Goiânia, GO, Brasil – *www.agro.ufg.br/pat*
ISSN 1517-6398

Pesquisa Agropecuária Tropical,
v. 38, n. 2, p. 141-145, jun. 2008

YIELD STABILITY AND ADAPTABILITY OF COMMON BEAN LINES DEVELOPED BY EMBRAPA[1]

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ABSTRACT

The objective of this research was to evaluate the common bean lines developed by the Embrapa Rice and Beans Research Center, concerning stability, adaptability, resistance to diseases and other desirable agronomic characteristics. The lines were divided in two experimental groups, one including 216 black grain lines, and the other with 56 color grain lines (*Carioca* and *Mulatinho*), both groups with four check varieties. The experimental design was the Federer's augmented blocks. The environmental indexes (I_j), the regression coefficients (b_i), and their deviation variances (s^2d_i) were obtained using the Eberhart & Russell's (1966) method. Among the 56 color grain lines, 40 showed stable performance, and among the 216 black grain lines, 49 were considered stable. The mean grain yield for the CNFP10080 line, which belongs to the black grain group, was significantly higher ($p < 0.05$) than the *Diamante Negro* check. The CNFP10099 and CNFP10123 black grain lines showed specific adaptability to unfavorable environments, that is, they presented b_i values significantly lower ($p < 0.05$) than the unit. Among the genotypes with stable behavior and good adaptability, the CNFC10276 (color grain group) and CNFP10207 (black grain group) lines showed good plant architecture; CNFM10258 and CNFC10283 (both from color grain group), and also CNFP10229 (black grain group) showed suitable architecture and resistance to rust; CNFM10249, CNFM10251, and CNFM10253 (all with colored seed), and also CNFP10212 (black seed) presented joint resistance to angular leaf spot and rust.

KEY-WORDS: *Phaseolus vulgaris*; disease resistance; plant breeding; grain yield.

RESUMO

ESTABILIDADE E ADAPTABILIDADE DE LINHAGENS DE FEIJOEIRO COMUM DESENVOLVIDAS PELA EMBRAPA

O trabalho objetivou avaliar linhagens de feijoeiro comum, geradas pela Embrapa Arroz e Feijão, quanto à estabilidade, adaptabilidade, resistência a doenças e outras características agronômicas desejáveis. As linhagens foram divididas em dois grupos, um com 216 linhagens de grãos pretos e o outro com 56 linhagens de grãos do grupo cor (Carioca e Mulatinho), ambos com quatro variedades testemunhas. O delineamento experimental foi o de blocos aumentados de Federer. Foram obtidos os índices ambientais (I_j), os coeficientes de regressão (b_i) e suas variâncias de desvios (s^2d_i), utilizando-se a metodologia de Eberhart & Russell (1966). Das linhagens de grãos de cor, 40 mostraram-se estáveis e, das linhagens de grãos pretos, 49 foram estáveis. O rendimento médio de grãos da linhagem CNFP10080 (grão preto) superou significativamente ($p < 0,05$) a testemunha Diamante Negro. As linhagens CNFP10099 e CNFP10123, de grãos pretos, mostraram adaptação específica a ambientes desfavoráveis, isto é, tiveram valores de b_i estatisticamente inferiores ($p < 0,05$) à unidade. Entre os genótipos estáveis e com boa adaptabilidade, as linhagens CNFC10276 (de grãos de cor) e CNFP10207 (de grãos pretos) mostraram boa arquitetura de planta; CNFM10258 e CNFC10283 (ambas de grãos de cor) e, ainda, CNFP10229 (grão preto) apresentaram arquitetura adequada e resistência à ferrugem; CNFM10249, CNFM10251 e CNFM10253, todas com grão de cor, e, também, CNFP10212, de grão preto, apresentaram resistência conjunta à mancha angular e à ferrugem.

PALAVRAS-CHAVE: *Phaseolus vulgaris*; resistência a doenças; melhoramento de plantas; produção de grãos.

INTRODUCTION

The common bean breeding program carried out by Embrapa Rice and Beans Research Center, in Brazil, has as one of its main goals to obtain high productivity cultivars. However, the farmers' preference is for grain yield stability over time, besides high yield. Thus, adaptability and yield stability are two important concepts in a common bean breeding program (Monge 1981).

