Seed Transmission Characteristics of Selected Bean Common Mosaic Virus Strains in Differential Bean Cultivars

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ABSTRACT

Morales, F. J., and Castaño, M. 1987. Seed transmission characteristics of selected bean common mosaic virus strains in differential bean cultivars. Plant Disease 71:51-53.

One necrosis-inducing strain and four mosaic-inducing strains of bean common mosaic virus (BCMV) were differentially seed-transmitted in 14 mosaic-susceptible bean (*Phaseolus vulgaris*) cultivars. Dubbele Witte, Redlands Greenleaf B, Michelite, Sanilac, and Red Mexican 35 consistently transmitted the US 1, US 2, US 5, NL 3, and NL 4 strains of BCMV in 39.7–54.4% of the seed produced by infected plants. On the contrary, Imuna and the Great Northern lines 31 and 123 transmitted the virus in less than 1% of the seed tested. Pinto 114 did not transmit BCMV US 2 in tests involving more than 1,000 seeds. Maximum seed transmission rates were observed for test plants inoculated at the primary leaf stage. Twelve of 14 cultivars tested did not transmit any of the selected BCMV strains in seeds of plants inoculated 30 days after sowing. Number and weight of seeds produced by test plants inoculated at the primary leaf stage were reduced in relation to the same yield components analyzed for bean plants inoculated 20 days later. The necrosis-inducing BCMV NL 3 strain proved highly transmissible in the seed of the navy cultivars Sanilac and Michelite commonly cultivated in regions where this necrotic BCMV strain constitutes a production problem.

Bean common mosaic virus (BCMV) is the most ubiquitous pathogen of the common bean (*Phaseolus vulgaris* L.). The worldwide distribution of BCMV is primarily a consequence of its seedborne nature. Seed transmission properties of BCMV were the subjects of various reports published before 1935 (8). In general, it is accepted that the virus is transmitted in a high but variable proportion of the seed produced by mosaic-affected plants, depending on the bean cultivar and growth stage at which plants become infected. Little or no transmission occurs if a plant is infected after the blossoming stage (5). In this study, we review these properties in light of the wealth of new information available on the genetics of plant resistance and pathogenicity of BCMV (4) and in view of the ongoing economic and phytosanitary importance of bean common mosaic.

MATERIALS AND METHODS

Differential bean cultivars. Two common mosaic-susceptible cultivars (Dubbele Witte and Stringless Green Refugee) and 12 bean cultivars known to possess BCMV strain-specific recessive resistance (4) (Redlands Greenleaf C, Imuna, Puregold Wax, Redlands Greenleaf B, Great Northern 123, Sanilac, Michelite 62, Red Mexican 34, Pinto 114, Monroe, Great Northern 31, and Red Mexican 35) were selected for this study. These genotypes are part of the set of cultivars currently used to differentiate BCMV strains (4). Virus-free seed of these cultivars is regularly produced under screenhouse conditions at CIAT.

BCMV strains. Four mosaic-inducing BCMV strains, US 1 (type), US 2 (New York 15), US 5 (Florida), and NL 4 (Great Northern), and one mosaic/necrosis-inducing strain, BCMV NL 3, were used (4). Systemic necrosis (hypersensitive reaction) is only induced by certain BCMV strains in genotypes that possess monogenic dominant resistance to common mosaic. All the BCMV strains used in this study are maintained at CIAT in infected seed of differential bean cultivars.

Inoculation of test plants. The 14 bean cultivars were inoculated with their respective pathogenic BCMV strains as shown in Table 1. For each treatment and bean cultivar tested, 10 plants were manually inoculated at three growth stages: 10, 20, and 30 days after sowing in trays (53 × 27 × 7 cm) containing sterilized soil. The plants were manually inoculated with a sterile cheesecloth pad impregnated with a 1:10 (w/v) homogenate of BCMV-infected tissue ground in 0.01 M potassium phosphate buffer, pH 7.5. Sixty plants of each cultivar were inoculated with buffer alone as controls. These tests were conducted under glasshouse conditions (870 μE m^{-1} sec^{-1}, 26 C, and 75% relative humidity, average annual values) at 4-mo intervals to complete three replicates.

