

Performance and response to web blight and angular leaf spot of tropical black bean genotypes

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ABSTRACT

Objective: To identify black bean genotypes resistant to web blight and angular leaf spot, with yield significantly superior to that of the Negro Jamapa variety.

Design/methodology/approach: Eleven genotypes were evaluated using a randomized complete block design with three replications. Their reactions to both diseases were rated using the 1 to 9 scale of the International Center for Tropical Agriculture (CIAT). Grain yield was estimated in kilograms per hectare. Analyses of variance were performed on the quantified variables, and a combined analysis was conducted for grain yield. Mean separation was carried out using the Least Significant Difference test at a 0.05 significance level.

Results: With mean disease severity values ranging from 2.0 to 3.33, five lines and the Verdín variety demonstrated resistance to web blight. Nine lines, along with Verdín, also exhibited resistance to angular leaf spot. Among these two groups of outstanding genotypes for disease resistance, Jamapa Plus/XRAV-187-3-4-4 and Jamapa Plus/XRAV-187-3-4-1 were the most productive, with average yields exceeding 2100 kg ha⁻¹, statistically similar to those of Verdín and Jamapa Plus/XRAV-187-3-1-2.

Limitations on study/implications: Although angular leaf spot did not significantly affect bean yield, the disease incidence and the severity in the regional control were sufficient to evaluate and classify the genotypes' reaction to this disease under natural infection conditions.

Findings/conclusions: The three lines derived from the Jamapa Plus/XRAV-187-3 cross and the Verdín variety exhibited resistance to both diseases and achieved an average yield significantly higher than that of the Negro Jamapa variety.

Keywords: *Phaseolus vulgaris* L., diseases, genetic resistance, productivity.

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INTRODUCTION

Fungal diseases are one of the main biotic factors that commonly affect bean cultivation in the tropical and subtropical regions of the state of Veracruz, Mexico (López-Salinas *et al.*, 2006). Among these, angular leaf spot, caused by the fungus *Phaeoisariopsis griseola* (Sacc.) Ferraris, stands out due to its prevalence in both residual moisture plantings during the autumn-winter cycle and rainfed plantings in the summer cycle. The latter are primarily



carried out in the Las Altas Montañas region in the central part of the state, at altitudes above 800 m (Tosquy-Valle *et al.*, 2012; Becerra-Leor *et al.*, 2021).

Angular leaf spot is characterized by causing angular lesions on the lower leaves, bordered by reddish-brown veins, where spores form and serve as the inoculum for secondary leaves. The lesions can spread across the entire leaf blade, causing defoliation. On the pods, the lesions are oval and circular, dark brown or reddish in color. Environmental conditions with high relative humidity (>70%), alternating with dry or low-humidity days and temperatures between 18 and 25 °C, promote infection and the development of angular leaf spot (Garza-García *et al.*, 2009), which can cause yield losses exceeding 70% in beans (Tosquy-Valle *et al.*, 2013).

Web blight, although less frequent in the state, also causes significant damage (Tosquy-Valle *et al.*, 2012). This disease is caused by the fungus *Thanatephorus cucumeris* (Frank) Donk in its perfect (sexual) stage, which infects the plant through basidiospores, while its imperfect (asexual) stage is known as *Rhizoctonia solani* Kühn (Becerra-Leor *et al.*, 2021). Symptoms include grayish-green to dark brown spots on the leaves, resembling hot water burns. The fungal mycelium spreads to other plant organs, growing in a web-like manner until it completely covers the plant. The leaves adhere to each other, leading to rapid and severe defoliation, while young pods may be entirely destroyed; in mature pods, lesions merge, causing severe damage (Araya-Fernández & Hernández-Fonseca, 2006; Atilio & Reyes, 2008).

The development of web blight is favored by periods of high precipitation, relative humidity above 80%, and temperatures between 20 and 30 °C (Gálvez *et al.*, 1989). This fungus can affect multiple bean plant organs at any phenological stage and, in severe cases, can cause total crop loss within one to two weeks, especially in lowland tropical areas (Rodríguez *et al.*, 1999; Pedroza-Sandoval *et al.*, 2010).

In Veracruz, web blight occasionally occurs in bean plantings in the central zone and the Las Altas Montañas region (Tosquy-Valle *et al.*, 2024), and more frequently during the autumn-winter cycle in the municipalities of Martínez de la Torre and Tlapacoyan, located in the northern zone, where it has caused significant reductions in grain yield (Rodríguez-Rodríguez *et al.*, 2016).

