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WHAT ARE THE IMPACTS OF THE COMMON BEAN PRODUCTION SYSTEM ON PRODUCTION AND QUALITY ATTRIBUTES OF THE GRAINS?

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ABSTRACT - The choice of a cultivar can significantly affect grain yield and quality of common bean crops in production systems. The objective of this work was to evaluate the effect of common bean cultivars of the carioca commercial group on grain yield and quality in a production system, and assess the correlation between their variables. The experiment was carried out in the Southeast region of Brazil, in the winter-spring crop season. A randomized block design was used, with 13 treatments and four replications per treatment. The treatments were consisted of common bean cultivars (Pérola, BRSMG-Majestoso, BRS-Estilo, BRSMG-Madrepérola, IPR-Campos Gerais, IPR-Tangará, IPR-Andorinha, IPR-139, IAC-Imperador, IAC-Formoso, IAC-Alvorada, IAC-Milênio, and TAA-Bola Cheia). The choice of a cultivar affects production and quality attributes of common bean in production systems, as it can result in increases of up to 34% in grain yield, 20% in grain yield in sieves equal to or higher than 12 (GYS≥12), 16% in grain protein contents, and 47% in cooking time. The cultivar BRSMG-Majestoso presented the highest grain yield (3,805 kg ha^{-1}), and IPR-Andorinha and BRSMG-Madrepérola stood out with GYS≥12 of 93% and grains with clear integument, respectively. Grain yield increases as the number of pods per plant and grains per pod increase, presenting a negative correlation with crude protein contents and cooking time.
Keywords: *Phaseolus vulgaris* L., correlation, genotypes, grain yield, protein contents.

QUAIS IMPACTOS DE UM SISTEMA DE PRODUÇÃO DE FEIJÃO-COMUM SOBRE OS ATRIBUTOS PRODUTIVOS/QUALITATIVOS DOS GRÃOS?

RESUMO - A escolha da cultivar pode promover impactos significativos na produtividade e na qualidade dos grãos do feijão-comum dentro de um sistema de produção. O objetivo deste trabalho foi avaliar o efeito de cultivares de feijão-comum do grupo comercial carioca sobre a produtividade e qualidade dos grãos em um sistema de produção, bem como verificar a correlação entre as variáveis. O experimento foi realizado no Sudeste do Brasil na safra de inverno/primavera. Utilizou-se o delineamento de blocos casualizados, contendo 13 tratamentos e 4 repetições por tratamento. Os tratamentos foram constituídos por cultivares de feijão-comum (Pérola, BRSMG Majestoso, BRS Estilo, BRSMG Madrepérola, IPR Campos Gerais, IPR Tangará, IPR Andorinha, IPR 139, IAC Imperador, IAC Formoso, IAC Alvorada, IAC Milênio e Bola Cheia). A escolha da cultivar interfere nos atributos produtivos e qualitativos do feijão-comum dentro de um sistema de produção, sendo que esse manejo pode promover incrementos de até 34% na produtividade, 20% no rendimento de peneira maior ou igual a 12 (RP≥12), 16% no teor de proteína dos grãos e 47% no tempo de cozimento. Dentre as cultivares, a BRSMG Majestoso apresentou a maior produtividade de grãos (3805 kg ha^{-1}) e as cultivares IPR Andorinha e BRSMG Madrepérola se destacaram quanto ao RP≥12 de 93% e pelos grãos com tegumento claro, respectivamente. A produtividade de grãos aumenta na medida em que se eleva o número de vagens por planta e o de grãos por vagem, correlacionando-se negativamente com o teor de proteína bruta e o tempo de cozimento.
Palavras-chave: *Phaseolus vulgaris* L., correlação, genótipos, produtividade, teor de proteína.

INTRODUCTION

Brazil is one of the largest producer and consumers of common bean (*Phaseolus vulgaris* L.) in the world; this legume is grown in all states of the country and the varieties of the carioca group are the most consumed (LEMOS et al., 2015; BRAZILIAN NATIONAL FOOD SUPPLY COMPANY (CONAB), 2021). Common bean grains are an important source of protein in Brazil, mainly because of its lower cost when compared to products of animal origin (FAGERIA et al., 2015). Common bean is a short-cycle plant that can be grown depending on the region in different seasons of the year (rainy season, dry season, winter season). It raised the interest of growers for its use in rotation and succession systems with other species in large areas, mainly in production systems with irrigation, resulting in high grain yields and profitability.

