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Morphological *in situ* Characterization of Mortiño (*Vaccinium floribundum* Kunth) in the Andes of Ecuador

Wilson Vasquez-Castillo [a,*], Kerly Ayala [a], Marcelo Almeida [a], Alejandro F. Barrientos-Priego [b], Pablo Moncayo-Moncayo [a], Álvaro Monteros-Altamirano [c]

[a] *Ingeniería Agroindustrial. Universidad de las Américas (UDLA). Granados E12-41 and Colimes, Quito, Ecuador.*
[b] *Posgrado en Horticultura, Departamento de Fitotecnia, Universidad Autónoma Chapingo. Chapingo, Estado de México, México.*
[c] *Departamento Nacional de Recursos Fitogenéticos. Estación Experimental Santa Catalina. Instituto Nacional de Investigaciones Agropecuarias, INIAP. Quito Ecuador.*
*Corresponding author: *wilson.vasquez@udla.edu.ec*

***Abstract*— *Vaccinium* is one of the largest in the Ericaceae family, distributed worldwide. Mortiño (*Vaccinium floribundum* Kunth) is an Andean fruit threatened by agriculture, livestock, and forestry activities, causing genetic erosion. The importance of the mortiño fruit is also because of its nutritional composition due to its high content of functional compounds in comparison to other Andean fruits. The characterization of a species allows scientists to estimate the population's genome variability. The morphological characterization reveals important distinctive morphological features, some of which will promote the species' commercial value. This study aims to apply morphological and agronomic descriptors to mortiño *in situ* in the paramos of Ecuador. Three locations in three different provinces of the Ecuadorian highlands were selected: San Pablo in Imbabura, Atacazo in Pichincha, and Quilotoa in Cotopaxi, all located between 3200 and 4050 masl. Forty-two descriptors were registered in 15 mortiño populations, of which 16 were quantitative and 26 qualitative. The results demonstrated the existence of two morphological groups of mortiño, the first formed by populations in Imbabura and the second by those in Pichincha and Cotopaxi. The discriminating descriptors of the mortiño plants in the three locations were: the altitude of the site, total soluble solids, and acidity of the fruit, plant height, growth habit, and flower characteristics. The floral formula of the mortiño is K (5); C (5); A (7); G (3). To the best of our knowledge, this study is the first comprehensive morphological description of Andean *Vacccinium floribundum*.**

***Keywords*— Andean fruit; descriptors; plant growth; plant variability.**

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I. Introduction

Vaccinium floribundum Kunth, commonly known as mortiño or Andean blueberry, is a woody perennial shrub from the Ericaceae family [1]. Mortiño is a native Andean fruit, which grows wild in the paramos and humid forests of Venezuela and then through the Andes to Argentina. Mortiño fruits are collected and sold at local markets in Colombia and Ecuador [2]. In the latter country, three species of *Vaccinium* have been identified: *V. floribundum* Kunth, which is distributed in all provinces of the Ecuadorian Andes between 3200 to 4050 masl; *V. distichum* Luteyn located in the province of Pichincha between 2000 and 2500 m and *V. crenatum* Sleumer located between 1500 and 3500 masl in Azuay province [3]. The ecosystem of the Andes varies greatly in altitude; the Andean paramos are above the line of continuous Andean forests and are places where plants survive right below the glaciers [4]. Knowing the parameters that affect plant growth will allow better crop management and productivity [5]. This area is characterized by high plant diversity and mycorrhiza [4]. [6] point to the importance of mycorrhiza for *Vaccinium* plant growth, even under favorable environmental conditions. Mortiño resists frost, has a variety of morphology ecotypes and grows and develops on sandy loam soils [3], [4]. However, in Ecuador, the fragility of the Andean ecosystem places mortiño in danger of genetic erosion due to the increase of the agricultural and livestock frontier, burning practices, and inappropriate methods for harvesting the fruits, similar to other parts of the world [7].