Regression is a very common method in research dealing with cultivar phenotypic adaptability and stability. This application was introduced by Yates & Cochran (1938), but received notoriety through the studies developed by Finlay & Wilkinson (1963), and Eberhart & Russell (1966). The Eberhart & Russell

1. Trabalho recebido em mar./2006 e aceito para publicação em jun./2008 (nº registro: PAT 609).
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(1966) methodology, more used and popular, is based on the simple linear regression analysis and uses as genotypic adaptability parameters, the regression coefficient (β_i) and average yield (μ_i), and, as phenotypic stability parameter, the regression deviation variance (σ^2d_i). Therefore, in general, this type of study, besides its intrinsic characteristics, is an alternative way to evaluate the magnitude and effects of the genotype by environment interaction (Vencovsky & Barriga 1992).

It is very important to know the performance of the advanced lines, regarding their adaptation and stability across crops and planting seasons, as well as disease resistance. Among the strategies of the integrated disease management, genetic resistance is considered an important feature. Resistant cultivars are easily adopted by farmers and are ecologically safe, since they contribute to reduce use of chemicals and to a better life quality.

It is important that dry bean cultivars own suitable agronomic characteristics, such as upright position and low rate of low pods. The occurrence of low pods can allow the contact between pods and soil, promoting their putrefaction and the emergence of stained grains.

The objective of this research was to evaluate the common bean lines developed by the breeding program carried out by the Embrapa Rice and Beans Research Center, regarding stability, adaptability, resistance to diseases, and other suitable agronomic characteristics.

MATERIAL AND METHODS

The lines were divided in two experimental groups: one with 216 black grain lines and with *Diamante Negro*, *Xamego*, MA7333327, and AN730116, as check varieties; and the other with 56 color grain lines and with *Pérola*, IPA-6, *Corrente*, and *Aporé* cultivars as checks. The experimental design was the Federer's augmented blocks (Federer 1956). The experimental unit consisted of four rows (4 m long, including two border lines), spaced 0.50 m, and twelve plants per meter.

The experiments were conducted at the Embrapa Rice and Beans Research Center, in Santo Antônio de Goiás, Goiás State, Brazil (16º28'00"S, 49º17'00"W, and 823 m altitude), for three consecutive dry seasons (June 1999, 2000, and 2001), and in the Palmital Farm, Brazabantes, Goiás State, Brazil (16º25'50"S, 49º23'21"W, and 761 m altitude), on February 2000, during the rainy season. Two more experiments were carried out in Ponta Grossa, Paraná State (25º05'42"S, 50º09'43"W, and 969 m altitude), on February 2000 and 2001.

The individual and combined variance analysis was performed using the SAS software, according to the model developed by Federer (1956). The Eberhart & Russell's method (1966) was used to obtain the environmental indexes (I_j – environmental mean deviation as related to the general mean) and the regression analysis that provide the estimates of the regression coefficients (b_i) and their regression deviation variances (s^2d_i).

The lines were considered stable when the value for s^2d_i did not differ significantly from zero and with good adaptability when the values of bi did not differ significantly from the unit, both at 5% probability. However, among those lines which did not differ statistically in mean yield over the check cultivars, Diamante Negro, in the black grain group, and Pérola, in the color grain group, were the only cultivars considered promising. These two control cultivars are largely recommended in several Brazilian states, due to their high yield and adaptability.

Under natural conditions of disease occurrence in the field, the reaction of lines to powdery mildew (*Erysiphe polygoni*), rust (*Uromyces appendiculatus*), common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli*), and angular leaf spot (*Phaeoisariopsis griseola*) were evaluated by using the scales defined by Costa et al. (1990), while the reaction to anthracnose (*Colletotrichum lindemuthianum*) was estimated according to Rava et al. (1993).

The genotypes were also evaluated for plant architecture and lodging, when the seeds reached physiological maturity. The plant architecture was evaluated by the distance between the first pod and the soil level (DP), based on a rank scale varying from 1 (upright plant, height – from the first pod to the soil – higher than 12 cm, compact plant without apical meristem) to 9 (quite branched plant, with pods touching the soil and excess of apical meristem). For lodging (LG), another scale was adopted, also varying from 1 (no lodged plants in the plot) to 9 (all plants lodged in the plot), described by Costa et al. (1999).