Common bean crops presented high technological evolution in the last 20 years due to the performance of researches that brought sustainable agronomic practices compatible with different production systems, mainly the development of cultivars with high production potential and adapted to the growing region (CARNEIRO et al., 2012;

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ALVES et al., 2020), including important studies on genotypes × environment interactions (PEREIRA et al. 2012; PEREIRA et al., 2018). However, the constant launch of cultivars requires studies on different environments and production systems to base the recommendation of these materials and assist in the use of more productive and commercially accepted cultivars (CARBONELL et al., 2010; LEAL et al., 2019; NUNES et al., 2021). The adequate choice of cultivars can result in gains of up to 120% in grain yield (ALVES et al., 2020) and more than 10% in grain protein contents (TERRA et al., 2019; FERREIRA et al., 2021), denoting its importance in production systems. However, the urbanization process in the latest decades and the decrease in the time available for food preparation have promoted changes in the feeding habit of part of the population, which started to look for more convenient and quick preparation products, thus decreasing the common bean consumption (IBGE), 2020).

Focused on reverting this consumption situation, a continued process for the obtaining of increases in grain yield and improvement of performance of cultivars is important. However, it should be combined with products with quality attributes desired by consumers, mainly low cooking time and high hydration capacity, and that present not only quantity, but quality of proteins (LEAL et al., 2021; MINGOTTE et al., 2021; NUNES et al., 2021). Other important quality attributes for growers of common bean, especially for varieties of the carioca group, are grain yield and integument color; large and clear grains present higher commercial value because consumers associate it with recently-harvested grains that present fast cooking (CARBONELL et al., 2010; LEMOS et al., 2015).

The objective of this work was to evaluate the effect of common bean cultivars of the carioca commercial group on the grain yield and quality in a production system and assess the correlation between their variables.

MATERIAL AND METHODS

The experiment was conducted at the São Paulo State University (UNESP), School of Agricultural and Veterinarian Sciences, Jaboticabal, SP, Brazil, in an area close to the coordinates 21°15'22"S and 48°18'58"W, with 565 m of altitude. The climate of the region is Aw, tropical wet with a rainy summer and a dry winter, according to Köppen climate classification.

The soil of the experimental area was classified as a Typic Hapludox (Latossolo Vermelho Eutroférrico) of clayey texture (540 g kg^{-1} of clay in the 0.00-0.20 m layer) (SANTOS et al., 2018). The chemical analysis of the 0.00-0.20 m soil layer before the implementation of the experiment showed the following results: pH ($CaCl_2$) of 5.4; 23 g dm^{-3} of organic matter; 55 mg dm^{-3} of P; 4.4 mmol$_c$ dm^{-3} of K; 37 mmol$_c$ dm^{-3} of Ca; 23 mmol$_c$ dm^{-3} of Mg; 31 mmol$_c$ dm^{-3} of H+Al; 95.4 mmol$_c$ dm^{-3} of cation exchange capacity, and 68% base saturation.

A randomized block experimental design was used, with 13 treatments (Pérola, BRSMG-Majestoso, BRS-Estilo, BRSMG-Madrepérola, IPR-Campos Gerais, IPR-Tangará, IPR-Andorinha, IPR-139 (Juriti Claro), IAC-Imperador, IAC-Formoso, IAC-Alvorada, IAC-Milênio and TAA-Bola Cheia) and four replications per treatment. Each experimental plot consisted of four 5-m rows, considering the two central rows for evaluation, discarding 0.5 m from each end. The experiment was implemented with conventional soil preparation, using one plowing and two harrowing. The seeds were sown on August 07, 2013, which defined it as a winter-spring crop season (PAULA JUNIOR et al., 2007), using 12 seeds per meter of furrows, and spacing of 0.45 m between rows.