Evaluation of seed transmission incidence. All inoculated test plants showing typical common mosaic symptoms were grown to maturity. Harvested seed was dried to an approximate 14% moisture content, counted, and weighed for each test plant. The seed was finally sown in new trays, and the mosaic-affected plants were counted 20–60 days later. In the presence of mild

Table 1. Pathogenicity of selected bean common mosaic virus (BCMV) strains in six groups of differential bean cultivars[a]

	BCMV strain				
Cultivar group	**US 1**	**US 5**	**US 2**	**NL 3**	**NL 4**
1. Dubbele Witte	+[b]	+	+	+	+
Stringless Green Refugee	+	+	+	+	+
2. Redlands Greenleaf C	−	+	+	+	+
Puregold Wax	−	+	+	+	+
Imuna	−	+	+	+	+
3. Redlands Greenleaf B	−	+	−	+	+
Great Northern 123	−	+	−	+	+
4. Sanilac	−	−	+	+	−
Michelite 62	−	−	+	+	−
Red Mexican 34	−	−	+	+	−
5. Pinto 114	−	−	+	+	−
6. Monroe	−	−	−	−	+
Great Northern 31	−	−	−	−	+
Red Mexican 35	−	−	−	−	+

[a]These cultivars possess recessive resistance to BCMV and were grouped by Drijfhout (4) according to the distribution of five strain-specific genes inherited independently at three loci.
[b]+ = Chronic systemic infection and − = no infection.

Accepted for publication 12 May 1986.

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mosaic symptoms or possible latent infections, test plants were checked serologically by the enzyme-linked immunosorbent assay (2) or serologically specific electron microscopy (3). A computer analysis of variance was done for all data obtained using Duncan's multiple range test to analyze the variables studied.

RESULTS

All BCMV strains tested were seedborne in bean; however, seed transmission incidence varied considerably depending on the bean genotype and BCMV strain tested. Four cultivars, Imuna, Great Northern 123, Pinto 114, and Great Northern 31, did not transmit any of the inoculated BCMV strains in tests involving between 126 and 252 seeds harvested from systemically infected plants (Table 2). When the number of seeds tested was increased, the cultivars Imuna, Great Northern 31, and Great Northern 123 were shown to transmit BCMV in a very low proportion of the seeds produced by plants inoculated at the primary leaf stage with specific BCMV strains. The cultivar Pinto 114 did not transmit the BCMV US 2 strain in tests involving more than 1,000 seeds produced by systemically infected plants (Table 3).

Inoculation date has a significant effect on the incidence of seed transmission. Inoculating test plants within the first 20 days of their vegetative period significantly increased the percentage of seed transmission. With the exception of Redlands Greenleaf B and those cultivars that did not produce infected seed in the first test, BCMV seed transmission incidence was highest when plants were inoculated 10 days after sowing. Only two of the 14 cultivars tested (Dubbele Witte and Puregold Wax) transmitted BCMV in seed produced by plants infected 30 days after sowing (Table 4). The effect of the inoculation date on the number of viable seeds (shown as number of plants evaluated) produced by the test plants was also appreciable (Table 4). Two yield components, number of seeds and seed weight per plant, were statistically analyzed (Table 5). Eight out of the 24 cultivars tested suffered a significant yield reduction in one or both of the components analyzed for the first two inoculation dates chosen. Despite the lack of statistical significance, the number of seeds produced per plant was also lower for the remaining cultivars at their first inoculation date. Table 6 shows the maximum seed transmission incidence observed for the 14 bean cultivars, inoculated at the primary leaf stage with the five BCMV strains selected.

Table 2. Mean seed transmission incidence of selected bean common mosaic virus (BCMV) strains in differential bean cultivars inoculated at three different growth stages