RESULTS AND DISCUSSION

The mean grain yield for the *Pérola* and *Diamante Negro* check cultivars were 2,603 kg ha^{-1} and 2,442 kg ha^{-1}, respectively. Table 1 presents the 40 color grain group genotypes, which showed to be stable. All those lines also presented general adaptability (b_i = 1), including the *Pérola* check cultivar. For the black grain lines, 49 lines were stable and are listed in the Table 2. The black grain line CNFP10080, with mean yield of the 3,008 kg ha^{-1}, was significantly higher than the *Diamante Negro* check variety. The black grain lines, CNFP10099, CNFP10123 and CNFP10137, with mean grain yields of 2,725 kg ha^{-1}, 2,544 kg ha^{-1}, and 2,460 kg ha^{-1}, respectively, showed specific yield adaptation to unfavorable environments (negative I_j - environments with averages lower than the general mean from all trials), that is, with b_i values significantly ($p < 0.05$) lower than the unit (Table 2). Thus, they may be recommended for environments with low input levels

Table 1. List of common bean stable lines and the cultivar check (*Pérola*) from color seed group, and their estimates of mean grain yield, regression coefficient (b_i), and regression deviation variance (s^2d_i), in kg ha^{-1}.

Lines	Environment[1]						Mean	b_i [2]	s^2d_i [2]
	1	2	3	4	5	6			
CNFR10241	2892	1996	3269	2531	2587	2699	2662	0.84	453540
CNFM10242	3196	1549	3595	2109	3112	2777	2723	1.21	945679
CNFM10243	2360	1243	3099	2815	1915	2726	2360	1.52	14977646
CNFR10245	2371	1297	3286	2852	2902	2433	2524	1.36	1200405
CNFM10247	1881	1143	3354	2230	2849	1500	2160	0.10	640280
CNFM10249	2572	1929	2400	2639	3112	3155	2635	0.54	190519
CNFM10250	2609	1345	3227	2623	2037	2899	2457	1.41	1378825
CNFM10251	1447	1926	3092	2533	2101	2677	2296	0.20	24990
CNFM10252	2732	1594	2227	1608	2443	2405	2168	0.56	205330
CNFM10253	2564	1823	2756	2064	1780	3175	2360	0.66	277783
CNFM10255	1961	1274	1931	2536	1909	2519	2022	0.95	584563
CNFM10256	1840	1768	2113	3036	2823	2537	2353	0.51	169041
CNFM10257	1898	1983	2463	2938	3028	3009	2553	0.30	58934
CNFM10258	2601	1669	3281	3203	2034	3169	2660	1.42	1294886
CNFM10260	2389	2002	2085	3256	2876	3344	2659	0.65	272003
CNFM10261	1294	1605	2699	2950	2380	3137	2344	0.51	169325
CNFM10264	2463	1391	1941	2606	1849	3034	2214	1.14	836359
CNFC10265	2957	2609	2727	3174	1988	3319	2796	0.57	206914
CNFC10266	2344	1632	2484	2034	2050	2773	2220	0.63	254734
CNFC10267	4139	2005	1954	2837	2128	2967	2672	1.48	1411476
CNFC10268	2943	2060	1679	3067	2213	1404	2228	0.86	477562
CNFC10269	2614	1899	2362	3386	1564	1439	2211	1.22	966376
CNFC10270	2709	2279	1761	2515	2490	1872	2271	0.22	30978
CNFC10271	2721	1749	1747	3047	2149	2884	2383	1.05	706124
CNFC10272	2961	1709	1683	2621	2347	3263	2431	0.96	596350
CNFC10273	3184	1852	2533	2240	2019	3238	2511	0.96	592420
CNFC10274	4210	1933	1466	2633	2003	1063	2218	1.45	1361298
CNFC10275	3450	1925	2676	3152	2556	1824	2597	1.41	1285285
CNFC10276	3442	1821	2405	3185	2647	1867	2561	1.46	1382282
CNFC10279	3825	1988	2545	2300	2516	1651	2471	1.13	822857
CNFC10280	2572	1196	3482	2145	2400	2194	2332	1.36	1185908
CNFC10282	3308	2003	2956	2264	2274	1640	2408	0.94	565307
CNFC10283	3479	2343	2300	3322	2174	1108	2454	1.10	781073
CNFC10285	3444	2044	2471	3526	2079	3494	2843	1.49	1433045
CNFC10286	2851	1713	2671	2538	2196	3258	2538	1.06	719364
CNFC10287	2606	2365	2249	2722	1817	2961	2453	0.36	83632
CNFC10288	3641	2317	2572	2711	1994	1437	2445	1.00	639289
CNFC10289	2707	2167	2246	3125	1597	3367	2535	0.83	447540
CNFM10304	2853	1847	2407	2096	2189	4308	2617	0.66	278399
Pérola	2865	1978	2457	3272	2426	2621	2603	1.08	439271
C.V.%	14.53	12.43	19.02	11.13	11.68	38.08	20.23	-	-