Soil fertilizer application at sowing was carried out using 300 kg ha^{-1} of the commercial N-P-K formulation 08-28-16, (24 kg ha^{-1} of N, 84 kg ha^{-1} of P_2O_5, and 48 kg ha^{-1} of K_2O). Topdressing was divided into two applications: the first at the V_{4-3} stage (third trifoliate leaf expanded) by applying 50 kg ha^{-1} of N and using the fertilizer formulation 20-00-20, and the second at the V_{4-6} stage (sixth trifoliate leaf expanded) by applying 50 kg ha^{-1} of N and using urea, followed by application of 15 mm of water in both cases. The crop was maintained under irrigation through a conventional sprinkler system to meet the plant water demands over the cycle: approximately 400 mm (FENNER et al., 2016).

Production attributes were assessed after the physiological maturation of the pods (R_9); 10 consecutive plants in the rows within the evaluation area of each plot were collected to determine the production components evaluated (number of pods per plant, number of grains per pod, and 100-grain weight). Grain yield (kg ha^{-1}) was evaluated after the harvest; plants in the evaluation area of each plot were manually harvested, subjected to sun drying and, then, mechanically threshed; the water content of grains was standardized to 13% on wet basis.

Quality attributes were determined after weighing the grains; it included grain yield in sieves (GYS), which was evaluated using grain samples from each experimental plot, which were subjected to sieving in a set of sieves with oblong holes with sizes of 10 (10/64”), 11 (11/64”), 12 (12/64”), 13 (13/64”), 14 (14/64”), and 15 (15/64”), after shaking for 1 min. The values obtained were used to calculate the grain yield in sieves equal to or higher than 12 (GYS≥12), being the sum of grains retained in sieves with oblong holes of 12 to 15. The grains retained in the sieve 13 were placed in paper bags and used for the other evaluations of quality attributes.

The grain gross protein contents (GPC) (AOAC, 1995) were obtained by the amount of nitrogen (N) in the grains, considering $GPC = (total\ N \times 6.25)$, where *GPC* is the grain gross protein contents (g kg^{-1}) and *total N* is the N content in the grains (BATAGLIA et al., 1983). The integument color of grains was determined with the aid of a colorimeter, through readings of luminosity (L), which evaluate the color luminosity of the sample. The higher the L value, the higher the color luminosity of the integument (RIBEIRO et al., 2008).

The cooking time was determined using samples hydrated in water for 12 h and placed in a Mattson cooker with water at temperature of 96°C, as carried out by Leal et al. (2021) and Mingotte et al. (2021). The hydration capacity was determined after 20 h, with evaluations of the volume of water not absorbed by the grains every 2 h, by removing it from the cylindrical graduated beaker. The water was totally drained and the grains were weighed at the end of the hydration time; the hydration ratio (HR) was determined by the ratio between the final and initial weights of the grains (Equation 1). A regression polynomial analysis between hydration time (h) and hydration capacity (mL) was carried out to determine the time required for the maximum hydration of grains.

$$HR = \frac{GW_{ah}}{GW_{in}} \qquad \text{(Equation 1)}$$

Where:
HR = hydration ratio
GW_{ah} = grain weight after hydration
GW_{in} = initial grain weight

The data were subjected to analysis of variance by the F test ($p<0.05$) and the means were grouped by the Scott-Knott test ($p<0.05$). Pearson's correlation analysis was carried out between the measured attributes. The significance of polynomial regressions between evaluation time and quantity of water absorbed by grains and correlations were evaluated by the t test ($p<0.05$). The statistical analyses were carried out using the AgroEstat software (BARBOSA; MALDONADO JÚNIOR, 2015).

RESULTS AND DISCUSSION

The cultivars presented significant differences for all production attributes evaluated (number of pods per plant, 100-grain weight, and grain yield), except for number of grains per pods (Table 1). The number of pods per plant of the cultivar BRSMG-Majestoso presented the highest value, with 13 pods per plant. This cultivar also presented the highest grain yield, which was 34% higher than the lowest grain yield found (IAC-Milênio). The mean grain yield found was 3,317 kg ha^{-1}, which is higher than the mean grain yield in the state of São Paulo (CONAB, 2021). The highest 100-grain weights were found for the cultivars Pérola (32.7 g), IAC-Milênio (32.1 g), and TAA-Bola Cheia (31.5 g), differing significantly from each other. The 100-grain weight of the cultivars varied from 32.7 g (Pérola) to 28.0 g (IAC-Alvorada).

