# Selection of common bean lines based on yield, grain type, growth habit and disease resistance

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## ABSTRACT

The development of improved common bean (*Phaseolus vulgaris* L.) varieties one should consider not only grain production but also other traits such as grain type, growth habit and disease resistance. Based on these traits, a population of 154 recombinant inbred lines (RIL´s) was developed from the cross between common bean cultivars Rudá and Ouro Negro aiming to establish a permanent population for mapping purposes and also to select promising lines to be evaluated in preliminary tests at EMBRAPA - Arroz e Feijão. Mean yield per plant, seed color and growth habit were determined for the 154 RILs in a randomized complete block design with additional commercial varieties as controls. Resistance of the RILs were also evaluated under controlled conditions for seven races of *Uromyces appendiculatus*, three races of *Colletotrichum lindemuthianum* and four races of *Phaeoisariopsis griseola,* the causative agents for rust, anthracnose, and angular leaf spot, respectively. Ten RILs were selected, two with "carioca" seed type, four with black seeds and four with beige seeds. All selected RILs presented type IIb growth habit and were resistant to the all *U. appendiculatus* and *C. lindemuthianum* races used in this work. RILs numbered 38 and 113 were also resistant to the all P. griseola races. The selected RILs may give rise to common bean varieties with "carioca" type or beige seeds, bearing important disease resistance genes, and also to productive black seeded varieties, resistant to several diseases and with growth habit type IIb.

**KEY WORDS:** Improvement, bean, rust, anthracnose, angular leaf spot.

## INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is an important crop in Brazil, not only economically but also socially. Brazil is the world's largest producer and consumer of common bean. The fact that a large part of the Brazilian population uses this legume as their main source of protein justifies the effort of breeders to create better adapted and higher yielding cultivars. High yields can be achieved with the use of improved cultivars in association with correct and adequate crop management.

To obtain improved cultivars, not only yield should be considered but also grain type, growth habit and disease resistance. Breeding should take into account the growers´ as well as the consumers´ needs (Ramalho and Abreu, 1998). Preference for a certain type of grain varies from region to region. Cultivars with "carioca" type grains are the most widely consumed in Brazil, however, varieties with black, beige and red grains are also consumed by a large portion of the population. In relation to growth habit, the cultivars with erect stands are preferred by the grower because they are easier to manage, harvesting losses are reduced, the quality of the grains is improved and the plant is less susceptible to attack by some types of pathogens. Several pathogens can attack the common bean causing considerable economic losses (Vieira, 1983). The use of resistant cultivars reduces the need for chemicals decreasing the costs of production and imposing less damage to the environment.

The Common Bean Breeding Program of BIOAGRO/UFV aims at developing bean varieties with "carioca-type" grains resistant to the main diseases affecting this crop. To this purpose it uses different progenitors like cultivars Rudá and Ouro Negro. Rudá, originated from CIAT, is a "carioca-type" cultivar, with growth habit IIb (semi-climber), high yielding but susceptible to several fungal diseases such as rust (Faleiro et al., 1996, 1999a), anthracnose (Lanza et al., 1997) and angular leaf spot (Nietsche, 1997). Cultivar Ouro

Negro (formerly Honduras 35), has black seeds, growth habit IIIb (prostrated or semi-climber), is highly productive, resistant to rust (Faleiro et al., 1996, 1999a), anthracnose (Lanza et al., 1997), angular leaf spot (Nietsche, 1997; Faleiro et al., 2001b), and besides, it has excellent cooking qualities (Araújo et al., 1991). The BIOAGRO/UFV Program developed a RIL population with 154 lines from a cross between Rudá and Ouro Negro. This permanent bean population can now be used for mapping purposes and also for selection of promising lines to be tested in the preliminary line tests conducted at EMBRAPA - Arroz e Feijão.

This work aimed at selecting and characterizing promising RILs with yield potential similar or higher than those of Rudá and Ouro Negro, with "carioca-type", black or beige grains, with non-prostrated stand, and resistant to rust, anthracnose and angular leaf spot.

## MATERIAL AND METHODS

Evaluation for yield, grain type and growth habit was done in a field assay conducted between April and July 1999 in the UFV Experimental Station at Coimbra, MG. Disease resistance was evaluated under controlled greenhouse and mist chamber conditions.

### Genetic Material

To obtain the RIL population, cultivar Rudá was crossed with Ouro Negro in the greenhouse. Approximately 40 $F_1$ seeds were sown and the color of the flowers was used as a marker to confirm the hybrid condition of the $F_1$ plants. One hundred and sixty $F_2$ seeds were advanced up to $F_7$ by the single seed descent (SSD) method. As suggest by Brim (1966), from each individual three seeds were sown in each generation to ensure that enough seeds would germinate. After emergence only one plant was maintained. This procedure was repeated until $F_7$ when a high degree of homozygosity was obtained. Each $F_7$ plant was considered an RIL and the corresponding seeds were multiplied in the greenhouse for the field tests.

