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# Agronomic characteristics of common bean and castor bean hybrids in intercropping and monocropping

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**Key words:**
*Phaseolus vulgaris* L.
*Ricinus communis* L.
association of crops
grain yield

**ABSTRACT**
Common bean has great importance in the Brazilian economy and castor bean is still emerging in Midwestern Brazil, but with great potential of exploitation by farmers due to the prevailing climatic conditions and flat topography. Hence, this study aimed to evaluate the agronomic characteristics of common bean cultivars and castor bean hybrids in intercropping and monocropping under the edaphoclimatic conditions of the Cerrado region. The randomized block design was used in 4 x 2 + 6 factorial scheme, with three replicates. Treatments were composed of four cultivars of common beans (BRS Pérola, BRS Esteio, BRSMG Realce and BRS Pitanga) intercropped with two castor bean hybrids (Tamar and Ag Ima), plus the respective crops in monocropping. In common bean cultivars, plant height was influenced in the intercropping with castor bean hybrids; however, agronomic characteristics of the castor bean hybrids were not influenced by common bean cultivars. The intercropping between common bean cultivars (BRS Esteio, BRSMG Realce and BRS Pitanga) and castor bean hybrids (Tamar and Ag Ima) was classified as viable by the area equivalence index, since this index presented values greater than 1.0 for the intercropping between these cultivars. This fact indicates that it would take more than one hectare in monocropping to produce the same amount than one hectare in intercropping.

**Palavras-chave:**
*Phaseolus vulgaris* L.
*Ricinus communis* L.
associação de culturas
rendimento de grãos

# Características agronômicas de cultivares de feijão-comum e híbridos de mamona consorciados e em monocultivo

**RESUMO**
O feijão-comum apresenta grande importância na economia brasileira e a cultura da mamona ainda é emergente no Centro-Oeste, porém com grande potencial de exploração pelos agricultores em razão das condições climáticas prevalecentes e topografia plana. Desta forma, objetivou-se neste trabalho avaliar as características agronômicas de cultivares de feijão-comum e híbridos de mamona oriundos de consórcio e monocultivo nas condições edafoclimáticas da região do Cerrado. Empregou-se o delineamento em blocos casualizados em esquema fatorial 4 x 2 + 6, com três repetições. Os tratamentos foram constituídos por quatro cultivares de feijão-comum (BRS Pérola, BRS Esteio, BRSMG Realce e BRS Pitanga) consorciadas com duas cultivares híbridas de mamona (Tamar e Ag Ima), acrescidos das respectivas cultivares em monocultivo. As cultivares de feijão-comum tiveram a altura de planta influenciada no consórcio com os híbridos de mamona, no entanto, os híbridos de mamona não tiveram suas características agronômicas influenciadas pelas cultivares de feijão-comum. O consórcio entre as cultivares de feijão-comum Esteio, Realce e Pérola e os híbridos de mamona Tamar e Ag Ima foi classificado como viável pelo índice de equivalência de área uma vez que este índice apresentou valores superiores a 1,0 para o consórcio entre estas cultivares, demonstrando que seria necessário mais de um hectare em monocultivo para produzir a mesma quantidade que um hectare em consórcio.

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## Introduction

Common bean (*Phaseolus vulgaris* L.) is of great importance in the Brazilian economy and stands out as an alternative of economic exploitation for rural properties, because approximately 2.5 million tons were produced in the 2015/16 season in the country, but the national consumption was approximately 2.8 million tons and is expected to increase to 3.4 million tons in the 2016/17 season, evidencing the importance and potential of the crop in the national scene (Vieira et al., 2006; CONAB, 2017). The highest percentage of common bean production occurs in the small rural property (IBGE, 2006), where it is cultivated predominantly in intercropping system, such as in Minas Gerais, where 60% of the common bean cultivated in the rainy period and 50% in the dry period is associated with maize and other crops (Costa & Silva, 2008).

Intercropping of grain crops is usual in Brazil, and the combination between common bean and maize is the most commonly adopted. However, the effective advantage of this technique compared with monocropping becomes more evident when the involved crops have differences in their requirements regarding the available resources, in either quality, quantity or period of demand (Jensen et al., 2010). An example is the case of common bean and castor bean, which have different nutritional requirements and cycles. In addition, these crops have demand in the country; common bean is staple food of Brazilians along with rice, whereas castor bean is valued for its oil, which is used in the industry to produce various products.