TABLE 1 - Number of pods per plant, number of grains per pod, 100-grain weight, and grain yield of common bean cultivars of the carioca commercial group[1].

Common bean cultivars	Number of pods per plant	Number of grains per pod	100-grain weight (g)	Grain yield (kg ha^{-1})
Pérola	10 b	4.4	32.7 a	3,086 d
BRS-Estilo	10 b	4.7	29.6 b	3,421 b
BRSMG-Madrepérola	10 b	4.4	29.7 b	3,090 d
BRSMG-Majestoso	13 a	4.3	29.7 b	3.805 a
IAC-Alvorada	11 b	4.5	28.0 b	3,453 b
IAC-Formoso	10 b	5.0	30.4 b	3,528 b
IAC-Imperador	10 b	4.4	29.1 b	3,310 c
IAC-Milênio	11 b	3.7	32.1 a	2,832 e
IPR-Andorinha	11 b	4.4	29.4 b	3,273 c
IPR-Campos Gerais	11 b	4.5	29.1 b	3,617 b
IPR-139	10 b	4.3	28.8 b	3,251 c
IPR-Tangará	10 b	4.0	30.3 b	2,975 d
TAA-Bola Cheia	11 b	4.5	31.5 a	3,477 b
General mean	11	4.4	30.02	3,317
F Value	6.29**	1.65^{ns}	2.14*	16.36**
CV(%)	6.82	11.85	6.13	4.06

[1]Means followed by different letters in the columns are statistically different from each other by the Scott-Knott test ($p<0.05$). *($p<0.05$), **($p<0.01$), and ^{ns} (not significant) by the F test.

A study conducted with common bean crops next to the experimental area of the present study, in the winter crop season in other agricultural year showed that the cultivar BRSMG-Majestoso presented the highest grain yield, with mean 120% higher than the cultivar that presented the lowest yield (Alves et al., 2020). In low-altitude regions of the Cerrado biome, Pereira et al. (2012) found that the cultivar BRSMG-Majestoso was within the cultivars with the highest grain yield in the winter crop season, and that this cultivar presents high adaptability and production stability in favorable environments. These results, combined with those found in the present study, show the adaptability of the cultivar BRSMG-Majestoso to the edaphoclimatic conditions studied and its high adaptability and production stability (PEREIRA et al., 2018).

The number of pods per plant is the production component that explained the highest grain yield of the cultivar BRSMG-Majestoso, considering the highest values of this variable for this cultivar. However, the cultivar BRSMG-Majestoso was not among the cultivars with the highest 100-grain weight. According to Fageria et al. (2015), there is an adjustment in the balance between production components of common bean due to the balance between source and drain. Thus, cultivars with higher number of grains per plant tend to present lower grain weights than cultivars with lower number of grains per plant. However, despite the differences in 100-grain weight between the cultivars, according to Pereira et al. (2012), the preferred 100-grain weight by consumers, for the varieties of the carioca group, is above 25 g. Thus, all cultivars studied presented satisfactory performance of this attribute.

The cultivars presented similar number of grains per pod, with mean of 4.4. Similar results were found by Leal et al. (2019) and Nunes et al. (2021), who evaluated 16 common bean cultivars of the carioca commercial group and found mean number of grains per pod of 3.9 and 3.8, respectively.

The evaluation of grain size of the cultivars showed that the grain yield in sieves equal to or higher than 12 (GYS≥12) was significantly different (Table 2). The cultivar with the highest GYS≥12 was IPR-Andorinha, which presented GYS≥12 higher than 90%. All cultivars presented GYS≥12 above 70%, which represents large grains and higher financial return (CARBONELL et al., 2010). The cultivar Pérola, despite presenting the highest 100-grain weight (32.7 g) had the lowest GYS≥12. Although it is an old cultivar, Pérola is still used in Brazil due to its wide adaptability, production stability, and standards for marketing and due to its grain shape and size (CARBONELL et al., 2010; CARNEIRO et al., 2020). The other cultivars had GYS≥12 above that of the Pérola, which denotes the advances of breeding programs for this quality attribute.

