Colegio de Postgraduados

PID 2: improved pinto common bean variety with high yield and slow darkening seeds

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ABSTRACT

Objective: The common bean production system in the state of Durango requires the development of an improved variety for irrigated and sufficient rainfed conditions (>450 mm of rainfall).

Design/Methodology/Approach: In accordance with the procedure for developing new varieties, the improved variety PID 2 (PT14053) was obtained via the pedigree method, using hybridization between Pinto Saltillo and multiple progenitors, resulting the following pedigree: PT Bayacora/Maverick///PT Claro/PT Saltillo//PT Saltillo/PT Villa-2-6.

Results: The variety PID 2 consists of indeterminate vining plants, a height of 43 cm and an average vine growth of 93 cm. Pods are green with red coloration; seeds are broad, elliptic-medium shaped, with a cream-white seed coat, brown mottling, and yellow hilum. Under irrigation PID 2 achieved an average yield of 2,783 kg ha^{-1}, with flowering at 47 days after sowing (DAS), intermediate maturity at 104 DAS, and a 100-seed weight of 36 g.

Findings: The experimental line PT14053, commercially registered as PID 2, was developed for irrigated conditions in the state of Durango. It outstanding features are disease resistance, acceptable yield (>1,640 kg ha^{-1}), seed coat color clarity, extended shelf-life, and seed weight exceeding 35 g per 100 seeds.

Keywords: *Phaseolus vulgaris*, genetic improvement, resistance, yield, grain quality.

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INTRODUCTION

The average annual planting area of common bean in the state of Durango between 2019 and 2023 was 194,000 hectares, with an average annual production of 61,000 t of grain and a mean yield of 360 kg ha^{-1} (SIAP, 2024). The pinto common bean class is produced in the largest proportion relative to the common bean-planted area in Durango, followed by black, canary (garbancillo), and flor de mayo types (Rosales-Serna & Flores-Gallardo, 2022). Bean producers within the value chain identified the need for a new variety that maintains slow darkening seed coat (Sauceda-Acosta *et al.*, 2023; Jiménez-Hernández *et al.*, 2018) and seeds of larger size and different shape compared to

Pinto Saltillo, a variety extensively used in commercial common bean plantings in México (Sánchez-Valdez *et al.*, 2004). In 2014, the improved line PT14053 (PID 2) was coded and evaluated at multiple sites aiming to determine its tolerance level to the factors that affect productivity and seed quality (Hortelano *et al.*, 2016). The principal factor negatively affecting productivity in common beans is water stress, which occurs even under irrigated conditions and reduces yield (Polón-Pérez *et al.*, 2013; Reyes-Matamoros *et al.*, 2014). The severity of water stress negatively impacts productivity depending on its intensity and phenological stage, as it damages the root zone (Polón-Pérez *et al.*, 2013; Polón-Pérez *et al.*, 2017), as well as affecting organ development and potentially causing flower and pod abortion (Barrios-Pérez & Álvarez-Toro, 2016). Seed quality is related to soil moisture availability and water deficit, which causes seed size reduction (Romero-Félix *et al.*, 2019). Therefore, the common bean crop needs to be redirected towards irrigated zones to avoid water deficiencies during its growth and development and consequently increase yield, total production and seed quality. However, this must also consider that it may lead to increased incidence and severity of various plant diseases. Among the most common diseases affecting bean yield and seed quality (Gill-Langarica & Mayek-Pérez, 2008) are anthracnose (*Colletotrichum lindemuthianum*), rust (*Uromyces appendiculatus* var. *appendiculatus*) and common bacterial blight (*Xanthomonas campestris=axonopodis* pv. *phaseoli*) (Rosales-Serna *et al.*, 2019), which control must be considered among the technological components to implement in the agronomic management of the common bean crop. During the variety adoption process, producers consider yield, quality and socioeconomic aspects (Hernández-Álvarez *et al.*, 2023), as was the case of the study conducted in the Pinto Saltillo variety. In preliminary studies under irrigated conditions, PID 2 recorded high yield (2,965 kg ha^{-1}) and larger seed size (42.8 g 100-$seeds^{-1}$) compared to that produced by Pinto Saltillo (2,185 kg ha^{-1}; 40.7 g 100-$seeds^{-1}$) (Rosales-Serna *et al.*, 2021). In addition, PID 2 achieved flowering at 52 DAS and maturity at 110 DAS, although with phenological flexibility (phenological plasticity), which allows it to escape the negative effects of low temperatures and water stress commonly recorded during October in Durango. In experimental trials and commercial plantings, PID 2 showed resistance to anthracnose and rust, moderate tolerance to common bacterial blight and root rots (*Fusarium oxysporum*, *Rhizoctonia solani* and *Pythium* spp.). Currently, PID 2 is in the technology transfer process, in order to promote variety adoption by common bean producers in Durango and other states in México.

