


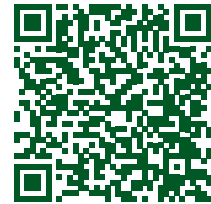
IAC 2560 Nelore: resistance to *Colletotrichum lindemuthianum*, with slow seed coat darkening

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Abstract: The common bean cultivar IAC 2560 Nelore has an indeterminate type II growth habit, a normal 80-day cycle, a mean 1000-seed weight of 290 grams, and a yield potential of 5,508 kg ha⁻¹. It is resistant to *Colletotrichum lindemuthianum* physiological races 81, 465, and 479.

Keywords: *Phaseolus vulgaris*, plant breeding, slow darkening, disease resistance



INTRODUCTION

Two major domestication centers are recognized for common bean (*Phaseolus vulgaris* L.): the Mesoamerican center and Andean center. These two independent gene pools differ in their composition of phaseolin, a major protein in the grain (Gepts et al. 1986), as well as in seed coat color and bean size, traits that reflect the genetic diversity of the species.

Total common bean production calculated for the 2023/24 crop year in Brazil was 3.249 million metric tons, 1.845 million tons of which were colored beans (CONAB 2024). These figures reflect the importance of carioca beans in the Brazilian market, highlighting the need to increase yield to meet growing consumer demand. Plant breeding programs have played a crucial role in this regard, by bringing about significant gains in agronomic traits and developing cultivars with superior performance compared to their predecessors (Federizzi et al. 2012) According to Barili et al. (2016), the average annual increase in carioca bean cultivar yield was 6.74% from 1990 to 2013. Improvement in 1000-seed weight has been observed since 1994, with average annual gains of 2.08%, while advances in bean visual quality have been documented since 1986, with annual gains of 1.36%.

Within this context, the aim of this study is to present the new carioca seed coat common bean cultivar designated as IAC 2560 Nelore (Gen 18-1-15-1-9). This cultivar combines superior agronomic traits, including resistance to multiple physiological races of the anthracnose pathogen, slow grain darkening, and high yield, meeting the main demands of the Brazilian market.

GENETIC ORIGIN AND DEVELOPMENT

In 2025, the IAC 2560 Nelore cultivar (Gen 18-1-15-1-9) was released by the Instituto Agronômico (IAC). It was derived from crossing the following

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genotypes: (Line 940 × TAA Dama) × IAC 2051. The LP 940 line was used in the cross with the aim of integrating upright growth habit and yield gains. The TAA Dama cultivar has slow grain darkening and good plant hardiness traits. The F_1 seeds from this cross were then crossed with the IAC 2051 cultivar, which combines slow grain darkening, high 1000-seed weight, high yield, and technological qualities.

In the 2017 winter crop season, the LP 0940 × TAA Dama cross was carried out. The resulting F_1 seeds were sown and crossed with 130 parental cultivars (including Line 97.2) in the 2018 winter crop season, generating the F_1 generation and then the F_2 generation, resulting in 635 plants. These plants were evaluated for their reactions to a mixture of three physiological races of anthracnose (65, 81, and 89), and only 269 plants proved to be resistant. Among them, 8 plants originated from Gen 18-1-15 (the 15th plant of the cross). Seeds from these plants were sown in the 2019 winter season in Campinas, SP, in 3-m rows to evaluate traits such as plant vigor, reaction to common bacterial blight (CBC), yield, and slow seed coat darkening in post-harvest.

Plants selected in F_2 and advanced by self-pollination to the F_4 generation ($F_{2.4}$) were once more evaluated in the 2020 rainy season for their reaction to the mixture of anthracnose races under laboratory conditions. This evaluation led to selection of the plant Gen 18-1-15-1. The $F_{2.5}$ generation was then sown to set up the trials for the next crop season.

The $F_{2.6}$ lines were evaluated for the slow seed coat darkening trait, and one line was assigned the name Gen 18-1-15-1-9. This line was sown in the field in the 2022 dry crop season, along with other $F_{2.6}$ lines, and achieved a mean yield of 2,350 kg ha⁻¹.