Castor bean (*Ricinus communis* L.) has potential of use in intercropping system, especially with short-cycle annual crops (Oliveira et al., 2010) such as common bean, but studies on the intercropping involving the use of short castor bean hybrids are rare.

In the Midwestern region, its potential of cultivation is great, as demonstrated by research results in which yield levels above 1500 kg $ha^{-1}$ have been obtained, equivalent to three times the national mean of this oilseed crop (CONAB, 2017). These studies involve taller cultivars (Teixeira et al., 2012; Pereira et al., 2015), as well as short hybrid materials adapted to mechanized harvest (Moro et al., 2011) and that have been used in areas after removing the cotton crop, aiming to eliminate root-knot nematodes (*Meloidogyne incognita*), because castor bean has reproduction factor of 0.4 (resistant), breaking the nematode's life cycle and causing its reduction and even elimination from the soil (Sá et al., 2015).

Investigative studies on the evaluation of production and yield components of common bean cultivars and castor bean hybrids in intercropping system are of great importance for technicians and producers to be better informed about the most efficient management in the system in question.

Hence, this study aimed to evaluate the agronomic characteristics of common bean cultivars and castor bean hybrids in intercropping system compared with monocropping, under the edaphoclimatic conditions of the Cerrado region in Goiás, Brazil.

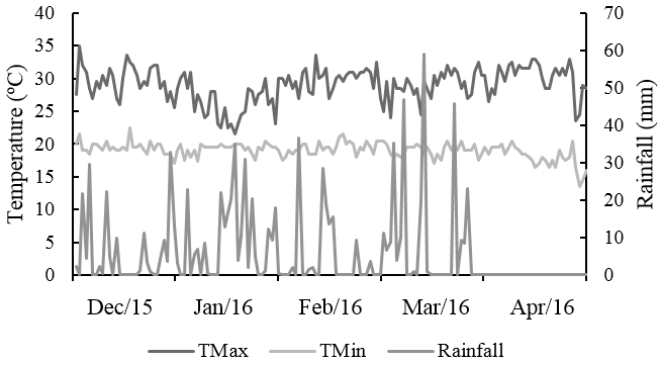
## Material and Methods

The experiment was conducted in the rainy period, since it is the main period of common bean cultivation by small farmers, in the 2015/16 season, in the field, in the municipality of Anápolis, GO, Brazil (16º 19' 48" S; 48º 18' 23" W; ~1,050 m). The climate of this region is AW, humid tropical according to Köppen's classification, characterized by dry winter and rainy summer. Monthly means of temperature (maximum and minimum) and cumulative rainfall along the experimental period, comprehended between December 2016 and April 2017, are presented in Figure 1.

Samples of soil classified as dystrophic Red Yellow Latosol were collected in the layers of 0-20 and 20-40 cm and sent to the laboratory for chemical analysis (EMBRAPA, 2011). The results found in the 0-20 cm layer were: pH ($CaCl_2$): 5.1; Ca: 3.2 $cmol_c dm^{-3}$; Mg: 1 $cmol_c dm^{-3}$; Ca+Mg: 4.2 $cmol_c dm^{-3}$; Al: 0 $cmol_c dm^{-3}$; H+Al: 3.1 $cmol_c dm^{-3}$; CEC: 7.6 $cmol_c dm^{-3}$; P (Mehlich I): 3 mg $dm^{-3}$; K: 0.3 $cmol_c dm^{-3}$; K: 132 mg $dm^{-3}$; Na: 2 mg $dm^{-3}$; Cu: 3.2 mg $dm^{-3}$; Fe: 262 mg $dm^{-3}$; Mn: 38 mg $dm^{-3}$; Zn: 1.7 mg $dm^{-3}$; OM: 23 g $kg^{-1}$; Al saturation (M%): 0%; Base saturation (V%): 60%. In the 20-40 cm layer, the results were: pH ($CaCl_2$): 5.1; Ca: 1.9 $cmol_c dm^{-3}$; Mg: 0.9 $cmol_c dm^{-3}$; Ca+Mg: 2.8 $cmol_c dm^{-3}$; Al: 0 $cmol_c dm^{-3}$; H+Al: 3.1 $cmol_c dm^{-3}$; CEC: 6.1 $cmol_c dm^{-3}$; P (Mehlich I): 3 mg $dm^{-3}$; K: 0.2 $cmol_c dm^{-3}$; K: 72 mg $dm^{-3}$; Na: 4 mg $dm^{-3}$; Cu: 3.2 mg $dm^{-3}$; Fe: 240 mg $dm^{-3}$; Mn: 20 mg $dm^{-3}$; Zn: 3.8 mg $dm^{-3}$; OM: 23 g $kg^{-1}$; Al saturation (M%): 0%; Base saturation (V%): 49%.

