Passiflora gustaviana, a New Species of Passiflora (Supersection Laurifolia) from Colombia Revealed by Multivariate Analysis

Citation:

Ocampo Pérez, John Albeiro; Molinari, Miguel. 2017. Passiflora gustaviana, a New Species of Passiflora (Supersection Laurifolia) from Colombia Revealed by Multivariate Analysis. Systematic Botany 42(4): 1-11

Publisher's DOI:
https://doi.org/10.1600/036364417X696555

Access through CIAT Research Online:

http://hdl.handle.net/10568/89930

Passiflora gustaviana, a New Species of *Passiflora* (Supersection *Laurifolia*) from Colombia Revealed by Multivariate Analysis

John A. Ocampo Pérez[a,b,c] and **Miguel Molinari**[d]

[a] Universidad Nacional de Colombia sede Palmira, Facultad de Ciencias Agropecuarias, Departamento de Ciencias Biológicas. Carrera 32 No. 12-00 Chapinero, vía Candelaria Palmira, Valle del Cauca, Colombia.

[b] International Center for Tropical Agriculture, Recta Cali-Palmira, Km. 17 – CIAT/Ecosystem Services, Palmira, Valle del Cauca, Colombia.

[d] Universidad de los Andes, Facultad de Ciencias Forestales, Associate Curator, Hebarium (MER), apartado 384, Mérida 5101, Mérida, Venezuela.

[c] Correspondence author (jaocampo@unal.edu.co)

Abstract—A new species of *Passiflora* (supersection *Laurifolia*, series *Laurifoliae*) from the Andean region of Colombia is described and illustrated using morphological descriptors analysis. This species is closely related to *P. popenovii* Killip and can be recognized mainly by its purple stem, leaf size (12.5–16.5 × 5.0–7.9 cm), biglandular petioles, pedicel length (8-10 mm), bracts light green, glandless, flowers length (28–30 mm), corona filaments in

five series, minute-filiform inner filaments length (1–4 mm), fimbriate purplish operculum margin, staminal filaments length (6.8–7.1 mm), ovary glabrous, yellow mature fruits mottled with irregular white dots, lightly pubescent, and total soluble solids content in fruit juice (13.5%–14.3%). The newly identified species ***P. gustaviana*** grows on the slopes of high mountains between 1,900 and 2,309 m above sea level, with an annual mean temperature of 16.2°C. It is considered a new endemic species of Colombia and may be regarded as endangered (EN) because of its limited occurrence. This new species constitutes an important unexploited genetic resource useful for the improvement of cultivated *Passiflora* species.

Keywords—Conservation, endemism, IUCN red list, *Laurifoliae*, PCA, Passifloraceae, Tropical Andes.

Passiflora L. is the largest genus in the family Passifloraceae Juss. ex Roussel, with more than 577 species of vines, lianas, shrubs, and trees. *Passiflora* is split into five subgenera (*Astrophea* (DC.) Mast., *Decaloba* (DC.) Rchb., *Deidamioides* (Harms) Killip, *Passiflora* L., and *Tetrapathea* (DC.) P. S. Green) distributed mainly in the Neotropics, from coastal zones up to 4,300 m above sea level in the Andean slopes at páramo limits (Ulmer and MacDougal 2004; Krosnick et al. 2009). Subgenus *Passiflora* includes ca. 240 species and is divided into six supersections with several particular features, such as having petiolar nectaries, variable leaf shape, large colorful flowers, large fruits (Killip 1938; Feuillet and MacDougal 2003; MacDougal and Feuillet 2004), a chromosome number that usually is $n = 9$, and an average genome size of 1.311 pg (Snow and MacDougal 1993; Yotoko et al.

2011). Pollinators include carpenter bees, bumblebees, honeybees, wasps, birds (mostly short and sword-billed hummingbirds) and bats, with specific suites of floral characteristics associated with each syndrome (Ulmer and MacDougal 2004; J. Ocampo pers. obs.).