[1]- 1: Embrapa Rice and Beans, June 1999; 2: Ponta Grossa, February 2000; 3: Palmital Farm, February 2000; 4: Embrapa Rice and Beans, June 2000; 5: Ponta Grossa, February 2001; 6: Embrapa Rice and Beans, June 2001.

[2]- All the estimates presented for b_i and s^2d_i were not significant, according to the F test, at 5% of probability, regarding their hypothesis, H0: β_i=1 and $H0_2$: $\sigma^2d_i = 0$, respectively.

Table 2. List of common bean stable lines and the cultivar check (*Diamante Negro*) from black seed group, and their estimates of mean grain yield, regression coefficient (b_i), and regression deviation variance (s^2d_i), in kg ha^{-1}.

Lines	Environment [1]						Mean	b_i [2]	s^2d_i [2]
	1	2	3	4	5	6			
CNFP10034	2787	688	2296	2887	2880	3041	2430	1.22	2277325
CNFP10036	2921	1167	1201	2880	2297	3450	2319	1.39	1966194
CNFP10037	3001	1645	2125	1975	1651	2782	2197	0.72	797268
CNFP10038	2551	1615	1785	2146	2731	3450	2380	0.87	1163221
CNFP10050	2961	1196	2264	2650	1809	2608	2248	0.94	1365449
CNFP10051	3015	1587	3066	3691	1950	3091	2733	1.15	2031975
CNFP10057	3323	1140	1165	3227	1914	3120	2315	1.40	3030154
CNFP10059	3613	1516	1506	2652	2068	2726	2347	0.84	1099441
CNFP10063	3216	1297	2758	2023	2466	3722	2580	1.20	2224343
CNFP10068	3580	1510	2721	2842	1281	3378	2552	1.37	2900138
CNFP10077	1736	1461	3052	3507	1974	3026	2459	1.08	1792853
CNFP10078	1902	1178	2547	3793	1568	3065	2342	1.43	3134344
CNFP10079	2564	1166	2840	3651	1741	1637	2267	0.60	563553
CNFP10080	3200	2313	3221	4100	2446	2768	3008*	0.57	505187
CNFP10082	2375	1442	2902	2787	3050	2044	2433	0.19	55546
CNFP10084	2800	1999	2746	2691	3120	3320	2779	0.59	536509
CNFP10091	1861	1901	2199	2603	2353	3356	2379	0.81	1003296
CNFP10098	2624	2236	3127	2136	1502	2734	2393	0.40	249452
CNFP10100	2837	2088	2361	2996	2027	2535	2474	0.46	325986
CNFP10101	2761	1687	2922	2272	2919	3641	2700	0.87	1181560
CNFP10103	2895	1460	2439	2885	2826	2394	2483	0.39	240919
CNFP10106	2025	2151	2934	2307	2701	4201	2720	0.97	1453674
CNFP10120	1725	2015	2405	1626	2706	2819	2216	0.16	40992
CNFP10122	3312	1867	2789	2591	1100	3633	2549	1.31	2635774
CNFP10152	2982	1311	2146	2502	2228	2384	2259	0.64	629062
CNFP10155	3118	1296	2277	2233	1859	2430	2202	0.70	766919
CNFP10164	2112	1461	2538	2985	1829	2754	2280	0.67	691168
CNFP10168	3127	2023	2339	2469	2149	2507	2436	0.35	195183
CNFP10174	1773	2079	2766	2037	1767	2949	2229	0.49	375191
CNFP10176	1555	2071	2232	2244	2270	2789	2194	0.34	185050
CNFP10184	2267	2191	2255	2375	2371	3398	2476	0.65	648113
CNFP10200	1893	1070	2460	1397	1682	3057	1927	0.97	1453764
CNFP10207	2636	1639	1936	2218	2597	3137	2361	0.73	822393
CNFP10212	2949	1706	2069	2020	2155	4088	2498	1.29	2546479
CNFP10213	3468	1959	2354	2177	998	3681	2440	1.25	2425533
CNFP10217	1546	1855	1956	2233	2607	3298	2249	0.66	672382
CNFP10220	2696	2130	1438	2751	1779	3671	2411	1.10	1858930
CNFP10221	2631	2484	2059	2442	2170	2991	2463	0.36	206493
CNFP10222	1699	2281	1828	2986	1729	3951	2412	1.17	2117624
CNFP10224	3090	2576	1578	2981	1888	4220	2722	1.20	2228125
CNFP10225	2637	2307	1870	1779	1731	3252	2263	0.57	512680
CNFP10229	3538	2025	2427	2969	1743	3166	2645	0.92	1315579
CNFP10233	2166	2229	2796	2329	1912	3633	2511	0.83	1058885
CNFP10235	3408	2000	1677	2501	1834	2984	2401	0.75	866117
CNFP10236	3126	2324	2061	3299	2808	3637	2876	0.84	1085099
CNFP10238	3788	2004	1886	2611	2135	2348	2462	0.36	200669
CNFP10099	2525	2528	2855	3039	2268	3133	2725	0.47	351896
CNFP10123	2504	1861	2698	2650	2733	2820	2544	0.46	328601
CNFP10137	2116	2264	2327	2680	2427	2946	2460	0.40	249416
Diamante Negro	2754	1134	2484	2874	2035	3369	2442	1.00	1554727
C.V.%	17.50	12.11	16.25	17.09	13.38	17.26	16.75	-	-