Most farmers in Veracruz use low-yielding landrace varieties, others of unknown origin, and some improved varieties such as Negro Jamapa, which was developed over six decades ago by the former INIA (Rosales-Serna *et al.*, 2004), all of which are susceptible to these diseases (Ugalde-Acosta *et al.*, 2014; Rodríguez-Rodríguez *et al.*, 2016; Tosquy-Valle *et al.*, 2024). Moreover, they generally do not apply fungicides due to the increased production costs (Tosquy-Valle *et al.*, 2013). The use of fungicides, the implementation of agronomic practices such as zero tillage, and the cultivation of improved varieties with high-yield potential and resistant or tolerant to web blight and angular leaf spot can significantly reduce yield losses and increase crop productivity (Rodríguez *et al.*, 1999; Tosquy-Valle *et al.*, 2013).

The objective of this study was to identify black bean genotypes resistant to web blight and angular leaf spot under field conditions, with higher grain yield than the Negro Jamapa cultivar, which is commonly used by farmers in Veracruz, Mexico.

MATERIALS AND METHODS

During the 2019-2020 autumn-winter agricultural cycle (September-February), a bean trial was conducted under residual moisture conditions in two locations within the municipality of Orizaba, in the Las Altas Montañas region of central Veracruz, Mexico: Rincón Grande (18° 51' N, 97° 06' W, altitude 1,248 m) and Rincón Chico (18° 50' N, 97° 05' W, altitude 1,191 m). The soils in both locations have a sandy loam texture, a high organic matter content (5.96% and 5.90%, respectively), and a moderately acidic pH (6.51 and 5.85, respectively).

Eleven advanced black bean lines were evaluated: five derived from the Negro Papaloapan/SEN 46 cross, three from the Negro Citlali/XRAV-187-3 cross, and three from the Jamapa Plus/XRAV-187-3 cross, along with the varieties Negro Medellín (López-Salinas & Acosta-Gallegos, 2002), Verdín (Tosquy-Valle *et al.*, 2016) and Negro Jamapa, as the regional control. All these materials were developed for the tropical areas of southeastern Mexico by the National Institute of Forestry, Agricultural, and Livestock Research (INIFAP).

The genotypes were planted at a density of 250,000 plants ha⁻¹, in a randomized complete block design with three replications and experimental plots consisting of three 5-meter-long rows, with the useful plot corresponding to the entire central row. Agronomic management was carried out according to the recommendations of INIFAP for bean cultivation in Veracruz (López-Salinas *et al.*, 2017).

During the trial, rainfall was recorded, and at the R8 stage (pod filling) of the genotypes, the severity of web blight was visually assessed in Rincón Grande and angular leaf spot in Rincón Chico. The general 1 to 9 scale from CIAT was used to evaluate the reaction of the black bean germplasm to fungal pathogens (van Schoonhoven & Pastor-Corrales, 1987), where a reaction score of 1 to 3 is considered resistant (no or very mild symptoms), 4 to 6 is intermediate (visible symptoms causing limited economic damage), and 7 to 9 is susceptible (severe to very severe symptoms, causing significant yield loss or plant death). After harvest, the grain yield was determined in each useful plot, adjusted to 14% moisture content, and expressed in kilograms per hectare.

Individual analyses of variance were performed for the quantified variables and a combined analysis for grain yield. The Least Significant Difference test at a 5% probability level (LSD, $\alpha=0.05$) was applied for mean separation (SAS Institute, 1999). Correlation analyses were also performed between the average severity values of each disease and the grain yield of the genotypes at each trial site to determine if these diseases caused significant damage to bean production (Olivares, 1994).

RESULTS AND DISCUSSION

Significant differences ($p \leq 0.01$) between treatments were detected in the individual analyses of variance for all quantified variables (Table 1), indicating that the genotypes showed differences in their reaction to web blight and angular leaf spot, as well as in their productive capacity.

In Rincón Grande, the high relative humidity (>85%) due to constant rainfall during the reproductive phase of the crop, and moderate to high temperatures (between 19 and

Table 1. Mean squares and statistical significance of quantified variables in the black bean genotypes trial in two environments of the Las Altas Montañas region, central Veracruz state. Fall-winter cycle of 2019-2020.

