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Assessment of pea seed quality in the production zone of the Nariño department

Evaluación de calidad de semilla de arveja en la zona productora del departamento de Nariño

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ABSTRACT

In Colombia, the largest pea production occurs in the south of the department of Nariño. Seed is the most important input for cultivation; however, practices used for its selection and storage can reduce its quality and viability. This research analyzed the physical, physiological, and sanitary quality of pea seeds from two sources: producers and those produced according to Colombian regulations (wineryhouse). Regarding quality variables, 58% of the samples in producer seed presented rough, whitish, or spotted grains, plant residues, and inert material. Their germination was lower than required by regulations; 75% presented a humidity percentage higher than recommended (14%). Environmental and phytopathogenic fungi were isolated, from which 15 consensus sequences of the ITS region of rRNA were obtained, allowing the identification of *Alternaria* sp., *Botrytis* sp., *Stemphylium* sp., *Arthrinium* sp., *Dydimella* sp., *Parastagonospora* sp., *Penicillium* sp., *Verrucoconiothyrium* sp., *Cladosporium* sp., *Trametes versicolor,* and *Epicoccum* sp. No presence of *Pseudomonas* spp. was detected in the seed. *Potyvirus* was present in 5 of the 24 samples evaluated. There were no impurities or atypical grains in the seed from the winery; germination was greater than 80% in the 24 months of evaluation, and humidity met the specifications for certified seed. The frequency of fungi and bacteria was lower than in the producers' conditions, although *Monilia* sp. and *Penicillium* sp. were found. The seed from producers has low quality, while warehouse seed complies with Colombian regulations, highlighting the importance of improving production and storage conditions by producers.

Keywords: Colombian regulation; germination; ITS of rRNA; *Pisum sativum* L; seedborne pathogens; viability

RESUMEN

En Colombia la mayor producción de arveja se registra en el sur del departamento de Nariño. La semilla es un insumo clave para el cultivo, sin embargo, las prácticas de selección y almacenamiento pueden afectar su calidad. Esta investigación analizó la calidad física, fisiológica

y sanitaria de semilla de arveja de dos procedencias: productor y semilla producida según la normatividad colombiana (bodega). En la semilla del productor, el 58% de las muestras presentó granos rugosos, blanquecinos o con manchas, residuos vegetales y material inerte, y su germinación fue inferior a lo requerido por la normativa; el 75% presentó un porcentaje de humedad mayor al recomendado (14%). Se aislaron hongos saprofitos y fitopatógenos, de los cuales se obtuvieron 15 secuencias consenso de la región ITS del rARN, permitiendo identificar *Alternaria* sp., *Botrytis* sp., *Stemphylium* sp., *Arthrinium* sp., *Dydimella* sp., *Parastagonospora* sp., *Penicillium* sp., *Verrucoconiothyrium* sp., *Cladosporium* sp., *Trametes versicolor* y *Epicoccum* sp. No se detectó *Pseudomonas* spp. y se encontró *Potyvirus* en 5 de 24 muestras de semilla. La semilla de bodega no presentó impurezas ni granos atípicos, la germinación fue superior al 80% durante 24 meses y la humedad fue inferior a 14%. La frecuencia de hongos y bacterias fue menor que en las condiciones de los productores, aunque se encontraron *Monilia* sp. y *Penicillium* sp. La semilla de productor presenta baja calidad, mientras que la de bodega cumple con la normatividad colombiana, por los que es importante mejorar las condiciones de producción y almacenamiento de los productores.

Palabras claves: fitopatógenos; germinación; ITS de rRNA; *Pisum sativum* L; regulación colombiana; viabilidad

INTRODUCTION

The Andean region of the Nariño department, located in the southwest of Colombia, has optimal environmental conditions for pea cultivation, enabling it to remain the country's leading producer for several years. In recent decades, the area planted with and overall production have increased, with 13,041 hectares and 42,452 tons recorded in 2022. This growth has lead to a greater demand for high-quality seed (Cadena *et al*., 2020; AGRONET, 2022).

In Colombia, the formal production and marketing of quality pea seeds are supervised by the Colombian Agricultural Institute (ICA) and regulated by Resolution 11340 of 2024 (ICA, 2024).

This regulation establishes four quality factors that the seed must meet: physical, physiological, genetic, and seed sanitary status. Genetic quality refers to genetic homogeneity and uniformity. Physiological quality relates to germination capacity and seed vigor. Physical quality involves the absence of contamination by seeds of other crops or weeds, inert matter, mechanical damage, discoloration, and undersize or underweight seeds. Sanitary status refers to the absence of infestation or infection by seed-borne pests, including microorganisms and insects (Dadlani & Yadava, 2023).