MATERIALS AND METHODS

The improved pinto common bean variety PID 2 originated from the cross (hybridization) between Pinto Saltillo and multiple progenitors (PT Bayacora/Maverick///PT Claro/PT Saltillo//PT Saltillo/PT Villa-2-6), carried out at the Valle del Guadiana Experiment Station of INIFAP located in the state of Durango (Rosales-Serna *et al.*, 2019). The objective of the cross was to obtain improved lines with yield superior to the state average under irrigation (1,640 kg ha^{-1}), as well as larger seed size (>35 g 100 $seeds^{-1}$) than that produced by Pinto Saltillo (31 g 100 $seeds^{-1}$), while maintaining testa color clarity, exhibiting slow darkening and prolonged shelf-life.

Pinto Saltillo was used as the progenitor for its resistance to accelerated seed coat darkening and productive adaptation in the management systems used in Durango (Cadena-Hernández *et al.*, 2019). The variety Pinto Villa was used as a gene source for drought tolerance and phenological plasticity at maturity, which supports extension of the biological cycle under favorable environments. To reinforce resistance to accelerated seed coat darkening, originally derived from Pinto Saltillo, the line Pinto Claro was used (Rosales-Serna *et al.*, 2021). The varieties Pinto Bayacora and Maverick were used for their high seed-size value (>37 g 100 seeds^{-1}), rust resistance and commercial seed quality (Rosales-Serna *et al.*, 2004; Santana-Espinoza *et al.*, 2024). For the development of PID 2 the pedigree breeding method was employed, involving hybridization of progenitors (Anaya-López *et al.*, 2021), followed by individual selection (F_2) and mass selection (F_4 onward). The original population, of modified triple cross method (PT Bayacora/Maverick///PT Claro/PT Saltillo//PT Saltillo/PT Villa), was obtained in 2010. The F_1 seed was advanced in the winter nursery in Los Mochis, Sinaloa, during the 2010-2011 winter cycle, from which the F_2 seed was obtained and mass selection applied. In 2011 in Durango, the F_2 seed was planted to perform individual selections (F_2:F_3) based on plant vigor, disease resistance, pod load and commercial seed quality, thus obtaining the family (PT Bayacora/Maverick///PT Claro/PT Saltillo//PT Saltillo/PT Villa-2). In 2012 the plants were grown one row per plant and mass selection was carried out in the F_3 families that showed reduced intra-population variation (Bermejo *et al.*, 2021). In those exhibiting segregation, individual selection was again applied (PT Bayacora/Maverick///PT Claro/PT Saltillo//PT Saltillo/PT Villa-2-6), directed toward obtaining pinto-seed plants, slow darkening seeds and large seed size (>35 g 100 seeds^{-1}). In 2013, a progeny test was sown and mass-selection oriented to the stability of morphological attributes was conducted —including seed color (pinto), tolerance to accelerated seed coat darkening and large seed size (>35 g 100 seeds^{-1}). In this way the improved pinto bean line PT14053 (PT Bayacora/Maverick///PT Claro/PT Saltillo//PT Saltillo/PT Villa-2-6) was obtained, which showed uniformity and was included in Preliminary Yield Trials (PYT) and Uniform Yield Trials (UYT) established in Durango, Guadalupe Victoria and Canatlán, Dgo., between 2014 and 2017. The PYT and UYT trials were established under a completely randomized design with five replications, with an experimental plot of two rows of 6 m and a useful plot of 5 m, spaced at 0.81 m (8.1 m^2). During the spring-summer 2015 cycle, a seed-increase plot was established and used to further purify the improved line (PT14053). Subsequently, in 2016 a seed-increase plot was established in Durango, Dgo., to produce sufficient seed for the validation and technology-transfer processes. The photoperiod response evaluation of line PT14053 (PID 2) was conducted in Durango, under early sowing nurseries (March-April) in 2017, and its sensitivity to long days (>13 h of light) and high temperature (minimum 13 °C and maximum 31 °C) was confirmed, which manifested as delayed flowering and maturity. In the spring-summer 2017 growth cycle, the third year of UYT was conducted, and simultaneously a seed-increase plot was planted, where the morpho-agronomic characterization of the improved line PT14053 was performed according to the technical guide of the National Seed Inspection and