SV	DF	Web blight ¹	Grain yield ¹	Angular leaf spot ²	Grain yield ²
Treatments	13	4.690**	171881.53**	2.703**	420000.00**
Blocks	2	2.952	32834.00	2.167	3056.00
Error	26	0.773	24293.85	0.731	47894.15
Total	41				
CV (%)		22.11	13.46	26.79	7.93

SV: source of variation. DF: degrees of freedom. 1: Rincón Grande. 2: Rincón Chico. **: Significant at 0.01 level. CV: coefficient of variation

30 °C), favored the incidence of web blight starting from the beginning of the pod-filling stage, which significantly reduced grain yield ($r = -0.810^{**}$). These results confirm what was reported by Takegami *et al.* (2004) and Costa-Coelho *et al.* (2014), in the sense that greater damage caused by web blight results in lower bean grain yield. The three lines derived from the cross Jamapa Plus/XRAV-187-3, along with the lines Negro Papaloapan/SEN 46-3-2 and Negro Papaloapan/SEN 46-2-6 and the variety Verdín, showed resistance to this disease, with average severity ratings between 2.0 and 3.33 (Table 2).

Table 2. Resistance reaction of black bean genotypes to web blight and angular leaf spot in two environments of the Las Altas Montañas region of Veracruz, Mexico. Fall-winter cycle of 2019-2020.

Genotype	Scale of 1 to 9 [†]	
	Web blight	Angular leaf spot
Negro Papaloapan/SEN 46-2-6	3.33 cde	2.67 cd
Negro Papaloapan/SEN 46-3-2	2.00 e	4.00 abc
Negro Papaloapan/SEN 46-7-7	4.33 bcd	4.00 abc
Negro Papaloapan/SEN 46-7-10	4.33 bcd	3.00 bcd
Negro Papaloapan/SEN 46-7-12	4.33 bcd	2.00 d
Negro Citlali/XRAV-187-3-1-5	5.67 ab	2.67 cd
Negro Citlali/XRAV-187-3-1-6	5.33 ab	3.00 bcd
Negro Citlali/XRAV-187-3-1-8	4.67 abc	2.67 cd
Jamapa Plus/XRAV-187-3-1-2	3.33 cde	3.33 bcd
Jamapa Plus/XRAV-187-3-4-1	2.00 e	2.00 d
Jamapa Plus/XRAV-187-3-4-4	3.00 de	3.33 bcd
Negro Medellín	4.33 bcd	5.33 a
Negro Jamapa (Regional control)	6.00 a	4.33 ab
Verdín	3.00 de	2.33 d
Environment average	3.97	3.19
LSD (0.05)	1.476	1.435

[†] Severity values using the general scale of 1 to 9 (van Schoonhoven & Pastor-Corrales, 1987). Means with the same letters in each column of averages are statistically similar according to the Least Significant Difference (LSD, 0.05).

In contrast, the variety Negro Jamapa was the most affected by web blight, with damage statistically similar to that shown by the three lines derived from the cross Negro Citlali/XRAV-187-3 and significantly higher than the rest of the genotypes (Table 2). The resistance of Verdín and the susceptibility of Negro Jamapa to web blight have already been documented (Rodríguez-Rodríguez *et al.*, 2016; Tosquy-Valle *et al.*, 2023).

In Rincón Chico, angular leaf spot appeared towards the end of the pod filling stage, so it did not significantly affect yield ($r = -0.454$ ns). These results are consistent with those reported by López-Salinas *et al.* (2006) in Medellín, Veracruz, and Tosquy-Valle *et al.* (2012) in Tecamachalco, Puebla, who also found a negative and significant relationship with grain yield in the presence of this disease from pod formation to filling.

Most of the genotypes had average severity ratings between 2.0 and 3.3, indicating that they only showed mild symptoms of angular leaf spot (van Schoonhoven & Pastor-Corrales, 1987), while the variety Negro Medellín was the most affected with an average severity value of 5.33, statistically similar to that of the variety Negro Jamapa and the lines Negro Papaloapan/SEN 46-3-2 and Negro Papaloapan/SEN 46-7-7, and significantly higher than the rest of the genotypes (Table 2).

Among the genotypes resistant to web blight in Rincón Grande, the three lines derived from the cross Jamapa Plus/XRAV-187-3 and the variety Verdín also stood out for their grain yield, which was statistically similar to that of the line Papaloapan/SEN 46-7-12. In contrast, the two lines derived from the cross Negro Citlali/XRAV-187-3 and the variety Negro Jamapa (which showed the greatest damage caused by this disease) were the least productive (Table 3).

In turn, in Rincón Chico, the lines Jamapa Plus/XRAV-187-3-4-4, Jamapa Plus/XRAV-187-3-4-1, and Negro Citlali/XRAV-187-3-1-6, as well as the variety Verdín, were the most productive with a grain yield greater than 3000 kg ha^{-1} , statistically similar to each other, while Negro Jamapa and Negro Medellín, which showed higher severity values for angular leaf spot, were the least productive (Table 3).