A randomized block design was used, in 4 x 2 + 6 factorial scheme, with three replicates. Treatments consisted of four common bean cultivars widely used by farmers (BRS Pérola [carioca grain] - type II/III – indeterminate growth and semi-erect; BRS Pitanga [purple grain] type II - indeterminate growth and erect; BRS Esteio [black grain] type II - indeterminate growth and erect; BRSMG Realce [striped grain] type I – determinate growth and erect), intercropped with two short hybrid cultivars of castor bean (Tamar and Ag Ima 110204), plus additional treatments composed of the genetic materials of common bean and castor bean in monocropping.

These common bean cultivars and castor bean hybrids previously cited showed the following characteristics: BRS Pérola – cycle of 85-95 days and semi-prostrate; BRS Esteio




Source: Meteorology and Hydrology System of Goiás (SIMEHGO)

Figure 1. Daily climatic data of maximum temperature (TMax) and minimum temperature (TMin) and cumulative rainfall along the cycle of common bean and castor bean plants in intercropping/monocropping in Anápolis-GO, Brazil

– cycle of 80-90 days and erect; BRSMG Realce – cycle of 75-85 days and erect; BRS Pitanga – cycle of 85-95 days and semi-erect. For the castor bean hybrid Tamar – cycle of 140-160 days, height of 1.60-1.70 m, sympodial growth and first raceme appearance at 30 DAE; for the castor bean hybrid Ag Ima 110204 – cycle of 140-160 days, height of 1.70-1.80 m, sympodial growth and first raceme appearance at 35 DAE.

Castor bean plots in the intercropping system were composed of four 5-m-long rows, at spacing of 0.5 m between plants and 3.0 m between rows. Four 5-m-long rows of common bean were planted in the castor bean interrows, with 12 plants per linear meter and spacing of 0.5 m between rows. Evaluations were made in the two central rows of castor bean and common bean. For the monocropping, castor bean and common bean plots consisted of four 5-m-long rows, at spacing of 0.9 and 0.5 m, respectively, also harvesting the two central rows for evaluations.

Plants were sown on December 1, 2015, and fertilization was performed according to soil analysis and recommendations of Chagas et al. (1999) for common bean and CFSEMG (1999) for castor bean, using 25% more seeds. At 15 days after emergence (DAE), plants were thinned to reach densities of 2 and 12 plants per linear meter for castor bean and common bean, respectively. At 30 DAE, top-dressing fertilization with nitrogen was applied in a continuous line along the rows, using urea as source.

Weeds were manually controlled, whereas ants (*Atta* sp.) were controlled using granule baits Mirex – S (Sulfluramid) for both crops.

To control caterpillars such as looper caterpillar (*Pseudoplusia includens)*, cotton bollworm (*Helicoverpa armigera*) and long-tailed skipper (*Urbanus proteus*), the common bean crop was also treated with the insecticides Rimon (Novaluron) and Keshet (Deltamethrin) at doses of 150 and 600 mL of the commercial product per hectare, respectively. The fungicide Nativo (Trifloxystrobin and Tebuconazole) was applied at dose of 700 mL of commercial product per hectare to control anthracnose and angular leaf spot. The castor bean crop was treated with the fungicide Rovral (Iprodione) at dose of 200 g of commercial product per hectare, to control gray mold (*Amphobotrys ricini*).

At harvest, in February for the common bean cultivar Realce and March for the others, the following characteristics were evaluated: final plant stand, plant height, number of pods per plant, number of grains per pod, 100-grain weight and grain yield. Final plant stand was obtained by counting all plants in the evaluated area of the plot, whereas plant height and yield components were determined by analyzing ten plants collected from the evaluated area. Grain yield was determined by threshing the plants harvested in the evaluated area, including the weight of grains from the ten plants used to determine the components and plant height.