### Field tests

*Experimental Design*: A randomized complete block design, with four replications was used and cultivars Rudá, Ouro Negro, Meia Noite and Pérola were used as additional controls. Each experimental plot contained 10 seeds distributed in a 1m row spaced from neighbouring rows by 0.5m. A border surrounding the whole experimental field was also planted. The cultural management was the usual recommended for the common bean. Irrigation was used when necessary.

Traits evaluated were the following: Final stand (FS): Number of total plants present in the plot at harvest; Total grain production (TOTPR): Total weight (g) of the grains present in the plot; Mean production per plant (PRPLA): Ratio between TOTPR and FS; Growth habit (GH): IIb or IIIb; Grain type (GT): Color of the grain - BL: black; CBL: cream with black strips; BG: Beige; CB: cream with brown strips or "carioca"; S: color segregation.

*Variance analyses:* Variance analysis of the PRPLA trait was to verify the existance of significant variability among treatments. The statistical model was as follows:

$$Y_{ij} = m + T_i + B_j + e_{ij},$$

in which:

$Y_{ij}$ = mean production per plant of the $i^{th}$ treatment in the $j^{th}$ block;

m = general mean;

$T_i$ = effect of the $i^{th}$ treatment. (i = 1,2,..., g+c), in which g is the number of RILs (154) and c, the number of controls (4);

$B_j$ = effect of the $j^{th}$ block (j = 1,2,...,r);

$e_{ij}$ = random error, $e_{ij} \sim NID(0, \sigma^2)$.

The treament sum of the squares was partitioned in the sum of the squares of the RIL´s, the sum of the squares of the controls and the sum of the squares of the groups (RIL´s *vs* controls). The effect of the treatments was assumed to be fixed. The variance analyses scheme and the expected mean squares are represented in Table 1.

*Genetic parameters and mean comparisons:* The genetic parameters heritability at the mean level ($h^2$) and environmental variation coefficient (CVe) were estimated through the following expressions:

$$h^2 (\%) = \frac{\phi_g}{\frac{MSg}{r}} 100$$

$$CVe (\%) = \frac{\sqrt{MSe}}{\bar{x}} 100, \text{ in which } \bar{x} = \text{mean of PRPLA}$$

The variance analyses and estimate of the genetic parameters were done with the aid of the statistical package Genes (Cruz, 1997). The minimal significant differences among the average of PRPLA for the treatments were evaluated by the Tukey test at the 5% probability level (Gomes, 1985).

**Evaluation for disease resistance**

The races used in this work were chosen because of the differential reactions of the two progenitors, Ouro Negro and Rudá, towards them. The original isolates were collected in the state of Minas Gerais, Brazil, and classified into specific races by the Bean Breeding Program of BIOAGRO/UFV. For each race one seed from each RIL and from each genitor were sown in the greenhouse. The seeds were pre-germinated in germitex paper at 36 °C. After emergence of the radicule the plantules were transferred to plastic trays containing a mixture of soil and dry manure in the 4:1 proportion plus 5kg of fertilizer (4-14-8) per cubic meter of substrate. The plants were maintained in the greenhouse after inoculation of the pathogen.

*Evaluation for rust resistance*

The following races of *Uromyces appendiculatus* were used for the evaluation of the RIL´s: 32 (32132212), 45 (33121211), 46 (33122211), 47 (33131113), 49 (33132212), 52 (33222232) and 56 (33232232) (Faleiro et al., 1999b, 1997). The monosporic cultures were kept at 5 °C and 50% relative humidity. They were multiplied in a susceptible host (US Pinto 111) right before the inoculation to preserve the viability of the uredospores. The primary leaves with approximately 2/3 of their full development were inoculated 10 days after sowing. The uredospores were suspended in distilled water containing 0.05% Tween 20 to a final concentration of $2 \times 10^4$/mL, and sprayed on both leaf surfaces with the aid of a De Vilbiss no. 15 atomizer. After inoculation and a quick air drying the plants were kept in a mist chamber (20 ± 1°C and >95% relative humidity) for 48 h under a photoperiod of 12 h. The plants were transferred back to the greenhouse (20 ± 5°C) where they stayed until symptom evalution. Average pustule size (APS) was estimated when 50% of the pustules had sporulated (latent period). For the symptom evaluation, six degrees were considered: 1- absence of pustules, 2- necrotic spots with no sporulation, 3- sporulating pustules with diameters < 300mm, 4- sporulating pustules with diameters ranging from 300 to 499mm, 5- sporulating pustules with diameters ranging from 500 to 800mm, 6- sporulating pustules with diameters > 800mm. The type of reaction was determined by visual analysis and with the aid of a diagram proposed by Castaño (1985). Plants with pustules predominantly > 300mm were considered susceptible.