The use of quality seeds ensures good emergence, vigorous plants, and high productivity (Miranda & Ayala, 2013). Seed quality is influenced by various factors during pre-harvest stage, harvesting, and storage, including temperature, relative humidity, seed moisture content, and exposure to insects, rodents, and microorganisms (Christensen & Kaufmann, 1969; McDonald & Nelson, 1986; Martín *et al*., 2022). While seeds primarily serve as carriers of genetic information, they can also act as vectors for the transmission of pathogens that cause diseases in peas, such as *Ascochyta* spp., *Colletotrichum* spp., *Pseudomonas syringae*, and up to 42 virus species belonging to 11 different families (Tamayo, 2000; Pabón-Villalobos & Castaño-Zapata, 2012; Dell'Olmo *et al*., 2023).

In the Nariño department, only 10-15% of the seed demand (approximately 765 tons) meets the quality standards established by the ICA resolution. Therefore, most of the seed used in the department comes from exchange, informal trade, or previous crops that were originally intended for fresh peas production but, due to

climatic conditions or commercial difficulties, are left to mature until dry grain (Realpe, 2017; Cadena *et al.*, 2020; Checa Coral *et al.*, 2022). These practices do not guarantee traceability in the production, conditioning, and storage of the seed. Pea research in the Nariño department has focused on the evaluation and development of new varieties with agronomically desirable traits (such as disease resistance and tolerance, high yields, and improved plant architecture), as well as studies on crop fertilization and agro-industrial processes (Casanova *et al.*, 2012; Torrado *et al.*, 2020; Valencia *et al.*, 2012). Currently, there are no reports on the quality of the seed used by producers in the region. Therefore, it is essential to conduct research aimed at optimizing storage and conditioning circumstances, to allow seeds to express their genetic potential in the field. Considering the above, the objective of the present study was to determine the physical and physiological quality, as well as the sanitary status of pea seed used by producers in the department of Nariño.

MATERIAL AND METHODS

Biological material

The evaluations were carried out on two groups of seeds from different origins. The first group consisted of 24 samples of 2 kg each, collected from farms of producers in the municipalities of Ipiales, Pupiales, Puerres, Gualmatán, Contadero, Ospina, Potosí, Córdoba, and Pasto in the department of Nariño (Colombia) (Figure 1). Each producers was interviewed regarding basic aspects of seed production conditions. The second group consisted of 22 seed samples of the Obonuco San Isidro variety, produced by AGROSAVIA, selected and stored following Colombian, ICA Resolution 11340 (ICA, 2024).

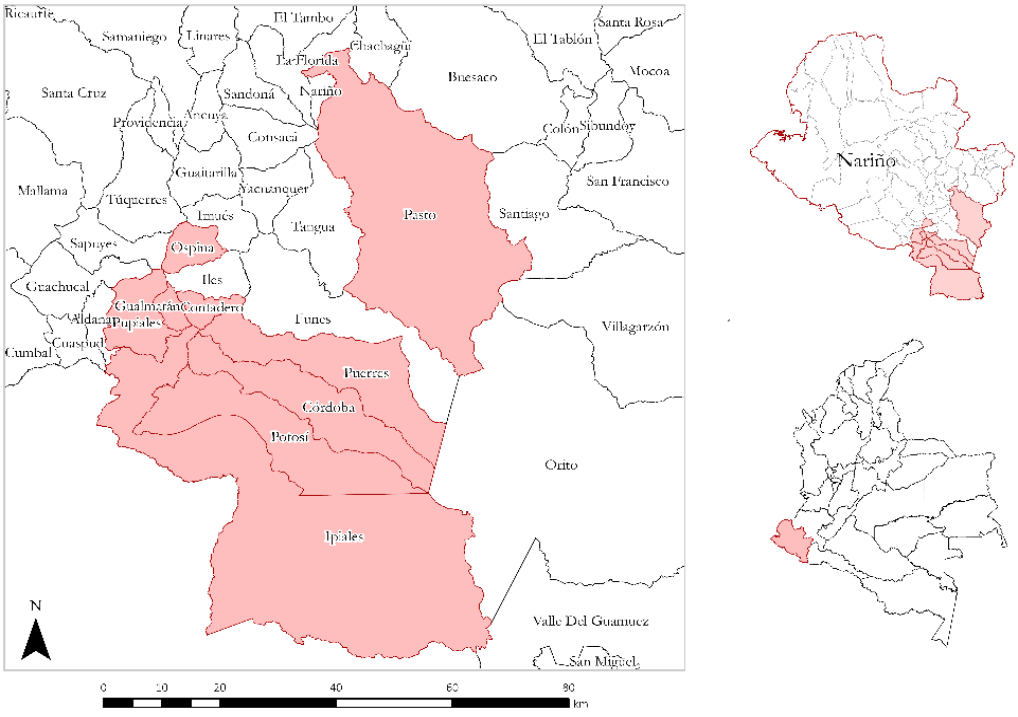

Figure 1. *Municipalities in southern Nariño, where pea seeds were collected.*

Physical evaluation of the seed

A visual inspection of the physical characteristics of the seeds was conducted. A total of 100 seeds from each sample were examined to identify the presence of surface spots, discoloration, and malformations. Based on the recorded data, the percentage of seeds exhibiting these alterations was calculated. Additionally, the presence of dry remains of the plant, stones, or any residue within the samples was assessed.