	BCMV strain				
Differential cultivar	**US 1**	**US 5**	**US 2**	**NL 3**	**NL 4**
Dubbele Witte	14.6[z] abA	19.7 aAB	5.2 bC	19.6 aA	13.2 abA
Stringless Green Refugee	22.2 aA	20.3 aAB	0.0 bD	1.2 bC	12.0 abAB
Redlands Greenleaf C	···	5.8 aBC	0.0 bD	0.0 bC	0.0 bB
Imuna	···	0.0 aC	0.0 aD	0.0 aC	0.0 aB
Puregold Wax	···	29.0 aA	0.5 cCD	0.0 cC	10.0 bAB
Redlands Greenleaf B	···	15.1 aAB	···	0.0 bC	6.8 abAB
Great Northern 123	···	0.0 aC	···	0.0 aC	0.0 aB
Sanilac	···	···	12.7 aB	20.1 aA	···
Michelite 62	···	···	18.1 aA	15.4 aAB	···
Red Mexican 34	···	···	2.5 aCD	10.4 aB	···
Pinto 114	···	···	0.0 aD	0.0 aC	···
Monroe	···	···	···	···	52.2 A
Great Northern 31	···	···	···	···	0.0 B
Red Mexican 35	···	···	···	···	51.9 A

[z] Values represent the means (%) of three replicates and inoculation dates (10, 20, and 30 days after sowing). Means followed by the same letter are not significantly different ($P = 0.05$) between strains (lowercase letters) or differential cultivars (capital letters). Absence of data signifies not tested because of lack of pathogenic interaction.

Table 3. Seed transmission assay of selected bean common mosaic virus (BCMV) strains in differential bean cultivars

Differential cultivar	**BCMV strain**	**Plants infected/evaluated (no.)**	**Seed transmission incidence (%)**
Imuna	US 5	1/273	0.4
Great Northern 123	US 5	2/314	0.6
Pinto 114	US 2	0/1,126	0.0
Great Northern 31	NL 4	2/326	0.6

Table 4. Mean seed transmission incidence of five bean common mosaic virus strains in different bean cultivars inoculated at different growth stages

	Inoculation date[x]		
Cultivar group	**1**	**2**	**3**
1. Dubbele Witte	41.8[y]a (382)[z]	2.8 b (614)	0.1 b (719)
Stringless Green Refugee	19.0 a (243)	16.6 a (304)	0.0 b (389)
2. Redlands Greenleaf C	3.1 a (210)	1.3 a (355)	0.0 a (387)
Imuna	0.0 a (282)	0.0 a (426)	0.0 a (427)
Puregold Wax	17.4 a (208)	11.2 a (316)	3.1 b (339)
3. Redlands Greenleaf B	9.6 a (176)	12.4 a (189)	0.0 a (243)
Great Northern 123	0.0 a (237)	0.0 a (340)	0.0 a (343)
4. Sanilac	40.1 a (239)	9.1 b (264)	0.0 b (262)
Michelite 62	46.5 a (191)	4.6 b (228)	0.0 b (222)
Red Mexican 34	11.2 a (160)	8.0 a (143)	0.0 a (230)
5. Pinto 114	0.0 a (124)	0.0 a (143)	0.0 a (143)
6. Monroe	42.2 a (67)	0.0 b (109)	0.0 b (104)
Great Northern 31	0.0 a (69)	0.0 a (76)	0.0 a (88)
Red Mexican 35	46.6 a (79)	5.7 b (104)	0.0 b (123)

[x] 1 = 10 Days, 2 = 20 days, 3 = 30 days, after sowing.
[y] Values represent the means (%) of three replicates and, if followed by common letters, are not significantly different ($P = 0.05$) between inoculation dates according to Duncan's multiple range test.
[z] Figures in parentheses represent the total number of plants evaluated.

DISCUSSION

The results obtained in this study confirm earlier observations on the main seed transmission properties of BCMV. Our results, however, clearly demonstrate the existence of seed-infection resistance mechanisms in common mosaic-susceptible bean genotypes. These cultivars would be particularly desirable for bean production areas where BCMV is regarded as a pathogen of phytosanitary rather than economic significance.

These results also helped identify the most appropriate differential bean cultivars to maintain the main BCMV strains in infected seed. For instance, BCMV US 5 would be best maintained in Puregold Wax; US 2 strain, in Michelite;

Table 5. Comparative effects of three inoculation dates on two yield components analyzed in differential bean cultivars infected with selected bean common mosaic virus strains