*Evaluation for anthracnose resistance*

*Colletotrichum lindemuthianum* races 73, 81 and 89 were used to evaluate the RILs. The original monosporic cultures were provided by EMBRAPA - Arroz e Feijão. Inoculum preparation and inoculation were according to Pio-Ribeiro and Chaves (1975). Conidia were obtained by inoculating each race in test tubes containing green bean pods partially immersed in agar-water medium followed by incubation for 10 days at 23 °C. Both surfaces of primary leaves of 10-day-old plants were inoculated with a conidia suspension ($1.2 \times 10^6$ conidia/mL with

**Table 1.** Variance analyses scheme and the expected mean squares for the randomized complete block design with additional controls.

| Source of variation | DF | MS | E (M.S.) [1/] | F |
|---|---|---|---|---|
| Blocks | r-1 | | | |
| Treatments (Tr) | (g+t)-1 | MStr | $\sigma^2 + r\phi_{tr}$ | MStr/MSe |
| Lines (G) | g-1 | MSg | $\sigma^2 + r\phi_{g}$ | MSg/MSe |
| Controls (Re) | t-1 | MSre | $\sigma^2 + r\phi_{re}$ | MSre/MSe |
| G *vs* Re | 1 | MSgr | | MSgr/MSe |
| Error | (r-1)(g+t-1) | MSe | $\sigma^2$ | |

[1/] $\phi_{tr}, \phi_{g}, \phi_{te}$ = Quadratic components associated with the effects of the treatment, lines and controls, respectively, in which:

$$\phi_{tr} = \frac{\sum_{i=1}^{g+t} Tr_i^2}{g+t-1}, \quad \phi_{g} = \frac{\sum_{i=1}^{g} G_i^2}{g-1}, \quad \phi_{re} = \frac{\sum_{i=g+1}^{g+t} Re_i^2}{t-1}$$

the aid of a De Vilbiss no. 15 atomizer. After inoculation and a quick air drying the plants were kept in a mist chamber for five days (20 ± 1°C and >95% relative humidity), under a photoperiod of 12 h. The plants were then transferred back to the greenhouse (20 ± 5°C) , where they stayed until symptom evalution. Evaluation was done 10 days after inoculation and the symptoms were expressed according to a 1 to 9 scale described by Pastor-Corrales (1992). Plants with grades greater than 3 were considered susceptible.

*Evaluation for angular leaf spot resistance*

*Phaeoisariopsis griseola* races 31.23, 31.55, 63.31 e 63.19 (Nietsche, 1997) were used to evaluate the RIL´s. A suspension of conidia and micelium fragments from each race was inoculated in medium containing vegetable juice V8 (Campbell Soup Co., USA). The medium plates were then incubated for 12 days at 24 °C. The conidia were suspended in water to a final concentration of 2 x $10^4$ conidia/mL and inoculated on both surface leaves of the plants 15 days after sowing, with the aid of a De Vilbiss no. 15 atomizer. After inoculation and a quick air drying the plants were transferred to a mist chamber (20 ± 1°C and >95% relative humidity) where they were kept for 48h under a photoperiod of 12h. The plants were then transferred back to the greenhouse (20 ± 5°C) where they were evaluated 15 days after inoculation according to a nine-degree scale (Van Schoonhoven and Pastor-Corrales, 1992). Plants with grades greater than 3 were considered susceptible.

**Selection of the most resistant lines**

Selection of lines with the highest resistance grades was based on the index proposed by Williams (1962), which makes a linear combination of the mean phenotypic values with their respective economic values. The phenotypic value was the mean symptom grade of each RIL to each pathogen race. An economical weight of 1 was assigned to each symptom degree. The resulting index was divided by the number of races used. In this manner a susceptibility index ($S_i$) was obtained for each line, and it was calculated by the following formula:

$$S_i = \frac{\sum_{j}^{n} g_{ij}}{n_i}$$

in which:

$S_i$ = Susceptibility index of the $i^{th}$ RIL (i = 1, 2, ..., 154);

$g_{ij}$ = Reaction degree of the $i^{th}$ RIL to the $j^{th}$ race. Seven races of *U. appendiculatus*, three races of *C. lindemuthianum* and four races of *P. griseola* were used in the experiments;

$n_i$ = Number of races used to evaluate the resistance of the $i^{th}$ RIL.

