

Proposal of descriptors to study the variability of *Vaccinium meridionale* Swartz

Propuesta de descriptores para estudiar la variabilidad de *Vaccinium meridionale* Swartz

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Clara Inés Medina-Cano^{1*}, Gustavo Adolfo Ligarreto-Moreno² and María Orfilia Vargas-Arcila¹

ABSTRACT

Keywords:

Underutilized species
Neotropical
Ericaceae
Berries
Genetic resources

Agraz, mortiño, or Andean blueberry (*Vaccinium meridionale* Swartz) is a fruit tree with high potential for national consumption since it is considered a functional food due to its high content of anthocyanins and antioxidants. The morphological description in plants involves both characterization variables that are highly heritable and easily detectable, as well as evaluation variables influenced by the environment and useful for genetic breeding that, together, are called descriptors and allow knowing the variability of the species. The aim of this study was to develop a list of morphological descriptors with the inclusion of variables to characterize and evaluate *Vaccinium meridionale* Swartz. Observations were made in natural populations of 11 municipalities in Antioquia, three in Boyacá, one in Cundinamarca, two in Nariño, and one in Santander, Colombia, as well as in the *ex situ* collection established in Rionegro Antioquia, between 2005 to 2011. A descriptor with 38 quantitative, binary, and multi-state variables was developed. Seven of these variables were obtained at the plant level, 10 from the leaf, six from the flower, 14 from the fruit, and one from the seed. The application of the morphological descriptors in *in situ* and *ex situ* conditions reported high polymorphism in the qualitative traits and high variation between individuals for the quantitative variables in the collections under study. These variables are of taxonomic and agronomic importance in the knowledge of the species and are essential for producing and marketing the fruit.

RESUMEN

Palabras clave:

Especie sub-utilizada
Neotropical
Ericácea
Bayas
Recurso genético

El agraz o mortiño (*Vaccinium meridionale* Swartz) es un frutal con alto potencial para el consumo nacional ya que se considera un alimento funcional por su alto contenido de antocianinas y antioxidantes. La descripción morfológica en plantas involucra tanto variables de caracterización que son altamente heredables y fácilmente detectables, como las de evaluación influenciadas por el ambiente y útiles para el mejoramiento genético, que en su conjunto se denominan descriptores y permiten conocer la variabilidad de las especies. El objetivo de este estudio fue desarrollar una lista de descriptores morfológicos con la inclusión de variables para la caracterización y evaluación del *Vaccinium meridionale* Swartz. Se realizaron observaciones en poblaciones naturales de 11 municipios de Antioquia, tres en Boyacá, una en Cundinamarca, dos de Nariño y una en Santander, Colombia, al igual que en la colección *ex situ* establecida en Rionegro Antioquia, entre el 2005 y el 2011. Se desarrolló un descriptor con 38 variables cuantitativas, binarias y multi-estado. Siete de estas variables se obtuvieron a nivel de planta, 10 de la hoja, seis de la flor, 14 del fruto y una de la semilla. La aplicación de los descriptores morfológicos en condiciones *in situ* como *ex situ* reportó alto polimorfismo en las características cualitativas y alta variación entre individuos para las variables cuantitativas en las colecciones en estudio. Estas variables son de importancia taxonómica y agronómica en el conocimiento de la especie e importantes para la producción y el mercadeo del fruto.

¹Corporación Colombiana de Investigación Agropecuaria - Agrosavia. Rionegro, Antioquia. cmolina@agrosavia.co , mvargasa@agrosavia.co 

²Universidad Nacional de Colombia. Facultad de Ciencias Agrarias. Bogotá, Colombia. galigarretom@unal.edu.co 

*Corresponding author

Agraz, mortiño, vichachá and camueza in Spanish, or Andean blueberry in English, are common names of *Vaccinium meridionale* Swartz a berry plant that belongs to the family Ericaceae Juss., tribe Vaccinieae Rehb that includes about 35 genera and more than 1,000 species (Luteyn 2002). The species belongs to the Pyxothamnus section and includes other species such as *V. consanguineum* Klotzsch, *V. floribundum* Kunth, and *V. puberulum* Klotzsch (Ehlenfeldt and Luteyn 2021).