Physiological evaluation of the seed

Germination percentage. A total of 100 seeds from each sample were placed in trays on paper moistened with sterile water and incubated at a temperature of 16 to 18 °C under conditions of darkness and constant humidity for seven days. After the time elapsed, the number of viable germinated seeds, non-germinated seeds, and non-viable germinated seeds (presence of malformations in the radicle and/or microbial growth on its surface) was counted. The germination percentage was calculated, and ranges were defined based on the distribution of values (Cadena *et al.,* 2022; Dadlani & Yadava, 2023).

Humidity. The moisture content of 60 g of seed from each sample was determined using the John Deere SW08120 grain meter, with the dry pea program established in the equipment (ICA, 2024).

Seed health status

Fungi. Thirty seeds from each sample were surface-disinfected by immersion in 70% ethanol for 1 minute, followed by 1% sodium hypochlorite for 1 minute, and then rinsed three times with sterile distilled water. The seeds were subsequently sown in Petri dishes containing Potato Dextrose Agar (PDA) and incubated at 25°C for 7-10 days (Pabón-Villalobos & Castaño-Zapata, 2012; ISTA, 2024a). The grown colonies were purified on PDA, identified to the genus level using taxonomic keys, and their isolation frequency was determined (Barnett & Hunter, 1998). The isolates were classified as either saprophytic or phytopathogenic fungi based on published reports.

To confirm fungal identity at the molecular level, DNA was extracted from the colonies using the Quick-DNA Fungal/Bacterial Miniprep kit, following the manufacturer's instructions. Polymerase chain reaction (PCR) was used to amplify a partial region of the Internal Transcribed Spacer (ITS) of the rRNA, using the primers ITS4F (5´- TCC TCC GCT TAT TGA TAT GC – 3´) and ITS5R (5´- GGA AGT AAA AGT CGT AAC AAG G – 3´) (White *et al.*, 1990). PCR reaction mixes were prepared in a final volume of 50 µL, consisting of 5 µL of DNA and 45 µL of Master Mix (5 µL of Taq Buffer (KCl-MgCl) 1X, 5 µL of $MgCl_2$ 2.5 mM, 5 µL of dNTPs 0.2 mM, 5 µL of forward primer 0.2 mM, 5 µL of reverse primer 0.2 mM, 19.5 µL of water, and 0.5 µL of Taq polymerase) (Koyyappurath *et al.*, 2016). PCR products were sequenced in both directions by the Molecular Genetics Laboratory of the Colombian Agricultural Research Corporation (AGROSAVIA). consensus sequences were edited using Geneious software (Kearse *et al.*, 2012), and taxonomic identity of the sequences was confirmed using the BLASTn tool (Altschul *et al.*, 1990).

Bacteria. Since *Pseudomonas* spp. can be seed-transmitted and cause significant yield losses in pea, this study aimed to determine the frequency of its isolation. The ISTA (2024b) methodology was used with modifications. A total of

100 seeds were surface-disinfected with 70% ethanol, 1% sodium hypochlorite, and three washes with sterile distilled water. They were then incubated in 100 mL of 0.85% saline solution at 150 rpm and 18 °C for 36 hours. Two 10-fold serial dilutions based were prepared and seeded, along with the extraction solution, in King's B (KB) medium. The seedings of the dilutions were incubated at 28 °C for 3 days. Bacterial colonies that grew in the culture medium were characterized microscopically with Gram stain and biochemically using the oxidase, catalase, KOH, oxidative fermentation (OF), growth in yeast extract-dextrose-CaCO3 (YDC), levan production, and fluorescence in KB medium tests (Grünwald *et al.*, 2004; Janse, 2006).

Virus. Potyvirus detection was performed on the 24 seed samples from producers using the ELISA method. Sixty grams of seed were macerated, and a 0.3 g sample was taken and analyzed using the ACP-ELISA Reagent Set and an Agdia Pathoscreen Kit. Samples with an absorbance result twice as high as the negative control were considered positive (Abidin *et al.*, 2025).

RESULTS

Analysis of seed produced and stored by producers in Nariño

Physical evaluation of the seed. The physical quality of the seed from the producers was variable. Of the total samples, 10 (42%) consisted of clean seeds, while 14 (58%) contained impurities such as plant residues and inert material. These impurities originated from the harvesting process, during which pods are manually removed and leaves, stem fragments, or seeds from nearby weeds may be collected inadvertently. In addition, some samples contained rough, whitish, or spotted seeds (Figures 2A and 2B).