TABLE 2 - Grain yield in sieves equal to or higher than 12 (GYS≥12), protein contents, integument color, cooking time, and hydration ratio of grains of common bean cultivars of the carioca commercial group[(1)].

Common bean cultivars	GYS≥12 (%)	Protein contents (%)	Integument color (L)	Cooking time (min.)	Hydration ratio
Pérola	78.0 e	19 c	50.38 c	22 d	2.00 a
BRS-Estilo	87.5 b	20 b	52.39 b	23 d	1.95 b
BRSMG-Madrepérola	79.5 e	20 b	55.73 a	22 d	1.99 a
BRSMG-Majestoso	80.0 e	21 a	50.36 c	24 c	1.93 b
IAC-Alvorada	79.0 e	21 a	51.64 b	19 f	2.00 a
IAC-Formoso	81.8 d	20 b	51.62 b	19 f	2.00 a
IAC-Imperador	84.0 c	20 b	50.74 c	20 e	1.97 a
IAC-Milênio	84.3 c	22 a	50.80 c	28 a	1.94 b
IPR-Andorinha	93.5 a	20 b	48.27 d	23 d	1.97 a
IPR-Campos Gerais	88.0 b	19 c	50.26 c	22 d	1.98 a
IPR-139	81.3 d	21 a	49.29 d	26 b	1.99 a
IPR-Tangará	82.0 d	21 a	50.02 c	22 d	2.02 a
TAA-Bola Cheia	83.0 c	20 b	50.50 c	23 d	1.99 a
Mean	83.2	20	50.92	23	1.98
Value F	64.74**	8.49**	24.55**	33.36**	2.35*
CV(%)	1.29	2.81	1.58	3.98	1.69

[(1)]Means followed by different letters in the columns are statistically different from each other by the Scott-Knott test ($p<0.05$). *($p<0.05$) and **($p<0.01$) by the F test.

The cultivars IAC-Milênio, BRSMG-Majestoso, IAC-Alvorada, IPR-139, and IPR-Tangará presented the highest gross protein contents. The protein contents varied from 19% to 22%, and only the cultivars Pérola and IPR-Campos Gerais presented values below 20%. These are similar results to those found by Santis et al. (2019) and Nunes et al. (2021) in common bean grains from winter crops, and are considered normal for common bean grains.

The integument color varied, expressing luminosity (L) values from 48.27 to 55.73. The cultivar BRSMG-Madrepérola presented the highest, and IPR-Andorinha and IPR-139 the lowest luminosity of grains. Luminosities higher than 55 denote grains with clear integument and higher market value (RIBEIRO et al., 2008). Only the cultivar BRSMG-Madrepérola presented results above these values, and it is a cultivar that presents delay in integument darkening (CARNEIRO et al., 2012).

Pinto et al. (2020) evaluated the effect of storing common bean grains of different cultivars for 8 months and found that the cultivar BRSMG-Madrepérola presented the lowest variation, proportionally, in integument color, confirming the delay in grain darkening in this cultivar. This quality attributes, combined with GYS≥12 which, in this case, was close to 80%, can enable competitive prices, compensating the low grain yield of this genotype, which was 3,090 kg ha^{-1}.

Regarding the cooking time, the cultivars had mean of 23 min., with significant differences between them; the cultivars IAC-Alvorada and IAC-Formoso presented the lowest results (19 min.). The cooking time varied from 19 to 28 min; the cultivars IAC-Alvorada, IAC-Formoso, and IAC-Imperador were in the class of medium susceptibility to cooking (16 to 21 min) and the other cultivars were in the class of normal resistance to cooking (21 to 28 min), according to Proctor and Watts (1987).

Regarding the hydration ratio, the cultivars BRS-Estilo, BRSMG-Majestoso, and IAC-Milênio had the lowest values, differing significantly from the others.