Cultivar group	Inoculation date[y] 1		2		3	
	No. seeds	Weight (g)	No. seeds	Weight (g)	No. seeds	Weight (g)
1. Dubbele Witte	3.0 b[z]	0.8 b	4.7 a	1.2 a	5.1 a	1.3 a
Stringless Green Refugee	2.5 b	0.6 b	2.8 b	0.7 b	4.4 a	0.9 a
2. Redlands Greenleaf C	2.2 b	0.4 a	3.0 a	0.6 a	3.2 a	0.6 a
Imuna	2.7 b	0.5 b	3.7 a	0.8 a	4.1 a	0.8 a
Puregold Wax	2.5 a	0.6 a	2.8 a	0.7 a	2.9 a	0.7 a
3. Redlands Greenleaf B	2.0 a	0.5 a	2.3 a	0.5 a	2.7 a	0.6 a
Great Northern 123	3.3 b	0.8 b	4.4 a	1.0 a	4.7 a	1.0 a
4. Sanilac	5.0 a	1.0 a	6.3 a	1.0 a	5.6 a	0.8 a
Michelite 62	4.6 a	0.7 a	5.7 a	0.9 a	5.0 a	0.8 a
Red Mexican 34	3.6 a	0.8 a	3.8 a	1.0 a	4.4 a	1.0 a
5. Pinto 114	2.9 b	0.7 a	3.5 a	0.8 a	3.6 a	0.9 a
6. Monroe	4.1 a	0.6 b	4.8 a	0.9 a	5.6 a	0.8 a
Great Northern 31	3.1 a	0.6 b	3.1 a	0.6 b	3.9 a	0.8 a
Red Mexican 35	3.6 a	0.7 b	4.2 a	0.8 ab	4.5 a	1.2 a

[y] 1 = 10 Days, 2 = 20 days, and 3 = 30 days after sowing.
[z] Mean values of three replicates representing the number of seeds produced and their weight (g) per plant. Values followed by the same letter are not significantly different ($P = 0.05$) between inoculation dates.

Table 6. Maximum seed transmission incidence of five bean common mosaic virus (BCMV) strains in differential bean cultivars

Cultivar group	BCMV strain US 1	US 5	US 2	NL 3	NL 4
1. Dubbele Witte	43.5[a]	57.5	20.23	43.2	37.1
Stringless Green Refugee	29.7*	29.7	0.0	8.3	26.5
2. Redlands Greenleaf C	···	12.3	0.0	0.0	0.0
Imuna	···	0.0	0.0	0.0	0.0
Puregold Wax	···	52.9*	1.6	0.0	25.0
3. Redlands Greenleaf B	···	28.7*	···	0.0	12.1
Great Northern 123				0.0	0.0
4. Sanilac	···	···	24.1	39.7	···
Michelite 62	···	···	54.4	34.7	···
Red Mexican 34	···	···	4.7	17.0	···
5. Pinto 114			0.0	0.0	···
6. Monroe	···	···	···	···	42.2
Great Northern 31	···	···	···	···	0.0
Red Mexican 35	···	···	···	···	46.6

[a] Values represent mean percentage of three replicates corresponding to the first inoculation date (10 days after sowing), with the exception of values accompanied by an asterisk, which were obtained for the second inoculation date (20 days after sowing). Absence of data means not tested because of lack of pathogenic interaction.

BCMV NL 3, in Sanilac; and BCMV NL 4, in either Monroe or Red Mexican 35. Dubbele Witte is suitable to maintain all of the BCMV strains tested, but it would not act as a differential cultivar.

The negative effect of the BCMV strains tested on two important yield components was also observed in this investigation, particularly for plants infected at the early stages of their vegetative growth period. Yield reduction was statistically significant, even in cultivars that do not efficiently transmit BCMV via the seed.

The necrosis-inducing NL 3 strain has a relatively low transmissibility in most of the differential cultivar groups (Table 1) proposed by Drijfhout (4) according to the presence or absence of five strain-specific recessive genes in these cultivars. In contrast, this strain has an appreciable seed transmission incidence in cultivars belonging to group 4, particularly in the navy (small white-seeded) cultivars Sanilac and Michelite. This is an interesting finding considering that the incidence of BCMV NL 3 is higher in areas such as central Chile (1), northeastern United States (6), and southeastern Africa (F. Morales, *unpublished*) that have a past (7) or present record of navy bean production. A high seed transmission incidence was also observed for the BCMV US 2 strain in Sanilac and Michelite. Seed-transmission properties of BCMV will continue to have important epidemiological implications as long as susceptible genotypes remain in cultivation.

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