

## IAC 2459 Navy: a new small white bean cultivar

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Crop Breeding and Applied Biotechnology  
 25(4): e53192543, 2025  
 Brazilian Society of Plant Breeding.  
 Printed in Brazil  
<http://dx.doi.org/10.1590/1984-70332025v25n4c48>

**Abstract:** *The cultivar IAC 2459 Navy, belonging to the white bean group, has small seeds, a 1000-seed weight of 160 grams, an average 80-day cycle, cooking time of around 23 minutes, 20% protein content, resistance to anthracnose, and yield potential of 3,785 kg ha<sup>-1</sup>.*

**Keywords:** Navy bean, disease resistance, yield



### INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is a highly important crop in Brazilian agriculture and a staple food in Brazil, where it forms what is known as the “perfect combination” when consumed with rice (CONAB 2024). Rich in proteins, carbohydrates, vitamins, minerals, fiber, and antioxidant phenolic compounds, common bean stands out for its high nutritional value, which contributes to its wide distribution throughout the country (Carbonell et al. 2021a, Carbonell et al. 2021b). In the third crop season of 2024/2025, planted area is 2.88 million hectares. With a mean yield of 1,132 kg ha<sup>-1</sup>, total production is 3.26 million metric tons, spread across all five regions and nearly every state of Brazil (CONAB 2024).

The increase in common bean grain yield over the years can be attributed to advances in crop management practices, including efficient use of inputs, adoption of appropriate agronomic techniques, and development of improved cultivars. Common bean breeding programs play a key role in increasing yield, with annual gains in Brazil ranging from 1.07% to 6.74% (Chiorato et al. 2010).

In this context, the Common Bean Breeding Program of the Instituto Agronômico (Programa de Melhoramento Genético de Feijoeiro do Instituto Agronômico de Campinas – PMGF-IAC) plays an essential role in developing improved common bean varieties. The program employs strategies to identify superior genotypes with traits such as high-quality grain, slow seed coat darkening, and enhanced resistance to diseases such as Fusarium wilt and anthracnose. This research also expands the cultivar portfolio, better meeting the demands of the production chain (Bezerra et al. 2021).

Thus, the aim of this study is to present the common bean cultivar IAC 2459 Navy (Gen 96 NB-20-4 advanced line) registered with the Brazilian Ministry of Agriculture (Ministério da Agricultura, Pecuária e Abastecimento – MAPA). It is in the white bean group developed by the common bean breeding program

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**Received:** 21 July 2025

**Accepted:** 04 September 2025

**Published:** 01 October 2025

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of IAC. The cultivar is characterized by small seeds, high yield potential, and anthracnose resistance; and it is adapted to growing conditions in Brazil.

## GENETIC ORIGIN AND DEVELOPMENT

The breeding work conducted in the 1996 dry crop season resulted in the Gen 96 NB-20-4 line, developed from crosses specifically designed to obtain small, white seed coat grain characteristic of navy beans. The breeding design included multiple parental sources: IAC Carioca Aruã, Mar 1, IAC Maravilha, GNN 27, IAC Carioca Pyatã, G 916, and VAC 32. Initially, F<sub>1</sub> plants from the double cross (IAC Carioca Aruã × Mar 1 / IAC Maravilha × GNN 27) were combined with F<sub>1</sub> plants derived from the single cross (IAC Carioca Pyatã × G 916 × VAC 32). The genetic basis of anthracnose resistance in this line is likely derived from IAC Carioca Pyatã, IAC Carioca Aruã, and IAC Maravilha, which are traditional cultivars recognized for their high levels of resistance to *Colletotrichum lindemuthianum*. The designation “Gen 96 NB-20-4” refers to genetics (Gen), the year of crossing (96), and navy bean (NB), indicating a navy bean type with small, white-colored grain obtained through these multiple crosses.

The F<sub>1</sub> seeds from this cross were multiplied in a greenhouse (GH) in the 1998 dry crop season to obtain F<sub>2</sub> seeds. In the 1998 winter and rainy crop seasons, samples of the F<sub>2</sub> seeds were sown in boxes containing vermiculite and sterilized substrate. In the laboratory at seven days after transplanting, the plants were artificially inoculated in inoculation chambers with three physiological races of anthracnose (*Colletotrichum lindemuthianum*: 65.773, 89, and 521), and resistant plants were selected. A total of 75 resistant seedlings and 41 susceptible seedlings were obtained from this cross.