At that time, Value for Cultivation and Use (VCU) trials began, spanning two years and six crop seasons (2022 winter – 2024 dry) in Region I (RS, SC, PR, SP, and MS) and Region II (RJ, ES, MG, MT, MA, BA, TO, GO, and DF). In these trials, the Gen 18-1-15-1-9 line showed strong performance, with yield comparable to or higher than that of the check cultivars (IAC 2051, TAA Dama, and IPR Sabiá), as well as resistance to several physiological races of the anthracnose pathogen *Colletotrichum lindemuthianum*. Based on its performance and high grain quality, the common bean breeding program of IAC chose to recommend it for release. It was given the name IAC 2560 Nelore, with this commercial name highlighting its hardiness, specifically referring to resistance to anthracnose, and the light/white color of the seed coat, in reference to the Nelore cattle breed (Figures 1A and 1B).

YIELD POTENTIAL

The IAC 2560 Nelore cultivar showed performance superior to the check cultivars evaluated. In the overall mean for Region I (Table 1), the cultivar outyielded IPR Sabiá by 493 kg ha⁻¹, TAA Dama by 228 kg ha⁻¹, and IAC 2051 by 106 kg ha⁻¹. Analyses across different crop seasons and sites showed that the new cultivar exceeded the mean yield of the check cultivars in 66.6% of the trials.



Figure 1. Morphological characteristics of the IAC 2560 Nelore cultivar: (A) mature grain; (B) dry pods.

Table 1. Grain yield of the IAC 2560 Nelore cultivar compared to the mean yield of three check cultivars, by site and crop season, in the Region I recommendation zone of MAPA

Site	Crop season	'IAC 2560 Nelore' (kg ha ⁻¹)	Check cultivars (kg ha ⁻¹)			Mean yield of the checks	CV (%)	F value calculated
			IPR Sabia	TAA Dama	IAC 2051			
Votuporanga, SP	Winter/2022	2,033	933	1,331	488	917	19.10	8.68*
Campinas, SP	Winter/2022	1,810	2,127	2,267	2,069	2,154	22.59	2.92*
Campinas, SP	Rainy/2022	3,308	3,131	2,333	2,922	2,795	22.71	2.05*
Monte Alegre do Sul, SP	Rainy/2022	5,508	3,583	3,858	3,983	3,808	18.60	2.18*
Tatui, SP	Rainy/2022	3,110	3,183	2,654	3,198	3,012	15.49	3.25*
Mococa, SP	Rainy/2022	2,747	2,373	368	2,447	1,729	21.12	8.05*
Campinas, SP	Dry/2023	2,345	2,795	1,591	2,809	2,398	21.48	2.66*
Monte Alegre do Sul, SP	Dry/2023	1,833	1,308	1,606	2,306	1,740	22.32	2.02*
Votuporanga, SP	Dry/2023	2,971	2,656	2,183	2,777	2,539	18.22	2.53*
Tatui, SP	Dry/2023	2,483	4,279	3,404	2,854	3,512	15.74	5.08*
Votuporanga, SP	Winter/2023	4,317	3,994	3,811	4,049	3,951	9.55	3.3*
Campinas, SP	Winter/2023	1,993	2,413	3,243	2,876	2,844	24.92	1.59*
Campinas, SP	Rainy/2023	3,471	2,088	1,230	3,085	2,134	19.95	3.91*
Capão Bonito, SP	Rainy/2023	2,478	2,452	3,165	2,871	2,829	15.50	6.63*
Campinas, SP	Dry/2024	1,793	1,452	1,761	1,876	1,696	18.33	1.98*
Mean of rainy (1st crop)		3,437	2,802	2,268	3,083	2,718	19.39	2.46*
Mean of dry (2nd crop)		2,285	2,498	2,109	2,525	2,377	19.02	1.45*
Mean of winter (3rd crop)		2,538	2,367	2,663	2,370	2,467	18.51	0.84
Overall mean (combined)		2,813	2,585	2,320	2,707	2,537	19.11	2.71*

* Significant at 5% in the F test.

In Region II (Table 2), IAC 2560 Nelore likewise exhibited strong performance, as it exceeded the mean yield of the check cultivars in 72.7% of the experiments. The mean yield of IAC 2560 Nelore was 2,485 kg ha⁻¹, while the combined mean yield of the check cultivars was 2,336 kg ha⁻¹.