However, these values are close to 2.0, i.e., the weight of water absorbed by the grains was similar to their initial weight, denoting satisfactory performance of this attribute. Common bean cultivars that do not present grains with hard peel always have hydration ratio close to 2.0, as found in other works in the literature, and is an intrinsic characteristic of common bean grains (TERRA et al., 2019; LEAL et al., 2021; MINGOTTE et al., 2021).

The regression equations for hydration time and quantity of water absorbed by common bean grains (Table 3) showed that the period required for the maximum hydration varied from 14 h and 33 min. (BRS-Estilo) to 15 h and 32 min. (IPR-139). The cultivars that had lower times, from 14 h and 30 min. to 15 h, were BRS-Estilo, BRSMG-Madrepérola, IAC-Formoso, and IAC-Milênio.

TABLE 3 - Regression equation for grain hydration time × quantity of water absorbed by grains and time for maximum grain hydration (TH) of common bean cultivars of the carioca commercial group(1).

Common bean cultivars	Regression equation (2)	R^2 (3)	TH (h, min.)
Pérola	$y = -0.000048x^2 + 0.0880x + 9.9222$	0.882**	15:12 a
BRS-Estilo	$y = -0.000046x^2 + 0.0803x + 13.6380$	0.751**	14:33 b
BRSMG-Madrepérola	$y = -0.000049x^2 + 0.0881x + 10.3929$	0.869**	14:59 b
BRSMG-Majestoso	$y = -0.000045x^2 + 0.0814x + 9.8313$	0.868**	15:09 a
IAC-Alvorada	$y = -0.000048\ x^2 + 0.0869x + 10.8018$	0.862**	15:05 a
IAC-Formoso	$y = -0.000050x^2 + 0.0886x + 11.3976$	0.848**	14:51 b
IAC-Imperador	$y = -0.000046x^2 + 0.0834x + 10.5987$	0.856**	15:12 a
IAC-Milênio	$y = -0.000044x^2 + 0.0792x + 11.5989$	0.812**	14:45 b
IPR-Andorinha	$y = -0.000043x^2 + 0.0791x + 11.1376$	0.838**	15:26 a
IPR-Campos Gerais	$y = -0.000044x^2 + 0.0797x + 11.5506$	0.825**	15:17 a
IPR-139	$y = -0.000048x^2 + 0.0896x + 8.1592$	0.920**	15:32 a
IPR-Tangará	$y = -0.000049x^2 + 0.0900x + 8.9602$	0.896**	15:19 a
TAA-Bola Cheia	$y = -0.000045x^2 + 0.0822x + 10.9346$	0.844**	15:19 a
Mean	-	-	15:08
F Value	-	-	2.64*
CV(%)	-	-	2.28

(1)Means followed by different letters in the columns are statistically different from each other by the Scott-Knott test ($p<0.05$). (2)x = hydration time (h), y = quantity of water absorbed (mL), (3) *($p<0.05$) by the F test. **($p<0.01$) by the t test.

The correlations showed that the grain yield increased as the number of pods per plant and the number of grains per pod were increased, with the proportion of 50% and 67%, respectively (Table 4). Significant and positive correlation between these attributes were also found by Barili et al. (2010 and 2011). The negative correlation between number of pods per plant and 100-grain weight is due to an adjustment in the balance of photoassimilates for the common bean reproduction structures; a high number of grains per plant results in grains with lower weights (FAGERIA et al., 2015).

TABLE 4 - Pearson's coefficient of correlation (r) between grain yield (GY), number of pods per plant (NPP), number grains per pod (NGP), 100-grain weight (100GW), grain yield in sieves equal to or higher than 12 (GYS≥12), gross protein contents (GPC), integument color (IC), cooking time (CT), hydration ratio (HR), and time for maximum grain hydration (TH) of common bean cultivars of the carioca commercial group(1).