In the Neotropics, the Ericaceae family is concentrated in northwestern South America, typically in mountainous habitats with cold and humid areas, between 1,500 and 3,000 meters above sea level (masl). Species of this family are mainly found in Colombia, Ecuador, Peru, and Venezuela, where almost 50% of the species are epiphytic, and approximately 94% are endemic (Luteyn 2002). The *Vaccinium* genus has a wide geographical distribution, found in cold and temperate tropical zones with representation in most continents, except Antarctica (Luteyn 2002), Australia, and most parts of Africa (Vander-Kloet 1990). Most of the species grow in acidic and well-drained soils with high organic matter content, coastal dunes, lake, and river margins, abandoned fields, or mountain terrains (Lyrene et al. 2003).

V. meridionale is found predominantly in the coastal and Andean areas of Venezuela, on the Andes of Colombia, on the island of Jamaica and on the mountains of Peru. Its habitats include high mountain cloud forests to moor thickets between 1,000 and 2,800 masl (Ehlenfeldt and Luteyn 2021). In Colombia, according to the National Institute of Natural Sciences, the distribution of *Vaccinium* species includes the departments of Antioquia, Boyacá, Cauca, Chocó, Cundinamarca, Magdalena, Meta, Nariño, Norte de Santander, Putumayo, Quindío, Santander, and Tolima. The highest number of reports are found in Antioquia, Boyacá, and Cundinamarca. The latter has more records of *V. floribundum*, a closely related species, and Antioquia has the highest number of records for *V. meridionale* (Ligarreto 2009).

The first report of the species was found using the name "mortiño", described as a Castilian (Spain) word applied to plants of the genus *Vaccinium*, a name imposed by the Spanish in America. The first reference to the expression

"mortiño" dates back to 1548, used in the Guaca region, the current province of Carchi, Ecuador, a town inhabited by the Pastos indigenous people (Patiño 2002).

V. meridionale produces a berry rich in flavonoids, mainly anthocyanins, with high antioxidant activity (Garzón et al. 2010), cardioprotective effect (Lopera et al. 2013) with ischemic lesions treatment potential (Shen et al. 2018), and antiproliferative activity (Agudelo et al. 2018), among others.

Genetic diversity is the heritable variations that occur in organisms, individuals, and between populations under more or less stable natural conditions. Population genetics and evolution study and conserve genetic diversity. Genetic variability is the basis of any breeding program, as it includes the diversity available for selection of sources for adaptation to different environments (Rimieri 2017).

Genetic resources are biological diversity are essential for the sustainable development of agriculture and to assure food security (Nass 2011). The International Treaty on Plant Genetic Resources for Food and Agriculture defines them as genetic material, whether propagated sexually or asexually, containing functional heredity units. Regardless of the genetic resources' definitions, these are the basis of plant breeding and agricultural production (Fowler and Hodgkin 2004).

Within the activities of germplasm banks, an essential task is the description of the variability of a crop in both the phenotype and genotype of the accessions conserved. However, a list of characters, called descriptors, is required to carry out the characterization process. In 1976, the basis of such a system was created, which initiated the development and formulation of a list of descriptors that are the basis of internationally standardized documentation developed by specialists in each crop (Gotor et al. 2008).

Characterization and evaluation descriptors provide insight into the variability of a crop. Characterization refers to the recording of variables with high heritability and controlled by a single or very few genes; they should be easy to measure and allow differentiation and expression of the trait in a precise and uniform way. Evaluation depends on the environment and is controlled by several genes expressing yield, agronomic productivity, stress

susceptibility, biochemical and cytological traits used in crop improvement (Romanciuc 2017).

Currently, there is no published descriptor for the species *V. meridionale* to allow for knowing and understanding its variability. Accordingly, this study aims to develop morphological descriptors for this species. This will enable the differentiation of the accessions included in a collection through specific attributes and obtain essential information that effectively allow of the domestication of this interesting plant genetic resource.

MATERIALS AND METHODS

For the construction of the preliminary version of the descriptor, the taxonomic keys of the genus *Vaccinium* and the description of the species *V. meridionale* presented by Sleumer (1941), Romero-Castañeda (1961), Berazaín-Ilturralde (1991), Vander-Kloet (1996) and Luteyn (1998) were used.