Colombia has 174 reported species of *Passiflora*, being the country with the highest *Passiflora* richness and with the greatest diversity in the Andean region (Ocampo et al. 2007; Hernández et al. 2017). The largest number of species is found between 1,000 and 2,000 m above sea level and the most common species thrive in disturbed habitats, such as roadsides, cultivated land, and secondary forests (Ocampo et al. 2010). Thirty three inventoried species are included in supersection *Laurifolia* (Cervi) Feuillet & MacDougal series *Laurifoliae* Killip ex Cervi with Colombia being the center of diversity with 12 species, followed by Brazil and Venezuela with 10 species each (Ocampo et al. 2011). *Laurifoliae* species include vigorous vines that often cover the trees used as support. Species in this series are very easy to recognize by their filiform to linear stipules, one pair of petiolar nectaries, and their generally long, dark green, glossy, unilobed and acuminate leaves (Rome and Coppens d´Eeckenbrugge 2017). The pendent flowers have a corolla that is often campanulate (except in *P. guazumaefolia* Juss., *P. odontophylla* Harms ex Glaziou, and *P. kikiana* Cervi & Linsingen) and of a delicate white or cream to red and purple color, frequently tinged slightly with violet (Ocampo et al. 2011). Their corona is formed of long pendent filaments striated with deep violet and attached to a short hypanthium. In other species, such as *P. ambigua* Hemsl., *P. popenovii* Killip, and *P. pergrandis* Holm-Nielsen & Lawesson, the flowers are grouped on small branches with minute leaves and short internodes, which gives the impression of a dense inflorescence (Ulmer and MacDougal 2004). The fruits are large (except in *P. gabrielliana* Vanderpl., 3.5–7.5 × 2.5–5.2 cm),

round to ovate, yellow to orange mottled with irregular white points, and with a thick mesocarp. The arils present a firm consistency, and the whitish translucent pulp is strongly aromatic. Most species have edible fruits and the seeds are dispersed by tree-climbing arboreal mammals (e.g. monkeys and coatis), because the fruits do not fall after maturing. The series *Laurifoliae* is particularly interesting for the economic development of new fruit crops, while its attractive and colorful flowers also give the plant an ornamental value (Ocampo et al. 2011; Rome and Coppens d´Eeckenbrugge 2017). Additionally, the remarkable capacity of species in the series to grow on flooded soils (e.g. *P. riparia* Mart. ex Mast., *P. gabrielliana*, *P. guazumaefolia*), as well their resistance to soil parasites (e.g. *P. nitida*, *P. odontophylla*) are of interest for developing rootstocks and for transferring the corresponding genes to other passion fruit species (Yockteng et al. 2011; Ocampo and Coppens d´Eeckenbrugge 2017).

On the other hand, the general similarity in most organs frequently makes it difficult to distinguish particular species, so as that the prominent *Passiflora* taxonomist Killip (1938) and other experts of series *Laurifoliae* (Vásquez 1998; MacDougal and Feuillet 2004; Rome and Coppens d´Eeckenbrugge 2017) have considered it as an "exceedingly difficult" group. In several cases, both experts as well as amateurs may have underestimated the infra-specific variation in widely distributed species, or even infra-individual variation, splitting well known species into several new species only distinguished by a few quantitative or qualitative traits, such as color. In series *Laurifoliae*, identification of species into several morphological groups demands experience and caution, even for the most common species such as *P. ambigua*, *P. nitida*, *P. laurifolia* and *P. tolimana* Harms,

which display high infra-specific variability and wide geographic distribution. For instance, *P. metae* M. Bonilla, C. Aguirre & C. Caetano was recently described from Colombia without taking into account the infra-specific variation; after rigorous revision based on herbaria and field observations we consider it synonymous with *P. tolimana* (M. Rome and G. Coppens, pers. comm.; J. Ocampo pers. obs.).

Multivariate analyses of morphological descriptors are a tool that can be used to solve issues between closely related taxa. Despite the remarkable morphological diversity described among species of series *Laurifoliae,* few studies have compared infra- and interspecific variation with statistical tools. A recent and detailed list of descriptors was used by Ocampo and Coppens d´Eeckenbrugge (2017) to study morphological divergence of 61 species of genus *Passiflora,* showing a clear separation among the subgenera *Astrophea, Decaloba* and *Passiflora* with special emphasis on quantitative and qualitative floral traits. The morphological cladistic analysis supported the delimitation of the species and with particular infra-specific morphological variation in some species, such as *P. popeonovii, P. nitida, P. maliformis* L., and *P. edulis* Sims.

In this paper we propose a new species, *P. gustaviana,* belonging to subgenus *Passiflora,* supersection *Laurifolia,* series *Laurifoliae,* discovered in Colombia. This new species is described, illustrated and compared with its closest relative *P. popeonovii,* using a phenetic approach.

