

# Resistance to Bean Golden Mosaic Virus in Bean Genotypes

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## ABSTRACT

Bianchini, A. 1999. Resistance to bean golden mosaic virus in bean genotypes. *Plant Dis.* 83:615-620.

Bean lines MD 806, MD 807, MD 820, MD 829, MD 808, and MD 821, all with high levels of resistance to bean golden mosaic virus (BGMV), were selected under field conditions. On a 1 to 9 scale (1 = symptomless plant; 9 = severe symptoms), the mean disease severity of the MD lines ranged from 1.7 to 3.9 for mosaic symptom (foliar yellowing) and from 1.7 to 2.2 for malformation. In contrast, disease severity in the susceptible cultivars Carioca, Carnaval, and Iapar 20 ranged from 4.1 to 8.7 for mosaic and from 4.0 to 7.3 for malformation. Symptoms on the selected lines were expressed later than on susceptible controls. The MD lines yielded 1.2- to 5.9-fold the yield of the cultivars Carioca and Iapar 20. Under greenhouse conditions, reactions of the bean genotypes to BGMV were similar to those observed in the field. MD 806 and MD 807 were obtained from early crosses involving genotypes that reacted to BGMV infection with mild mosaic (Aeté 1/38 and TMD-1) and mild malformation (Porriño Sintético and Turrialba 1). Parents of the lines MD 820 and MD 829 were *Phaseolus coccineus* (of unknown reaction to BGMV) and Carioca. Line MD 648 (DOR-selected line) was the ancestral parent of lines MD 808 and MD 821, which had the highest levels of resistance or tolerance to BGMV. Severity of all BGMV symptoms showed gradual reductions from the earliest parents to their later selected progenies. Responses of the parent genotypes and progenies to BGMV infection suggest a combination of resistance characters in the selected MD lines. MD 806, MD 820, and MD 821 were released in the state of Paraná under the names Iapar 57, Iapar 72, and Iapar 65, respectively.

Additional keywords: geminivirus, whitefly-transmitted virus

Since first reported in 1965 (9), bean golden mosaic has become the most damaging disease of dry beans (*Phaseolus vulgaris* L.) in Brazil. The disease is caused by the whitefly-transmitted geminivirus bean golden mosaic virus (BGMV) (9). In the state of Paraná, environmental conditions are favorable for rapid population increases of the whitefly vector (*Bemisia tabaci*) from January until April. During this period, BGMV affects almost all the bean plants in most of the growing areas. Losses can reach 100% due to reductions in yield and grain quality (6). The disease is also important in bean growing areas of the states of São Paulo, Minas Gerais, Mato Grosso do Sul, Goiás, and Bahia. Bean golden mosaic is also a problem in other Latin American countries, such as Argentina, Mexico, Dominican Republic, El Salvador, and Guatemala (13).

A complex of symptoms described as golden mosaic occurs on dry bean in the state of Paraná. The symptoms include characteristic mosaic with intense foliar

yellowing, leaf curling, pod distortion, and severe plant stunting with abnormal axillary sprouting (typical of witches'-broom symptoms (7,16)). The range of symptoms is probably due to different BGMV strains (20), to mixed infections with other geminiviruses, or to mixed infections with other viruses from different groups (12). In Brazil, the witches'-broom symptom on bean is usually associated with infection by Abutilon mosaic virus from malvaceous weeds (11); however, this symptom may also be caused by Euphorbia mosaic virus or by uncommon strains of the BGMV complex (11). The witches'-broom that occurs in Paraná may also be caused by mixed infection of BGMV with a comovirus or with southern bean mosaic virus (12). Mixed infections of BGMV with Abutilon mosaic virus may occur, but the witches'-broom symptoms may be temporary because the BGMV probably suppresses the Abutilon mosaic virus (10).