[1]- 1: Embrapa Rice and Beans, June 1999; 2: Ponta Grossa, February 2000; 3: Palmital Farm, February 2000; 4: Embrapa Rice and Beans, June 2000; 5: Ponta Grossa, February 2001; 6: Embrapa Rice and Beans, June 2001.

[2]- All the estimates presented for b_i and s^2d_i were not significant, according to the F test, at 5% of probability, regarding their hypothesis, $H0_1$: β_i=1 and $H0_2$: $\sigma^2d_i = 0$, respectively. (* - average significantly higher than the mean check variety).

The bean crop has been spread to cultivation areas which demand cultivars characterized by upright plants (with pods that do not touch the soil, short apical meristem and bushy), and lodging tolerance. That promotes the use of mechanized harvest, with low loss levels, a better grain quality and a lower incidence of diseases, due to a better crop aeration and reduction of the contact between pods and soil.

The CNFM10258, CNFC10276, and CNFC 10283 lines, with color grain, and CNFP10207 and CNFP10229, with black grain, displayed good plant architecture (average values for DP and LG lower than 4). The CNFM10258, CNFC10283 (color grain group), and CNFP10229 (black grain group) lines were also resistant to rust, with disease scores lower than 3 (Table 3).

As disease resistance is one of the most important objectives of the breeding program, all the lines included in those experiments were previously selected for resistance to the pathotypes 55 (Lambda race), 89 (Alpha-Brazil race), 95 (Kappa race) and 453 (Zeta race) of *C. lindemuthianum*, and to the BCMV (Bean Common Mosaic Virus). Therefore, the lines that showed resistance to pathogens that occurred in the test locations fulfill the above cited objectives of the program.

The CNFM10249, CNFM10251 and CNFM 10253 lines, from the color grain group, and the CNFP10212 line, from the black grain group, showed resistance reaction (mean scores lower than 4) to the angular leaf spot and rust (Table 3). A high incidence of powdery mildew occurred in Ponta Grossa, on February 2000, and in the CNPAF, on June 2000, where the CNFC10265, CNFC10266, CNFC10274, and CNFC10276 lines, all of color grain, showed resistance reaction (mean scores lower than 4). Among them, the CNFC10276 line showed good plant architecture, with mean score values for DP and LG lower than 4 (Table 3).