In 1999, 75 resistant seedlings were multiplied in the dry crop season, thus obtaining the F<sub>2.3</sub> generation, whose bean grain was commercially classified as navy beans. In the winter and rainy seasons of that same year, the seeds from that generation was sown to obtain the F<sub>2.4</sub> generation, from which desirable commercial types were selected among plants of the family.

In the following year, seeds were sown in Espirito Santo do Pinhal, SP, to obtain the F<sub>2.5</sub> generation. Upright plants with high agronomic value were selected among plants of the same family. In the winter and rainy crop seasons of the same year, the F<sub>2.6</sub> generation was obtained in Pindorama, SP, selecting plants within families. The aim was to select lines combining agronomically desirable traits within the navy bean commercial type.

In the 2001 dry crop season, a preliminary evaluation was conducted in Monte Alegre do Sul, SP, and Tatuí, SP, with three replicates to assess growth cycle, plant architecture, and resistance to pathogenic agents. In this same year, preliminary evaluations were performed in the dry season in Capão Bonito, SP; Monte Alegre do Sul, SP; and Tatuí, SP in a randomized block experimental design (RBD) with three replicates to evaluate yield and disease resistance.

In the three crop seasons of 2002, 2003, and 2004, preliminary evaluations were performed to assess yield, grain quality, and resistance to common mosaic virus and anthracnose. Artificial inoculation tests were conducted under controlled conditions of temperature, humidity, and photoperiod. The plant material showed resistance, and a promising line with navy type beans was identified, which was designated Gen 96 NB-20-4.

This line was stored from 2005 to 2022 in a cold chamber by the IAC bean breeding program to preserve it in a period of low market demand. This storage was necessary given the limited knowledge of the navy bean type in both Brazil and the export market.

In 2022, Value for Cultivation and Use (VCU) trials began for a two-year period, encompassing six crop seasons (Winter 2022, Rainy 2022, Dry 2023, Winter 2023, Rainy 2023, Dry 2024), to evaluate common bean lines with seed coats other than the carioca and black bean types. These trials, called VCU-OTG (VCU - Other Types of Grain) by the IAC bean breeding program, included 23 lines and 3 check cultivars of Cranberry, White, and Dark Red Kidney commercial bean types. These trials carried out in Region I (RS, SC, PR, SP, and MS) achieved a mean yield of 1,850 kg ha.

## YIELD POTENTIAL

In Region I, the GEN 96-NB-20-4 line exhibited yield performance greater than or equal to that of the check cultivars IAC 2153, IAC 2154, and IAC 2156, as shown in Table 1. Due to its high quality grain, the IAC bean breeding program

**Table 1.** Mean grain yield, in kg ha<sup>-1</sup>, of the IAC 2459 Navy cultivar, evaluated in relation to three check cultivars by site, crop season, and year

Site	Crop season	Year	IAC 2459 Navy cultivar (kg/ha <sup>-1</sup> )	Check cultivars (kg ha <sup>-1</sup> )			Mean yield of the checks (kg ha <sup>-1</sup> )	CV (%)	F value
				IAC 2153	IAC 2154	IAC 2156			
Votuporanga, SP	Winter	2022	2,071	871	1,775	1,142	1,263	22.54	10.52*
Tatui, SP	Winter	2022	2,716	2,398	2,496	1,829	2,241	16.66	15.17*
Campinas, SP	Rainy	2022	2,081	2,248	2,985	1,107	2,113	20.11	4.63*
Tatui, SP	Rainy	2022	2,929	3,475	2,858	1,846	2,726	22.84	3.34*
Mococa, SP	Rainy	2022	817	1,759	1,951	1,539	1,750	21.34	5.09*
Campinas, SP	Dry	2023	402	300	1,001	679	660	21.17	25.03*
Tatui, SP	Dry	2023	1,668	1,171	1,508	1,241	1,307	21.21	2.57*
Mococa, SP	Dry	2023	1,380	1,808	1,585	1,365	1,586	16.71	4.44*
Votuporanga, SP	Winter	2023	3,785	3,514	4,196	2,834	3,515	13.78	5.94*
Campinas, SP	Winter	2023	2,491	1,851	3,036	1,950	2,279	23.86	3.03*
Campinas, SP	Rainy	2023	933	1,143	1,356	1,274	1,258	22.22	7.22*
Capão Bonito, SP	Rainy	2023	2,171	1,914	1,473	1,106	1,498	21.89	5.48*
Campinas, SP	Dry	2024	1,927	1,742	2,045	1,332	1,706	17.51	4.60*
Mean of rainy (1st season)			1,786	2,108	2,124	1,374	1,869	23.49	1.66*
Mean of dry (2nd season)			1,344	1,255	1,535	1,154	1,315	19.22	0.81
Mean of fall-winter (3rd season)			2,766	2,158	2,875	1,938	2,324	18.71	5.99*
Overall mean (Combined)			1,952	1,861	2,174	1,480	1,838	21.14	4.06*