Several measures have been examined for control of BGMV in Paraná. Intercropping of bean with coffee, corn, or *Sorghum bicolor* and manipulation of seeding dates may reduce the BGMV incidence by more than 50% (3-5). Although chemical control of the insect vector may reduce BGMV incidence, it does not significantly reduce the damage under high whitefly pressure (6,14). Resistance has been intensively investigated on local bean cultivars and accessions. Immunity or high level resis-

tance to BGMV has not been found in the existing bean germplasm. Some cultivars, such as Aeté 1/37, Aeté 1/38, Aeté 1/40, Rosinha G2/69, and Carioca 99, were selected as resistant to BGMV (21). Although these genotypes reacted to the virus infection with mild mosaic symptoms, they showed severe leaf curling and stunting under high BGMV incidence (1,12). The bean mutant genotype TMD-1, obtained by EMS seed treatment of the cultivar Carioca, has shown a high level of tolerance to BGMV (22). This mutant, however, yields poorly and hence is not suitable for commercial purposes (23). TMD-1 has also shown severe stunting under high BGMV incidence (1). TMD-1 and the cultivar Aeté 1/38 have been used as sources of resistance to BGMV in the bean breeding program at the Instituto Agronômico do Paraná (IAPAR), Londrina, PR, Brazil.

This paper reports the development of agronomically and commercially acceptable bean cultivars with high levels of resistance to the BGMV complex.

## MATERIALS AND METHODS

Bean lines IAPAR MD and IAPAR BAC, and genotypes from IAPAR's bean germplasm and accessions that have shown mild mosaic symptoms (foliar yellowing) or mild plant malformation, were used in the breeding program for BGMV resistance. IAPAR MD and IAPAR BAC, selected from early crosses for BGMV and bacterial resistance, respectively, were named MD and BAC. The main genotypes used were: (i) bean lines MD 632, MD 648, BAC 32, BAC 25, and BAC 38; (ii) selected interspecific lines from crosses between *P. vulgaris* (cv. Carioca) and *P. coccineus* (S. T. Mohan, unpublished data); (iii) local cultivars Carnaval and Goiano Precoces; and (iv) Porriño Sintético from Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, and GF3127 from Centro Nacional de Arroz e Feijão/Empresa Brasileira de Pesquisa Agropecuária (CNPAP/EMBRAPA), Goiânia, GO, Brazil. Several crosses were made with different combinations among these genotypes and their progenies. The basic criteria for all crosses were the combination of different BGMV resistance traits and seed quality.

Crosses were made under greenhouse conditions by manual emasculation and pollination. The F1 generation was advanced in the greenhouse and the F2 in the field. The single seed descendant (SSD) method was used, with eventual selection

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Accepted for publication 5 March 1999.

Publication no. D-1999-0430-01R  
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in the F2 generation. The selections were accomplished in the F3 generation by genealogical and bulk methods. Large numbers of plants were selected in the F3 and F4 generations. Plants with mild symptoms of mosaic and malformation, and those showing only one type of bean golden mosaic symptom in addition to promising agronomic characteristics, were selected. Selection was carried out under natural infection of BGMV, with disease incidence ranging from 90 to 100% of infected plants in the susceptible cultivars at 35 days after planting (DAP). Mosaic (yellowing) and plant malformation symptoms were evaluated separately. Malformation included foliar curling, pod distortions, and plant

stunting. The degree of disease severity was determined using a 1 to 9 scale (1 = symptomless plant; 2 = mild chlorosis and stunting of the young leaflets; 3 = mild mosaic and mild stunting affecting the terminal growth; 4 = moderate mosaic covering less than 25% of the leaf area or moderate malformation affecting the terminal growth; 5 = moderate mosaic or malformation affecting more than 25% of the leaf area and the plant size; 6 = severe mosaic or malformation affecting approximately 50% of the leaf area and plant size; 7 = severe mosaic or malformation affecting more than 50% of the leaf area and plant size; 8 = severe mosaic or malformation affecting approximately 75% of

the leaf area and plant size, with excess of lateral sprouts (witches'-broom symptom); 9 = severe mosaic or severe malformation affecting more than 75% of the leaf area and the plant size, with witches'-broom symptom. Plants or lines with disease severity lower than 4 for mosaic and lower than 3 for malformation were considered resistant.