This fruit is also of nutritional importance due to its high content of anthocyanins and polyphenols in comparison to other Andean fruits, such as blackberries (*Rubus glaucus*), tree tomatoes (*Solanum betaceum*), and naranjilla (*Solanum* *quitoense*) [8]–[10]. These characteristics are similar to other *Vaccinium* spp. [11], [12]. Mortiño is also rich in vitamins and other nutritional components [13]. Nevertheless, when the mortiño fruit is processed, the content of the bioactive compounds is reduced by the temperature and the drying time [14]. Superfoods are characterized by the nutritional compounds and health benefits [15] such as mortiño. Also, plants that have antioxidants compounds are considered anti-aging [16].

Characterization can be morphological, agronomic, or molecular [9]. The morphological diversity of plants can occur through the characteristics of flowers, fruits, leaves, growth habit, among others [17]. In Ecuador, a molecular characterization with microsatellites (Simple Sequences Repeated shortened to SSR) was conducted on 22 mortiño accessions collected in Cotopaxi and Bolivar provinces, although no difference was found among materials from these locations [18]. [1] used SSRs and found that mortiño accessions presented moderate genetic differences between provinces and localities. On the other hand, 14 morphological descriptors determined morphological groups in *Vaccinium floribundum* unrelated to the provinces in which they were collected. Morphological characterization and the determination of the most discriminant traits are important for developing guidelines for distinction, uniformity and stability (DUS) tests [19] to be used by member countries of the International Union for the Protection of New Varieties Plants (UPOV). This study aimed to morphologically characterize the in-situ diversity of wild populations of mortiño through qualitative and quantitative descriptors to identify the most discriminant ones and the grouping of the studied plants.

II. Materials and Method

According to a previous study, the selected sites were based on the genetic diversity of mortiño according to a previous study [1]. Our study was set up in the northern and central highlands of Ecuador: Imbabura (San Pablo, 0°13´57.96´´N and 78°10´47.28´´W), Pichincha (Atacazo, 0°50´23.02´´S and 78°57´51.08´´W) and Cotopaxi (Quilotoa, 1°0´18´´S and 78°27´10.8´´W), located between 3389 and 4049 masl. Five populations were chosen in each locality, following the methodology (quadrants and transects) [4]. In total, fifteen wild mortiño populations were evaluated *in situ*. Table 1 shows the physical and chemical characteristics of the soil of the three studied localities.

TABLE I
PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOIL IN THE THREE LOCATIONS WHERE MORTIÑO (*VACCINIUM FLORIBUNDUM* KUNTH) GROWS NATURALLY.

Characteristics	San Pablo	Atacazo	Quilotoa
pH	5.44	5.57	5.62
Organic Mater	18.08	6.69	6.56
Nitrogen (%)	0.9	0.33	0.33
Phosphorous (mg/kg)	<3.5	<3.5	<3.5
Potassium (cmol/kg)	0.3	0.18	0.15
Calcium (cmol/kg)	8.44	1.01	4.63
Magnesium (cmol/kg)	1.12	0.25	0.82
Iron (mg/kg)	439.9	326.1	472.8
Manganese (mg/kg)	39.17	13.55	7.77
Copper (mg/kg)	7.29	7.26	4.09
Zinc (mg/kg)	7.59	3.29	2.88

Soil analysis conducted for this study (Agrocalidad Laboratory).

The evaluation was carried out using 42 morphological descriptors (19 quantitative and 23 qualitative) related to the characteristics of the plants, leaves, flowers, and fruits. These descriptors were selected from the *Vaccinium* [2] and blueberry descriptors [20]. High quality morphological descriptions are critical for understanding of biological systems [19]. Standard classification algorithms were used for the analysis, such as decision trees and random forests. The color of the plant structures was identified using the respective color code table [21]. Additional fruit descriptors were considered due to their importance in the potential commercial promotion of mortiño consumption. For pH determination, a sample of fresh fruit was prepared, then the potentiometer electrode (ORION 3 Star pH Benchtop) was submerged in the sample, and the reading was recorded directly. For the Brix, 0.2 ml of fresh juice was placed in a refractometer (ATAGO PAL-1, Japan), and the data were recorded directly.