MATERIALS AND METHODS

In June 2004, Gustavo Morales of the Botanical Garden of Bogotá "José Celestino Mutis" - JBB (Cundinamarca, Colombia) found a mature fruit of a *Passiflora* plant belong to *Passiflora* series *Laurifoliae* along the roadside in a secondary forest in right margin in Kilometer 2 between the municipalities of Pacho and Supatá (2,079-2,150 m), department of Cundinamarca. Its seeds were extracted and later germinated and two seedlings were planted in the JBB at 2,550 m above sea level in June 2006. Four years later, the plants bloomed for the first time in August and theirs fruits were harvested in October of that same year. Afterwards, this probable new species was compared with other species of *Laurifoliae* and based on previous studies (Ocampo et al. 2011; G. Morales. pers. obs.), *P. popenovii* was established as its morphologically closest relative species.

The morphological description was carried out *in situ* on living specimens of *P. gustaviana* and the morphologically similar species *P. popeonovii*, using 42 quantitative and 51 qualitative vegetative and reproductive descriptors (Table 1). These descriptors were assessed for individual sample taken from Colombia: two cultivated plants of *P. gustaviana* planted in the JBB, and four plants of *P. popenovii* cultivated in home gardens in the municipalities of Chachagui (Nariño) and Timbio (Cauca). Five measurements were taken for the quantitative characters of each individual. A principal component analysis (PCA) was carried out with quantitative data applying the varimax normalized rotation option, and factors with an eigenvalue greater than one were retained. Additionally, Duncan's multiple comparison test between means (95% confidence level) for each descriptor was used to compare variation among species, using the *R* package (Pardo and Del Campo 2007). The total soluble solids content (˚Brix) found within the fruit´s juice of quantitative characters was estimated with the help of a hand held Brix refractometer (ATC). The color of the

qualitative characters was then recorded, using the Royal Colour Chart (Royal Horticultural Society 2001). We followed the infrageneric classification of Feuillet and MacDougal (2003).

Three expeditions to study highland *Laurifoliae* species in the field were carried out in 2010 to 2016 in 42 different localities within six departments (Antioquia, Boyacá, Cundinamarca, Nariño, Tolima, and Valle del Cauca) of Colombia. Identifying data were recorded for each specimen collected, which include locality, habitat, elevation and geographic coordinates. Additionally, we examined specimens of series *Laurifoliae* from the major herbaria in Colombia (AFP, CAUP, CDMB, CHOCO, COL, COAH, CUVC, FAUC, FMB, HUA, HUQ, JBB, JAUM, MEDEL, PSO, SURCO, TOLI, TULV, VALLE, and UIS) and other countries (F, GH, K, QCA, MA, MO, MOL, NY, P, TX, US, and USM). Dried specimens were recorded and photographed to create a species description of Colombian *Laurifoliae*. This database of field and herbaria data that we employed was supplemented with specimens mentioned in various species descriptions published by Killip (1938, 1960), Holm-Nielsen et al. (1988) and Ulmer and MacDougal (2004). The description was created following the *Passiflora* morphological terminology proposed by Tillett (1988). The data were gathered and cleaned with OpenRefine (Verborgh and de Wilde 2013) to generate a dot map of the distribution of the *P. gustaviana* collections, using the ArcMap 10.3 software. Finally, conservation status was assessed according to IUCN (2014) categories and supported with geographic distribution data, based on the extent of occurrence (EOO) and area of occupancy (AOO), found using the Geospatial Conservation Assessment Tool - GeoCAT (Bachman et al. 2011).

RESULTS

Two specimens belonging to the new *P. gustaviana* were registered during the collection trips, found growing mostly in disturbed habitats like road borders and secondary forest margins. Regarding herbaria revisions, only four dried specimens deposited in the herbaria of the Instituto de Ciencias Naturales (ICN) of the Universidad Nacional de Colombia Bogotá branch (COL), and the José Celestino Mutis Botanical Garden of Bogotá (JBB) were recorded as *P. gustaviana*. In relation its closest relative *P. popenovii*, 20 records from herbaria (12) and field collections (8) under cultivation were registered in the departments of Cauca and Nariño in the south-west of Colombia. A dot map of the spatial distribution of *P. gustaviana* based on the six known records of the species, representing our recent field collections and existing herbarium specimens, is shown in Fig. 1.