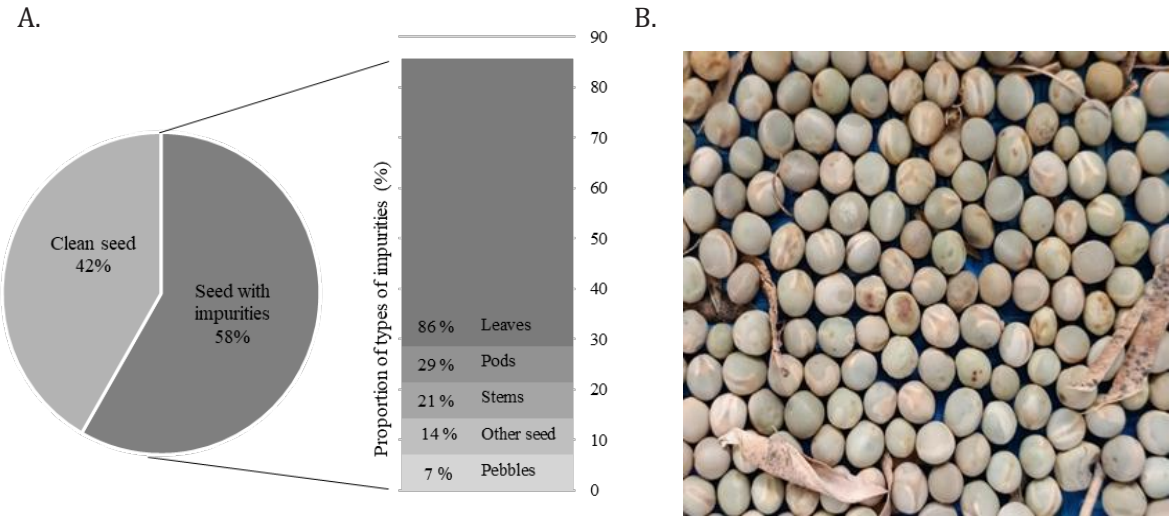

Figure 2. *Physical quality of seed samples produced and stored by producers in Nariño with impurities. (A) Proportion and type of impurities. (B) Seed of low physical quality.*

Physiological evaluation of the seed. Regarding germination, nine of the 24 samples (38%) showed values above 80% (Figure 3A), as required by current ICA regulations. The remaining 62% included samples with values between 0 and 50%. Some producers reported storing their seed in "cabuya" or polypropylene sacks, on pallets or shelves to avoid direct contact with the soil. The maximum reported storage time was two years, in dry locations and without direct exposure to sunlight. In terms of moisture content, only 25% of the samples were within the recommended range for storage (≤ 14%), while the remaining samples exceeded 15%, surpassing the limit established by the ICA regulations (Figure 3B).

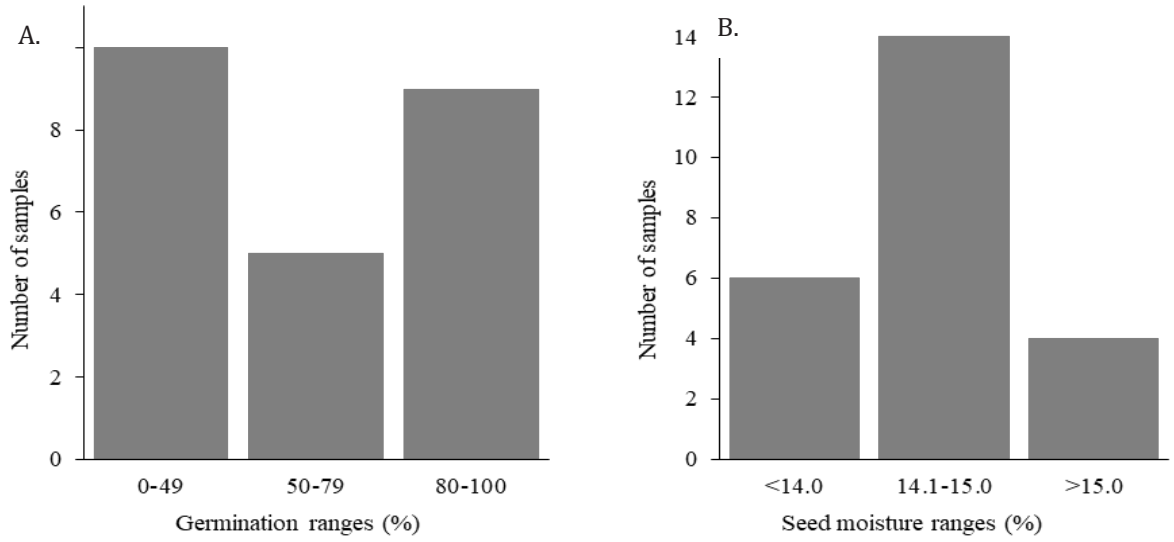

Figure 3. *Physiological variables evaluated in pea seeds produced and stored by producers in Nariño. (A) Germination. (B) Seed moisture.*

