Reaction of Select Tepary Bean to Bean Golden Mosaic Virus

Phillip N. Miklas¹ and Jose Santiago

U.S. Department of Agriculture, Agricultural Research Service, Tropical Agriculture Research Station, P.O. Box 70, Mayagüez, PR 00681

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Abstract. Cultivated tepary bean (*Phaseolus acutifolius* A. Gray var. *latifolius* Freeman) has potential for production during the hot, dry seasons in the tropics. Bean golden mosaic virus (BGMV), however, seriously limits production of *Phaseolus* spp. in such environments. Twelve select tepary beans were evaluated for reaction to BGMV across four field nurseries near Isabela, Puerto Rico. Disease reaction was principally determined by measurement of seed yield (kg·ha⁻¹) and weight (g 100/seeds). All tepary beans possessed some tolerance to BGMV, as they produced comparatively moderate seed yield despite expression of severe foliar yellow mosaic symptoms. On average, tepary bean yielded 133% of the BGMV-resistant dry bean (*Phaseolus vulgaris* L.) control 'Dorado'. Four teparies, Neb-T-6-s, GN-610-s, Neb-T-8a-s, and PI 321637-s, expressed superior tolerance to BGMV as they yielded above the trial mean in at least three of four trials. Harvested seed quality was uniformly poor across all lines, averaging 18% less weight than in the non-BGMV trials. The combination of the observed tolerance with escape mechanisms and cultural disease control practices may enable production of tepary bean in regions and seasons that experience moderate to severe BGMV epidemics.

The cultivated tepary bean, an annual legume similar to dry bean, is indigenous to the Sonoran region of Mexico and the southwestern United States (Nabhan and Felger, 1978). Teparies are also grown in Central America where production is mostly limited to the arid coastal plains. Because of their domestication in these hot, dry environments, tepary bean is adapted to extreme heat and drought stress (Nabhan, 1979). For this reason, tepary bean has received considerable attention as a potential crop in arid regions around the world and in places with hot, dry seasons (e.g., some tropical regions). In addition, traits from tepary bean have been used to improve dry bean, as monogenic resistance to common bacterial blight caused by *Xanthomonas campestris* pv. *phaseoli* (Smith) Dye, and its transfer via interspecific hybridization using embryo rescue, has been well documented (Drijfhout and Blok, 1987; Honma, 1956; Parker and Michaels, 1986; Scott and Michaels, 1992).

Bean golden mosaic virus (BGMV) limits the yield of tepary bean on the coastal plains of Honduras and Nicaragua and is a major disease of common bean throughout the warmer regions of the Americas (Beebe and Pastor-Corrales, 1991). We sought to evaluate the potential for tepary bean to produce an ad-

equated seed crop during BGMV epidemics by screening a select group of high-yielding tropically adapted tepary beans (Miklas et al., 1994) for disease reaction to natural BGMV infection in the field.

Materials and Methods

Germplasm. Twelve tropically adapted tepary bean genotypes were evaluated for disease reaction to natural BGMV infection across four field environments. The 12 genotypes were Neb-T-1-s, Neb-T-6-s, Neb-T-8a-s, Neb-T-15-s, GN-605-s, GN-610-s, PIs 321637-s, 321638-s, 440788-s, 440806-s, 502217-s, and PI 312122-s. Their development and general characteristics were reported by Miklas et al. (1994). 'Dorado' (formerly DOR 364; Beebe and Pastor-Corrales, 1991) and 'Arroyo Loro', tropically adapted and high-yielding dry beans, were included as BGMV-resistant and -susceptible controls, respectively. The original accessions underwent single-plant and bulk selection to obtain tepary bean lines of more uniform agronomic type (maturity, seed color and shape, growth habit) and resistance to disease, particularly common bacterial blight (Miklas et al., 1994). All 12 lines exhibited adequate seed weight (>10 g 100/seed) and high yield potential across an array of tropical environments in Puerto Rico and Honduras, and some possessed uniform resistance to rust [*Uromyces appendiculatus* (Pers.) Unger var. *appendiculatus*] and powdery mildew (*Erysiphe polygoni* DC.) (Miklas et al., 1994).