Through the formula one can observe that the higher the value for $S_i$ the more susceptible the RIL is.

## RESULTS AND DISCUSSION

The results of the variance analyses for the character PRPLA, the mean squares, general mean, variation coefficient, and heritability are depicted in Table 2. PRPLA was not affected by the final plant stand.

The F statistic (F = MStr/Qme) indicated that there were significant differences (P<0.01) among the treatments for PRPLA. The analysis of the partition of the sum of the squares of the treatments showed that there were significant differences among the RIL´s but not among the controls. This genetic variability allows for selection among the RIL´s. The F statistic also indicated that the average performance of the RIL´s in relation to the controls was not significantly different.

As for the precision of the experiment, the variation

**Table 2.** Variance analyses, general mean and heritability estimates at the level of the mean and of the environmental variation coefficients of the characteristic PRPLA evaluated in 154 bean RILs and four references in Coimbra, MG.

| Source of Variation | DF | MS | F |
|---|---|---|---|
| Blocks | 3 | 45.251 | |
| Treatments (Tr) | 157 | 27.092 [1/] | 1.606 |
| Lines (G) | 153 | 27.330 [1/] | 1.620 |
| Controls (Re) | 3 | 22.624 [2/] | 1.341 |
| G *vs* Re | 1 | 4.016 [2/] | 0.238 |
| Error | 471 | 16.867 | |
| General mean (g/plant) | 15.32 | | |
| CVe (%) | 26.81 | | |
| $h^2$ (%) | 38.28 | | |

[1/] significant at 1% probability by the F test; [2/] not significant.

coefficient obtained of 26.81% is considered high by the classification of Gomes (1985). However, this value is within the acceptable limit for an experiment in agriculture (Castoldi, 1991). The CV obtained might help to explain the low genotypic determination coefficient or heritability of 38.28% obtained.

The mean test (Table 3) confirmed the similarity between the RIL´s and the controls in relation to PRPLA. The combining abilities and the high yielding potential of the genitors Ouro Negro and Rudá certainly help to explain these results.

The frequency distributions of the RIL´s in relation to PRPLA, GT, GH, and $S_i$ are shown in Figure 1. PRPLA presented a normal distribution typical of a trait which is inherited in a quantitative manner. The population showed four grain types: black (BL), cream with black strips (CBL), beige (BG) and cream with brown strips or "carioca" (CB). There was segregation for grain type in 10 out of the 154 RIL´s. This type of distribution confirms the complex genetic control over GT in the common bean. On the other hand, GH showed a distribution of 1:1 in the population most probably due to the action of a single gene (Figure 1). In relation to $S_i$, the distribution was typical of a qualitative trait distribution in which a large number of the RIL´s were grouped in the same classes of the progenitors.

An interesting aspect depicted in Figure 1 is that the genitors were not grouped in the most extreme classes for PRPLA and $S_i$. This may be due to environmental effect and/or the action of complementary genes present in both parents (Falconer, 1987). The performances of several of the RIL´s for these two parameters were better than those of Rudá or Ouro Negro.

The classification of the RIL´s based on $S_i$, GT, GH is shown in Table 4. The RIL´s with $S_i$ smaller than that of Ouro Negro were divided into three groups based on GT: black seeded, "carioca" and beige. The RILs with growth habit type IIIb, with cream grains with black strips or segregating for GT, with PRPLA smaller than Ouro Negro were discarded. According to these criteria, 10 RIL´s were semected and characterized in a greater depth for resistance to rust, anthracnose, and angular leaf spot (Table 5).

RILs 38´ and 113 were resistant to all 14 races of the three pathogens tested in this study. Their $S_i$ values were 2.071 and 2.143, respectively. This means that their resistance was not complete, they were not