Yields of selected bean lines were evaluated under high and moderate BGMV incidence in field conditions. The evaluations were carried out in experiments in a randomized block design with 15 m<sup>2</sup> plots and four replicates per experiment. These experiments were carried out for 4 years. Not all lines were evaluated in all years.

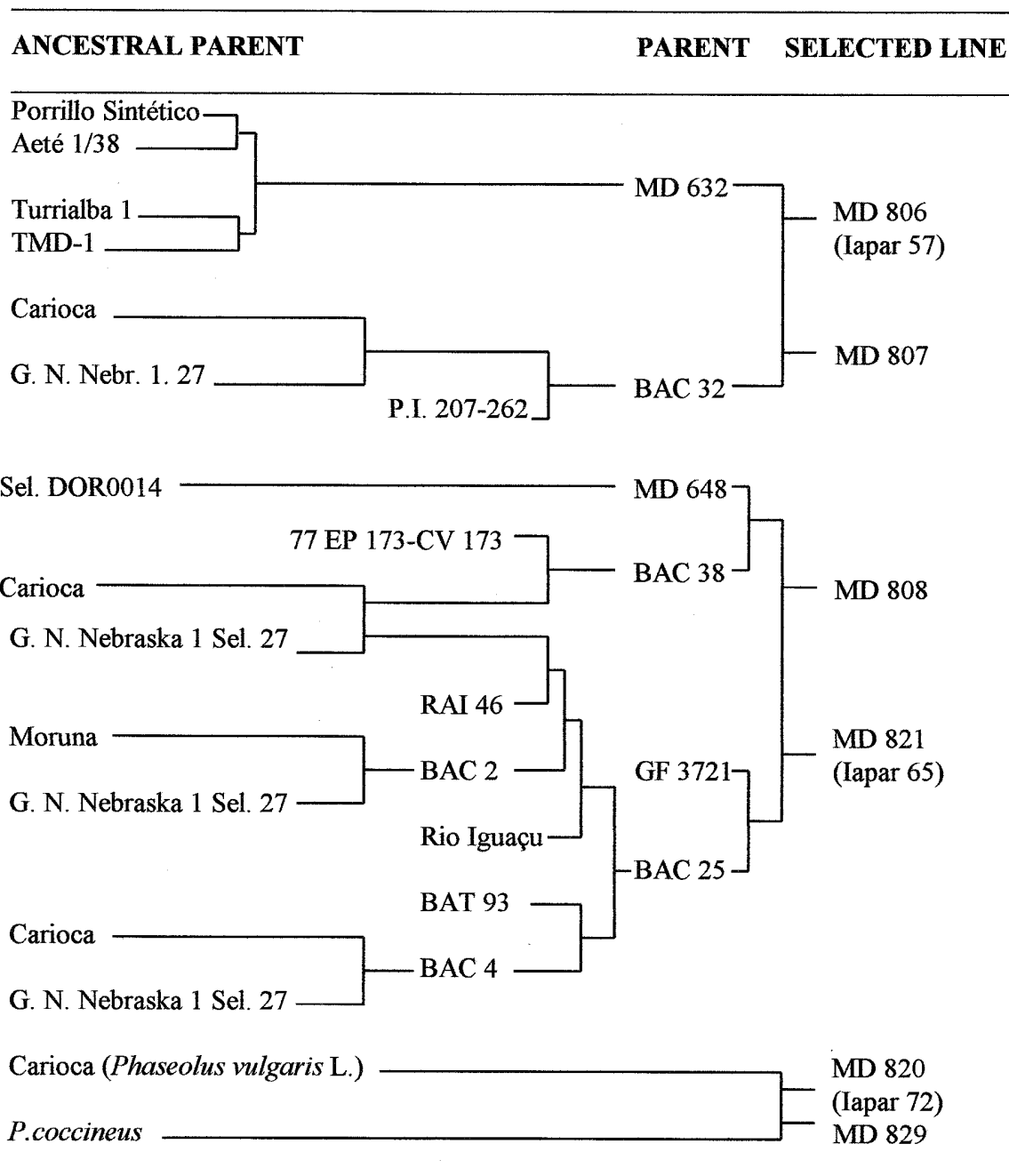


Fig. 1. Genealogy of improved bean lines bred for resistance to bean golden mosaic virus.