OTHER CHARACTERISTICS

The new carioca seed coat cultivar has an indeterminate type II growth habit with semi-upright plant architecture, in which the main stem continues to lengthen even after flowering. This growth pattern facilitates efficient direct mechanical harvesting. After emergence, the cultivar reaches flowering in 32 days and physiological maturity in 80 days, which is considered to be a normal cycle. The 1000-seed weight is 290 grams. Its light brown seed coat has intermediate shine and slow darkening, maintaining these traits for a longer time (Figure 1).

The cooking time (Table 3) of IAC 2560 Nelore was significantly shorter than that of the TAA Dama cultivar, and its protein content is within the range observed for the check cultivars. The IAC 2560 Nelore cultivar has notable resistance to important plant pathogens (Table 4), such as anthracnose (*Colletotrichum lindemuthianum*) and angular leaf spot, and it shows tolerance to *Fusarium oxysporum* and to common bacterial blight (*Xanthomonas axonopodis*).

Anthracnose resistance was evaluated under controlled conditions of temperature, humidity, and photoperiod, using five replicates and an inoculum concentration of 10⁶ spores mL⁻¹. In the VCU trials, inoculations were performed with races 81, 465, and 479. Disease severity was assessed using the rating scale proposed by Rava et al. (1993), where resistance is indicated by scores from 1 (no anthracnose symptoms) to 3 (lesions limited to veins on the abaxial surface of the primary leaf, affecting up to 3% of the veins). Scores of 4 or more, indicate susceptibility, characterized by initial symptoms on veins of the adaxial leaf surface affecting 1% and progressing to score 9, indicating plant death.

The same number of replicates was used for *Fusarium oxysporum* (10⁶ spores mL⁻¹), inoculated with race 3.349 during the VCU trials. Disease severity was assessed using the scale proposed by Schoonhoven and Pastor-Corrales (1987), based on symptoms observed on the hypocotyl, where scores from 1 to 3 indicate resistance, and scores from 4 to 9 indicate susceptibility.

Table 2. Grain yield of the IAC 2560 Nelore cultivar compared to the mean yield of two check cultivars, by site and crop season, in the Region II recommendation zone of MAPA

Site	Crop season	'IAC 2560 Nelore' (kg ha ⁻¹)	Check cultivars (kg ha ⁻¹)		Mean yield of the checks	CV (%)	F value calculated
			TAA Dama	IAC 2051			
Patrocínio, MG	Rainy/2022	4,963	4,057	4,492	4,275	15.61	3.45*
Alfenas, MG	Rainy/2022	2,679	1,863	2,275	2,069	11.02	3.74*
Canarana, MT	Dry/2023	1,069	1,097	779	938	22.00	3.32*
Patrocínio, MG	Dry/2023	3,497	3,754	4,245	4,000	10.66	9.82*
Sorriso, MT	Dry/2023	2,123	2,689	2,055	2,372	21.61	3.75*
Rio Verde, GO	Dry/2023	3,139	3,000	3,259	3,130	18.53	4.73*
Rio Verde, GO	Rainy/2023	1,966	1,485	1,636	1,561	11.45	3.73*
Uberlândia, MG	Rainy/2023	3,032	2,854	2,698	2,776	4.72	4.25*
Alto Garça, MT	Dry/2024	1,843	1,915	1,826	1,871	16.28	17.68*
Palmas, TO	Dry/2024	1,665	1,633	1,245	1,439	20.05	3.03*
Luis Eduardo Magalhães, BA	Dry/2024	1,359	1,362	1,174	1,268	23.99	11.37*
Mean of rainy (1st crop)		3,160	2,564	2,776	2,670	13.56	1.38
Mean of winter (3rd crop)		2,099	2,297	2,083	2,190	18.78	1.64
Overall mean (Combined)		2,485	2,337	2,335	2,336	16.45	1.64

* Significant at 5% in the F test.