Certification Service (SNICS, 2017). During 2018, a commercial seed plot (2,500 m^2) of line PT14053 was sown for internal validation; the improved line was designated PID 2 (Pinto Developed in Durango Number 2) in preparation for its registration with SNICS. In the validation-technological transference processes (2018 to 2023) five systematic samples (two rows of 5 m) were taken to determine yield and 100-seed weight. In 2023, the common bean variety PID 2 received registration number FRI-116-270923 with breeder's title number 3320, in its description highlighting the climbing growth habit and medium lenght vines with slow growth rate, therefore considered of prostrate indeterminate growth habit (Type III; CIAT, 1984). In the development of PID 2, mainly agricultural fields located at altitudes above 1,877 m were used, with predominance of loam, sandy and clay-loam soils, which have intermediate moisture-retention capacity, medium depth, 0-4% slope, pH 7.9 and are nutrient-poor. The predominant climate is temperate semi-arid [BS_1 k w (w) (e)], with summer-rainfall regime, strong temperature variation and an annual mean of 17.4 °C (García, 1987). Annual accumulated rainfall averaged 476 mm, with high values between June and September (Medina *et al.*, 2005). At all sowing sites disease incidence and severity were evaluated (damage at organ, plant and population levels) using a 1-to-9 scale, where 1-3 indicate resistance, 4-6 intermediate resistance and 7-9 susceptibility (CIAT, 1987).

RESULTS AND DISCUSSION

Morpho-agronomic characterization of line PT14053

The average canopy height of PID 2 plants was 43 cm; the vine exhibits a moderate growth rate reaching 93 cm in length. Flowering occurred on average at 47 days after sowing (DAS) and physiological maturity at 104 DAS (Table 1). These results were similar to those reported for the progenitor Pinto Saltillo, which start flowering at 49 DAS and reached the physiological maturity at 101 DAS (Sánchez-Valdez *et al.*, 2006). The improved variety PID 2 is photoperiod-sensitive under irrigated conditions: when days are long and warm (approximately 13 hours of sunlight and temperatures exceeding 25 °C), the biological cycle is extended, with a maturity date prolonged to >120 DAS.

The variety PID 2 has medium-sized seeds, determined based on its weight, with an average value of 36 g per 100 seeds (31 to 43 g per 100 seeds) compared to Pinto Saltillo reported for the same region averaging 33 g per 100 seeds (Table 2). The grain of PID 2 is broad and elliptic-medium in cross-section, and its longitudinal view is elliptic. The seed color is cream-white with brown mottling and a yellow hilum, which contrasts with the seed coat coloration. The average yield of PID 2 was 2,783 kg ha^{-1} with a range between 1,161 kg ha^{-1} and 5,365 kg ha^{-1} (Tables 1 and 2). In some sites, PID 2 was out-yielded by the variety Pinto Saltillo (Durango 2015 and 2022); however, in most cases the new variety showed higher seed yield (Table 2). In the majority of the evaluation sites it was observed that PID 2 had a higher 100-seed weight (36 g per 100 seeds) than the control Pinto Saltillo (33 g per 100 seeds) (Rosales-Serna & Flores-Gallardo, 2022) and although moisture stress reduced this trait (31 g per 100 seeds at La Roca), the trend held across cultivation environments.

Table 1. Yield and characteristics of the PID 2 common bean variety evaluated in Durango and Aguascalientes, México.