Seed health status. A total of 13 fungal isolates were obtained from the 24 seed samples collected from producers and were taxonomically identified to the genus level as *Penicillium, Aspergillus, Cladosporium, Alternaria, Stemphylium*, and *Botrytis*. Some isolates could not be identified due to the absence of reproductive structures. The taxonomic identity of several fungi with high isolation frequency was confirmed through molecular analysis. In total, 15 consensus sequences corresponding to the ITS region of rRNA were obtained in this study (Table 1). These sequences, with accession numbers PQ046086 to PQ046100, were registered in the National Center for Biotechnology Information (NCBI).

Table 1. *Fungi identified in pea seeds from producers in Nariño by sequencing the ITS region of rRNA.*

Code of Isolation	Identified species or genus	GenBank deposit accession number	% similarity	Closest sequences in GenBank
IPI101-H1	*Alternaria* sp.	PQ046086	100	MN077468, OU989240, MN313283
IPI101-H2	*Botrytis* sp.	PQ046087	100	MT573470, MN589855, OU989292, MK217911, OR528633

Code of Isolation	Identified species or genus	GenBank deposit accession number	% similarity	Closest sequences in GenBank
COR201-H1	*Botrytis* sp.	PQ046097	100	MT573470, MN589855, OU989292, MK217911, OR528633
IPI102-H1	*Stemphylium vesicarium*	PQ046088	100	MN596833, MH879836
PUP203-H1	*Stemphylium* sp.	PQ046092	100	OW983036, MK432743
IPI102-H2	*Arthrinium* sp.	PQ046089	100	FJ466728, FJ466703
PUE1204-H1	*Dydimella* sp.	PQ046090	100	MH325465
COR202-H2	*Dydimella* sp.	PQ046099	100	MH325465
PUE201-H3	*Parastagonospora* sp.	PQ046091	100	KY090647
IPI203-H3	*Penicillium* sp.	PQ046093	97	OQ211124
CON201-H2	*Penicillium* sp.	PQ046094	100	MT530014, MT446172
CON201-H4	*Verrucoconiothyrium* sp.	PQ046095	100	MK432792, MH454105
CON205-H1	*Cladosporium* sp.	PQ046096	99	KF938436, MH865203
COR201-H3	*Trametes versicolor*	PQ046098	100	MN749366
COR202-H3	*Epicoccum* sp.	PQ046100	100	OQ673640

According to the literature, *Penicillium* spp., *Aspergillus* spp., *Parastagonospora* spp., *Verrucoconiothyrium* spp., *Arthrinium* spp., *Trametes versicolor*, and *Epicoccum* spp. are considered saprophytic fungi. In contrast, *Cladosporium* sp., *Alternaria* spp., *Stemphylium*, *Botrytis*, and *Didymella* are considered phytopathogenic fungi, as they have been reported to cause disease in pea crops. The isolation frequencies of saprophytic and phytopathogenic fungi from producer seed samples were 83% and 70%, respectively (Figure 4A).

Regarding bacteria, a total of 76 isolates were obtained from the 24 seed samples. Gram staining revealed that 60% were Gram-negative bacilli, 45% were Gram-positive bacilli, and 18% Gram-positive cocci (Figure 4B). Isolates exhibiting the morphology of Gram-positive bacilli and cocci were excluded from subsequent biochemical testing. Among the Gram-negative bacilli, 11 distinct macroscopic colony morphologies were selected, all showing positive oxidase and negative catalase reactions. However, none of these isolates exhibited fluorescence on KB medium, levan production, or oxidative metabolism in OF medium. Therefore, they were not considered typical isolates of *Pseudomonas* spp., and molecular characterization was not performed. In the virus analysis, the presence of *Potyvirus* was detected in five of the 24 seed samples collected from the municipalities of Potosi, Puerres, and Pasto. These samples were considered positive, as their absorbance values were above the cutoff threshold (0.3904).

