Description of cultivar

Rubí: a new improved variety of black beans for the tropical areas of Veracruz and Chiapas

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Abstract

In Veracruz and Chiapas, Mexico, bean cultivation is mainly affected by the incidence of viral diseases, the occurrence of terminal drought in residual moisture sowings and low-fertility acidic soils. To help solve this problem, the bean variety 'Rubí' was developed. In 2015, the Jamapa Plus/XRAV-187-3-1-8 line, which gave rise to the Rubí variety, along with 49 other lines and 20 black bean varieties were screened by artificial inoculation and the use of molecular markers, to determine their resistance to bean common mosaic virus (BCMV), bean common mosaic necrosis virus (BCMNV) and bean golden yellow mosaic virus (BGYMV), in said study, Rubí showed resistance to BCMV and low incidence of BGYMV. During 2015 and 2016, Rubí was evaluated together with two regional controls in an adaptation nursery in six environments of Veracruz and Chiapas, to determine its productive response, under rainfed, residual moisture, irrigation and terminal drought conditions. In four of the six environments, Rubí was superior in yield to the two regional controls, with an overall average of 10.3 and 18.1% higher than that obtained for the Negro Comapa and Negro Grijalva varieties, respectively. During 2016 and 2017, Rubí was evaluated in a uniform yield trial in 10 environments in Veracruz and Chiapas. The new variety obtained a significantly outstanding average yield and showed better adaptation than Negro Comapa and Negro Grijalva. In 2019, the National Seed Inspection and Certification Service (SNICS) granted the definitive registration in the National Catalogue of Plant Varieties, with number FRI-099-06119, for its commercial use.

Keywords: *Phaseolus vulgaris* L., adaptability, cultivar, GxA, yield.

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In Veracruz and Chiapas, Mexico, almost all bean sowings are carried out with varieties of small opaque black grain, tropical type, since these have the highest commercial demand in southeastern Mexico. In this region, both states stand out for their considerable bean sowing area, which was 150 784 ha in total during 2016. However, the average yield is low (<650 kg ha^{-1}) (SIAP, 2018), because the crop is affected by biotic and abiotic factors, among which are: the incidence of diseases such as the bean golden yellow mosaic virus (BGYMV) and the bean common mosaic virus(BCMV) (López *et al*., 2006; Tosquy *et al*., 2012), terminal drought, which frequently occurs after the flowering of the crop under residual moisture conditions, particularly during the autumn-winter cycle (Tosquy *et al*., 2014; 2017).

The yield is also low when beans are sown in acidic soils deficient in nutrients, with pH below 5 and poor in their organic matter content (<1.5%) (Zetina *et al*., 2002; Villar *et al*., 2003; Tosquy *et al*., 2008; 2020). In order to compensate for this problem, during 2018, the Bean Program of the National Institute of Forestry, Agricultural and Livestock Research (INIFAP, for its acronym in Spanish) generated the bean variety Rubí for the tropical and subtropical areas of southeastern Mexico, particularly for the Mexican states of Veracruz and Chiapas.

Origin and obtaining process

The Rubí variety originated from the simple cross Jamapa Plus/XRAV-187-3 made in 2007 at the Bajío Experimental Field (CEBAJ, for its acronym in Spanish) of INIFAP in Celaya, Guanajuato. The line Jamapa Plus was used as a progenitor of wide adaptation to the tropics, with favorable characteristics of the grain for its commercial acceptance. On the other hand, the elite line XRAV-187-3 was used as a source of resistance to the BCMV, BCMNV and BGYMV viruses, since it has the molecular marker SR2 linked to the bgm-1 gene for resistance to BGYMV, as well as the molecular marker SW13 linked to the I gene, which gives it resistance to BCMV (Beaver *et al*., 2014).