Statistical analyses of the 42 morphological characteristics recorded in the study (25 observations from 5 populations per locality) were carried out using multivariate techniques. 1) Groupings based on the UPGMA algorithm were made to quantify the similarity between the mortiño plants by generating a dendrogram that shows similarities between groups. 2) Principal components were analyzed using the R statistical package [22], allowing us to identify groups of discriminating morphological characteristics of mortiño. 3) The Random Forests analysis allowed us to assign the level of contribution of each morphological characteristic in the discrimination of plant groups. This level of contribution was analyzed using GINI coefficients, which measured the average importance of a variable when forming the branches in the decision trees. The variability of the morphological (quantitative) characteristics of mortiño was analyzed using descriptive statistics (mean, standard deviation, coefficient of variation, maximum, minimum, and median) using [22]. A frequency analysis was performed for the qualitative variables. The colors of the different structures of the plant were established using the color chart [21].

The floral structure of mortiño was evaluated in 10 marked floral buds from 3 plants, giving a total of 30 flowers. The floral structure was characterized by measuring and recording the shape and color of the different structures of the flowers (petals, sepals, anthers, pistil, and stamen). Colors were measured using the color chart [21]. The mortiño's floral formula was achieved by assessing the ovary's arrangement, symmetry, and position and counting the number of carpels. The internal structures of the flower and fruit were described by means of a stereoscope attached to a photographic camera using the protocol of Plant Histology developed by Universidad de las Américas.

III. Results and Discussion

A. Cluster Analysis

The cluster analysis with the hierarchical method allowed us to measure the similarity between the observations by calculating the distance matrix. The recorded characteristics of the mortiño populations were treated as n-dimensional vectors, and subsequently, the observations were grouped according to a distance threshold of 200 units, which was established based on the number of locations studied. With these considerations, two groups were identified (Figure 1): group 1 (G1) comprised the accessions of "Atacazo", and group 2 (G2) had two subgroups (SG1 and SG2) belonging to "Quilotoa" and "San Pablo". These subgroups show sufficient discriminant characteristics, among which geographical location stands out, despite being in the same group. Our molecular characterization of mortiño found in Vega-Polo *et al.* [1] that accessions from Quilotoa (Cotopaxi province) were different from those of the Pichincha and Imbabura provinces. Llivisaca *et al.* [23] also found genetic differentiation of materials from Cotopaxi (Quilotoa) to materials from Pichincha and Chimborazo. However, in our study, the Quilotoa materials were more similar to San Pablo (Imbabura) (Figure 1 and Table 2).

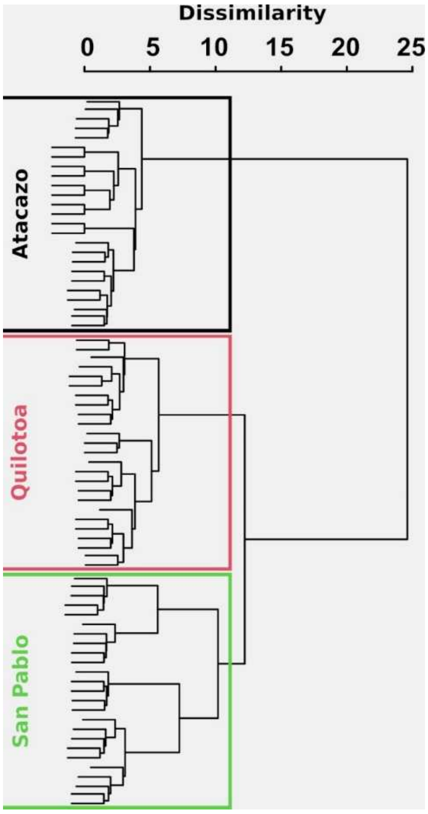

Fig. 1 Hierarchical grouping diagram on the qualitative and quantitative descriptors of the 15 populations of mortiño (*Vaccinium floribundum* Kunth) in Atacazo, Quilotoa, and San Pablo, Ecuador.

A moderate level of genetic diversity and low to moderate population differentiation in the study locations were found [1]. Although not the same sites, our research corresponds to the three provinces studied previously [1]. The differences identified in this research are based on the quantitative and qualitative morphological characteristics of the mortiño populations.