Evaluations. Each entry (12 teparies and two dry bean controls) was planted at 160,000 seeds/ha in a randomized complete block with three replications. Plots were single rows, 1.0 m long. For the 1995 trial, the plot size was two rows, each 2 m long, and spacing between rows in both trials was 0.9 m. Each plot repre-

sented an experimental unit. Granular fertilizer (kg·ha⁻¹), 59N–40P–2.3K, was sidedressed ≈18 days after planting. A combination of preemergence herbicide and mechanical and hand cultivation was used to control weeds. Overhead irrigations were applied when needed. About 45 days after planting, combined disease incidence and severity was scored using a 1–9 scale (Morales and Singh, 1993; Schoonhoven and Pastor-Corrales, 1987), where the percentage of canopy with mosaic was 1 = 0%, 3 = 10% to 20%, 6 = 50% to 65%, and 9 = greater than 95%. Once plots matured, they were combined using a stationary small-plot thresher. Seeds were dried in a mechanical air-flow oven for 48 h at 38°C to equalize moisture content before cleaning (by hand-held screens) and obtaining weights. After drying and cleaning the seed, yield (kg·ha⁻¹) and weight (g 100/seeds) were recorded for each plot.

Inoculation. Four BGMV field screening trials were conducted at the U.S. Dept. of Agriculture, Agricultural Research Service Research Farm near Isabela, Puerto Rico, during Spring (planted 16 Feb.), Summer (25 May), and Fall (28 Sept.) 1994, and late Spring (12 Apr.) 1995. To increase natural BGMV inocula, groups of three rows of 'Arroyo Loro' were sown first, on each side of, and every 20 m within, the eventual experimental area. Once yellow mosaic symptoms were relatively uniform across these spreaders (≈28 days after planting), the tepary lines and dry bean controls were sown. The trials, excluding 1995, were contiguous and planted using a relay system, whereby spreaders for the new trial were planted beside the preceding trial as it approached physiological maturity. To promote movement of BGMV by the whitefly vector (*Bemisia argentifolia* and *B. tabaci*) across a new planting, seed were sown on the leeward side of the previous planting. Relay-cropping in this manner maintained an adequate population of the vector and provided a reservoir of BGMV inoculum for each succeeding planting.

Analysis. The combined data across four BGMV trials were subjected to analysis of variance using the GLM procedure of SAS (SAS Inst., 1987). Homogeneity of error variance (Bartlett's test) was detected across experiments for each trait. Simple correlations (*r*) were computed between mean seed yield and seed weight obtained across the BGMV trials of this study and non-BGMV-infected trials from a previous study (Miklas et al., 1994).

Results and Discussion

The tepary bean lines apparently possessed tolerance to BGMV, as they produced a moderate seed yield despite expression of severe foliar yellow mosaic symptoms (Tables 1 and 2). The 12 tepary bean lines varied in their tolerance to BGMV within and across environments, however, as evidenced by significant (*P* < 0.05) line and line × environment effects for seed yield and seed weight. Neb-T-6-s, GN-610-s, Neb-T-8a-s, and PI 321637-s

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¹Current address: U.S. Dept. of Agriculture, Agricultural Research Service, Irrigated Agriculture Research and Extension Center, 24106 N. Bunn Rd., Prosser, WA 99350-9687; to whom reprint requests should be addressed.

Table 1. Mean seed yield and bean golden mosaic virus (BGMV) score of 12 cultivated tepary bean and two dry bean controls grown across four BGMV field-screening nurseries near Isabela, Puerto Rico.