According to the combined analysis, yield also varied significantly between environments, genotypes, and their interaction ($P \leq 0.01$). The highest average yield was obtained in Rincón Chico (Table 3), largely due to the favorable humidity (total rainfall of 374.1 mm) and temperature (average of $17.8 \text{ }^\circ\text{C}$) conditions during the crop cycle, even though angular leaf spot was present, it did not significantly affect bean yield. In contrast, in Rincón Grande, despite beans were sown in soil rich in organic matter with a pH close to neutrality, optimal for crop development (Edmeades *et al.*, 2012; Kyomuhendo *et al.*, 2020), the presence of web blight significantly reduced bean yield.

In the genotype factor, eight lines and the Verdín variety were placed in the outstanding group for average grain yield, with Jamapa Plus/XRAV-187-3-4-4 and Jamapa Plus/XRAV-187-3-4-1 being the most productive. The first line has shown significantly outstanding average grain yields in previous evaluations conducted in different environments with fungal and viral disease incidence in the states of Veracruz and Chiapas (Tosquy-Valle *et al.*, 2019). On the other hand, the Negro Jamapa variety was the least productive, mainly due to significant damage from web blight and angular leaf spot, with its average

Table 3. Grain yield of black bean genotypes evaluated in two environments in the Las Altas Montañas region of Veracruz, Mexico. Autumn-winter cycle of 2019-2020.

Genotype	Rincón Grande [†]	Rincón Chico [†]	Average
Negro Papaloapan/SEN 46-2-6	1166.67 cd	2718.67 def	1942.67 abc
Negro Papaloapan/SEN 46-3-2	1233.33 bcd	2933.33 bcd	2083.33 ab
Negro Papaloapan/SEN 46-7-7	1222.00 bcd	2654.67 def	1938.33 abc
Negro Papaloapan/SEN 46-7-10	1117.67 d	2503.33 ef	1810.50 bc
Negro Papaloapan/SEN 46-7-12	1326.67 abcd	2662.00 def	1994.33 ab
Negro Citlali/XRAV-187-3-1-5	789.00 f	2531.00 ef	1660.00 bc
Negro Citlali/XRAV-187-3-1-6	715.33 f	3227.67 ab	1971.50 ab
Negro Citlali/XRAV-187-3-1-8	1131.00 cd	2528.33 ef	1829.67 bc
Jamapa Plus/XRAV-187-3-1-2	1388.67 abc	2827.00 cde	2107.83 ab
Jamapa Plus/XRAV-187-3-4-1	1462.33 ab	3260.33 ab	2361.33 a
Jamapa Plus/XRAV-187-3-4-4	1497.67 a	3315.00 a	2406.33 a
Negro Medellín	1069.00 de	2364.33 fg	1716.67 bc
Negro Jamapa (Regional control)	849.00 ef	2021.00 g	1435.00 c
Verdín	1244.33 abcd	3093.67 abc	2169.00 ab
Environment average	1158.05 b	2760.02 a	1959.03
LSD (0.05)	353.66	367.38	518.91

[†]: Yield in kg ha⁻¹. Means with the same letters in each column are statistically similar according to the Least Significant Difference (LSD, 0.05).

yield statistically similar to that of the Negro Medellín variety and the lines Negro Citlali/XRAV-187-3-1-5, Negro Papaloapan/SEN 46-7-10, and Negro Citlali/XRAV-187-3-1-8 (Table 3).

The highly significant effect of the interaction between both factors indicated that the productive response of some genotypes varied with the evaluation environment; this is the case of the line Negro Citlali/XRAV-187-3-1-6, which in Rincón Grande showed a lower grain yield, primarily due to damage caused by web blight, while in Rincón Chico, under adequate humidity and temperature conditions during the crop cycle, it was among the most productive. Similarly, the line Negro Papaloapan/SEN 46-7-12, which in Rincón Grande, in the presence of web blight, obtained a significantly outstanding grain yield, statistically similar to the most productive line (Jamapa Plus/XRAV-187-3-4-4), whereas in Rincón Chico, despite only showing mild symptoms of angular leaf spot, it was one of the least productive (Table 3).

CONCLUSIONS

Under the environmental conditions of the Las Altas Montañas region of Veracruz, Mexico, the lines Jamapa Plus/XRAV-187-3-4-4, Jamapa Plus/XRAV-187-3-4-1, and Jamapa Plus/XRAV-187-3-1-2, as well as the variety Verdín, showed resistance to web blight and angular leaf spot, and were the ones with the highest average yield, significantly superior to that of Negro Jamapa, the regional control.

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