The process of obtaining Rubí was as follows: from 2009 to 2010, mass selection in F_2 and F_3 was carried out in the Bajío Experimental Field (CEBAJ, for its acronym in Spanish) and mass composite in F_4 and F_5 was carried out in the Cotaxtla Experimental Field (CECOT, for its acronym in Spanish), in Medellín de Bravo, Veracruz. In 2011, individual selections were made at CECOT, to derive selected lines F_{5-6} and mass composite in the following generations (F_7 and F_8) in Rincón Grande, Orizaba, Veracruz. In 2013, the selected lines of the Jamapa plus/XRAV-187-3 cross were coded. During 2015, the line Jamapa Plus/XRAV-187-3-1-8 $F_{6:10}$, which gave rise to the Rubí variety (along with 49 other lines and 20 bean varieties), was screened by artificial inoculation and the use of molecular markers, to determine its resistance to BCMV, BCMNV and BGYMV, the results of which were previously reported (Anaya *et al*., 2018).

Rubí was evaluated in 16 environments in Veracruz and Chiapas; in six of which it was evaluated as part of an adaptation nursery from 2015 to 2016 and in the other 10, as part of a uniform yield trial during 2016 and 2017. The environments included rainfed, residual moisture, acidic soil, irrigation, and terminal drought conditions. Finally, in 2019, the definitive registration of Rubí in the National Catalogue of Plant Varieties (CNVV, for its acronym in Spanish) of the SNICS for its commercial use was obtained.

Agronomic characteristics

Plants of the Rubí variety are of indeterminate growth, shrubby and erect type II, with medium vines, dark green leaves and an average canopy height of 42.5 cm (UPOV, 2012; SNICS, 2017). Its flowers are violet, the pods are yellow at physiological maturity and its grain is black, opaque, circular to elliptical in shape and small, with an average weight of 17.5 g per 100 seeds, classified as the type of very light commercial grain (SNICS, 2017) demanded by the consumer of southeastern Mexico.

Rubí has an early cycle; its flowering occurs on average at 38 days after sowing, its physiological maturity at 71 days; it can be harvested at 82 days after sowing (Ibarra *et al*., 2018), which allows escaping terminal drought and obtaining grains at least eight days before the Negro Jamapa variety and the native beans that are commonly sown in the region (UPOV, 2012).

One of the most outstanding characteristics of this variety is its resistance to the bean common mosaic virus (BCMV) and its low incidence of the bean golden yellow mosaic virus (BGYMV), because it has the I and bgm-1 genes previously determined (Anaya *et al*., 2018), while most of the native varieties and the Negro Jamapa variety, commonly used in Veracruz and Chiapas, are susceptible to these diseases. Among other qualities of Rubí, its wide adaptation to the tropical and subtropical areas of Veracruz and Chiapas as well as a greater yield potential than the varieties stand out.

Grain commercial quality

The bean variety Rubí has a small grain, circular to elliptical in its longitudinal section and with an average weight of 17.5 g per 100 seeds, classified as very light (UPOV, 2012), similar to that of the Negro Jamapa and Negro INIFAP varieties, of great commercial acceptance in southeastern Mexico. Rubí grain has a testa content of 11.6%, which is associated with its good digestibility, as well as a water absorption capacity of 94.7% (after 18 hours of soaking), so it is considered soft for cooking (Guzmán *et al*., 1995).

Virus resistance evaluation

In 2015, Rubí along with 49 other recombinant lines and 20 varieties of opaque black beans from the Mesoamerican pool were evaluated in the Molecular Biology Laboratory of CEBAJ and Forest and Agricultural Health Laboratory of the Central Experimental Field of Chiapas of INIFAP, to determine their resistance to BCMV, BCMNV and BGYMV by artificial inoculation with the strains BCMNV NL-3 and BGYMV-MX under greenhouse conditions and the use of molecular markers associated with genes I, bc-3, bc12 and bgm-1, which give resistance to these viruses.

The results indicated that all Rubí plants had the marker SW-13 and developed necrotic lesions when inoculated with the strain BCMNV NL-3, which together confirmed the presence of gene I and its resistance to the common mosaic (Pasev *et al*., 2013), and although only 25% of the plants had the molecular marker SR2 associated with the bgm-1 gene, 89% of the plants agro-inoculated with the strain BGYMV-MX were asymptomatic, which confirmed Rubí's resistance to BGYMV (Anaya *et al*., 2018).