Line	Yield (kg·ha ⁻¹)						BGMV score ^y
	1994			1995	Disease	Nondisease	
	Spring	Summer	Fall	Summer	mean	mean ^z	
Tepary bean							
Neb-T-6-s	832	1262	251	547	723	1450	7.8
GN-610-s	1108	628	108	682	632	1368	7.8
Neb-T-8a-s	1087	1040	145	221	623	1389	8.4
PI 321637-s	615	1236	188	375	604	1010	8.6
Neb-T-1-s	606	746	36	751	535	1328	8.0
PI 502217-s	915	703	66	290	493	1339	7.9
GN-605-s	760	827	52	169	452	1052	7.8
Neb-T-15-s	692	565	30	493	445	1276	8.1
PI 440788-s	931	393	29	173	381	1348	7.3
PI 312122-s	574	823	64	115	394	---	8.1
PI 440806-s	574	696	93	87	363	1158	8.3
PI 321638-s	841	414	52	74	345	1329	7.2
Dry bean controls							
Dorado	536	301	398	265	375	---	4.1
Arroyo Loro	120	45	81	9	64	---	7.3
Mean ^x	728	691	114	303	461	---	7.6
LSD _(0.05)	352	321	96	323	143	---	0.7
CV%	63	29	28	50	38	---	11.2

^xMean seed yield averaged across six non-BGMV-infected field trials (Miklas et al., 1994).

^yAverage disease (1–9) score obtained across the four environments, where the percentage of canopy with mosaic was: 1 = 0%, 3 = 10% to 20%, 6 = 50% to 65%, and 9 = greater than 95% (Morales and Singh, 1993; Schoonhoven and Pastor-Corrales, 1987).

^zAdditional LSDs ($P \leq 0.05$) for the combined analysis of seed yield across four BGMV trials: environment = 76; line × environment = 86. Trial means include the dry bean controls.

Table 2. Mean seed weight of 12 cultivated tepary bean and two dry bean controls grown across four bean golden mosaic virus field-screening nurseries near Isabela, Puerto Rico.

Line	Seed wt (g 100/seeds)					
	1994			1995	Disease	Nondisease
	Spring	Summer	Fall	Summer	mean	mean ^z
Tepary bean						
PI 321637-s	15.7	10.3	11.8	10.5	12.1	13.3
PI 440806-s	15.8	10.0	9.9	11.7	11.8	12.8
Neb-T-6-s	13.8	9.8	9.8	10.2	10.9	13.8
GN-610-s	15.3	9.7	9.1	9.7	10.9	12.7
PI 502217-s	15.2	8.8	9.2	9.7	10.7	13.4
Neb-T-8a-s	14.3	9.3	10.4	8.4	10.6	13.0
PI 440788-s	14.8	8.2	7.8	9.0	10.0	12.0
Neb-T-15-s	13.2	8.5	8.7	9.7	10.0	13.8
PI 312122-s	11.7	8.5	8.9	10.7	9.9	---
Neb-T-1-s	12.7	8.0	9.1	8.5	9.6	10.7
GN-605-s	11.8	7.0	6.7	9.3	8.7	10.7
PI 321638-s	12.5	6.5	7.0	7.8	8.4	11.0
Dry bean						
Dorado	17.0	13.5	14.2	15.2	15.0	---
Arroyo Loro	14.0	11.0	12.2	13.4	12.6	---
Mean ^y	14.1	9.2	9.6	10.2	10.8	---
LSD _(0.05)	1.3	0.9	1.6	0.9	0.6	---
CV%	6.8	6.2	9.7	5.2	7.2	---

^xMean seed weight averaged across five non-BGMV-infected field trials (Miklas et al., 1994).

^yAdditional LSDs ($P \leq 0.05$) for the combined analysis across four BGMV trials: environment = 0.3; line × environment = 1.3. Trial means include the dry bean controls.

were the most tolerant lines across environments. The line × environment interactions suggest that multiple environment testing is necessary to identify those tepary bean lines with the greatest tolerance to BGMV.