**Table 3.** Means for PRPLA (g) evaluated in 154 bean RILs and four references in Coimbra, MG [1/].

| Trt. [2/] | Mean | Trt. | Mean | Trt. | Mean | Trt. | Mean | Trt. | Mean |
|---|---|---|---|---|---|---|---|---|---|
| 78 | 24.76a | **T1** | **17.45abc** | 114 | 15.84abc | 83 | 14.50abc | 145 | 12.99abc |
| 52 | 23.12ab | 53 | 17.42abc | 54 | 15.83abc | **T2** | **14.50abc** | 12 | 12.94abc |
| 82 | 21.72abc | 115 | 17.40abc | 150 | 15.77abc | 101 | 14.47abc | 70 | 12.69abc |
| 86 | 20.36abc | 42 | 17.31abc | 41 | 15.74abc | 140 | 14.43abc | 77 | 12.68abc |
| 125 | 19.54abc | 147 | 17.23abc | 93 | 15.73abc | 4 | 14.39abc | 116 | 12.58abc |
| 87 | 19.41abc | 56 | 17.21abc | 67 | 15.65abc | 128 | 14.33abc | 17 | 12.56abc |
| 75 | 19.40abc | 15 | 17.12abc | 98 | 15.59abc | 124 | 14.28abc | 20 | 12.54abc |
| 5 | 19.30abc | 132 | 17.04abc | 113 | 15.59abc | 37 | 14.27abc | 137 | 12.52abc |
| 129 | 19.29abc | 131 | 17.01abc | 138 | 15.44abc | 149 | 13.92abc | 59 | 12.49abc |
| 110 | 19.16abc | 79 | 16.91abc | 105 | 15.38abc | 100 | 13.83abc | 39 | 12.47abc |
| 62 | 19.00abc | 60 | 16.87abc | 23 | 15.31abc | 134 | 13.79abc | 24 | 12.36abc |
| 104 | 18.99abc | 11 | 16.86abc | 31 | 15.28abc | 130 | 13.78abc | 97 | 12.22abc |
| 81 | 18.96abc | 117 | 16.81abc | 58 | 15.20abc | 148 | 13.78abc | 84 | 12.20abc |
| 16 | 18.91abc | 154 | 16.76abc | 88 | 15.20abc | 112 | 13.68abc | 50 | 12.17abc |
| 57 | 18.91abc | 21 | 16.75abc | 152 | 15.18abc | 9 | 13.64abc | 80 | 12.15abc |
| 38 | 18.83abc | 92 | 16.75abc | 35 | 15.17abc | 29 | 13.59abc | 85 | 11.94 bc |
| 25 | 18.66abc | 107 | 16.75abc | 40 | 15.15abc | 151 | 13.59abc | 8 | 11.74 bc |
| 45 | 18.34abc | 48 | 16.64abc | 89 | 15.06abc | 143 | 13.58abc | 26 | 11.52 bc |
| 69 | 18.34abc | 141 | 16.64abc | 55 | 15.04abc | 46 | 13.56abc | 139 | 11.52 bc |
| 36 | 18.32abc | 74 | 16.53abc | 90 | 15.03abc | 119 | 13.55abc | 126 | 11.47 bc |
| 102 | 18.24abc | 1 | 16.51abc | 122 | 15.03abc | 106 | 13.51abc | 133 | 11.34 bc |
| **T4** | **18.15abc** | 33 | 16.42abc | 49 | 14.99abc | 121 | 13.40abc | 32 | 11.29 bc |
| 10 | 18.12abc | 64 | 16.36abc | 7 | 14.97abc | 34 | 13.38abc | 51 | 11.27 bc |
| 66 | 18.10abc | 43 | 16.23abc | 27 | 14.74abc | 91 | 13.36abc | 65 | 11.19 bc |
| 120 | 18.08abc | 127 | 16.21abc | 22 | 14.68abc | 103 | 13.33abc | 99 | 11.16 bc |
| 71 | 18.07abc | 136 | 16.14abc | 73 | 14.63abc | 146 | 13.32abc | 3 | 11.11 bc |
| 144 | 18.05abc | 118 | 16.09abc | 28 | 14.57abc | 6 | 13.31abc | 61 | 11.04 bc |
| 123 | 18.01abc | 96 | 15.91abc | 14 | 14.54abc | 76 | 13.29abc | 109 | 10.85 bc |
| 44 | 17.96abc | 142 | 15.89abc | 30 | 14.54abc | 153 | 13.25abc | 111 | 10.04 c |
| 68 | 17.92abc | 135 | 15.87abc | 47 | 14.53abc | 94 | 13.19abc | 63 | 9.63 c |
| 95 | 17.68abc | 18 | 15.84abc | 108 | 14.52abc | 19 | 13.16abc | | |
| 2 | 17,66abc | 72 | 15.84abc | 13 | 14.51abc | **T3** | **13.15abc** | | |

[1/] The means followed by at least one letter in common do not differ among them at a 5% probability level by the Tukey test; [2/] Trt. - Treatment: 1-154: RILs; In boldface T1: Rudá; T2: Ouro Negro; T3: Meia Noite and T4: Pérola.

immune to all races tested. The slight difference between the two RIL´s might reflect the differential action of minor effect genes which complement the resistance conferred by the major genes (Hammond-Kosack and Jones, 1996).

