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'IAC Milênio' – Common bean cultivar with high grain quality

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Abstract – *The Instituto Agronômico de Campinas – IAC registered the carioca type common bean cultivar IAC Milênio. The cultivar has a mean yield of 2831 kg ha^{-1}, high grain quality with tolerance to darkening, and resistance to Fusarium oxysporum and physiological races 81, 89, and 95 of the anthracnose pathogen* (Colletotrichum lindemuthianum).

Key words: Phaseolus vulgaris *L., common bean, yield, genetic breeding.*

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is one of the most important constituents of the Brazilian diet as it is an excellent source of protein. Brazil has established itself as the world's largest producer of common bean, with total production of 3.77 million tons on 3.91 million hectares for the 2011/2012 crop season (CONAB 2012). In addition to its importance in the Brazilian diet, it is an agricultural product of great economic and social importance as it is grown in large areas and due to the laborers employed during the crop cycle (Carneiro et al. 2012, Pereira et al. 2012). In consideration of this importance, the common bean genetic breeding program of IAC, carried out in the Centro de Análise e Pesquisa Tecnológica do Agronegócio dos Grãos e Fibras of the Instituto Agronômico de Campinas (IAC), Campinas, São Paulo, has made high-yielding common bean cultivars of the carioca grain type available to the productive sector (Carbonell et al. 2008, Carbonell et al 2010, Chiorato et al. 2010).

The main goal of the common bean genetic breeding program of IAC is to develop common bean cultivars that have high grain quality, especially for the characteristics of size and appearance, as well as to develop cultivars resistant to at least one of the main diseases that attack the crop, within the context of anthracnose as the main disease worked with in plant selection; genotypes susceptible to this pathogen are not released on the market.

Selection activities aim at genotypes that have at least 60% of the grains in sieve size 13 (13/64 x 3/4 inch), a clear milky type color background without marbling, and tolerance to early darkening of the grain after harvest. Selections for anthracnose are made in early F_2 and F_3 generations, and the selection method applied is genealogical.

The aim of the present study was to describe the characteristics of the new common bean cultivar IAC Milênio developed by the common bean genetic breeding program in the Instituto Agronômico – IAC.

MATERIAL AND METHODS

The cultivar IAC Milênio is derived from the simple cross made in 2005 between the cultivar BRSMG Majestoso and the line Gen 96A98-15-3-52-1, which is a sibling line of the

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cultivar IAC Alvorada evaluated in the VCU trials (Value for Cultivation and Use – crop registration trials) of 2006 and 2007. The line Gen 96A98-15-3-52-1 was used in the crosses since it has high grain quality and high resistance to the anthracnose pathogen. It was not recommended as a cultivar because it exhibited low productive potential. The cultivar BRSMG Majestoso was used in the cross since it has high yield and resistance to Fusarium wilt. The crosses were carried out in a greenhouse with controlled temperature and humidity. Already in 2005, 27 F_1 seeds were obtained, derived from seven crosses made (seven pods were obtained).

In 2006, at the time of planting the winter crop, the F_1 seeds were multiplied in a greenhouse to obtain the F_2 generation. Once the F_2 generation was obtained, the cross was designated as C4-7.

In the rainy season of 2006, the seeds were divided up into two groups, in which half the seeds were sown under field conditions in four-meter rows, without replications, in the municipality of Monte Alegre do Sul, SP, Brazil, for selection of plants by the genealogical method to obtain the $F_{2:3}$ generation. The other half of the seeds were sown in plastic trays filled with vermiculite in which seedlings seven days after emergence were sprayed with a suspension of the mixture of conidia of the anthracnose (*Colletotrichum lindemuthianum*) pathogen of the physiological races 81, 89, and 95. Seedlings that proved to be resistant to the pathogen were transplanted in pots in the greenhouse to obtain the $F_{2:3}$ generation.

In 2007, two groups of selection were obtained where individual plants selected in the municipality of Monte Alegre do Sul in the dry season of 2007 were inoculated for the physiological races 81, 89, and 95 of anthracnose. Seedlings that proved to be resistant to the pathogen were transplanted in pots in a greenhouse to obtain seeds of the $F_{2:4}$ generation, with a total of seven plants being selected for this cross. Seeds of the $F_{2:3}$ generation obtained from plants resistant to anthracnose in regard to the first inoculation were sown in Monte Alegre do Sul for selection of plants by the genealogical method to obtain the $F_{2:4}$ generation, in which only two plants were selected. With the selections

