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Description of cultivar

'San Luis 22': a variety of shiny black rainfed beans for north-central Mexico

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Abstract

'San Luis 22' is a medium-sized variety of shiny black beans, it has a prostrate type III indeterminate habit. It has an intermediate maturity cycle, with 95 to 100 days to physiological maturity. Its potential yield under rainfed conditions is 1 450 kg ha^{-1}. In El Bajío, in field plantings, it is tolerant to common blight and resistant to rust, anthracnose, halo blight, and bean common mosaic. It has the following molecular markers: SW13, associated with the *I* gene of resistance to the bean common mosaic virus; Sk14, SI19 and SAD12, associated with the rust resistance genes *Ur-3*, *Ur-5*, and *Ur-7*; and SY20, SAS13, and SF10, associated with the anthracnose resistance genes *Co-4*, *Co-4* ^{2}, and *Co-10*, respectively. 'San Luis 22' is recommended for rainfed conditions in El Bajío and the Altiplano of northern Guanajuato, Querétaro, San Luis Potosí, and Zacatecas. In El Bajío and northern Guanajuato, under rainfed conditions, 'San Luis 22' exceeded Negro Otomí by 191 kg ha^{-1}, particularly in late sowing in August, which suggested greater phenological plasticity.

Palablas clave:

Phaseolus vulgaris L., BCMV, rendimiento, resistencia genética.

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In Mexico, Shiny and Opaque Black beans are the most produced and consumed. The production of Shiny Black beans is carried out under rainfed conditions in the highlands, mainly in the states of Zacatecas, Durango, and Guanajuato (FIRA, 2022). In this region, scarce and irregular rainfall, soils poor in nutrients and organic matter, and phytosanitary problems are the main factors that reduce yield and limit bean production (Anaya-López *et al*., 2021).

There are few improved varieties of Shiny Black beans; the production is carried out with native varieties of the Querétaro and San Luis Black types. Although native materials have excellent adaptation in the agroecological niches where they have been used for a long time, some lack the quality and uniformity characteristics demanded by the market. To increase the productivity, competitiveness, and self-sufficiency of bean cultivation in the highlands of the country, it is necessary to have varieties that are improved, adapted to rainfed conditions and with resistance to diseases. The new variety of Shiny Black beans, 'San Luis 22', developed by the Bean Program of INIFAP in the Bajío Experimental Field (CEBAJ, for its acronym in Spanish), is described below.

Origin and process of obtaining

'San Luis 22' was derived from the simple cross of the uniform line F_9 [(Flor de Junio Marcela/Flor de Mayo Anita) //Island] / Negro 8025, made in 2009; the first two parents of the line are adapted to the Bajío region (in Guanajuato) and the third is a Canadian variety of Pinto type and the male parent is of the Opaque Black type. For its development, the genealogical method was used, combining individual selection in early generations and mass selection in advanced generations (Fehr, 1987).

In 2009, hybridization and advancement from F_1 to F_2 was carried out in a greenhouse; in 2010, the generation advancement from F_3 to F_4 was carried out in the field and it was subjected to the natural pressure of diseases. Selection in intermediate generations was made from individual plants in generations F_5 to F_7 in 2011-2012 and from F_8, the harvest was massive; two generations per year were obtained. The selections were made in Celaya, Guanajuato based on the reaction to diseases and load of pods under rainfed conditions in July sowings; the sowings in February with irrigation were for generational advancement. In 2013 and from 2015 to 2022, the line was evaluated in localities in Guanajuato and in 2022, in one locality in Querétaro.

In 2018, it was evaluated in four localities of the municipality of Ocampo, Guanajuato. In 2019, validation plots were established under rainfed conditions in farmers' fields in Guanajuato. In 2019 under rainfed conditions and in 2020 under irrigation, the line was purified in an isolated lot, removing plants that were not of the type, and its description was carried out in accordance with the technical guide for the varietal description of beans (SNICS, 2017).

In 2021, 'San Luis 22' was genotyped with the molecular markers Sk14, SI19, and SAD12, associated with the rust resistance genes *Ur-3*, *Ur-5*, and *Ur-7* and with the markers SY20, SAS13, and SF10, associated with the anthracnose resistance genes *Co-4*, *Co-4* ^{2} , and *Co-10* (BIC, 2010). In 2022, resistance to common mosaic virus was confirmed by inoculation with the NL3 strain of the common mosaic necrosis virus (BCMNV) under confined greenhouse conditions and it was genotyped with the molecular marker SW13, associated with the *I* gene, following the methodology described by Anaya-López *et al*. (2018).

Morphological and agronomic characteristics

The plants of 'San Luis 22' are of prostrate type III indeterminate habit, with a short-day reaction to the photoperiod, with medium anthocyanin pigmentation of the hypocotyl, the primary leaf has a moderately smooth texture, it is low in canopy height (38 cm) and has an intermediate cycle of 90 to 95 days to physiological maturity. The terminal leaflet is circular to rhombic in shape, medium in size, with a very strong green color, and moderately weak roughness. The flower has a violet banner and wing, with large bracts.

The pod is green, slightly rough, medium in length, medium width and thickness with weak concave curvature, with 4 to 5 seeds per pod. The seed is shiny black, with weak venation, crown of the same

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color as the testa, average weight of 32 g in 100 seeds, elliptical in shape, medium length and width in cross-section, and the cross-section is narrow elliptical. 'San Luis 22' was evaluated in various locations in Guanajuato along with 15 other genotypes, including Negro Otomí (Acosta-Gallegos *et al*., 2001) as a control. Of these, 'San Luis 22', line 9, and the control presented the best attributes.