Multivariate analysis identified 31 quantitative descriptors with high interspecific variation. Three principal components with an eigenvalue superior to one were retained, representing 96.1% of the total variation (Table 2). The first component (62%) is primarily associated with 24 descriptors characterizing internode length, stipule length, lobe size, petiole nectaries, bract size, flower length, longest inner filament of corona length, sepal length, petal width, nectary chamber size, hypanthium diameter, androgynophore length, staminal filaments length, ovary length, fruit size/weigth/total soluble solids content in juice, and seed length. The second component (26%) is represented by pedicel length, the corona`s outermost filament length, petal length, sepal width, hypanthium length, and styles length. The third component (7.4%) is only associated with operculum length. Fig. 2 shows the

individuals in the principal plane (88.3% variance total), showing a clear grouping by species and geographic origin. The representatives of *P. gustaviana* are placed on the right side along the first axis in relation to their larger size of leaves, flowers and fruits, and greater total soluble solids content in fruit juice (˚Brix), in relation to individuals of *P. popenovii*. Additionally, the 31 descriptors selected by PCA showed significant differences according to Duncan's multiple comparison test between the individuals of *P. gustaviana* and *P. popenovii* (Table 2).

Qualitative descriptors analysis identified 10 of the 51 descriptors evaluated on the basis of their potential to discriminate among species. These descriptors were associated with stem color (mature branch), and bract color and glandless, shape and color of inner filaments of the corona, operculum margin, ovary pubescence, and color of mature fruits. Table 3 synthesizes the observations for quantitative and qualitative descriptors between *P. gustaviana* and its closest relative *P. popenovii*.

TAXONOMIC TREATMENT

Passiflora gustaviana Ocampo & Molinari, sp. nov.—TYPE: COLOMBIA. Cundinamarca: Bogotá D.C, frutales de clima frío, de semillas colectadas en Supatá vía Pacho (Cundinamarca). Alt. 2,550 m.s.n.m, 17 August 2010, *Gustavo Morales 3190* (holotype: JBB!);

Plant woody vine or liana. Stem terete, slender, striate, glabrous, purple colored (mature branch) to green colored (young branch). Stipules narrowly linear, 8–13 mm long, 0.5 mm wide, not glandular, green, soon deciduous. Tendrils glabrous, red to purple colored and up to green. Petioles 1.5–2.7 cm long, slightly canaliculate adaxially, glabrous, a pair of round sessile glands (about 1.5 mm long), located on the middle of the petiole, green. Leaves unlobed, oblong-ovate, 12.5–16.5 cm long, 5–7.9 cm wide, mucronate and generally acuminate, rounded at base, lustrous on both surfaces, penninerved (lateral nerves 7 or 8 pairs), subcoriaceous, margins entire, glabrous, green. Peduncles terete, slender, solitary (sometimes in pairs), 10.5–12.8 cm long (including pedicel 0.8–1.0 cm long). Bracts ovate, concave, 3.5–4 cm long, 2–2.4 cm wide, rounded, entire, free, glabrous, persistent (until fruit maturity), light-green, glandless. Flowers pendulous, fragrant, 2.8–3.0 cm long (from the base of the nectary chamber to the ovary apex) × 6.0–7.2 cm wide, sometimes seen in clusters on pseudoracemes (small branches with short internodes ca. 2–3 cm, small leaves, and flowers at each node). Nectary chamber glabrous, 4–5 mm long x 20–20.1 mm wide, green outside and white inside. Hypanthium campanulate, 6–7.8 mm long x 22–24 mm diameter (at the base of the sepals), glabrous, green outside and white inside. Sepals oblong, 4–4.5 cm long x 2.0–2.3 cm wide, adaxial surface light-green, abaxial surface white, slightly concave, glabrous, keeled dorsally just below the apex, the keel terminating in a light-green awn about 2 mm long, glabrous. Petals white, linear-oblong, 3.8–4.1 cm long x 1.4–1.8 cm wide, glabrous, reflexed. Corona filaments in five series, two major outer series, white, banded (4–7 bands) purplish blue, the bands purple near base, thickened, fleshy, the second outer series filaments longer (3.6–3.9 cm long) than the outermost series, the three inner series 1.0–4.0 mm long, minute, filiform, purplish. Operculum membranaceous, 3.6–4.5 mm long, slightly recurved, white, fimbriated-filamentous at the