Table 1. Listing of lines/cultivars, type of grain, and holders of common bean genotypes evaluated in the VCU trials in the 2011-2012 two-year period in the state of São Paulo

Line/Cultivar		Grain Type	Institution
1	IAC Alvorada	Carioca Control	IAC
2	IPR 139	Carioca Control	IAPAR
3	IAC Diplomata	Black Control	IAC
4	IAC Una	Black Control	IAC
5	CNFC 10729	Carioca	EMBRAPA
6	BRSMG Realce	Striped	Embrapa/Epamig/UFLA/UFV
7	CNFC 10762	Carioca	EMBRAPA
8	CNFC 10794	Black	EMBRAPA
9	CHC-01-175	Carioca	EPAGRI
10	CHP-98-66-20	Black	EPAGRI
11	SM1107	Black	FEPAGRO
12	SM1810	Black	FEPAGRO
13	Gen C4-7-8-1-2	Carioca	IAC
14	Gen C2-6-4-1-1	Carioca	IAC
15	Gen C2-6-6-2-1	Carioca	IAC
16	Gen C4-7-2-2-1	Carioca	IAC
17	Gen C4-7-7-2-2	Carioca	IAC
18	Gen C5-3-6-1-1	Carioca	IAC
19	Gen Pr11-2-8-1-1	Black	IAC
20	Gen Pr14-2-10-1-2	Black	IAC
21	Gen Pr14-2-2-1-1	Black	IAC
22	Lp 07-80	Carioca	IAPAR
23	Lp 09-40	Carioca	IAPAR
24	Lp 09-192	Black	IAPAR
25	Lp 08-90	Black	IAPAR
26	BRSMG Madrepérola	Carioca	Embrapa/Epamig/UFLA/UFV
27	MAII – 2	Carioca	UFLA/Embrapa

made in the field and inoculations for the anthracnose pathogen, nine families were obtained, in which the cross was designated as C4-7-7-2.

In 2008 in the winter crop season, seeds of the nine families obtained from the C4-7-7-2 cross composed the experiment carried out in Ribeirão Preto, SP, with evaluation of 227 other families derived from other crosses made. From this experiment, the seeds of the $F_{2:5}$ generation were obtained, in which 10 plants were selected considering the traits of resistance to anthracnose, resistance to the Fusarium wilt pathogen, upright plant growth habit, and grain appearance. The experiment carried out in Ribeirão Preto exhibited the occurrence of fusarium wilt, allowing identification of resistant genotypes. Seeds of the 10 plants designated as new lines through being in the $F_{2:6}$ generation were multiplied in Campinas in the rainy season of 2008. By inoculations performed in the laboratory for anthracnose and Fusarium wilt, only two lines were selected, being designated as C4-7-7-2-1 and C4-7-7-2-2.

In 2009, the line C4-7-7-2-2 composed the experiment carried out in the winter season of 2009 in Campinas, with a total of 139 advanced lines. Only 40 lines were selected from the experiment carried out, and the line C4-7-7-2-2 was selected through exhibiting mean yield of 3150 kg ha^{-1}.

In the dry season of 2010 the 40 lines, selected in 2009, were evaluated at the Pólo de Pesquisa da Agência Paulista de Tecnologia dos Agronegócios - APTA of the Southwest of São Paulo, located in the municipalities of Tatuí and Capão Bonito. From these experiments, only 17 lines were selected. In the rainy season of 2010, the 17 lines were once more evaluated for resistance to anthracnose for the physiological races 81, 89, and 95 and were also sown in a field in the municipality of Campinas artificially contaminated with different isolates of *Fusarium oxysporum*. Of the 17 genotypes evaluated, only nine lines were selected to compose the Value for Cultivation and Use trials of the 2011/2012 two-year period, in which the line designated as Gen C4-7-7-2-2 was selected for exhibiting resistance to the pathogens tested. In the Value for Cultivation and Use trials of the 2011/2012 two-year period in the state of São Paulo, 27 genotypes were evaluated, with 12 derived from IAC, five from the Instituto Agronômico do Paraná – IAPAR, one from the program developed together with the Universidade Federal de Lavras and Embrapa – UFLA/Embrapa, two from the Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina – EPAGRI, three from the Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA, two from the Fundação Estadual de Pesquisa Agropecuária do Rio Grande do Sul – FEPAGRO, and two developed together with the programs of Embrapa/Epamig/UFLA/UFV (Table 1). During the VCU trials, as the line