A first list of proposed variables, developed by Agrosavia, was done *in situ* by Lopera (2005) in four to six plants per locality included in his study. Later Ligarreto et al. (2011), studied a total of 177 natural populations located in the departments of Antioquia, municipalities of Belmira (30), Don Matías (8 populations), El Retiro (1), Entrerrios (8), Guarne (9), La Ceja (1), Medellín, Corregimiento de Santa Helena (23), Rionegro (1), San Jerónimo (2), San

José de la Montaña (11), San Pedro de los Milagros (4), Santa Rosa de Osos (41), and Yarumal (9). In Boyacá, the municipalities of Chiquinquirá (4), Ráquira (5) and Tinjaca (4) were visited, and in Cundinamarca, only the municipality of Guachetá (2). In Nariño, the municipalities of Buesaco (1) and Pasto (2), and in Santander, the municipality of California (11) were visited (Medina et al. 2009).

Subsequently, a modified version was applied in the previous process (Lopera 2005), also including the variables and states found in the natural populations of 102 accessions of the *V. meridionale*. Germplasm collection established in the Research Center "La Selva" of Agrosavia, located in Rionegro, Antioquia. The area is located at 06°08'06" N and 75°25'03" W at 2,120 masl, where the average temperature was 17 °C, average relative humidity of 78%, and photosynthetically active radiation (PAR) of 357 Watts m⁻².

RESULTS AND DISCUSSION

Descriptor

A descriptor for *V. meridionale* was developed with 38 quantitative, binary, and multistate variables, of which seven were obtained at the plant level, 10 from the leaf, six from the flower, 14 from the fruit, and one from the seed (Table 1). This descriptor had variables with taxonomic and agronomic importance, vital for production and marketing.

Table 1. List of variables, state, and description proposed as a descriptor for *Vaccinium meridionale* Sw.

Variable	State	Description
	Plant	
Plant height	Given in centimeters and recorded from the neck to the apex of the main stem.	
Stem diameter	Given in centimeters and measured 10 cm from the ground, on the main stem.	
Growth habit	1. Prostrate. 2. Intermediate. 3. Erect.	

Table 1

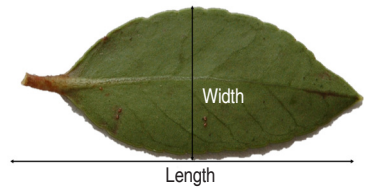
Variable	State	Description
Plant		
Branch density	1. Scarce. 2. Intermediate. 3. Dense.	Rate the number of branches formed per plant.
Branch pubescence	0. Absent. 1. Scarce. 2. Abundant.	Observe the terminal part of the branches.
Presence of wax on the stem	0. Absent. 1. Present.	Observe in young branches.
Color in branches	0. Absent. 1. Scarce. 2. Medium. 3. High.	 0 1 2 3
Leaf		
Leaf density	Register the number of leaves formed in 10 cm; in the middle part of a branch or shoot.	
Leaf blade length	Average length of five leaves, given in centimeters; from the middle part of the branch.	
Leaf blade width	Average width of five leaves, given in centimeters; from the middle part of the branch.	
Leaf blade shape	1. Elliptical: ellipse-shaped, rounded, and curved, and widest in the central part. 2. Ovate: egg-shaped. 3. Lanceolate: shaped like an iron spear figure. 4. Oval: elliptical with the blade width considerably larger in the middle of the length. 5. Oblong lanceolate. 6. Other.	 1 2 3 4 5
Leaf margin shape	1. Serrated: Serrated with sharp and proximate teeth. 2. Slightly serrated. 3. Crenate. 4. Other.	 1 2 3

Table 1

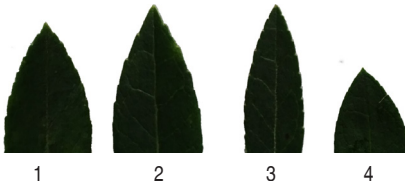
Variable	State	Description			
		Leaf			
Leaf base shape	1. Cuneate. 2. Rounded. 3. Other.				
		1	2		
Apex shape	1. Acuminate: ending in an acumen. 2. Acute: the edges form an acute/sharp angle. 3. Very acute/sharp. 4. Obtuse: the edges form an obtuse angle at the apex. 5. Obtuse. 6. Other.				
		1	2	3	4
Presence and size of nectaries or glands on the leaf margin	0. Absent. 1. Small. 2. Big.				
Anthocyanin in the leaf margin	0. Absent. 1. Present.				
Anthocyanin in the petiole	0. Absent. 1. Present.				
Inflorescence and flower					
Inflorescence length	Given in centimeters and recorded from its insertion with the branch to its apex.				
Number of flowers per inflorescence	Counted. In five inflorescences per plant, all the flowers of the inflorescence are counted, even those that have already fallen.				
Presence of anthocyanin in the inflorescence	1. Absent. 2. Present.				
Calyx color	1. Green. 2. Red-wine. 3. Light green and dark green. 4. Green and red wine. 5. Red wine and light green and dark green. 6. Other.				