B. Discriminant Descriptors

The incidence of qualitative and quantitative descriptors in the discrimination of mortiño populations in the three study locations was carried out by considering the average GINI coefficient, which orders the discrimination descriptors and their level of contribution within a group. It is important in forming each decision tree, which results from the analysis of Random Forests concerning the measurements of each plant's characteristics recorded in the three locations. Five groups were identified for the most discriminating characteristics based on the GINI coefficient. In group 1, there were four morphological characteristics with the highest GINI index (> 3), namely: 1) altitude (masl) at which the mortiño populations are located; 2) Total soluble solids of the fruit (°Brix); 3) fruit pH; and 4) plant height (cm). This means that in future studies of mortiño, it is important to consider the establishment of the morphological variability of this species. In Quilotoa, the mortiño populations are located at 3509.6 masl and had an average of 10 °Brix, pH of 3.6, plant height of 105.2 cm, and internode length of 10 cm. In Atacazo, mortiño is present at 4049.8 masl, and the fruits have an average of 11 °Brix, pH of 3.6, plant height of 64.6 cm, and internode length of 9.8 cm. In the San Pablo community, the mortiño plants are located at 3389 masl, and have a 9 °Brix, pH of 3.6, plant height of 177.2 cm, and internode length of 22.6 cm. In group 2, only the qualitative characteristics of the mortiño plant were considered, which had a GINI coefficient of between 2 and 2.6. The most important characteristics were the density of plants and the main color of the leaf, branches, and corolla. Group 3, on the other hand, was made up of the qualitative and quantitative characteristics of the flower and branch plant structures, with a GINI coefficient that fluctuated between 1.5 and 2. The qualitative and quantitative characteristics are presented in groups 4 and 5, with a coefficient of less than 0.5, whose contribution is minimal; therefore, they should not be considered as discriminant characteristics in determining the morphological variability of the mortiño. In Table 2, descriptive statistics for the 19 quantitative morphological characteristics are included, based on the grouping identified in Figure 1. In future studies, our discriminant descriptors should be considered; also, new available technologies such as 2D images could help in measuring morphological variability in plants [24].

In the Andes of Ecuador, the mortiño has adapted to high altitudes, which means that this Andean fruit is resistant to low temperatures, high relative humidity, and high light intensity. The cuticular wax layer acts as the first protective structure against biotic and abiotic stresses factors [25]. The morphological variation of *V. floribundum* for plant size, flower color, and size of fruits was noticed when germplasm collections were performed in Ecuador. Alarcón-Barrera *et al.* [26] indicated that mortiño fruits are small (8 mm in diameter), which coincides with the average we recorded in San Pablo, Imbabura. We found even smaller fruits in the other two locations: 5 mm in Quilotoa and 6.8 mm in Atacazo. The fruit collected in Cotopaxi had pH values of between 2.6 and 3.1, which are lower than those reported in this study [26].

In terms of correlations between the variables, we found a positive and direct correlation between the Brix and the altitude of the locality (r=0.94). Meanwhile, the correlation with acidity was negative (r=-0.99). In addition, there was a high and negative correlation between acidity and °Brix (r=-0.87). This indicates that the higher the acidity, the lower Brix the mortiño fruits have. This tendency was reported by Silva *et al.* [27] in a study conducted to determine the chemical changes that occurred during the ripening time of four Portuguese blueberries (*V. corymbosum* L.) cultivars. Environmental effects on polyphenols and antioxidants contents were found in Ecuadorian *V. floribundum* materials collected in a different location by [23]; even pathogen inhibitory effects have been determined for *V. floribundum* [23] and other *Vaccinium* spp. [28].

Regarding the qualitative descriptors for the plant (Table 3), a spreading growth habit was found in 100% of plants in Quilotoa and San Pablo, while in Atacazo, 20% displayed a spreading growth habit and 80% semi-upright. The upright category was not detected in any population of the studied sites.