Evaluation of 'Rubí' in an adaptation nursery

During 2015 and 2016, Rubí was evaluated along with 49 other lines and the commercial varieties Negro Comapa and Negro Grijalva, through an adaptation nursery that was conducted in six environments in Veracruz and Chiapas, under rainfed, residual moisture, irrigation and terminal drought conditions. Table 1 shows a summary of the yield results of the three varieties in question. Under rainfed conditions, Rubí obtained a grain yield similar to Negro Comapa and 23.9% higher than the yield of the Negro Grijalva bean. With residual moisture, Rubí obtained a yield of 9.2 and 17.9% higher than that of these varieties, respectively.

Table 1. Grain yield (kg ha^{-1}) of 'Rubí' compared to two commercial varieties, evaluated in an adaptation nursery in six environments in Veracruz and Chiapas.

Locality/state	Cycle/year	Moisture condition	Rubí	Negro Comapa	Negro Grijalva
Orizaba, Veracruz	S 2015	Rainfed	1 825	1 845	1 473
IYC (%)				-1.1	23.9
Medellín, Veracruz	AW 2015-16	RM	1 900	1 862	1 690
CEIXTA, Tlapacoyan, Veracruz	AW 2015-16	RM	1 711	1 443	1372
Average			1 805.5	1 652.5	1 531
IYC (%)				9.2	17.9
Ocozocoautla, Chiapas	AW 2015-16	RM - drought	500	297	118
Medellín, Veracruz	IP 2016	Drought	822	408	489
Average			661	352.5	303.5
IYC (%)				87.5	117.8
Medellín, Veracruz	IP 2016	Irrigation	1 861	1 832	1 949
IYC (%)				1.6	-4.5
Overall average			1 436.5	1 281.2	1 181.8
IYC (%)				12.1	21.5
DYC (kg ha^{-1})				155.3 ns	254.7*

AW= autumn-winter; IP= spring-summer; S= summer; RM= residual moisture; IYC= increase in the yield of the Rubí variety with respect to the controls; DYC= difference in the yield of the Rubí variety with respect to the controls; ns= non-significant difference between yield means, according to Student's t-test (0.05). Significant difference between yield means, according to Student's t-test (0.05).

In the presence of drought, during the reproductive stage of the crop, the yield of Rubí was also much higher (87.5 and 117.8%) than that of the Negro Comapa and Negro Grijalva varieties. Under irrigation conditions, the yield of Rubí was similar to that of Negro Comapa and slightly lower than that of Negro Grijalva. According to Student's t-test (0.05), the overall average yield of Rubí was statistically similar to that of Negro Comapa and significantly higher than that of Negro Grijalva.

Evaluation of 'Rubí' in a uniform yield trial

During 2016 and 2017, Rubí along with 11 other lines previously selected in the adaptation nurseries were evaluated in a uniform yield trial, which included the improved varieties Negro Grijalva and Negro Comapa as controls, in 10 environments of Veracruz and Chiapas. Rubí along with five other lines and the two controls obtained an average grain yield of the 10 environments significantly outstanding and similar to each other (Table 2); however, in the stability analysis with AMMI (Crossa *et al*., 1990), Rubí showed the least interaction with the environment (much higher than that shown by Negro Comapa and Negro Grijalva).

Table 2. Grain yield (kg ha^{-1}) of black bean genotypes evaluated in 10 environments in Veracruz and Chiapas. Summer 2016, autumn-winter 2016-17 and winter-spring 2017 cycles.