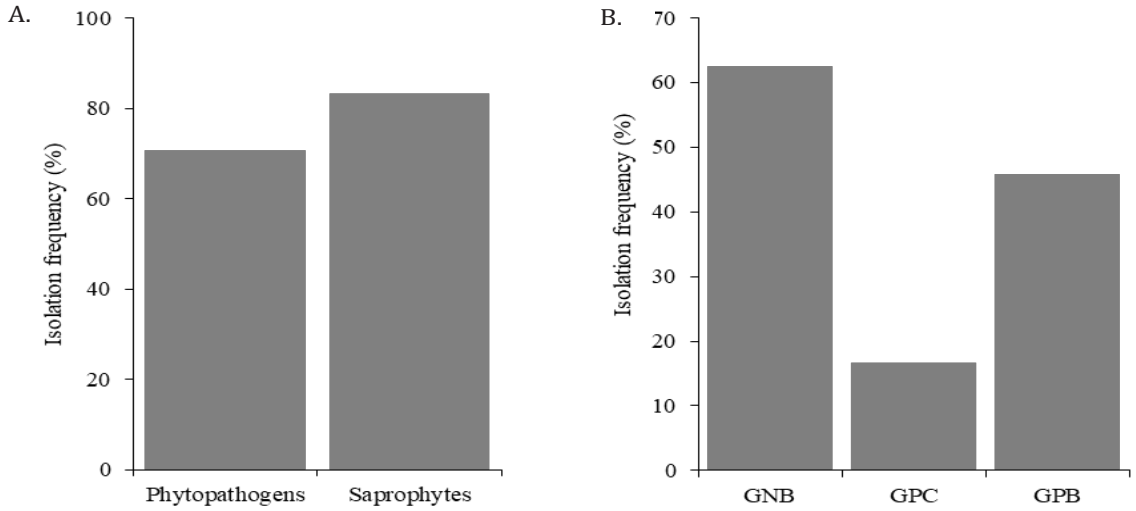

Figure 4. *Frequency of isolation of microorganisms in samples of pea seeds produced and stored by producers in Nariño. (A) Fungi. (B) Bacteria. GNB: Gram Negative Bacillus; GPC: Gram Positive Coccus; GPB: Gram Positive Bacillus.*

Analysis of seed produced and stored according to Colombian regulations

Physical evaluation of the seed. The seed showed uniformity in the evaluated attributes; 100% of the samples (22 in total) met the physical quality required by Colombian regulations for seed production (Figure 5A). These seed samples originated from production lots and post-harvest processes conducted according to the recommendations of Cadena *et al.* (2020). The process involved multiple positive selection steps, integrated crop management, timely harvesting, calibrated mechanized shelling, impurity removal, manual selection, and classification of seeds based on size, color, and shape. This rigorous production and conditioning protocol ensured the physical quality of the seed.

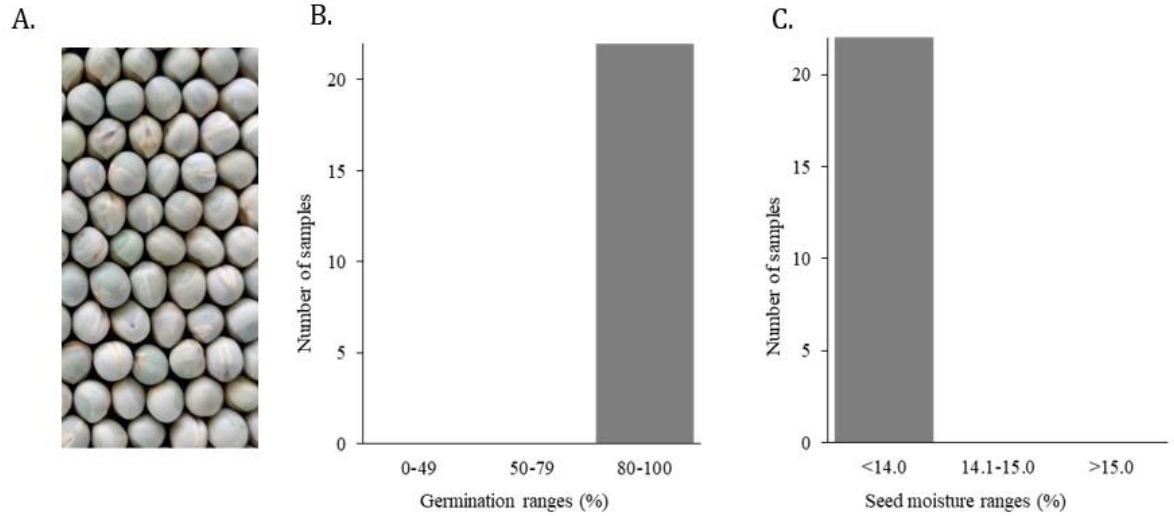

Figure 5. *Physical and physiological variables evaluated in pea seeds produced, selected, and stored according to Colombian regulations. (A) Physical quality. (B) Germination. (C) Seed moisture.*

Physiological evaluation of the seed. The seed was packed in 30-kilogram polypropylene sacks on pallets, separated 20 cm from the wall, in a clean, well-ventilated area free from humidity and direct sunlight. These storage conditions contributed to germination rates above 90% for all 22 samples evaluated (Figure 5B), maintaining a humidity of less than 14% after 24 months of storage (Figure 5C), and complying with the specifications for certified seed (ICA, 2024).