At the harvest of castor bean hybrids, in April, the following variables were determined in the evaluated area of each experimental unit: number of racemes per plant, 100-grain weight, plant height, final plant stand, stem diameter and grain yield. Yield components of the castor bean hybrids were determined by analyzing four plants collected in the evaluated area, as well as plant height and stem diameter. Plant height was measured considering the distance from the soil and disregarding the root system, while stem diameter was determined using a digital caliper (0.01 mm accuracy) approximately 2 cm above the soil. Grain yield was obtained by threshing the plants harvested in the evaluated area of the plot, including the weight of grains from the four plants used to determine the components.

To determine the mean 100 grain weight (g) and yield (kg $ha^{-1}$), the moisture contents in common beans and castor beans were corrected to 12 and 8% (wet basis), respectively. 100 grain weight was determined by counting four replicates of 100 grains per plot, whereas yield was determined by extrapolating the production obtained in each plot.

For each system evaluated, the area equivalence index (AEI), described by Vieira et al. (2006), was also determined. This index quantifies the number of hectares needed for the production in monocropping to become equal to that of one hectare of the same crops in association (Eq. 1).

$$AEI = \frac{F_i}{F_m} + \frac{M_i}{M_m} \quad (1)$$

where:

$F_i$ - yield of common bean intercropped;
$F_m$ - yield of common bean in monocropping;
$M_i$ - yield of castor bean intercropped; and,
$M_m$ - yield of common bean in monocropping.

Intercropping is efficient when AEI is higher than 1.0, because more than 1 hectare of monocropping will be required to produce the same as 1 hectare of intercropping.

The obtained data were subjected to analysis of variance by F test at 0.05 probability level and, when pertinent, subjected to Skott-Knott test at 0.05 probability level. All statistical procedures were carried out using the program Sisvar 5.3 (Ferreira, 2014).

## Results and Discussion

For the agronomic characteristics of common bean, the individual factor common bean cultivars had significant influence on the number of pods per plant, number of grains per pod, 100-grain weight and yield, while the factor castor bean hybrids influenced only plant height.

Regarding the interaction between the factors common bean cultivars × castor bean hybrids, significant interaction occurred only on plant height. For the additional treatments, significant difference was observed for plant height, 100-grain weight and yield. Although plant height showed significant difference by F test, this characteristic did not show significant difference at 0.05 probability level according to the means test used and, therefore, no follow-up analysis was performed. Lastly, for the interaction of intercropping × monocropping, significant difference was observed for plant height, 100-grain weight and grain yield.

The common bean cultivars Esteio and Pitanga exhibited the highest values of plant height for the interaction of common

bean cultivars × castor bean hybrids. In this context, significant difference occurred in the height of common bean plants affected by the intercropping with castor bean hybrids, and the intercropping with the cultivar Tamar showed the highest value (Table 1).

The highest mean values of plant height observed in the common bean cultivars Esteio and Pitanga are due to their indeterminate growth habit.

For the common bean cultivars Pérola and Realce, neither of the two showed significant difference with respect to the castor bean hybrids. For plant height in common bean, in general, significant difference was observed for all cultivars tested. Despite that, the mean values of plant height in common bean cultivars intercropped with castor bean hybrids, except the cultivar Esteio, were lower than those reported by Oliveira et al. (2014), who evaluated the agronomic performance of different common bean cultivars in monocropping, in soil with the same classification as the one of the present study, and obtained lower values for plant height (63.36 cm) compared with the ones of the present study, indicating that competition between crops in the intercropping system did not cause aggressive etiolation in the plants.

For the 100-grain weight of common bean in monocropping, all cultivars differed significantly (Table 2).

This occurs because the common bean cultivars have different morphological characteristics in the grains. The common bean cultivar Realce had the highest mean value for 100-grain weight (28 g). However, EMBRAPA (2015) cites value of 43 g for this characteristic, higher than that found in the present study. This may have resulted from a drought period (dry spell) occurred during the grain filling stage of this cultivar, since it has semi-early cycle and may have responded with lower value of this characteristic.

For grain yield in monocropping, the common bean cultivars Esteio and Pérola showed the highest mean values (Table 2). The highest values of grain yield for these cultivars are due to their higher production potential, corroborating the results of Lemos et al. (2012) and Teixeira et al. (2012), who used the same genetic materials.