\* Significant at 5% in the F-test.

recommended its release as the cultivar IAC 2459 Navy. The name has the following components: i) IAC – Instituto Agrônômico de Campinas; ii) 24 – year of registration in the RNC (National Cultivar Registry) of the Brazilian Ministry of Agriculture (Ministério da Agricultura, Pecuária e Abastecimento - MAPA); iii) 59 – corresponds to the 59th common bean cultivar developed by the PMGF-IAC; and iv) Navy – a trade name that originated from its use as a canned bean on military ships, and includes the aspects of resistance to anthracnose and its white seed coat color.

## OTHER CHARACTERISTICS

The IAC 2459 Navy cultivar has an indeterminate growth habit and type II plant architecture. The mean 1000-seed weight is 160 grams, with an average cycle of 80 days from emergence to physiological maturity, considered as normal. The plant has medium to tall height, a maximum of 70 cm, and has dark green leaves. Its long pods, containing an average of 5 seeds, are green in color during morphological maturation and turn beige at physiological maturity. The uniform white beans have a mean cooking time of approximately 23 minutes after pre-soaking and protein content of around 20% (Table 2), a value similar to or higher than that of the check cultivars.

The IAC 2459 Navy cultivar showed resistance to anthracnose when artificially inoculated with *Colletotrichum lindemuthianum* races 65.773, 89, and 521. However, it was susceptible to Fusarium wilt caused by *Fusarium oxysporum* race 6. The genotype exhibited moderate resistance to common bacterial blight when assessed with isolate XAP 19 of *Xanthomonas axonopodis*, as well as to bacterial wilt assessed with isolate IBSBF 2869 of *Curtobacterium flaccumfaciens* pv. *flaccumfaciens* (Cff). Reaction to angular leaf spot was determined under natural field infection conditions (Table 3).

Anthracnose assays were carried out under controlled environmental conditions, maintaining temperature, humidity, and photoperiod within predetermined ranges. Plants were inoculated with a suspension of 10<sup>6</sup> spores mL<sup>-1</sup> using the three races already mentioned, with five replicates per treatment. Disease intensity was rated according to the scale proposed by Rava et al. (1993): plants rated between 1 (no visible lesions) and 3 (lesions restricted to a maximum of 3% of the veins on the lower surface of the primary leaf) were considered resistant, whereas plants with scores from 4 (initial lesions on the adaxial veins, approximately 1% affected) to 9 (plant death) were considered susceptible.

**Table 2.** Mean response for cooking time and crude protein content of the bean grain of the new IAC 2459 Navy cultivar compared to two check cultivars: IAC 2153 and IAC 2154

Crop season	IAC 2459 Navy cultivar		Check cultivars			
	Cooking time (min) <sup>1</sup>	Protein content (%) <sup>2</sup>	IAC 2153		IAC 2154	
Cooking time (min)			Protein content (%)	Cooking time (min)	Protein content (%)	
Winter 2022	24.50	19.00	33.20	21.00	22.20	18.50
Rainy 2022	23.20	20.00	41.00	20.50	23.10	19.00
Dry 2023	21.00	19.50	35.20	22.00	22.50	19.32
Winter 2023	25.10	21.00	32.50	22.20	24.00	18.90
Rainy 2023	22.10	21.50	36.00	21.00	19.80	19.20
Dry 2024	24.00	20.00	34.80	22.00	20.00	21.00
Mean	23.32	20.17	35.45	21.45	21.93	19.32

<sup>1</sup> Assessed with the Mattson Cooker (Proctor and Watts 1987). <sup>2</sup> Crude protein content determined by the micro-Kjeldahl method (AOAC 1980, Bataglia et al. 1983).

**Table 3.** Reaction of common bean cultivars (IAC 2459 Navy, IAC 2153, IAC 2154) to anthracnose (*Colletotrichum lindemuthianum* – races 65, 81, 89, and 521), Fusarium wilt (*Fusarium oxysporum*, race 6), angular leaf spot, common bacterial blight (isolate XAP 19 of *Xanthomonas axonopodis*), and bacterial wilt (isolate IBSBF 2869 of *Cff*)

Cultivar	Reaction to Anthracnose <sup>1</sup>	Reaction to Fusarium wilt <sup>2</sup>	Reaction to Angular Leaf Spot <sup>3</sup>	Reaction to Bacterial Blight <sup>4</sup>	Reaction to Bacterial Wilt <sup>5</sup>
IAC 2459 Navy	R	S	R	MR	MR
IAC 2153	R	R	R	MR	MR
IAC 2154	S	S	S	S	R