Locality	Year	[1]DF	A	R	B	DPM	SY (kg ha^{-1})	100-SW (g)
Durango	2014	50	1	1	6	110	5,365	38
Durango	2015	41	1	2	5	110	1,544	36
Canatlán	2015	42	1	1	6	101	1,161	34
Durango	2016	48	1	1	6	94	3,499	39
Durango	2017	52	1	1	6	110	2,965	43
Durango	2018	57	1	1	5	120	3,386	37
Durango	2019	50	1	1	5	102	3,117	37
Nombre de Dios	2019	51	1	1	6	104	2,624	35
Durango	2020	45	1	1	5	104	4,223	33
Durango	2021	47	1	3	4	108	3,085	32
La Roca	2021	40	1	1	5	98	2,614	31
Durango	2022	52	1	1	5	110	2,762	34
Sta. Catalina	2022	49	1	1	5	100	1,596	33
Durango	2023	51	1	1	5	108	3,270	40
Gpe. Victoria	2023	--	--	--	--	--	1,740	40
Aguascalientes	2023	41	1	1	4	96	1,613	34
Aguascalientes 2	2023	41	1	1	4	96	2,743	34
Average		47	1	1	5	104	2,783	36

[1]DF=Days to Flowering; DPM=Days to Physiological Maturity; SY=Seed Yield; 100-SW=100-Seed Weight; Response to: A=Anthracnose, R=Rust, B=Common Bacterial Blight.

Table 2. Grain yield and 100-seed weight for the common bean varieties PID 2 and Pinto Saltillo evaluated at different production sites in Durango and Aguascalientes, México.

Locality	Year	Yield (kg ha^{-1})		100-seeds weight (g)	
		PID 2	PT Saltillo	PID 2	PT Saltillo
Durango	2014	5,365	--	38	--
Durango	2015	1,544	2,508	36	35
Canatlán	2015	1,161	--	34	--
Durango	2016	3,499	--	39	--
Durango	2017	2,965	2,185	43	41
Durango	2018	3,386	--	37	--
Durango	2019	3,117	--	37	--
Nombre de Dios	2019	2,624	--	35	--
Durango	2020	4,223	2,883	33	31
Durango	2021	3,085	3,016	32	32
La Roca	2021	2,614	2,234	31	32
Durango	2022	2,762	3,419	34	33
Sta. Catalina	2022	1,596	1,104	33	27
Durango	2023	3,270	2,723	40	35
Gpe. Victoria	2023	1,740	2,089	40	40
Aguascalientes	2023	1,613	--	34	--
Aguascalientes 2	2023	2,743	--	34	--
Average		2,783	2,509	36	33

The variety PID 2 represented a genetic advance in the common bean crop for irrigated-yield and disease resistance, which was achieved through multiple-parent crosses. The experimental and field validation results show that PID 2 exhibits acceptable yield and larger seed size relative to Pinto Saltillo (Rosales-Serna & Flores-Gallardo, 2022). Furthermore, the shape and size of the seed positions PID 2 in the common bean market with greater appeal to the consumer, similar to findings reported in other studies (Herrera *et al.*, 2012), where an average weight of 31 g per 100 seeds was obtained for pinto common bean produced in Chihuahua. It is worth noting that PID 2 can be sown in Durango and other states with similar agro-ecological conditions. For the new variety to express its full genetic yield potential, it is recommended that it be cultivated under irrigation and an annual mean temperature between 17 and 28 °C, with daily minimum temperature above 12 °C. At INIFAP, Valle del Guadiana Experiment Station, located in Durango, the breeder seed of PID 2 is available for foundation seed production, which can be offered for registered and certified seed production and commercialization.

CONCLUSIONS

A new common bean variety, PID 2, was developed which surpassed the state of Durango average yield under irrigation. The seed quality is characterized by a clear testa color, slow darkening seeds, and seed weight higher than that recorded for Pinto Saltillo. Although it is attacked by the most common diseases, it has been demonstrated that, with proper agronomic management, damage is minimal. The variety PID 2 provides a new alternative for common bean production and consume, thus contributing to the supply of grain to satisfy national and international demand for this legume.

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