The cultivars Pitanga and Realce did not differ significantly, although Realce showed higher 100-grain weight compared with Pitanga (Table 2). This occurred probably due to the lower availability of water in the grain filling stage of Realce, which has semi-early cycle, as previously reported. In addition, the cultivars Realce and Pitanga significantly differed from Esteio and Pérola, and the former two genetic materials showed lower mean values of yield, corroborating the results found by Santos et al. (2013).

Regarding the cultivation systems, plant height showed significant difference, and the intercropping led to lower mean value of this characteristic. On the other hand, monocropping led to highest mean value of plant height (Table 3).

Significant difference was also observed for 100-grain weight, and the monocropping system showed the highest mean value of this characteristic (Table 3). The monocropping system promoted higher biomass accumulation in the grains due to the lower competition between plants. Ferreira et al. (2014), working with intercropping of common bean and castor bean, also found significant difference for 100-grain weight, and the monocropping system showed the highest mean value.

For grain yield, significant difference occurred between both systems, and the intercropping led to lower mean value of this characteristic (Table 3). However, the difference of yield between the monocropping and intercropping systems was 17.32%, which is lower than those found by Costa & Silva (2008) and Ferreira et al. (2014), who observed reductions of 50 to 80% in common bean yield when cultivated in intercropping system.

This shows the potential of the castor bean hybrids Tamar and Ag Ima for utilization in intercropping systems with the common bean crop because, despite the average reduction of 463.66 kg ha$^{-1}$ in common bean yield, there was an increment of 536.32 kg ha$^{-1}$ in the yield of the hybrids, which represents a mean increment of R$ 979.79 per ha in the income of the producer, based on the current market values.

Among the agronomic characteristics evaluated in castor bean hybrid cultivars, only stem diameter was influenced by the individual factor castor bean hybrids. On the other hand, the individual factor common bean cultivars had no influence on the agronomic characteristics of castor bean crop in intercropping system. The interaction of common bean cultivars × castor bean hybrids in the intercropping system had no influence on the evaluated characteristics of the castor bean. In monocropping system, significant difference occurred

Table 1. Plant height (cm) of common bean intercropped with castor bean hybrids for the interaction of common bean cultivars × castor bean hybrids

| Castor bean hybrids | Common bean cultivars | | | |
|---|---|---|---|---|
| | Esteio | Pitanga | Pérola | Realce |
| Tamar | 84.87 Aa | 70.93 Ab | 61.50 Ac | 43.50 Ad |
| Ag Ima | 72.23 Ba | 58.06 Bb | 59.73 Ac | 47.73 Ad |
| Means | 78.55 | 64.49 | 60.62 | 45.62 |

Means followed by the same letter, uppercase in the column and lowercase in the row, do not differ statistically by Scott-Knott test at 0.05 probability level

Table 2. 100-grain weight (100GW) and yield (Y) of common bean cultivars in monocropping (additional treatments)

| Common bean cultivars | 100GW (g) | Y (kg ha$^{-1}$) |
|---|---|---|
| Esteio | 21.40 c | 3,189.33 a |
| Pitanga | 19.02 d | 2,420.00 b |
| Pérola | 24.57 b | 3,025.33 a |
| Realce | 27.94 a | 2,068.67 b |
| Mean | 23.23 | 2,675.83 |

Means followed by the same lowercase letter in the column do not differ statistically by Scott-Knott test at 0.05 probability level

Table 3. Plant height (PH), 100-grain weight (100GW) and yield (Y) of common bean cultivars in monocropping and intercropping systems

| Cultivation system | PH (cm) | 100GW (g) | Y (kg ha$^{-1}$) |
|---|---|---|---|
| Monocropping | 78.87 a | 23.23 a | 2,675.83 a |
| Intercropping | 62.32 b | 22.12 b | 2,212.17 b |
| Mean | 70.59 | 22.67 | 2,444.00 |

Means followed by the same lowercase letter in the column do not differ statistically by F test at 0.05 probability level

for stem diameter and 100-grain weight between the tested castor bean hybrids, while for the interaction of intercropping × monocropping systems there was significant difference in the final plant stand, plant height and number of racemes per plant between both castor bean hybrids.

In monocropping, the hybrid castor bean hybrids showed significant difference for stem diameter, and Ag Ima exhibited the highest mean value (21.12 mm), followed by the cultivar Tamar (16.74 mm). Lima et al. (2014) found similar values of stem diameter in the castor bean cv. BRS Energia, which is short (on average, 1.06 m). Also in monocropping, 100-grain weight significantly differed between the castor bean hybrids, and Ag Ima had the highest value (30.14 g), followed by Tamar (28.09 g). These values are close to those found by Nobre et al. (2014), evaluating the castor bean cultivar BRS Energia (29.80 g), which has grains with morphological characteristics similar to those of the cultivars evaluated in the present study.