In Ponta Grossa, on February 2000 and 2001, a high incidence of anthracnose (*C. lindemuthianum*) occurred and the *Pérola* cultivar presented a susceptible reaction to the pathogen (disease scores 7 and 8). Nevertheless, all the tested lines showed resistance reaction when inoculated with the pathotypes 89, 55, 95, and 453. The CNFM10258 (color grain group) and CNFP10079 (black grain group) lines were susceptible in the field, showing disease scores 7 and 6, respectively (Table 3). These results indicate the occurrence of a pathotype *C. lindemuthianum*, different from the ones that were previously used for testing the lines.

The outstanding lines assessed in this research have been included in regional and national trails, and used as parental lines for obtaining segregate populations in the breeding program carried out by the Embrapa Rice and Beans Research Center, for commercial grain species, in Brazil.

CONCLUSIONS

1. For color grain group lines, it was possible to notice that all the stable genotypes showed high grain yield, and also general adaptability to the tested environments.
2. For the black grain group, the CNFP 10099, CNFP 10123 and CNPP 10137 lines presented specific adaptation to the most unfavorable environments, besides being stable and expressing a high grain yield.
3. Concerning diseases, the CNFC 10276 (color seed group – *Carioca*) line showed to be resistant to

Table 3. Evaluation of common bean lines for plant architecture, lodging and disease reaction[1], under natural field conditions, for six cropping Brazilian environments.

Lines	Environment [2]																							
	1		2						3					4			5					6		
	DP	LG	PM	RST	CBB	AN	DP	LG	CBB	RST	ALS	DP	LG	PM	DP	LG	AN	ALS	DP	LG	DP	LG		
	---------- Color seed ----------																							
CNFM10249	4	4	5	1	1	1	3	7	1	1	2	3	4	4	2	2	1	3	4	3	3	6		
CNFM10251	5	5	4	1	1	1	3	8	1	1	2	4	7	5	4	6	1	4	3	7	3	7		
CNFM10253	6	3	5	1	5	1	4	6	1	1	3	4	4	7	3	2	1	3	3	5	3	6		
CNFM10258	2	4	6	1	1	1	4	3	1	1	3	4	3	8	4	1	7	6	4	2	4	4		
CNFC10265	8	4	2	1	2	1	5	7	1	1	6	4	8	4	4	5	1	-	5	3	5	5		
CNFC10266	1	6	2	1	5	1	5	8	1	1	6	5	3	3	4	1	1	-	5	1	5	6		
CNFC10274	5	5	2	4	4	1	5	6	1	1	5	5	2	3	3	6	1	-	5	1	5	4		
CNFC10276	3	4	3	5	1	1	4	4	1	1	4	4	4	4	3	3	1	4	4	2	4	4		
CNFC10283	3	4	2	3	1	1	4	4	1	1	4	4	3	6	3	4	1	7	4	2	-	-		
	---------- Black seed ----------																							
CNFP10079	3	4	3	6	6	1	3	4	1	1	5	4	5	6	4	1	6	8	4	6	4	5		
CNFP10207	4	3	6	2	1	1	4	2	1	2	5	4	1	6	4	2	1	4	4	1	4	-		
CNFP10212	6	3	6	3	1	1	5	1	1	1	2	3	8	7	3	2	1	3	4	4	4	5		
CNFP10229	1	4	5	1	2	1	4	3	1	1	5	4	3	7	3	2	1	8	4	2	3	4		

[1]- DP: distance of the first pod from the soil (plant architecture), in a nine-rank scale, where 1 = more than 12 cm, and 9 = pods in contact with the soil. LG: lodging, in a nine-rank scale, where: 1 = upright plants, and 9 = completely lodged. AN: anthracnose; PM: powdery mildew; RST: rust; CBB: common bacterial blight; ALS: angular leaf spot, in a nine-rank scale, where 1 = no symptoms, and 9 = plants dead or near to collapse.

[2]- 1: Embrapa Rice and Beans, June 1999; 2: Ponta Grossa, February 2000; 3: Palmital Farm, February 2000; 4: Embrapa Rice and Beans, June 2000; 5: Ponta Grossa, February 2001; 6: Embrapa Rice and Beans, June 2001.

angular leaf spot, besides presenting good plant architecture. The CNFC10283 (*Carioca* group) and CNPF 10229 (black seed group) lines showed good plant architecture and high rust resistance.

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