Table 3. Cooking and nutritional quality of the beans of the IAC 2560 Nelore cultivar compared to the two check cultivars—IAC 2051 and TAA Dama—according to crop seasons

Crop Season	IAC 2560 Nelore		Check cultivars			
			IAC 2051		TAA Dama	
	Cooking time (min) ¹	Protein content (%) ²	Cooking time (min)	Protein content (%)	Cooking time (min)	Protein content (%)
Winter/2022	34.12	19.00	32.72	18.00	39.63	19.50
Rainy/2022	40.30	21.00	47.17	22.00	49.37	20.00
Dry/2023	32.96	20.00	23.96	19.00	32.59	22.10
Winter/2023	32.95	19.50	24.00	20.00	33.00	21.00
Rainy/2023	42.72	21.50	51.80	21.00	43.41	19.00
Dry/2024	31.90	20.00	26.20	20.50	31.50	19.50
Mean	35.82	20.17	34.31	20.08	38.25	20.18

¹ Evaluated by the Mattson Cooker (Proctor and Watts 1987).² Crude protein content evaluated by the micro-Kjeldahl method (AOAC 1980, Bataglia et al. 1983).**Table 4.** Mean values of traits of the IAC 2560 Nelore cultivar compared to the IAC 2051 and TAA Dama cultivars

Cultivar	Physiological maturity cycle (days)	No. 12 sieve yield (%)	1000-seed weight (grams)	Reaction to anthrac- nose (races 81, 465, and 479) ¹	Reaction to <i>Fusarium</i> <i>oxysporum</i> (race 3.349) ²	Reaction to angular leaf spot ³	Reaction to CBB ⁴
IAC 2560 Nelore	85	88	290	Resistant	Tolerant	Resistant	Tolerant
IAC 2051	85	90	310	Susceptible	Tolerant	Susceptible	Tolerant
TAA Dama	90	88	290	Susceptible	Tolerant	Resistant	Tolerant

¹ Scoring scale described by Rava et al. (1993), ranging from 1 to 9 (1-3 = resistant and 4-9 = susceptible). ² Disease severity evaluated using the Schoonhoven and Pastor-Corrales (1987) scale (1-3 = resistant and 4-9 = susceptible). ³ Evaluated under field conditions. ⁴ Disease severity evaluated using the Rava (1984) scale, ranging from 0 to 6 (0-2.0 = resistant and 2.1-6.0 susceptible).

For *Xanthomonas axonopodis* (10⁸ CFU mL⁻¹), five replicates were also used. Disease severity was evaluated using the scale proposed by Rava (1984), ranging from 0 to 6, where 0.0 to 2.0 denotes resistance and 2.1 to 6.0 denotes susceptibility. Symptom development was assessed at the inoculation site on the leaf, where cuts were made to facilitate pathogen entry. In contrast, evaluations for angular leaf spot were carried out under field conditions.

Seed coat color was evaluated using a colorimeter (Minolta CR-410), which measures color based on three parameters: L, a, and b*. For this study, only the L* axis (Lightness) was used, which ranges from 0 (black) to 100 (white). Beans with lighter colored seed coats, represented by L* values above 55, are associated with greater consumer visual appeal and higher market value (Ribeiro et al. 2008). The slow seed coat darkening trait was assessed under controlled lighting conditions in an environmental chamber (Biotronette Mark III), following the methodology described by Spitti et al. (2019). Measurements were taken at four points in time (0, 16, 24, and 40 hours), with three replicates per sample. Seed samples were collected from three locations: Tatuí, Capão Bonito, and Adamantina.

Samples of the cultivars IAC 2560 Nelore, IAC 2051, and TAA Dama were exposed to 40 hours of light, in triplicate, and the cultivar with the best tolerance index (slowest seed coat darkening) was IAC 2560 Nelore (Table 5).

TECHNICAL RECOMMENDATIONS AND SEED PRODUCTION

The IAC 2560 Nelore cultivar is recommended for growing in the rainy, dry, and winter crop seasons in the states of the Region I recommendation zone of MAPA (RS, SC, PR, SP, and MS) and for the winter and rainy crop seasons in Region II (RJ, ES, MG, MT, MA, TO, GO, BA, and DF). The cultivar was registered on 18 Sep. 2024 under number 57677 in the Brazilian National Cultivar Registry (Registro Nacional de Cultivares – RNC).

DATA AVAILABILITY

The datasets generated and/or analyzed during the current research are available from the corresponding author upon reasonable request.

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Table 5. L value for each cultivar over progressive exposure time to ultraviolet light

Cultivar	Exposure time (hours) ¹			
	0	16	24	40
	L*			
IAC 2560 Nelore	60.01	55.71	54.73	53.18
IAC 2051	59.38	54.45	53.48	51.75
TAA Dama	57.86	53.43	52.59	51.08

¹ Evaluated with three replications in three different municipalities/counties (Tatuí, Capão Bonito, and Adamantina).

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