Genotype	Test environments					
	A1	A2	A3	A4	A5	
Papaloapan/SEN 46-3-7	2 116*	1 120	1 379	2097*	1 367	
Papaloapan/SEN 46-6-6	1 403	1 004	1 449	1952*	1 097	
Papaloapan/SEN 46-7-7	1 973*	560	1 538	1 693	1 518	
Papaloapan/SEN 46-7-11	1 181	848	2357*	1980*	1713*	
N Citlali/XRAV-187-3-1-6	1 905	1 007	2096*	1 238	1580*	
N Citlali/XRAV-187-3-1-8	1 655	1 068	2409*	1 298	1742*	
N Citlali/XRAV-187-3-14-6	1 748	1 068	1 872	1720*	1 260	
N Citlali/XRAV-187-3-14-7	1 401	568	2420*	1 438	1548*	
N Citlali/XRAV-187-3-16-7	1 343	1335*	1 378	1 368	1 368	
J P/XRAV-187-3-1-8 (Rubí)	1 615	1 231	2586*	1 447	1 460	
Jam. Plus/XRAV-187-3-1-2	2276*	1304*	1 692	1 505	1660*	
Jam. PlusX/RAV-187-3-4-4	1 144	1 071	2159*	1 563	1887*	
Negro Comapa	1 876	1484*	2387*	1 480	1 270	
Negro Grijalva	1 863	1324*	2 038	1 469	1 450	
Average	1678 b	1071 c	1983 a	1589 b	1 494 b	
ANVA	**	**	**	*	**	
CV (%)	12.52	13.67	15.10	19.60	14.35	
LSD (0.05)	352.8	245.7	502.7	522.8	360	
	A6	A7	A8	A9	A10	Average
Papaloapan/SEN 46-3-7	598	482	1755*	1 328	1 094	1333.5 abcde
Papaloapan/SEN 46-6-6	693	505	1645*	1 146	729	1162.2 e
Papaloapan/SEN 46-7-7	653	394	1603	1 276	820	1202.8 de
Papaloapan/SEN 46-7-11	582	396	1609	1 203	594	1246.4 bcde
N Citlali/XRAV-187-3-1-6	633	455	1729*	1 302	1 080	1302.6 abcde
N Citlali/XRAV-187-3-1-8	911*	706*	1876*	1 250	859	1377.5 abcde
N Citlali/XRAV-187-3-14-6	627	442	1375	1 031	573	1171.6 e
N Citlali/XRAV-187-3-14-7	689	480	1538	1 297	838	1221.7 cde
N Citlali/XRAV-187-3-16-7	576	369	1473	1 318	922	1144.9 e
J P/XRAV-187-3-1-8 (Rubí)	603	481	1775*	1974*	1 203	1437.3 abcd

Genotype	Test environments					
	A6	A7	A8	A9	A10	Average
Jam. Plus/XRAV-187-3-1-2	715	475	1609	2271*	1536*	1504.3 a
Jam. PlusX/RAV-187-3-4-4	767	576	1759*	1 703	963	1359.3 abcde
Negro Comapa	661	512	1444	1964*	1385*	1446.2 abc
Negro Grijalva	639	459	1724*	2307*	1437*	1471 ab
Average	668 d	481 d	1637 b	1526 b	1 002 c	1312.9
ANVA	**	**	**	**	**	**
CV (%)	11.08	11.77	8.75	20.04	16.29	16.36
LSD (0.05)	124.2	94.9	240.3	513.4	274.1	238.7

T= treatment (genotype); A1= Nuevo México, Villaflores, Chis, acidic soil with application of 2 t ha^{-1} of dolomite to reach a pH greater than 5.6, S 2016, rainfed; A2= Nuevo México, Villaflores, Chis., acidic soil with pH of 4.3, S 2016, rainfed; A3= Venustiano Carranza, Ocozocoautla, Chiapas, AW 2016-17, residual moisture; A4= Rincón Grande, Orizaba, Veracruz, AW 2016-17, residual moisture; A5= El Rubí, Medellín, Veracruz, AW 2016-17, residual moisture; A6= Rodríguez Clara, Veracruz, acidic soil with application of 2.5 t ha^{-1} of dolomite to reach a pH greater than 6.1, AW 2016-17, residual moisture; A7= Rodríguez Clara, Veracruz, acidic soil with pH of 4.6, AW 2016-17, residual moisture. A8= CEIXTA, Tlapacoyan, Veracruz, AW 2016-17, residual moisture; A9= El Rubí, Medellín, Veracruz, WS 2017, irrigation during the crop cycle; A10= El Rubí, Medellín, Veracruz, WS 2017, suspension of irrigation at the beginning of the reproductive stage of the crop (terminal drought). *= statistically superior genotypes, according to the least significant difference (LSD, 0.05). Averages of environments and genotypes with the same letters in the row and column, respectively, are statistically similar according to the LSD test, 0.05.