The disease severity and the percentage of infected plants at different ages were also evaluated for the entire plots of 240 plants. The disease severity for each plot was determined based on the average of the scores and the number of infected plants.

The score of disease for a genotype in one experiment was determined based on the average of four plots (replicates). The final score of disease for each genotype was the average of the scores obtained in each year of evaluation. Carioca, which has a cream colored seed coat with brown stripes, Carnaval, which has a cream colored seed coat with purple spots, and Iapar 20, a black-seeded genotype, were used as susceptible controls.

The most promising lines were also evaluated for golden mosaic resistance under greenhouse conditions. Fifteen plants of each line, parental genotype, and the susceptible controls Carioca, Carnaval, and Iapar 20 were evaluated in a completely randomized design with three replicates. The plants were grown in an insectary holding a large population of viruliferous whiteflies (more than 50 insects per plant). At 10 DAP, all plants were transferred to a whitefly-free greenhouse. Evaluations of disease severity and percentage of infected plants were accomplished at 15, 30, 50, and 65 DAP.

## RESULTS

**Resistant lines.** Several bean lines with high levels of resistance to BGMV were selected under natural disease pressure in the field. The most promising were placed in three groups according to their genealogy: two groups with variable seed coat colors and one group of black-seeded genotypes. The non-black-seeded groups included the lines MD 806 and MD 807 (obtained from the cross MD 632 × BAC 32), and the lines MD 820 and MD 829, selected from interspecific progenies of the cross between *P. vulgaris* (cv. Carioca) and *P. coccineus*. The black-seeded group included the lines MD 808 and MD 821, obtained from the crosses (MD 648 × BAC 38) × (GF 3721 × BAC 25) (Fig. 1).

The line MD 632 was selected from early crosses that had as parents TMD-1, Aeté 1/38, Porrillo Sintético, and Turrialba 1. The lines BAC 32, BAC 38, and BAC 25 were obtained from breeding IAPAR BAC lines originated from a common cross between Carioca and Great Northern Nebraska 1 sel. 27 (17,18), or by crossing IAPAR BAC lines with introduced accessions and local genotypes. MD 648 was selected at IAPAR from DOR bean lines obtained from the cross (P566 × P709) carried out at CIAT (Fig. 1). TMD-1 is a mutant from the cultivar Carioca, obtained at Centro de Energia Nuclear na Agricultura (CENA)/Universidade de São Paulo (USP) (23). Among the ancestral parents, TMD-1, Aeté 1/38, Porrillo Sintético, and

Turrialba 1 are genotypes that have shown either mild symptoms (mosaic or malformation) or resistance to severe stunting when infected with BGMV. The cultivars Rio Iguaçú and Moruna, and the lines RAI 46 and G. N. Nebr. 1. 27, ancestral parents of the line BAC 25, are genotypes used in the bean breeding program of IAPAR for resistance to fungal and bacterial diseases and are susceptible to BGMV, with the exception of G. N. Nebr. 1. 27, which is of unknown reaction.