Seed health status. A total of three fungi isolates were obtained from samples and were taxonomically identified as *Monilia* spp., and *Penicillium* spp. These fungi were isolated at a lower frequency compared to those recorded in seeds from the producer's farm and were considered as saprophytic. Consequently, no phytopatogenic fungi were detected in the seed produced and stored according to Colombian regulations (Figure 6A). For this reason, molecular identification of the isolates was not performed. Regarding bacteria, all isolates found in the samples were Gram-positive bacilli (Figure 6B). Based on colony morphology, Gram staining and biochemical tests, particularly the absence of fluorescence on KB medium, the presence of typical *Pseudomonas* colonies was rule out.

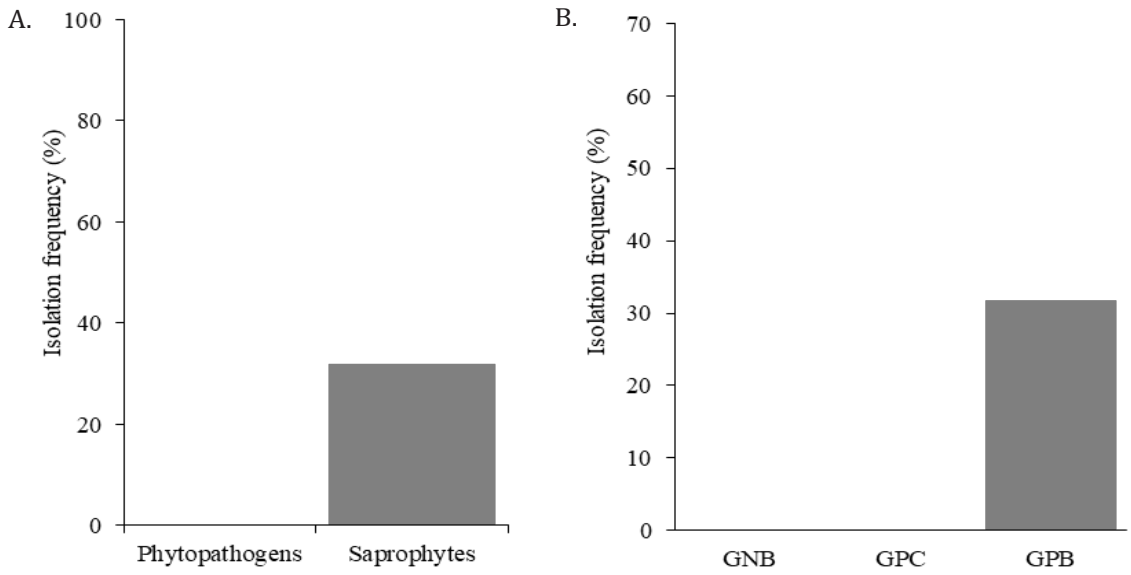

Figure 6. *Frequency of microorganisms in samples of pea seeds produced, selected, and stored according to Colombian regulations. (A) Fungi. (B) Bacteria. GNB: Gram Negative Bacillus; GPC: Gram Positive Coccus; GPB: Gram Positive Bacillus BG.*

DISCUSSION

The results of this study indicate that seed samples from producers exhibited low levels of physical, physiological and sanitary quality. In contrast, high levels of these attributes were observed in the seed stored according to Colombian regulations.

Several authors agree that low physical quality represents a significant issue in both seeds and grains intended for export, with post-harvest practices being a major influencing factor. The impact forces applied during pea shelling, whether manual or mechanized, can affect the quality of the grain. These impacts are

conditioned by factors such as the speed and energy of the impact, the structure of the seed, its variety, and its moisture content (Shahbazi *et al.,* 2017; Arévalos *et al.,* 2021).

Regarding physiological quality, the low germination percentages found in the evaluated samples from producers may be due to the storage of the seed in non-hermetic containers, which exposes it to fluctuating environmental conditions (temperature and relative humidity), as well as to insects, animals, chemical substances, and poor sanitation in the storage area. These factors can lead to contamination and negative impact germination. The findings align with the statements of Pabón-Villalobos and Castaño-Zapata (2012), who notes that the greatest source of contamination occurs during the drying and storage period. Another important factor to consider is the condition of the seeds prior storage. In the field, crop may have been exposed to pest attacks, pathogenic organisms or unfavorable moisture levels, all of which can accelerate deterioration and, subsequently, reduce germination at the time of evaluation (SAGARPA, 2017).

The high seed moisture content (>15%) observed in the producer's seed negatively affects quality, as it increases grain deformation during mechanical shelling. Previous studies have shown that seed moisture interacts with impact force during shelling, significantly increasing the likelihood of grain breakage in peas (Shahbazi, 2017). This factor may have contributed to the physiological deterioration of the seeds (Arévalos *et al.*, 2021), and consequently, to low germination rates observed. Furthermore, Shahbazi *et al.* (2011) reported that a seed moisture content of 17.5% in pinto beans resulted in a 15.3% reduction in germination rate.