For plant (shrub) density, the classification of "dense" was applied to 100% of the San Pablo populations; "semi-dense" to 72% of the Quilotoa populations; and 20% of the Atacazo populations. Meanwhile, "low density" was applied to 28% in Quilotoa and 80% in Atacazo; this has a direct relationship with the amount of fruit expected to be harvested

TABLE II

STATISTICS OF THE QUANTITATIVE DESCRIPTORS OF MORTIÑO IN THE THREE LOCATIONS OF THE ECUADORIAN ANDES

Variable	altitude	height	int. leng	leaf.w	leaf.l	len.ped	inflor	len.inflor	len.ped	w.cor	len.cor	cal.dia	len.cor.t	num.fru	fru.wid	dia.cav	dep.cav	fru.sw	fru.pH
Group 1: Quilotoa																			
Mean	3509	105	10.0	8.3	12.1	2.5	7.4	3.4	3.0	2.2	7.2	2.1	3.0	8.2	5.0	2.8	2.0	10.0	3.6
S.D.	0.8	16.2	7.3	1.9	1.9	0.6	1.3	5.0	0.0	0.6	0.9	0.1	0.7	0.4	1.0	0.4	0.0	0.0	0.0
CV (%)	0.0	15.4	73.3	22.7	15.9	23.3	17.0	145.5	0.0	26.2	12.5	3.8	21.5	5.0	20.2	14.6	0.0	0.0	0.0
Min.	3508	84.0	5.0	7.0	9.0	2.0	5.0	1.0	3.0	2.0	6.0	2.0	2.0	8.0	3.0	2.0	2.0	10.0	3.6
Max.	3510	124	28.0	14.0	17.0	4.0	9.0	18.0	3.0	4.0	8.0	2.2	4.0	9.0	7.0	3.0	2.0	10.0	3.6
Group 2: Atacazo																			
Mean	4049	64.6	9.8	7.5	13.7	3.0	8.4	3.1	2.7	3.4	6.0	2.9	2.6	7.9	6.8	2.8	2.1	11.0	3.6
S.D.	1.2	6.7	5.6	1.3	2.8	0.7	1.1	3.0	0.9	0.6	1.3	0.6	0.5	1.0	1.8	0.4	0.3	0.0	0.0
CV (%)	0.0	10.4	57.2	16.9	20.7	24.8	13.3	98.7	32.8	19.0	21.4	20.8	19.8	12.0	25.6	14.6	13.3	0.0	0.0
Min.	4049	55.0	4.0	5.0	10.0	2.0	5.0	1.5	2.0	3.0	5.0	2.0	2.0	5.0	4.0	2.0	2.0	11.0	3.6
Max.	4052	72.0	21.0	10.0	18.0	4.0	10.0	10.0	5.0	5.0	9.0	4.0	3.0	9.0	9.0	3.0	3.0	11.0	3.6
Group 3: San Pablo																			
Mean	3389	177.2	22.6	8.7	15.7	4.2	7.6	2.0	3.0	3.0	5.0	2.9	2.4	8.0	8.0	2.8	2.0	9.0	3.6
S.D.	8.0	56.2	2.5	0.9	1.8	1.0	0.7	0.0	0.8	0.7	0.8	0.5	0.5	0.8	0.5	0.4	0.0	0.0	0.0
CV (%)	0.2	31.7	11.2	10.2	11.6	23.7	8.5	2.0	27.7	21.5	16.7	16.7	20.8	10.6	6.3	14.6	0.0	0.0	0.0
Min.	3380	116	20.0	7.0	13.0	3.0	7.0	2.0	2.0	2.0	4.0	2.0	2.0	7.0	7.0	2.0	2.0	9.0	3.6
Max.	3403	250	30.0	10.0	18.0	5.0	9.0	2.2	4.0	4.0	8.0	4.0	3.0	10.0	9.0	3.0	2.0	9.0	3.6

Note: The codes of the quantitative variables are as follows: altitude (masl); height (plant height, cm); int.leng (internode length, cm); leaf.w (width of totally developed leaf, mm); leaf.l (length of totally developed leaf, mm); len.ped (lenght of flower pedicele, cm); inflor (number of flowers per inflorescence); len.inflor (length of inflorescence, cm); len.ped (lenght of flower pedicele, cm); cor.w (width of developed corolla, mm); len.cor (length of developed corolla, mm); cal.dia (calyx diameter, mm); len.cor.t (length of corolla tube, mm); num.fru (number of fruits per infructescence); fru.wid (fruit width, mm); dia.cav (diameter of calyx cavity, mm); dep.cav (depth of calyx cavity, mm); fru.sw (fruit sweetness: °Brix); fr.pH (fruit pH). n=25