Table 1

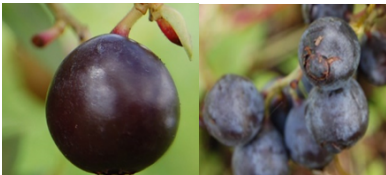
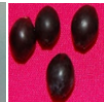
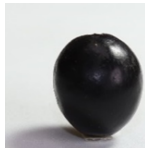
Variable	State	Description
Inflorescence and flower		
Pedicel and bract color	1. Green. 2. Red-wine. 3. Light green and dark green. 4. 1 and 2. 5. Other.	
Color of the Corolla	1. White. 2. White tinged with pink. 3. Other.	
Fruit		
Polar length	Measured in centimeters in five fruits per plant.	
Equatorial width	Measured in centimeters in five fruits per plant, in its widest part.	
Fruit weight	Average weight of five fruits and expressed in grams.	Find the average weight of the harvested fruits.
Number of locules per fruit	Split the fruit transversely and count the average number of locules in five fruits per plant.	
Presence of wax in the fruits	0. Absent. 1. Present.	 01
Color of mature fruits. See color Table of the Royal Horticultural Society (RHS)	1. Blue. 2. Purple. 3. Black.	
Persistence of the sepals when mature	0. Absent. 1. Present.	 01

Table 1

Variable	State	Description
Fruit		
Fruit shape	1. Spherical. 2. Elongated round. 3. Flattened. 4. Cordiform. 5. Ovate. 6. Elliptical. 7. Other.	 
Fruit cracking	0. Absent. 1. Present.	
Shape of petiole insertion in the fruit	1. At level. 2. Slightly sunken.	
Sepal scar shape	1. Flat. 2. Protuberance. 3. High protuberance. 4. Sunken. 5. Medium protuberance and deep hole.	
Presence of ribs in the fruit. Ribs are slight depressions around the base of the fruit.	0. Absent. 1. Present.	
Brix degrees	Measured in a refractometer.	
Fruit pH	Measured on a potentiometer.	
Seed		
Number of seeds per fruit	Average number of seeds in five fruits.	

Qualitative variables

Five qualitative variables were included in the stem level descriptor; seven were selected for the leaf, four for the inflorescence and flower, and eight for the fruit, for a total

of 24 variables (Table 1). In the *ex situ* characterization of 102 materials carried out with the final proposal of the descriptor, polymorphism in 24 qualitative traits were found, with the presence of 67 states out of the 70 included in the

list of the descriptors for the species (95.7%) (Table 2). This result indicates a broad morphological variability related to attributes of this nature. The only states not observed in this characterization were large foliar nectaries found only in one specimen deposited in the “Josep Cuatrecasas y Arumi” herbarium of Universidad Nacional de Colombia - Palmira Headquarters. The color of its calyx is red-wine, and the color of the fruit is blue.

In the *in situ* characterizations carried out in Antioquia in natural populations and plants that had already started their reproductive stage, broad qualitative variability was found, recording 46 out of the 48 states described (Medina et al. 2009) but not reporting blue-colored fruits. In the departments of Cundinamarca, Boyacá, Nariño, and Santander, 20 natural populations were characterized *in situ*, with 17 qualitative variables included in the descriptor,

but not finding the following states: absence of stem pubescence (branches), light and dark green colors in the calyx, light and dark green colors in the pedicel and bracteole, and a blue fruit color (Ligarreto et al. 2011).

The blue color of the berries, not observed at the *in situ* characterizations, is reported for some species of *Vaccinium*, giving the plant the name “blueberry”. For the specie *V. meridionale*, the colors of the mature fruit range from purplish and purple to dark purple, violet, and black (Buitrago–Guacaneme et al. 2015).

Various authors report that the corolla is reddish-white or pink (Romero-Castañeda 1961), and research carried out in Guachetá (Cundinamarca) and San Miguel de Sema (Boyacá) indicates that the flowers have a white or light to intense pink color (Chamorro and Nates–Parra 2015).

Table 2. List of variables and states included and reported in the *ex situ* collection.