This indicates that Rubí has greater yield stability and better adaptation in the test environments than the two control varieties and the most yielding line (Jamapa Plus/XRAV-187-3-1-2) (Tosquy *et al*., 2019). This last line showed specific adaptation, mainly in environments with stress due to edaphic acidity in central Chiapas and terminal drought in central Veracruz (Figure 1) (Tosquy *et al*., 2019).

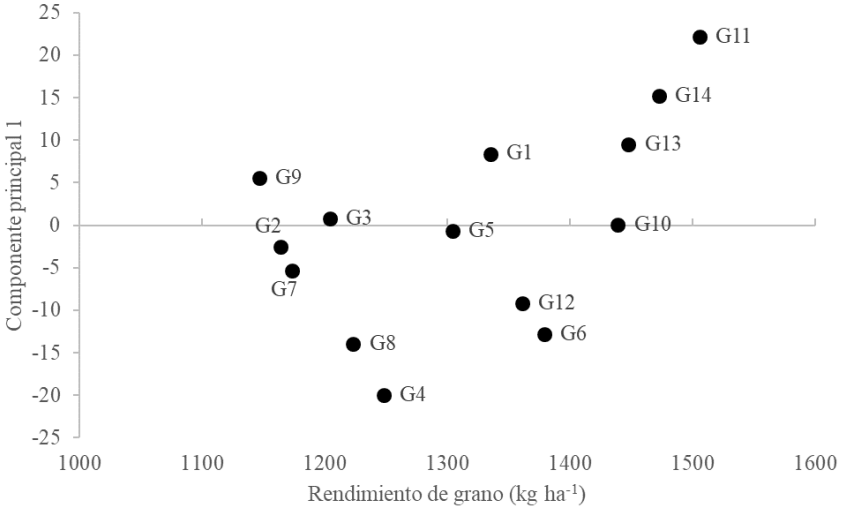

Figure 1. Main effects and interaction observed for the yield of 14 black bean genotypes. G1= Papaloapan/SEN 46-3-7; G2= Papaloapan/SEN 46-6-6; G3= Papaloapan/SEN 46-7-7; G4= Papaloapan/SEN 46-7-11; G5= N Citlali/XRAV-187-3-1-6; G6= N Citlali/XRAV-187-3-1-8; G7= N Citlali/XRAV-187-3-14-6; G8= N Citlali/XRAV-187-3-14-7; G9= N Citlali/XRAV-187-3-16-7; G10= Jamapa Plus/XRAV-187-3-1-8 (Rubí); G11= Jamapa Plus/XRAV-187-3-1-2; G12= Jamapa PlusX/RAV-187-3-4-4; G13= Negro Comapa; G14= Negro Grijalva.

Agroecological conditions and recommendations for use

The Rubí variety has adaptation in the tropical and subtropical areas of the states of Veracruz and Chiapas. It can be grown in the summer cycle under rainfed conditions and in the autumn-winter cycles with residual moisture, in areas with altitudes from 0 to 1 200 m, rainfall of at least 300 mm well distributed during the crop cycle and in soils of different textures, preferably well drained and with pH of 5.5 to 7. It can also be sown in areas that have water and equipment for irrigation, where the availability of a water sheet of around 300 mm is ensured, distributed in six or seven irrigations, with an interval of between 10 and 15 days each during the crop cycle, depending on the moisture conditions in the soil and the temperature of the environment (Ruiz *et al*., 2013).

Seed availability

In the Cotaxtla Experimental Field, original seed of the Rubí variety is available, to produce basic and registered seed, in case producer associations or seed companies wish to acquire it, to produce the certified seed. The definitive registration number of this cultivar in the National Catalogue of Plant Varieties established by the SNICS is FRI-099-061119.

Conclusions

With the black bean variety Rubí, an average yield of the 10 environments significantly outstanding and similar to that of the Negro Comapa and Negro Grijalva varieties and to that of the most productive line Jamapa Plus/XRAV-187-3-1-2 was obtained. However, Rubí was shown to have greater yield stability and wider adaptation than these three genotypes. This variety is resistant to BCMV because it has incorporated the dominant I gene and shows a low incidence of BGYMV under field conditions. The Rubí variety is of early cycle and its opaque black grain, of small size, meets the type and characteristics of the bean demanded by producers and consumers in the states of Veracruz and Chiapas, Mexico.

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