**Disease severity and type of reaction under field conditions.** Under a BGMV incidence of 100% on susceptible cultivars, the mean disease severity scores per experiment for mosaic symptoms of selected bean lines ranged from 1.7 to 3.9. Less than 5% of the plants in all plots showed mosaic severity higher than 5.0. MD 829, a white-seeded bean, and MD 806, with a cream colored seed coat and brown stripes, similar to Carioca, showed the lowest mosaic severity, with mean scores of 1.7 and 2.0 and maximum scores in a single plot of

3.0 and 4.0, respectively. The MD lines had relatively low scores for malformation and stunting, with means of 1.7 to 2.7 and a maximum of 4.0 (Table 1). Less than 1% of the plants of these lines showed severe stunting or witches'-broom symptom. The susceptible controls, Carioca, Iapar 20, and Carnaval, showed higher disease severity than MD lines in all experiments. Carioca and Iapar 20 had a moderate mosaic symptom expression and the highest severity of plant malformation and stunting, with means of 7.3 and 6.6, respectively, and scores ranging from 3 to 9. Carnaval had a moderate severity of plant malformation and the highest mosaic symptom expression, with severity between 8 and 9. The parents MD 632 and BAC 38 had a mosaic symptom expression similar to MD 808 and MD 821, but the severity of plant malformation was higher than in MD lines and ranged from 2.0 to 7.0. The ancestral parent Porrillo Sintético had a higher severity of mosaic symptom than parents MD 632 and BAC 38, while the severity of

**Table 1.** Disease severity for mosaic and foliar malformation and stunting caused by bean golden mosaic virus in selected MD bean lines, their parents, and susceptible genotypes under field conditions<sup>w</sup>

Genotype	Years	Mosaic		Malformation and stunting	
		Mean <sup>x</sup>	Range <sup>y</sup>	Mean	Range
MD 806	4	2.0	1-4	2.2	1-4
MD 807	4	2.9	2-4	1.7	1-4
MD 820	3	2.6	2-4	2.2	1-3
MD 829	2	1.7	1-3	2.0	1-3
MD 808	4	3.9	2-5	2.7	2-4
MD 821	3	3.7	3-4	2.1	2-4
LM30630	3	6.2	5-8	3.4	2-6
MD 632(p) <sup>z</sup>	3	3.5	2-6	4.0	2-6
BAC 38(p)	4	3.6	2-5	4.2	3-7
Porrillo Sintético(p)	4	6.3	4-8	4.9	3-7
Carioca(c)	4	4.6	3-6	7.3	3-9
Carnaval(c)	4	8.7	8-9	4.0	2-7
Iapar 20(c)	4	4.1	2-6	6.6	5-8

<sup>w</sup> Results are from 2 to 4 years of trials in Londrina, PR, Brazil.

<sup>x</sup> Mean score for all years of evaluation.

<sup>y</sup> Lowest and highest disease score for a single plot (240 plants) considering all years of evaluation.

<sup>z</sup> p = parent, c = susceptible control.

**Table 2.** Percentage of diseased plants in improved bean lines, their parents, and susceptible control genotypes under conditions of moderate and high incidence of bean golden mosaic virus in the northeast and north regions of the state of Paraná, Brazil

Genotype	Moderate incidence (Days after planting)			High incidence (Days after planting)		
	20	35	50	20	35	50
MD 808	1.2 a <sup>y</sup>	15 a	93 bc	12 a <sup>y</sup>	99 ab	100
LM 30630	1.8 a	19 a	96 bc	12 a	100 b	100
MD 632(p) <sup>z</sup>	1.8 a	23 a	96 bc	13 a	100 b	100
MD 809	0.8 a	23 a	91 ab	14 a	97 ab	100
FT 120	1.4 a	38 ab	98 bc	16 a	100 b	100
MD 807	1.6 a	32 ab	93 bc	17 ab	98 ab	100
MD 806	2.1 a	28 ab	88 a	25 abc	93 a	100
Carnaval(c)	5.2 a	69 c	98 bc	34 bcd	100 b	100
MD 828	2.2 a	69 c	96 bc	35 cd	100 b	100
BAC 38(p)	5.4 a	53 bc	96 bc	41 cde	96 ab	100
Carioca(c)	5.1 a	73 c	96 bc	49 de	100 b	100
Iapar 20(c)	2.5 a	72 c	99 c	58 e	100 b	100

<sup>y</sup> Means followed by the same letter in the columns are not significantly different according to Tukey's HSD test ( $P \geq 0.05$ ).