R: resistant; MR: moderately resistant; S: susceptible. <sup>1</sup> Anthracnose reaction was classified using the scale proposed by Rava et al. (1993), ranging from 1 to 9, where 1-3 denoted resistance and 4-9 susceptibility. <sup>2</sup> Evaluation of Fusarium wilt followed the Schoonhoven and Pastor-Corrales (1987) scale, also ranging from 1 to 9, where 1-3 denoted resistance and 4-9 susceptibility. <sup>3</sup> Angular leaf spot was assessed under natural field conditions. <sup>4</sup> Common bacterial blight was rated according to the scale proposed by Rava (1984), ranging from 0 to 6; where 0.0-2.0 indicated resistance and 2.1-6.0 susceptibility. <sup>5</sup> Bacterial wilt severity was rated on a 1-9 scale, where 1-3 corresponded to resistance, 4-6 to intermediate susceptibility, and 7-9 to high susceptibility.

Fusarium wilt was evaluated using the same inoculum density and replication scheme as for anthracnose. Symptom expression on the hypocotyl was assessed according to the classification scale proposed by Schoonhoven and Pastor-Corrales (1987), with scores from 1 to 3 indicating resistance and scores from 4 to 9 indicating susceptibility.

In trials assessing susceptibility to common bacterial blight, plants were inoculated with a suspension of  $10^8$  CFU mL<sup>-1</sup>, with five replicates per treatment. Assessments followed the Rava (1984) scale (0–6), where values up to 2.0 characterized resistant plants and those between 2.1 and 6.0 susceptible plants. The evaluation was based on lesion development at the inoculation sites, which had been mechanically injured to facilitate bacterial entry. In contrast, angular leaf spot reactions were monitored under field conditions without artificial inoculation.

The methodology of Maringoni (2002) revealed moderate resistance to bacterial wilt (*Cff*). Plants were inoculated at the first trifoliolate stage by injecting a bacterial suspension ( $10^8$  CFU mL<sup>-1</sup>) directly into the hypocotyl. The inoculum was prepared from cultures grown in Nutrient Broth at 28 °C for 48 h and adjusted with sterile distilled water. Disease development was promoted under conditions of 25-28 °C and high humidity. Severity was assessed between 7 and 15 days after inoculation, using a 1–9 scale: values from 1 to 3 indicated resistance, 4 to 6 corresponded to intermediate susceptibility, and 7 to 9 represented severe susceptibility, including wilting, vascular discoloration, and even plant death.

A 50-cm row spacing and 9-12 plants per linear meter is recommended, depending on soil fertility, temperature, and other climate conditions, which results in a plant density of 180,000 to 240,000 plants ha<sup>-1</sup>. The yield of the IAC 2459 Navy cultivar varies according to the crop season, the growing region, and the technological level adopted by the grower, including practices such as fertilization, disease and weed control, an adequate water supply, and other production factors. Waterlogged soils and areas outside the zones for growing common bean should be avoided. The yield potential in VCU trials was 3,785 kg ha<sup>-1</sup> (63.1 bags ha<sup>-1</sup>), achieved under crop management practices recommended by IAC Boletim 100.

## TECHNICAL RECOMMENDATIONS AND SEED PRODUCTION

The IAC 2459 Navy cultivar exhibited strong agronomic performance, with mean yields of 1,786 kg ha<sup>-1</sup>, 1,344 kg ha<sup>-1</sup>, and 2,766 kg ha<sup>-1</sup> during the rainy, dry, and winter crop seasons, respectively (Table 1). Compared to the check cultivars (IAC 2153, IAC 2154, and IAC 2156), IAC 2459 showed variations of -4.44%, +2.21%, and +19.02% in the rainy, dry, and winter seasons, respectively. The cultivar showed resistance to several physiological races of the anthracnose pathogen (*Colletotrichum lindemuthianum*), and it is recommended for cultivation in all three seasons in the states comprising Region I (RS, SC, PR, SP, and MS) of the MAPA Recommendation Zones.

The IAC 2459 Navy cultivar was registered in the Brazilian National Cultivar Registry (Registro Nacional de Cultivares - RNC) of the Brazilian Ministry of Agriculture (Ministério da Agricultura, Pecuária e Abastecimento - MAPA) on 18 Sep. 2024 under registration number 57686. Foundation seed is available for seed production at the Seed Production Center of the Instituto Agronômico (IAC).

## 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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