, M.A.P.; ABREU, A.F.B.; SILVA, F.B. 2008. Genetic control of early grain darkening of carioca common bean. **Crop Breeding and Applied Biotechnology**, 8: 299-304. *http://dx.doi.org/10.12702/1984-7033.v08n04a07*.