<sup>z</sup> p = parent, c = susceptible control.

plant malformation was not different among these three genotypes (Table 1).

The percentage of infected plants was lower on the selected bean genotypes than on the susceptible cultivars under moderate BGMV pressure. The improved genotypes, including the parent MD 632, showed 15 to 32% of plants infected, while the susceptible controls had 69 to 73% of plants infected, at 35 DAP (Table 2). Under conditions of high viruliferous whitefly populations, the incidence of BGMV in the selected MD lines was significantly lower than in the susceptible controls during the initial growth stages (Table 2).

Bean golden mosaic symptoms were usually more severe at the beginning of their expression, followed by an apparent recovery of the plants. This recovery, however, was not enough to prevent significant yield loss in the susceptible cultivars. The response to BGMV infection was different in the susceptible controls. Carioca showed the most variable symptoms among the plants, including mild mosaic with severe foliar malformation and severe stunting, and intense yellowing with mild plant malformation, or a combination of these symptoms. Carnaval showed an intense

yellowing, while Iapar 20 showed predominantly foliar and pod distortion and severe stunting. The plant recovering capacity from BGMV infection was higher in Carioca than in the other susceptible controls. Iapar 20 had the most severe flower abortion and consequently the greatest yield reduction.

**Greenhouse conditions.** Under high viruliferous whitefly populations, mosaic severity scores in MD 806, MD 820, and MD 821 ranged from 2.8 to 3.4, and malformation scores ranged from 1.9 to 4.0. On susceptible controls Carioca, Carnaval, and Iapar 20, the mosaic scores ranged from 3.0 to 7.4, and malformation scores ranged from 5.4 to 8.4. The levels of severity for mosaic and malformation on Porrillo Sintético were 5.2 and 4.6, respectively (Table 3). At 15 DAP, a significant difference in the percentages of infected plants was observed between MD 821 and the susceptible cultivars. This delay in symptom expression was not observed in the other selected lines.

**Yield evaluation.** The most resistant lines, MD 806, MD 807, MD 820, MD 829, MD 808, and MD 821, always yielded higher than the susceptible controls under

BGMV incidence. When the infection occurred at the early stages of plant development, the disease severity and the yield damages increased on the susceptible cultivars. However, increased virus incidence was not correlated with yield damage in the resistant lines (Table 4). These lines had higher yields than the controls even under the highest disease pressure, and the average annual yields of all experiments ranged from 762 to 1,909 kg/ha. The most promising new lines yielded from 1.2- to 2.8-fold the yield of Carioca and from 2.2- to 5.9-fold the yield of Iapar 20 (Table 5).

The recovering capacity of Carioca from virus infection was more evident under moderate BGMV pressure, and the differences in yield between this cultivar and the resistant MD lines were significantly reduced. On the other hand, Carnaval had lower yield damages than Carioca under high virus pressure, while Iapar 20 showed the lowest yield under all conditions (Table 5). In addition to yield reductions, Carioca and Iapar 20 showed poor seed quality.

## DISCUSSION

The MD lines, under different BGMV pressure and environmental conditions, showed mild and delayed symptom expression and low yield damages, which demonstrates that they have resistance or tolerance to BGMV. The resistance to BGMV and better agronomic performance, as demonstrated during several years of trial, provide support for the commercial use of the MD lines wherever BGMV is known to occur. In addition, they may be used as sources of BGMV resistance in bean breeding programs.

The genotypes evaluated under greenhouse conditions had reactions to BGMV similar to those observed in the field, providing further evidence that the reactions of the selected MD lines to the virus were due to genetic factors.