The highest yields were obtained in rainfed sowings in the first half of July in 2017 (2 421 kg ha^{-1}), 2018 (2 555 kg ha^{-1}), and 2019 (2 551 kg ha^{-1}). In 2018 and 2020, under irrigation, line 9, with a neutral reaction to the photoperiod (*ppd ppd*), surpassed 'San Luis 22' and the Negro Otomí control, the latter with a short-day reaction (sensitive to the photoperiod *Ppd Ppd*) (White and Laing, 1989). As the variety to be registered is for rainfed conditions, 'San Luis 22' was higher: 2 979 *vs.* 2 600 kg ha^{-1} (July 2018), 1 506 *vs.* 1 006 kg ha^{-1} (August 2018), and 3 266 *vs.* 2 664 kg ha^{-1} (July 2019).

In addition, 'San Luis 22' had a higher yield than line 9 and Negro Otomí in late sowing in August, which suggests greater plasticity under rainfed conditions. The ANOVA showed significant differences ($p< 0.05$) between localities, genotypes, and their interaction; the interaction was due to changes in position between line 9 and 'San Luis 22' in eight of the 10 localities.

In 2022, 'San Luis 22' was validated in semi-commercial plots in two rainfed locations (Table 1). In CEBAJ, Guanajuato, the sowing was on July 17 and in Regina, Querétaro, on August 4. In these plots, six 6 m furrow segments (4.5 m^2) were randomly taken to determine the grain yield and weight of 100 seeds randomly taken from each sample. The data were analyzed by Anova with the F-test using a 2 x 3 factorial design (two localities and three materials) with six replications.

Table 1. Yield and weight of 100 seeds of three bean genotypes in two rainfed locations in the spring-summer 2022 cycle.

Genotype	Yield (kg ha^{-1})			W100S (g)		
	CEBAJ	Regina	Average[1]	CEBAJ	Regina	Average[1]
Line 9	2 504 a[1]	600 a	1 552 a	31.4 b	29.6 b	30.5 b
San Luis 22	2 444 a	702 a	1 573 a	33.3 a	31.5 a	32.4 a
Negro Otomí	2 356 a	573 a	1 464 a	29.1 c	27.4 c	28.2 c
Average[2]	2 435 a	625 b		31.3 a	29.5 b	

[1] = Average differences between materials; [2]= Average differences between localities; W100S= weight of 100 seeds. Different letters indicate differences between materials in each locality according to Tukey's test at 0.05.

The average yield and weight of 100 seeds obtained in CEBAJ were higher ($p< 0.001$) than those of Regina, 2 435 *vs.* 625 kg ha^{-1} and 31.3 *vs.* 29.5 g, respectively. The low yield in Regina was due to low rainfall (220 mm) and its erratic distribution. In comparison, rainfall in CEBAJ was 350 mm. In both localities, grain yield was statistically similar between genotypes while the weight of 100 seeds was higher in 'San Luis 22'.

Disease response

'San Luis 22' is resistant to the rust races (*Uromyces appendiculatus* var. *appendiculatus*) present in El Bajío and to the bean common mosaic virus. In the field, it showed resistance to anthracnose (*Colletotrichum lindemuthianum*) and halo blight (*Pseudomonas syringae* pv. *phaseoli*) and tolerance to common blight (*Xanthomonas campestris* pv. *phaseoli*). Readings for reaction to rust, common blight, and halo blight (van Schoonhoven and Pastor-Corrales, 1987) were performed in the reproductive stage in the 2021 rainfed cycle in CEBAJ, where there was no incidence of anthracnose (Table 2).

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Table 2. Reaction to diseases, days to flowering, days to maturity, and weight of 100 seeds of 'San Luis 22' in rainfed environments in Celaya, Guanajuato.

Genotype	Days to		Reaction to diseases[1]			Weight of 100 seeds[2]
	Flowering	Maturity	Rust	Common blight	Halo blight	
Line 9	37	88	4	3	4.3	28.8-30.2
San Luis 22	38	91	2	3	3	30.5-33.4
Negro Otomí	39	89	3	3.5	3.5	27.3-27.5

[1] = reaction in the reproductive stage in the 2021 rainfed cycle. The days to flowering and maturity correspond to the average of nine trials; [2]= Weight range in grams; Line 9= line of shiny black beans.

The resistance analyzed in 'San Luis 22' is due to the fact that it carries the molecular markers Sk14, SI19 and SAD12, associated with the rust resistance genes *Ur-3*, *Ur-5*, and *Ur-7* (Osorno *et al*., 2021), the molecular markers SY20, SAS13, and SF10, associated with the anthracnose resistance genes *Co-4*, *Co-4* ^{2} , and *Co-10* and the molecular marker SW13, associated with the dominant *I* gene of resistance to common mosaic (Miklas *et al*., 2006).

The presence of the *I* gene was confirmed by inoculation with the necrotic strain NL3 of BCMNV in a greenhouse (Anaya-López *et al*., 2018). The average phenology of the three materials in nine trials, as observed in the values for days to flowering and maturity, indicates their similarity.

Registration and breeder's title

'San Luis 22' has the definitive registration number FRI-108-240522 in the National Catalog of Varieties and the Breeder's Title number 2970 issued by the National Agricultural Registry of the Secretariat of Agriculture and Rural Development.

Conclusions

The 'San Luis 22' Shiny Black bean variety is resistant to the diseases that commonly occur in El Bajío Guanajuatense, except to the BCMNV, and has greater yield potential than the Negro Otomí variety, especially in delayed sowing under rainfed conditions. This last aspect is important when considering the erratic precipitation due to climate change in process. The size and physical appearance of the 'San Luis 22' seed, similar to that of the San Luis landrace, is attractive to producers, marketers, and consumers.

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