Severe disease pressure occurred in all four trials as evidenced by low seed yields and intermediate disease scores for the BGMV-resistant control ‘Dorado’ and extremely low yields and high disease scores for the susceptible control ‘Arroyo Loro’ (Table 1). Tepary bean seed yields averaged 133% of the resistant dry bean ‘Dorado’ across all four trials. Only in the fall trial (1994) did tepary bean average less yield than ‘Dorado’. Although

tepany bean lines exhibited severe foliar yellow mosaic, they did not possess the susceptible symptoms (Galvez and Morales, 1989) of severely twisted and deformed pods, and low seed yield, as is usually characteristic of dry bean germplasm not previously selected for resistance to BGMV. The 12 tepary bean lines thus showed a mechanism similar to the dry beans ‘Honduras 46’ and DOR 316 for tolerance to BGMV (Beebe and Pastor-Corrales, 1991), i.e., moderate seed yield despite severe foliar yellow mosaic symptoms.

The BGMV-induced yield reduction of Neb-T-6-s, GN-610-s, Neb-T-8a-s, and PI 321637-s, as deduced from seed yields from

non-BGMV-infected trials in a previous study that involved 11 of the same lines (Miklas et al., 1994), was the lowest among the genotypes and ranged from 40% to 55%. The yield reduction of the seven remaining lines in the previous study ranged from 57% to 74%. The low ($r = 0.27$, 9 df, NS) correlation between mean seed yields from the diseased and nondiseased trials (Miklas et al., 1994) also reflected the differential seed yield response of tepary bean to BGMV infection. In the present study, Neb-T-1-s, GN-605-s, Neb-T-15-s, and PIs 312122-s, 321638-s, 440788-s, 440806-s, and 502217-s appeared to possess relatively intermediate levels of tolerance to BGMV because they averaged about the same yield across environments as did the BGMV-resistant dry bean ‘Dorado’.

Although moderate seeds yields in the presence of severe mosaic symptoms were achieved, the quality of the harvested seed was poor. Seed weights (g 100/seeds) across tepary bean lines (Table 2) were 83% of those observed across non-BGMV trials in a previous study (Miklas et al., 1994). The apparent reduction in seed weight of tepary bean resulting from BGMV infection was slightly less than that which occurred for the dry bean controls ‘Dorado’ (74%) and ‘Arroyo Loro’ (79%). A significant correlation between average seed weight from infected and noninfected trials ($r = 0.77$, 9 df, $P \leq 0.01$) indicates that the amount of reduction in seed weight due to BGMV was relatively uniform across lines. Moreover, this correlation suggests that the differential reduction in seed yield among lines described above results more from differences in the number of seeds harvested than differential reduction of the mean weight of harvested seeds.

If tolerance to BGMV is quantitatively controlled, then transfer of this trait to dry bean via interspecific hybridization will be extremely difficult. The tolerance expressed by the dry bean ‘Honduras 46’ has been readily transferred intraspecifically and suggests that interspecific transfer of BGMV tolerance is possible. PI 321638, the tepary line least tolerant to BGMV, is known to produce semi-fertile interspecific lines when crossed with *P. vulgaris* (Thomas and Waines, 1984). The four most tolerant lines (Neb-T-6-s, GN-610-s, Neb-T-8a-s, and PI 321637-s) may not combine with dry bean as readily as PI 321638, posing another challenge to the interspecific transfer of BGMV tolerance.

Tolerance to BGMV alone will not ensure successful production of tepary bean in the hot, dry seasons in the tropics where they are best adapted (Miklas et al., 1994), because BGMV epidemics in those environments can be extremely severe. Integrated management practices that combine tolerance with escape mechanisms (e.g., early maturity) and cultural practices (e.g., eradication of alternate hosts, rouging diseased plants, instituting fallow periods between plantings, and strategic plantings that avoid buildup of BGMV inoculum or the whitefly vector) may enable production of tepary bean in those regions that experience moderate to severe BGMV epidemics.

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