Variable	State	
	Total reported states	Reported in the <i>ex situ</i> collection
Growth habit	3	3
Branch density	3	3
Branch pubescence	3	3
Presence of wax in the stem	2	2
Anthocyanin in branches	4	4
Leaf blade shape	5	5
Leaf margin shape	3	3
Leaf base shape	2	2
Leaf apex shape	4	4
Presence of foliar nectaries	3	2
Anthocyanin in the leaf margin	2	2
Anthocyanin in the petiole	2	2
Anthocyanin in the inflorescence	2	2
Calyx color	5	4
Pedicel and bract color	4	4
Flower color	2	2
Presence of wax on fruit	2	2
Fruit color	3	2
Fruit shape	6	6
Fruit cracking	2	2
Shape of petiole insertion in the fruit	2	2
Sepal scar shape	4	4
Presence of ribs in the fruit	2	2
Total	70	67
Percentage (%)	100	95.7

Quantitative variables

14 quantitative variables were included as follows: two from the entire plant, three from the leaf, two from the flower, six from the fruit, and one from the seed (Table 3). In the *ex situ* characterization of the 102 accessions, the variability between individuals for these types of attributes was evident without a defined grouping pattern between subregions from which the populations were collected or at the intrapopulation level.

On the other hand, the *ex situ* quantitative variability indicated the presence of 278 out of 280 total plants, i.e., 99% of the plants, with a distance between them or differences due to quantitative genes. Applying the proportion criterion of “different clones” of Persson and Gustavsson (2001), the value obtained was 0.99. It should be noted that, in the case of quantitative expressions, these were recorded in a common planting site with homogeneous traits and with similar management practices, removing, to a high degree, the environmental effect, as it is a response to a common locality with similar cultural management.

For the quantitative variables included in the descriptor, various authors report variability in the number of flowers per raceme (between 10-15 flowers) in mortiño or agraz populations (Romero-Castañeda 1961). In works carried out in natural populations in Guachetá (Cundinamarca) and San Miguel de Sema (Boyacá), the inflorescences measure 7.2 ± 0.5 mm long, with 12 ± 3 flowers per raceme (Chamorro and Nates-Parra 2015). Fruit weight and other fruit dimensions varied according to the pollination treatments evaluated and the location (Chamorro and Nates-Parra 2015). The equatorial diameter of agraz fruits ranges between 6 and 20 mm. The average fresh weight of 1.60 g, and the number of seeds per fruit ranges between 15 and 37 depending on fruit size (Magnitskiy and Ligarreto 2009). Agraz fruits harvested in Cundinamarca have about 14.13 °Brix of total soluble solids (Ávila-Rodríguez et al. 2007), and other authors report Brix degrees for fruits harvested in Antioquia between 12.6 and 15.2 and pH between 2.2 and 2.7 (Gaviria et al. 2009).

Table 3. List of quantitative variables and their measurement units, average, standard deviation (SD), and maximum and minimum values included in the descriptor and used in the *ex situ* characterization.

Variable	Average	SD	Maximum	Minimum
Stem height (cm)	67.46	32.99	148.5	13
Stem diameter (cm)	1.35	0.52	2.8	0.5
Leaf density (number of leaves*)	21.00	3.312	30	16
Leaf length (cm)	2.55	0.278	3.27	1.51
Leaf width (cm)	1.16	0.157	1.71	0.77
Inflorescence length (cm)	3.47	0.982	5.9	0.94
Number of flowers per inflorescence	15.03	3,194	22	1.06
Fruit length (cm)	0.93	0.153	2	0.56
Fruit width (cm)	0.98	0.123	1.22	0.57
Fruit weight (g)	0.68	0.287	1.93	0.16
Locus number	4.00	0.198	5	4
Brix degrees	15.93	1.923	22.2	7.2
Juice pH	2.56	0.213	3.75	2.23
Number of seeds per fruit	28.61	14,382	168	11
Weight of 200 seed (g)	0.09	0.115	1.06	0.008

*Counted on a section of 10 cm in the middle part of a branch.

Quantitative diversity shows an adaptive potential that could favor its use to combine attributes and cope with variations in potential planting environments in relation to global climate change and the diverse sites where

natural populations were found. The conservation and maintenance of adequate quantitative variability is the basis for coping with environmental changes that may occur (Kramer and Havens 2009).

CONCLUSIONS

The importance of this descriptor lies in the fact that the scientific community can research with a standardized characterization protocol that favors the use and exchange of information on the species, which allows working with similar data between national and international institutions.

The descriptor proposed indicated that the species has variability that must be evaluated in any work carried out with the species.

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