Table 2. Grain yield (kg ha^{-1}), experimental coefficient of variation (CV%), and least significant difference (Dunnett-5%) in relation to the best standard cultivar by growing season and combination of the crop seasons of the common bean cultivar IAC Milênio, in 12 environments of the state of São Paulo in the VCU trials of the 2011-2012 two-year period

Common Bean Cultivars	Growing Season			Mean 2011/2012 (kg ha^{-1})
	Rainy (5 environ-ments)	Dry (3 environ-ments)	Winter (4 environ-ments)	
	kg ha^{-1}			
IAC Milênio	3124	3760	1611	2831
IAC Alvorada	3125	3103	1676	2635
IPR 139	2770	3325	1428	2507
Mean[1] (kg ha^{-1})	2971	3243	1520	2555
C.V. (%)	15.06	12.34	16.19	14.83
LSD[2] (kg ha^{-1})	490	569	302	266

[1] Experimental mean containing 27 cultivars and lines in the VCU Trials and with coefficient of variation less than 25%.
[2] Dunnett Test (5%) in relation to the best standard cultivar (IAC Alvorada or IPR 139).

Table 3. Technological and nutritional quality: mean values of cooking time in minutes by the Mattson Cooker and protein content (%) of the common bean cultivar IAC Milênio in 12 environments in the state of São Paulo in the VCU Trials of the 2011-2012 two-year period.

Growing Season	IAC Milênio		IPR 139		IAC Alvorada	
	Cooking time (min)	Protein content (%)	Cooking time (min)	Protein content (%)	Cooking time (min)	Protein content (%)
Rainy	28.59	18.47	29.11	19.52	28.37	22.50
Dry	30.58	24.11	29.46	20.50	31.36	23.00
Winter	36.12	20.59	39.08	19.78	36.41	22.16
Overall Mean	31.76	21.06	32.55	19.93	32.04	22.55

Gen C4-7-7-2-2 exhibited yield capacity of 4625 kg ha^{-1}, resistance to the main races of anthracnose, and resistance also to Fusarium wilt, it was recommended to the productive sector and denominated as IAC Milênio.

RESULTS AND DISCUSSION

The VCU trials began in 2011 in the rainy season and also included the dry, winter, and rainy seasons of 2012. From the experiments performed, the yield potential observed from the cultivar IAC Milênio was 4625 kg ha^{-1}, observed in the experiment carried out in the municipality of Avaré in the dry season of 2012 among the 12 VCU trials carried out in the state of São Paulo.

The mean yield of ´IAC Milênio´ in the VCU trials was 3124 kg.ha^{-1}, 3760 kg ha^{-1}, and 1611 kg ha^{-1} for the rainy (5 trials), dry (3 trials), and winter (4 trials) seasons, respectively (Table 2). For comparison of the mean values of the genotypes, the statistical analysis of Dunnett was used at the level of 5% probability. In combined analysis of the growing seasons in relation to the best standard cultivar for yield for the carioca type grain (IAC Alvorada or IPR 139), no significant differences were observed among the genotypes for the different growing seasons. Thus, the cultivar IAC Milênio obtained yield statistically equal to these standard cultivars that also exhibit high technological quality of grains and yield.

In relation to the characteristics that define the cultivar IAC Milênio, semi-upright plant architecture and indeterminate bush type growth habit (type III) stands out, which is an important characteristic that facilitates mechanized harvest. During the experiments, it was possible to confirm resistance to anthracnose and also to Fusarium wilt through planting made in areas with high infestation of the pathogens. The results were confirmed through the presence of susceptible cultivars in the experiments. The 1,000 seed weight evaluated was 290 grams, with carioca type grains (beige with light brown stripes). In the experiments, the cultivar showed a cycle from emergence to physiological maturity (presence of yellow pods/straw) of around 90 to 95 days, in accordance with the environmental conditions in which it was grown.

Mean cooking time (minutes) for the cultivar IAC Milênio (31.76) analyzed in the experiments, using the Mattson cooker (Proctor and Watts 1987) was similar to that of the cultivar IAC Alvorada (32.04 min) and to that of the cultivar IPR 139 (32.55 min.), exhibiting light-colored, whole grains at the end of cooking. The protein content varied with the environment and, on average, 'IAC Milênio' exhibited 21.06% in the grains (Table 3). Through its characteristics of yield, grain quality, and resistance to pathogens, the Instituto Agronômico – IAC chose to release the cultivar IAC Milênio to the productive sector, also extending growing to the states of Rio Grande do Sul, Santa Catarina, Paraná, and Mato Grosso do Sul, in accordance with the agricultural zoning in effect for the species.

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