Saprophytic and phytopathogenic fungi were isolated from the producer's seed, whereas only saprophytic fungi were isolated from seed stored under conditions established by Colombian regulations. The producer´s seed also exhibited low physical quality and a low germination percentage. Seeds with mechanical damage or malformations are more susceptible to fungal infection, and the presence of fungi can lead to seed discoloration, embryo death, reduced germination and seedling vigor, mycotoxin production, and the transmission of plant diseases (McDonald & Nelson, 1986; Martín *et al.*, 2022; Dell'Olmo *et al.*, 2023; Ragukula & Makandar, 2023).

Saprophytic fungi may reach the seed either in the field, during post-harvest handling, or throughout storage. In the field, they are present in the soil, vegetation, and senescent plant parts such as pods. These fungi can infect the seed when pods remain in the field for extended periods, particularly during times of high rainfall, which promotes fungal growth in the pea grain. During post-harvest handling, if plant residues and inert material are not properly removed, seeds can become contaminated through contact with them. Similarly, during storage, inadequate practices such as exposure to high environmental humidity, can contribute to fungal contamination (McDonald & Nelson, 1986).

The phytopathogenic fungi *Cladosporium* spp., *Alternaria* spp., *Botritys* spp., and *Dydimella* sp. have been reported as important pathogens in the pea cultivation (Youssef *et al.*, 2018; Moparthi *et al.*, 2023; Ragukula & Makandar, 2023). For *Botrytis* spp., it has been reported that the fungus can reach the seed through the vascular bundles of the mother plant or via the flower. Under high humidity conditions, the conidia present in the flower germinate, infecting surrounding tissues and subsequently the developing pods (Brauna-Morževska *et al.*, 2019). *Didimella* pycnidia have been found in seeds, most commonly on the seed coat and, to a lesser extent, in the embryo, making the seed a vehicle for disease dissemination (Dell'Olmo *et al.*, 2023).

Colonies of the genus *Stemphyllium* spp. were also isolated with high frequency. There are few reports of this genus causing disease in peas; one such report o from India described small, round to oval, pale to brown, sunken spots on the leaves, stem, and pods (Tiwari, 1997). Therefore, it would be advisable to continue studying the potential of this fungus to cause disease in pea crops in Nariño.

There was no presence of typical *Pseudomonas* colonies in either the producer's seed or in the seed stored under the conditions established by Colombian regulations. This contrasts with the findings of Pabón-Villalobos and Castaño-Zapata (2012), who reported the presence of *Pseudomonas syringae* in seeds obtained from a marketplace in the department of Caldas, Colombia. Similarly, in India, *Pseudomonas syringae* pv. *pisi* was identified in seeds exhibiting brown to black spots and discoloration (Verma & Meena, 2021). This bacterium is considered a seedborne pathogen and has been found in the space between the seed coat and spermoderm, on the inner side of seed coat, in the endosperm, radicle, and hilum region (Roberts *et al.*, 1996). Its presence in the seed causes necrosis, the formation of lytic cavities, and a reduction in cellular contents (Verma & Agrawal, 2018).

The presence of *Potyvirus* in the samples from producers is consistent with previous reports of virus from this genus in pea, including *Pea seed-borne mosaic virus* (PSbMV), which is the most important virus affecting this crop and is transmitted by the seed. Its transmission is associated with the invasion of the immature embryo from the mother plant (Roberts *et al.*, 2003). Therefore, the only way to prevent the presence of viruses in the seed is to detect diseased plants in the field, eliminate them, and control their vector, which are aphids (Coutts *et al.*, 2008; Congdon *et al.*, 2016).

Since seed is the main input in agricultural production and expresses the genetic potential of the species, it must come from plots managed with proper agronomic practices during the production process. This ensures the genetic, physical, physiological, and sanitary quality of the planting material. A higher guarantee of seed quality is achieved when it originates from fields inspected by the competent plant health authority (Patiño-Moscoso *et al.*, 2022).

It is essential to increase training in seed production and storage so that producers can manage their own seeds effectively, reducing the risk of deterioration due to microorganisms and meeting the productivity expectations of the varieties. Additionally, research is needed to better understand the implications of phytopathogen presence in pea seeds and to implement detection techniques accessible to seed producers in the region.

CONCLUSIONS

The seed used by producers in southern Nariño exhibits low physical, physiological, and sanitary quality. This is evidenced by alterations in seed color and shape, the presence of inert materials, low germination rates, moisture levels exceeding those recommended by technical standards, and the presence of phytopathogenic fungi such as *Alternaria, Botrytis, Stemphylium, Dydimella,* and *Cladosporium*, as well as viruses from the Potyvirus family. In contrast, seed produced and storage in compliance with Colombian regulations maintains the

quality and uniformity of its attributes. No typical *Pseudomonas* spp. colonies were detected in either seed group. These findings underscore the importance of improving pea seed production and storage practices on farms to ensure seed quality and, consequently, a reliable supply for regional producers.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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