The selected RIL´s may give rise to common bean varieties with "carioca" type or beige seeds, bearing important disease resistance genes, and also to productive black seeded varieties, resistant to several diseases and with growth habit type IIb. They are now being tested at EMBRAPA - Arroz e Feijão in preliminary line assays.

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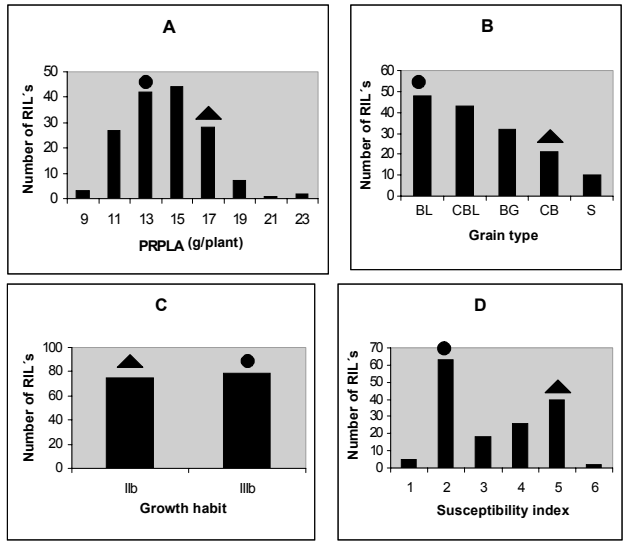


**Figure 1.** Frequency distributions of 154 bean RILs for PRPLA (A), grain type (BL: black; CBL: cream with black strips; BG: beige; CB: cream with brown strips or "carioca"; S: segregating for GT) (B) and GH (C). Class of the progenitor Ouro Negro (●); class of the progenitor Rudá (▲).

**Table 4.** Susceptibility indexes ($S_i$) for rust, anthracnose and angular leaf spot, grain type (GT) and growth habit (GH) for the 154 bean RILs and two controls.