The range of symptoms expressed by the susceptible cultivars indicates the existence of variability in the BGMV strains that occur in the state of Paraná. The expression of one type of symptom in a given cultivar suggests the presence of specific resistance to individual traits of the BGMV complex (12,19). This kind of reaction has been demonstrated by the ancestral parents of the MD lines. Aeté 1/38 and TMD-1 react to BGMV infection with low severity of mosaic (21,23) but are susceptible to plant malformation and stunting (1,12). On the other hand, the other ancestral parents, Porrillo Sintético and Turrialba 1, react to BGMV infection with moderate to severe mosaic but low or moderate plant malformation (A. Bianchini, unpublished data). Porrillo Sintético and Turrialba 1 are considered resistant to severe stunting (1) and resistant and moderately resistant, respectively, to Abutilon mosaic virus (12). Porrillo Sintético has shown the lowest degree of severity to different BGMV traits

**Table 3.** Mosaic, plant malformation, and stunting severity induced by bean golden mosaic virus and percentage of infected plants at 15 days after planting in bean selected lines, parent, and susceptible controls, inoculated with viruliferous whiteflies under greenhouse conditions

Genotype	Severity score		
	Mosaic	Malformation and stunting	% Infected plants
MD 820	3.2 a <sup>y</sup>	3.0 a	90 b
MD 821	3.4 a	1.9 a	40 a
MD 806	2.8 a	4.0 ab	97 b
Porrillo Sintético(p) <sup>z</sup>	5.2 b	4.6 ab	82 b
Carnaval(c)	7.4 c	5.4 bc	86 b
Carioca(c)	5.8 b	6.8 cd	96 b
Iapar 20(c)	3.0 a	8.4 d	96 b

<sup>y</sup> Means followed by the same letter in the columns are not significantly different according to Tukey's HSD test ( $P \geq 0.05$ ).

<sup>z</sup> p = parent, c = susceptible control.

**Table 4.** Yield and percentage of diseased plants (DP) in improved bean lines, their parents, and susceptible genotypes under field conditions with moderate and high bean golden mosaic virus incidence at 35 days after planting in the northeast and north regions of the state of Paraná, Brazil

Genotype	Virus incidence			
	Moderate		High	
	% DP	Yield (kg/ha)	% DP	Yield (kg/ha)
MD 808	15 a <sup>y</sup>	934 bc	99 ab	1,300 a
MD 807	32 ab	1,210 a	98 ab	1,265 a
LM 30630	19 a	934 bc	100 b	1,085 ab
MD 806	28 ab	974 b	93 a	952 abc
MD 809	23 a	1,189 a	97 ab	946 abc
FT 120	38 ab	947 bc	100 b	869 bc
MD 632(p) <sup>z</sup>	23 a	965 bc	100 b	794 bcd
BAC 38(p)	53 bc	880 bc	96 ab	762 bcd
Carnaval(c)	69 c	784 c	100 b	759 bcd
MD 828	69 c	1,043 ab	100 b	696 cd
Carioca(c)	73 c	778 c	100 b	459 de
Iapar 20(c)	72 c	493 d	100 b	220 e

<sup>y</sup> Means followed by the same letter in the columns are not significantly different according to Tukey's HSD test ( $P \geq 0.05$ ).

<sup>z</sup> p = parent, c = susceptible control.

among several genotypes tested at CIAT; therefore it was considered the most widely used source of BGMV resistance (19). In the present work, Porrillo Sintético showed moderate to severe mosaic and low to severe plant malformation (Table 1). Parental lines BAC 25, MD 648, MD 632, and BAC 38 had low to moderate mosaic severity and plant malformation and stunting (A. Bianchini, unpublished data), demonstrating progress in breeding for resistance to BGMV compared with the best ancestral parents, which showed resistance to specific BGMV traits. Besides the increment in the level of resistance of the selected MD lines, there was also an improvement in yield and in the commercial seed type. The genotype of *P. coccineus* used as parent of the lines MD 820 and MD 829 has an unknown reaction to BGMV; thus it was impossible in this study to determine the main source of resistance to BGMV in these MD lines. Considering the susceptibility of Carioca, the other parent, and its failure to produce progenies with resistance to BGMV in crosses with other genotypes, *P. coccineus* is the likely source of BGMV resistance observed in these crosses.