Variables	GY	NPP	NGP	100GW	GYS≥12	GPC	IC	CT	HR	TH
GY	1.00									
NPP	0.50**	1.00								
NGP	0.67**	-0.13	1.00							
100GW	-0.45**	-0.12	-0.29*	1.00						
GYS≥12	-0.04	-0.02	-0.05	-0.17	1.00					
GPC	-0.38**	0.27	-0.61**	-0.09	-0.11	1.00				
IC	-0.09	-0.11	0.25	-0.05	-0.44**	-0.09	1.00			
CT	-0.36**	0.41**	-0.67**	0.35*	0.18	0.51**	-0.23	1.00		
HR	-0.19	-0.63**	0.23	-0.09	-0.32*	-0.23	0.07	-0.60**	1.00	
TH	0.06	-0.02	-0.21	-0.20	0.07	-0.03	-0.61**	0.03	0.39**	1.00

(1) *($p<0.05$), **($p<0.01$) by the t test.

The highest value found for the correlation between the attributes studied was referring to the correlation between grain yield and number of grains per pod; thus, this was the attribute that most contributed to the increase in grain yield of the cultivars, despite no significant differences was detected by the variance and mean grouping tests (Table 1). The GYS≥12 had low estimate of coefficient of correlation to grain yield, denoting that, in this case, the highest GYS≥12 is not associated to the most productive cultivars.

Grain yield also presented significant and negative correlation to quality attributes, such as gross protein contents and cooking time. Nunes et al. (2021) also found negative correlation between grain yield and protein contents of common bean, with decreases of 0.37% for each increase of 100 kg ha^{-1} in grain yield, which could indicate that the selection of most productive cultivars by breeding programs would result in genotypes with lower protein contents. However, Zeffa et al. (2020) evaluated the genetic progress of nitrogen use efficiency by common bean cultivars and found that decreases in protein contents are due to a dilution effect, as modern common bean cultivars do not present decreases in grain protein contents.

Another expressive result was the significant and negative correlation between number of grains per pod and quality attributes referring to gross protein contents and cooking time, i.e., cultivars with higher number of grains per pod presented a trend to reduce the amount of protein, however, with decrease in grain cooking time. This is due to the balance of photoassimilates between reproduction structures (FAGERIA et al., 2015) and the effect of dilution of grain protein contents (ZEFFA et al., 2020).

The cultivars with the highest numbers of pods per plant and 100-grain weights presented a trend to increase the cooking time, at the proportion of 41% and 35%, respectively. The same result was found between cooking time and gross protein contents, with values of 51%. Mingotte et al. (2021) also found significant (0.20*) and direct correlation between protein contents and cooking time. However, Leal et al. (2021) found indirect correlation between protein contents and cooking time. These contrasting results are due to a high variability in the quality attributes that depend on the environment and common bean cultivar evaluated.

The integument color presented significant and negative correlation to GYS≥12 and time for maximum hydration, denoting that the cultivars with higher grain luminosity result in grains that require shorter times for water absorption, however, present smaller sizes.

The hydration ratio presented significant and negative correlation to number of pods per plant (r = -0.63**) and GYS≥12 (r = -0.32*). The same result was found between hydration ratio and cooking time (r = -0.60**). Leal et al. (2021) and Mingotte et al. (2021) also found inverse correlation between hydration ratio and cooking time, i.e., the higher the capacity of the grains to absorb water, the shorter the cooking time. According to these studies, grains with higher water absorption present integument with higher permeability, which facilitates the cooking of grains. Hydration ratio presented significant and positive correlation to time for maximum hydration of grains, i.e., grains with higher water absorption need longer times to reach the maximum hydration.

This denotes the importance of choosing a correct cultivar for the production system to increase grain yield, obtain grains with high technological quality, and improve the profit for farmers. These results denote the importance of the choice of genotypes by farmers and the need for studies that show the economic impact of this choice on the income obtained by farmers.

CONCLUSIONS

The choice of a cultivar affects production and quality attributes of common bean grains in production systems, as it can result in increases of up to 34% in grain yield, 20% in grain yield in sieves equal to or higher than 12 (GYS≥12), 16% in grain protein contents, and 47% in cooking time.

BRSMG-Majestoso is among the cultivars that presented the highest grain yield (3,805 kg ha^{-1}), and the cultivars IPR-Andorinha and BRSMG-Madrepérola stands out with GYS≥12 of 93% and grains with a clear integument, respectively.

Grain yield increases as the number of pods per plant and grains per pod increase, presenting a negative correlation with gross protein contents and cooking time.

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