| Trt. [1/] | $S_i^{GT, GH}$ | Trt. | $S_i^{GT, GH}$ | Trt. | $S_i^{GT, GH}$ | Trt. | $S_i^{GT, GH}$ | Trt. | $S_i^{GT, GH}$ |
|---|---|---|---|---|---|---|---|---|---|
| 119 | $1.786^{BG,2}$ | 136 | $2.357^{CBL,3}$ | 90 | $2.786^{CBL,2}$ | 70 | $4.321^{BL,3}$ | 107 | $5.357^{BL,3}$ |
| 33 | $1.846^{CBL,2}$ | 48 | $2.429^{BG,2}$ | 127 | $2.786^{CBL,2}$ | 25 | $4.357^{BL,3}$ | 144 | $5.357^{CB,2}$ |
| 20 | $1.857^{BL,3}$ | 1 | $2.462^{CB,2}$ | 14 | $2.885^{CB,3}$ | 85 | $4.417^{S,3}$ | 152 | $5.385^{BG,2}$ |
| 112 | $1.929^{CB,2}$ | 126 | $2.462^{BL,2}$ | 66 | $2.929^{CBL,2}$ | 47 | $4.464^{CB,3}$ | 49 | $5.393^{S,2}$ |
| 121 | $1.929^{CBL,2}$ | 68 | $2.500^{BG,3}$ | **T2** | $\mathbf{2.929^{BL,3}}$ | 30 | $4.500^{CBL,2}$ | 154 | $5.429^{CB,3}$ |
| 36 | $2.000^{BG,3}$ | 122 | $2.500^{CBL,2}$ | 151 | $3.071^{BL,2}$ | 32 | $4.500^{CBL,3}$ | 28 | $5.500^{BG,3}$ |
| 81 | $2.000^{S,3}$ | 23 | $2.571^{CBL,3}$ | 129 | $3.143^{BL,2}$ | 62 | $4.500^{BL,3}$ | 53 | $5.500^{BG,2}$ |
| 99 | $2.000^{CB,2}$ | 58 | $2.571^{CB,2}$ | 59 | $3.214^{CB,2}$ | 71 | $4.571^{CBL,3}$ | 50 | $5.536^{BG,2}$ |
| 3 | $2.071^{CB,2}$ | 76 | $2.571^{CBL,2}$ | 138 | $3.214^{BL,2}$ | 87 | $4.571^{CBL,3}$ | 5 | $5.571^{CBL,3}$ |
| 26 | $2.071^{CBL,3}$ | 77 | $2.571^{CBL,3}$ | 140 | $3.231^{CBL,2}$ | 97 | $4.607^{S,3}$ | 7 | $5.571^{BL,3}$ |
| 38 | $2.071^{BL,2}$ | 78 | $2.571^{BL,2}$ | 19 | $3.357^{BL,2}$ | 133 | $4.769^{BL,3}$ | 11 | $5.571^{CBL,3}$ |
| 4 | $2.143^{CBL,3}$ | 86 | $2.571^{BL,3}$ | 18 | $3.393^{BG,2}$ | 29 | $4.786^{BL,2}$ | 72 | $5.571^{S,3}$ |
| 63 | $2.143^{CBL,3}$ | 96 | $2.571^{BL,3}$ | 109 | $3.464^{BL,3}$ | 89 | $4.786^{CBL,3}$ | 142 | $5.571^{S,2}$ |
| 80 | $2.143^{BL,2}$ | 131 | $2.571^{BG,2}$ | 43 | $3.500^{BL,2}$ | 146 | $4.786^{BL,2}$ | 116 | $5.607^{BL,2}$ |
| 98 | $2.143^{CBL,2}$ | 132 | $2.571^{CBL,3}$ | 139 | $3.500^{BL,2}$ | 34 | $4.923^{CBL,2}$ | 93 | $5.643^{CB,3}$ |
| 101 | $2.143^{BG,2}$ | 134 | $2.571^{BL,3}$ | 64 | $3.536^{BL,2}$ | 143 | $4.923^{CB,3}$ | 123 | $5.643^{BG,3}$ |
| 110 | $2.143^{BG,2}$ | 44 | $2.615^{BG,3}$ | 145 | $3.643^{CBL,3}$ | 10 | $4.929^{CBL,2}$ | 42 | $5.692^{BL,3}$ |
| 113 | $2.143^{BG,2}$ | 130 | $2.615^{CBL,2}$ | 108 | $3.786^{CB,3}$ | 39 | $5.000^{BL,3}$ | 83 | $5.708^{CBL,2}$ |
| 95 | $2.167^{BL,3}$ | 103 | $2.636^{CBL,2}$ | 117 | $3.786^{BL,2}$ | 52 | $5,000^{BL,3}$ | 41 | $5.769^{CBL,2}$ |
| 125 | $2.167^{BG,3}$ | 88 | $2.643^{S,2}$ | 74 | $3.808^{BL,3}$ | 61 | $5.000^{CBL,3}$ | 153 | $5.769^{BG,2}$ |
| 22 | $2.214^{CBL,3}$ | 6 | $2.714^{S,S}$ | 120 | $3.846^{CB,2}$ | 45 | $5.071^{BG,3}$ | 17 | $5.786^{BL,2}$ |
| 51 | $2.214^{BL,3}$ | 12 | $2.714^{BG,2}$ | 27 | $3.857^{BL,3}$ | 69 | $5.071^{BL,2}$ | 135 | $5.786^{BG,2}$ |
| 104 | $2.214^{CB,2}$ | 15 | $2.714^{CB,2}$ | 75 | $3.923^{CBL,2}$ | 84 | $5.077^{BL,3}$ | 114 | $5.857^{BL,3}$ |
| 111 | $2.214^{CBL,2}$ | 55 | $2.714^{BL,2}$ | 147 | $4.000^{CBL,3}$ | **T1** | $\mathbf{5.107^{CB,2}}$ | 148 | $5.857^{BL,2}$ |
| 8 | $2.231^{CB,2}$ | 56 | $2.714^{S,2}$ | 149 | $4.000^{BG,2}$ | 2 | $5.143^{BG,3}$ | 150 | $5.857^{BL,3}$ |
| 91 | $2.250^{BG,2}$ | 65 | $2.714^{BG,2}$ | 35 | $4.071^{BL,3}$ | 13 | $5.143^{CBL,3}$ | 92 | $5.964^{BL,3}$ |
| 73 | $2.286^{BG,3}$ | 94 | $2.714^{BG,3}$ | 37 | $4.071^{CBL,3}$ | 16 | $5.143^{CB,3}$ | 21 | $6.385^{CBL,3}$ |
| 79 | $2.286^{S,2}$ | 106 | $2.714^{BG,3}$ | 60 | $4.107^{CBL,3}$ | 102 | $5.250^{BG,3}$ | 82 | $6.385^{CBL,3}$ |
| 118 | $2.286^{CBL,2}$ | 115 | $2.714^{BL,3}$ | 31 | $4.214^{CB,3}$ | 9 | $5.308^{CB,2}$ | | |
| 124 | $2.286^{BL,3}$ | 137 | $2.714^{BG,3}$ | 67 | $4.214^{BG,3}$ | 105 | $5.308^{BL,3}$ | | |
| 128 | $2.286^{BL,2}$ | 46 | $2.769^{CBL,3}$ | 40 | $4.231^{BG,2}$ | 141 | $5.321^{BL,2}$ | | |
| 54 | $2.357^{CBL,3}$ | 57 | $2.786^{BL,2}$ | 24 | $4.286^{CBL,2}$ | 100 | $5.357^{CB,2}$ | | |

[1/] Trt. - Treatment: 1-154: RILs; In boldface T1: Rudá; T2: Ouro Negro; GT: Grain type (BL: black; CBL: cream with black strips; BG: beige; CB: cream with brown strips or "carioca"; S: segregating) and GH: Growth habit (2: IIb; 3: IIIb).