The different reactions of the parents involved in this bean breeding program and the gradual improvement in the levels of resistance of the progenies compared with their parents indicated that the resistance to BGMV in the MD lines probably is a combination of different resistance characters inherited from different sources. Experiments to determine the genetic heritability of some resistant lines demonstrated that the resistance to BGMV is controlled by polygenic factors with additive effects; there was a tendency to dominance for the resistance to plant malformation and to recessive expression for the resistance to mosaic (8). This indicates the occurrence

of different BGMV resistance traits in the MD lines and in their parents. Types of responses shown by the MD lines, such as the mild and delayed symptom expressions and the small reduction in plant growth and yield, have been classified as quantitative resistance (15) or field resistance (2,19).

The MD 806, MD 821, and MD 820 lines were released, respectively, as cultivars Iapar 57, Iapar 65, and Iapar 72 in the state of Paraná. Iapar 57 and Iapar 72 belong to the Carioca seed type group, while Iapar 65 belongs to the black-seeded group, with dull seeds. These cultivars have shown resistance to all BGMV traits and have proved to be valuable when cultivated under any conditions of virus incidence. Iapar 57 is the first bean cultivar resistant to BGMV in Brazil. Furthermore, the selected bean lines have been used as parents in the IAPAR's breeding program, producing new lines with improved levels of BGMV resistance and desirable agronomic qualities.

#### ACKNOWLEDGMENTS

I thank Rui P. Leite and Edegar Mariot for their helpful corrections and suggestions on the manuscript. Paulo D. Faria and Avelino Aragão provided invaluable technical assistance in the greenhouse and field trials.

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**Table 5.** Yield of improved bean lines with resistance to bean golden mosaic virus compared with that of susceptible controls under high virus disease incidence in the field<sup>w</sup>

Genotype	Yield <sup>x</sup> (kg/ha)			Proportion in relation to the controls					
	Mean	Lowest	Highest	Carioca			Iapar 20		
				Lowest	Highest	S/T <sup>y</sup>	Lowest	Highest	S/T
Non-black-seeded group									
MD 820	1,259	887	1,909	1.6	2.2	(3/3)	3.5	3.9	(2/2)
MD 807	1,287	750	1,697	1.3	2.7	(3/4)	2.7	5.7	(2/2)
MD 806	1,050	762	1,519	1.3	2.1	(2/4)	2.7	4.8	(3/3)
MD 829	1,186	970	1,412	1.2	1.3	(0/2)	...	...	...
MD 632(p) <sup>z</sup>	1,016	794	1,547	1.3	1.7	(0/3)	2.7	4.0	(3/3)
BAC 38(p)	826	478	1,409	1.2	1.7	(0/4)	1.7	4.4	(1/2)
Carioca(c)	623	406	1,165	1.0	1.0		1.8	3.2	(1/4)
Carnaval(c)	600	472	759	0.7	1.1	(0/4)	1.7	3.4	(1/4)
Black-seeded group									
MD 821	1,280	920	1,640	1.4	2.3	(2/3)	4.1	4.1	(1/1)
MD 808	1,307	957	1,638	1.4	2.8	(4/4)	3.4	5.9	(2/2)
P. Sintético(p)	826	459	1,157	1.0	2.0	(1/4)	2.1	2.1	(0/1)
Iapar 20(c)	262	220	315	0.3	0.6	(1/4)	1.0	1.0	

<sup>w</sup> Results are from 2 to 4 years of trials.

<sup>x</sup> Mean for all years, lowest and highest mean for a single experiment considering all years of evaluation.

<sup>y</sup> S = years with yield significantly higher than the susceptible controls according to Tukey's HSD test ( $P \geq 0.05$ ), T = total years of evaluation.

<sup>z</sup> p = parent, c = susceptible control.

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