TABLE III

QUALITATIVE DESCRIPTORS OF MORTIÑO IN THE THREE LOCATIONS OF THE ECUADORIAN ANDES

		Location			
Descriptor	**Category**	**Quilotoa (%)**	**Atacazo (%)**	**San Pablo (%)**	**Total (%)**
Growth habit	1: Spreading	100	20.0	100.0	73.3
	2: Semi-upright		80.0		26.7
Shrub density	1: Dense			100.0	33.3
	2: Semi-dense	72.0	20.0		30.7
	3: Low density	28.0	80.0		36.0
Color of branch	1: 200A Dark grayish reddish brown		20.0		6.7
	2: 200B Grayish reddish brown		20.0		6.7
	3: 200C Moderate brown		20.0	100.0	40.0
	4: 144A Strong yellowish green	20.0			6.7
	5: 144B Strong yellow	80.0			26.7
	6: 199B Light olive brown		40.0		13.3
Leaf: shape	4: Ovate		4.0	16.0	6.7
	5: Lanceolate-ovate	100.0	96.0	84.0	93.3
Leaf: main color of upper side	1: N137A Grayish olive green		40.0	100.0	46.7
	2: 137B Moderate olive green	100.0	60.0		53.3
Presence of secondary color on the leaf's upper side	0: Absent		100.0	100.0	66.7
	1: Present	100.0			33.3
Leaf: secondary color of upper side	0: Absent		100.0	100.0	66.7
	2: 71B Strong purplish red	100.0			33.3
Leaf: main color of underside	1: 144A Strong yellowish green		20.0		6.7
	2: 144C Strong yellowish green			20.0	6.7
	3: 145A Strong yellowish green	100.0			33.3
	4: 146C Moderate yellowish green		40.0		13.3
	5: 146D Moderate yellowish green		40.0	80.0	40.0

Leaf: secondary color of underside	0: Absent		60.0	100.0	53.3
	1: 71B Strong purplish red	100.0			33.3
	2: 59A Dark red		40.0		13.4
Leaf: edge	2: Serrated	100.0	100.0	100.0	100.0
Corolla: main color	1: 63C Strong purplish pink	100.0	100.0	100.0	100.0
Presence of secondary corolla color	0: Absent	100.0			33.3
	1: Present		100.0	100.0	66.7
Corolla: secondary color	0: Absent	100.0			33.3
	1: 61A Deep purplish red		100.0	100.0	66.7
Flower: shape of corolla	1: Urceolate	100.0	100.0	100.0	100.0
Calyx main color	1: 143A Strong yellowish green		100.0	100.0	66.7
	2: 134A Vivid yellowish green	100.0			33.3
Presence/absence of calyx secondary color	0: Absent	100.0	100.0	100.0	100.0
Flower bud: anthocyanin coloration	2: 134B Strong yellowish green	100.0	100.0	100.0	100.0
Edges in the corolla tube	1: Present	100.0	100.0	100.0	100.0
Attitude of sepals	1: Incurved	100.0	100.0	100.0	100.0
Infructescence: density	1: Sparse		8.0		2.7
	2: Medium		44.0		14.7
	3: Dense	100.0	48.0	100.0	82.7
Unripe fruit: color	1: 138B Moderate yellowish green		40.0		13.3
	4: 143C Strong yellowish green	100.0	60.0	100.0	86.7
Pruine color	(3) 203C Bluish black	100.0	60.0	60.0	73.3
	(4) 203D Black		40.0	40.0	26.7
Epidermis color (after pruine removal)	1: 59B Deep purplish red	100.0		20.0	40.0
	2: 157A Pale yellowish green		20.0	80.0	33.3
	3: 152B Light olive		80.0		26.7

Regarding branch color, a variation of six colors was determined. In Atacazo, there was more color variation (four categories), followed by Quilotoa with two categories (20 % strong yellowish-green and 80 % strong yellow), while in San Pablo, moderate brown was found in 100 % of the plants. The leaf descriptors of the mortiño plant were determined as follows. 1) The shape of the leaf was classified into five categories, but only two categories were relevant to the leaves studied: category 5 (lanceolate oval) with 93.3 % and category 4 (oblate) with 6.7 %. 2), something similar was reported in chilli peppers by [29]. Regarding leaf color, in Quilotoa, the main color of the upper side of the leaf was 100 % greenish-brown, while in San Pablo, 100 % was dark green, and in Atacazo, 40 % was dark green and 60 % dark greenish-brown. The main color of the underside of the leaf had five categories (Table 3) with several colors for Atacazo and San Pablo, but it was uniform in Quilotoa with 100 % strong yellowish-green. The leaf edges were serrated for all materials (100 %) at the three study locations.