Significant difference was found between the cultivation systems for the final plant stand, plant height and number of racemes per plant (Table 4).

Plant height was significantly different between both cultivation systems, but this difference was minimal, evidencing uniformity in the heights of the castor bean hybrids Tamar and Ag Ima 110204 in both cultivation systems (Table 4).

Although the same quantity of seeds was planted per linear meter in both systems (2 seeds $m^{-1}$), the lowest mean value for final plant stand in the intercropping is due to the competition with common bean in the beginning of the cycle, when common bean seedlings emerge from the soil first and have a faster vegetative growth, compared with castor bean, which may have caused the death of some plants by the shading.

For the number of racemes per plant and final plant stand, Ferreira et al. (2014), working with intercropping of common bean and castor bean, found higher values for these characteristics in the castor bean cultivars BRS Energia and BRS Paraguaçu, but no significant difference between the systems.

The area equivalence index (AEI) showed production advantage in the combination between common bean and castor bean hybrids in the intercropping system, compared with the monocropping, for all factors evaluated, except, the combination between the common bean Pitanga and castor bean hybrids (Table 5). The combinations with advantage obtained AEI ranging from 1.07 to 1.37. Hence, it can be claimed that the common bean/Tamar hybrid and common bean/Ag Ima hybrid intercropping systems are 3 and 10% more efficient in comparison to the monocropping, respectively. In addition, it can be said that the mean AEI values of 1.03 and 1.10 indicate that 0.03 and 0.10 additional hectares of monocropping of the investigated species must be incorporated, compared with the intercropped area, to obtain yields identical to those of the monocropping (Vieira et al., 2006).

Table 4. Mean values for final plant stand (FPS), plant height (PH) and number of racemes per plant (NRP) for hybrid cultivars of castor bean in monocropping and intercropping

| Cultivation system | FPS | PH (cm) | NRP |
|---|---|---|---|
| Monocropping | 19.50 a | 1.01 b | 5.96 a |
| Intercropping | 19.10 b | 1.02 a | 5.73 b |
| Mean | 20.30 | 1.02 | 5.85 |

Means followed by the same lowercase letter in the column do not differ statistically by F test at 0.05 probability level

Table 5. Relationship between grain yield of common bean cultivars in intercropping and monocropping (CMBi/CMBm), relationship between grain yield of castor bean hybrids in intercropping and monocropping (CTBi/CTBm) and area equivalence index (AEI)

| Common bean cultivars | Cultivar Tamar | | | Cultivar Ag Ima | | |
|---|---|---|---|---|---|---|
| | CMBi/CMBm | CTBi/CTBm | AEI | CMBi/CMBm | CTBi/CTBm | AEI |
| Esteio | 0.80 | 0.27 | 1.07 | 0.78 | 0.34 | 1.12 |
| Pitanga | 0.33 | 0.48 | 0.81 | 0.31 | 0.30 | 0.61 |
| Pérola | 0.85 | 0.30 | 1.15 | 1.05 | 0.32 | 1.37 |
| Realce | 0.87 | 0.22 | 1.09 | 0.98 | 0.32 | 1.31 |
| Mean | 0.71 | 0.32 | 1.03 | 0.78 | 0.32 | 1.10 |

The results obtained for AEI are consistent with those of other studies, in which medium to tall castor bean plants, intercropped with other species were more efficient than the monocropping (Oliveira Filho et al., 2016, Teixeira et al., 2012). In addition, the superiority of the intercropping of common bean cultivars with short castor bean hybrids was confirmed compared to the monocropping, for most common bean cultivars evaluated, except Pitanga.

## Conclusions

1. Intercropping of the common bean cultivars Esteio, Realce and Pérola with the castor bean hybrids Tamar and Ag Ima was more efficient than the monocropping, unlike the results of the association between the common bean cultivar Pitanga and the castor bean hybrids tested.

2. The common bean cultivar Pérola adapted best to the intercropping with the castor bean hybrids.

3. Common bean height is influenced by the intercropping with castor bean hybrids, but no agronomic characteristic of the hybrids is influenced by the common bean cultivars.

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