**Table 5.** Resistance of 10 selected RILs and the genitors Rudá (T1) and Ouro Negro (T2) to different races of *Uromyces appendiculatus*, *Colletotrichum lindemuthianum* and *Phaeoisariopsis griseola* [1/, 2/].

| Trt. | GT | PRPLA | Races | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | "carioca" | 16.51 | R | R | R | R | R | S | R | R | R | R | R | S | - | R |
| 58 | "carioca" | 15.20 | R | R | R | R | R | R | R | R | R | R | S | R | R | S |
| 78 | BL | 24.76 | R | R | R | R | R | R | R | R | R | R | R | S | S | R |
| 57 | BL | 18.91 | R | R | R | R | R | R | R | R | R | R | R | S | S | S |
| 38 | BL | 18.83 | R | R | R | R | R | R | R | R | R | R | R | R | R | R |
| 55 | BL | 15.04 | R | R | R | R | R | R | R | R | R | R | R | S | S | R |
| 110 | BG | 19.16 | R | R | R | R | R | R | R | R | R | R | S | R | R | R |
| 131 | BG | 17.01 | R | R | R | R | R | R | R | R | R | R | S | R | R | S |
| 48 | BG | 16.64 | R | R | R | R | R | R | R | R | R | R | S | R | R | S |
| 113 | BG | 15.59 | R | R | R | R | R | R | R | R | R | R | R | R | R | R |
| **T2** | **BL** | **14.50** | **R** | **R** | **R** | **R** | **R** | **R** | **R** | **R** | **R** | **R** | **S** | **R** | **R** | **S** |
| **T1** | **"carioca"** | **17.45** | **S** | **S** | **S** | **S** | **S** | **S** | **S** | **S** | **S** | **S** | **R** | **S** | **S** | **R** |

[1/] 1 to 7: *U. appendiculatus* races 56, 52, 49, 45, 46, 47, and 32, respectively; 8 to 10: *C. lindemuthianum* races 73, 81, and 89, respectively and 11 to 14: *P. griseola* races 31.23, 31.55, 63.31, 63.19, respectively; [2/] R: resistant; S: susceptible and (-): not evaluated. All selected RILs presented growth habit type IIb.


## RESUMO

**Seleção de linhagens de feijoeiro-comum com base na produção, tipo de grão, hábito de crescimento e resistência a doenças**

Para a obtenção de cultivares melhoradas de feijão, além da produção de grãos, outros caracteres como tipo de grão, hábito de crescimentÿ e resistência a doenças devem ser considerados. Com base nestas características contrastantes e complementares, foi desenvolvida um população de 154 linhagens endogâmicas recombinantes (RILs) a partir do cruzamento inicial entre as cultivares Rudá e Ouro Negro, objetivando o desenvolvimento de uma população permanente para o mapeamento genético intra-específico do feijoeiro-comum e a obtenção de linhagens promissoras a serem avaliadas no ensaio preliminar de linhagens (EPL) conduzidos pela EMBRAPA - Arroz e Feijão. Foram avaliados a produção média por planta (PRPLA), a cor da semente e o hábito de crescimento das 154 RILs com base em um ensaio de campo em blocos casualizados utilizando-se variedades comerciais como testemunhas. Foi também avaliada a resistência das RILs a sete raças fisiológicas de *Uromyces appendiculatus*, três raças de *Colletotrichum lindemuthianum* e quatro raças de *Phaeoisariopsis griseola* em condições controladas. Foram selecionadas dez RILs, sendo duas com grãos tipo carioca, quatro com grãos pretos e quatro com grãos bege. As RILs selecionadas apresentaram hábito de crescimento IIb e foram resistentes a todas raças fisiológicas de *U. appendiculatus* e *C. lindemuthianum* utilizadas no estudo. As RILs 38 e 113 foram resistentes a todas as raças, inclusive as de *P. griseola*. As RILs selecionadas podem dar origem a cultivares de feijão com grãos tipo carioca e bege, contendo importantes genes de resistência e também a cultivares produtivas, com grão preto, resistentes a doenças e com hábito de crescimento não prostrado (IIb).


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