The flower descriptors indicated that the main color of the corolla is pinkish-blue in all locations. The secondary color of the corolla flower in Atacazo and San Pablo was purple, but in Quilotoa, there was none. The shape of the corolla flower was urceolate in 100 % of the plants in the three locations. The main color of the calyx was dark green in Atacazo and San Pablo and green in Quilotoa. In all three locations, the corolla tubes presented dark green anthocyanin pigmentation. The sepals of the flower were incurved.

The descriptors of the fruit were determined by the infructescence, which was dense in Quilotoa and San Pablo, but in Atacazo, we found several densities: sparse (8 %), medium (44 %), and dense (48 %). There were two different unripe fruit colors: strong yellowish-green in Quilotoa and San Pablo (100 %), while in Atacazo, 40 % had moderate yellowish green and 60% strong yellowish-green. A bluish-black color of the pruine was present in 100 % of the fruits in Quilotoa, and 60 % of the samples were from Atacazo and San Pablo; the remaining 40 % was black in these two locations. This cuticular wax in *Vaccinium* spp. plays an important role in fruit postharvest quality and as a protective barrier against biotic and abiotic stresses [25]. Finally, the color of the epidermis after removing the pruine varied according to the populations of the localities: in Quilotoa, 100 % was deep purplish-red; in Atacazo, 20 % was pale yellowish-green and 80 % light olive; and in San Pablo, 20 % was deep purplish-red and 80 % pale yellowish-green.

C. *Principal Component Analysis*

The principal component analysis (PCA) was performed to generate groups of descriptors that contrast with each other. The evidence of the contrast between groups of descriptors is represented in the two-dimensional spaces, which minimizes the loss of information in relation to all the variability registered in the populations of mortiño in the three locations. This analysis was performed with the quantitative and qualitative morphological characteristics recorded in all plants studied in the three locations. We estimated the eigenvalues associated with principal components and their respective relative and accumulative variance. The first two components explained 50.46 % of the total variability. Most of the variation was distributed up to the 10th principal component, which was responsible for 87.96 %. Considering that the cumulative variability of the first two components is low (50.46 %), the first five components were considered since these explain 73.94 %. The descriptors with the largest weight in component 1 explained 29.94 % of the total variance. Meanwhile, component 2 accounted for 20.51 % of the variance. Component 3 explained 10.86 % of the total variance. The descriptors of component 4 explained 8.74 % of the variance and component 5 only 3.87 %.

The PCA measured the descriptors that had the greatest impact concerning other characteristics and the relationship between them (Figure 2).

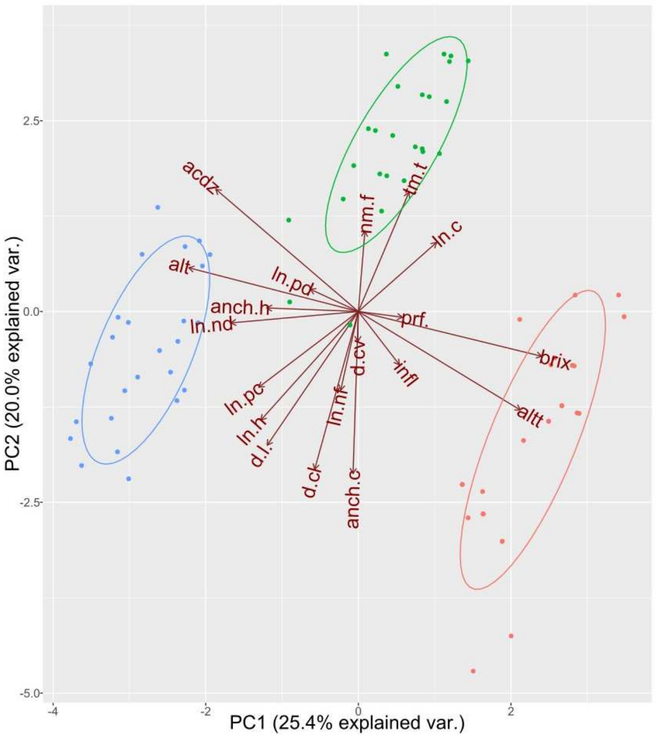

Fig. 2 Principal Component Analysis of the qualitative and quantitative variables of mortiño from three locations. Groups: Atacazo (Red), Quilotoa (Green), and San Pablo (Blue).

The ellipses around the variables grouped in the three collection sites show that the following descriptors most influenced the group of San Pablo plants: shrub density (dense), the main color of the upper side of the leaf (brown-green, 137A), internode length (cm), and petiole length (cm). It is important to note that the observations presented a lower dispersion in terms of the values of the main components 1 and 2. For the group of mortiño plants studied in Atacazo, the descriptors with the largest weight were: diameter of the calyx, the width of the corolla, number of flowers per inflorescence, and epidermis color (after pruine removal) (green-brown, 152B). These descriptors had the greatest and most positive influence in this locality. Regarding component 2, the dispersion of the observations in this site is greater than in San Pablo and more compact in relation to component 1. The most important characteristics of the Quilotoa plants were the color of the epidermis after removing the pruine (dark purple red, 59B), shrub density (semi-dense), and color of the branch (green group). This group was more compact concerning its first two main components than observations in the other two locations (Figure 2). Similarly, [30] showed that the plant growth characteristics of purple passion fruit were the highest contributors to the first principal components.

D. *Flower characteristics*

The mortiño flower is hermaphrodite (Figure 3) with four lobes and a central placenta. The corolla is composed of 5 petals (3.56 mm long and 1.36 mm wide). The main color of the petals is between codes 168A (orangey-brown) and N66 C (bluish pink), according to the color chart [21]. The calyx is formed by 5 (1.3 mm long and 0.68 mm wide) brownish-green sepals corresponding to code 194B. The androecium comprises seven brownish-green stamens (2.15 mm length) corresponding to code 193A. On average, the mortiño flower is 7.7 mm long and 3.8 mm wide. The floral formula of the mortiño is K (5); C (5); A (7); G (3), as seen in Figure 3. The physical characteristics of the mortiño fruit were established by analyzing 20 fruits that had reached physiological maturity. A mortiño fruit is round with flattened poles (8.81 mm polar and 8.11 mm equatorial diameter). On average, each fruit weighs 0.47 g and has 79 seeds. The floral structure is typical of a plant belonging to the Ericaceae family. More in-depth floral studies could establish physiological and breeding studies as in [31].

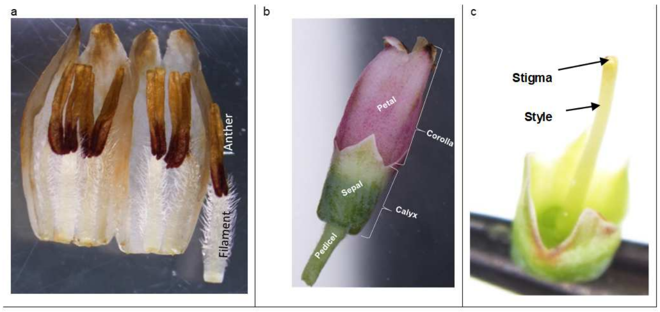

Fig. 3 Flower structures: a) stamen: filament and anthers; b) parts of the flower; and c) pistil: stigma and style. Floral formula of the mortiño: K (5); C (5); A (7); G (3).4.

IV. Conclusion

The discriminating descriptors of the mortiño plants in the three locations were: the altitude of the site, total soluble solids of the fruit, the acidity of the fruit, plant height, growth habit, and flower characteristics. Based on the cluster analysis of the quantitative and qualitative characteristics of mortiño plants, two groups were observed: 1) Atacazo and 2) a group formed by the accessions of San Pablo and Quilotoa. To the best of our knowledge, this study is the first comprehensive morphological description of Andean *V. floribundum*.

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