margin, purplish. Limen none. Androgynophore white (sometimes speckled with dark purple), 16–17 mm long, trochlea 5–7 mm long. Gynophore white, 1 mm long. Staminal filaments white (sometimes finely speckled with dark purple), 9.0–10.0 mm long. Ovary glabrous, ovoid, 5–6 mm long, olive green. Styles white (occasionally finely speckled with dark purple at base), 6–7 mm long, stigmas greenish-white. Fruit ovoid, 8.1–8.5 cm long × 6.5–6.7 cm diameter, lightly pubescent, immature green mottled with irregular white dots; mature weights 78–120 g, yellow mottled with irregular white dots, pericarp 1.1–1.3 cm thick; pulp aromatic, pleasant odor, flavor slightly sweet and acidic, total soluble solids content in fruit juice 13.5–14.3 (˚Brix), edible. Seeds obovate, 9–10 mm long × 4–5 mm wide, dark brown, testa reticulate, acute at apex, 78–84 seeds per fruit, surrounded by a translucent white aril. Figures 3, 4.

Geographical Distribution—Rare, endemic to the Colombian Department of Cundinamarca (4,3853˚ to 5,0712˚ North and 74,2048˚ to 74,4339˚ West), Municipalities of Albán (2,309 m), Silvania (1,900 and 2,000 m), Pacho (2,079 m), and Supatá (2,150 m) on the Eastern flank of the Cordillera Oriental in the Andean region (Fig. 1).

Etymology—The specific epithet honors the Colombian botanist Gustavo Morales, who discovered this new species, has spent most of his life enriching the knowledge of Colombian botany, and has constantly fought for the conservation of plant resources, especially passion flowers.

Ecology—Passiflora gustaviana was observed on hillsides, along roadsides and along secondary cloud forest margins, climbing onto trees found in thickets, at elevations ranging from 1,900 to 2,309 m above sea level in the department of Cundinamarca. This species

grows in areas with soils derived of volcanic ashes with middle organic matter content levels, and with a sandy-clay-loam texture; the annual mean temperature is 16.2°C and the annual rainfall is 1,241 mm (regular rainfall); and on average 4–5 sunshine hours per day (Ideam 2016).

Phenology—This new species has been observed flowering in the months of March-April to August-September, and fruiting from May-June to October-November. Carpenter bees (*Xylocopa* sp.) were observed visiting open flowers and may be associated as a pollinator of the species.

Conservation Status—Passiflora gustaviana is known only from few collections and would likely be classified as endangered (EN) based on two assessment criteria, B2a and D, if we had fully conducted its conservation assessment using IUCN (2014) guidelines. Within category B, the new species is classified as B2a, as its area of occupancy is estimated as less than 500 km^2 (20 km^2), and its extended range of occurrence is less than 5,000 km^2 (890.9 km^2); habitats are severely fragmented and it is known to exist at five locations. Regarding criterion D, the population size is estimated to be less than 50 mature individuals, with just three plants observed during the collection trips.

Additional Collections Examined—COLOMBIA. Cundinamarca: Silvania, Cordillera Oriental, vertiente occidental; estribaciones de la Cuchilla de la Cruz Grande, Km 5-6, arriba de Fusagasugá, La Aguadita, 1,900-2,000 m, 28 May 1954, *J.M. Idrobo & J. Hernández* 1660 (COL); Albán, frente a la estación del ferrocarril, 2,309 m, 1 Jul 1945, *H. García-Barriga 11610* (COL); Pacho, 2 km vía a Supatá, vereda la Esmeralda, 2,150 m, 20 June 2004, *G. Morales, M. Quintero & C. González 2369* (JBB).

Additional Collections Examined of Passiflora popenovii—COLOMBIA. Cauca: El Tambo, 1,700 m, 15 January 1938, *K. von Sneiden 1444* (US); Gazaabarita, 14 January 1965, *J.M. Idrobo 5636* (COL); entre el Tambo y el Alto del Rey, cultivada, 1,800 m, 11 January 1979, *L.K. Escobar & D. Escobar-Uribe 1017* (HUA); corregimiento San Joaquín, vereda Pomoroso, finca los Naranjos, cultivada, 1,767 m, 6 February 2004, *C. M. Caetano, L. Barrios, M. Restrepo & J. Ocampo 009* (VALLE); Timbío, zona urbana Barrio Boyacá, cultivada, 1,875 m, 5 May 2002, C.A. *Chicangana 22* (CAUP); Vereda Santa María, n.v. Granadillo de Quijos, 1,700 m, 1990, *R. Durán & J. Otálora 01* (TOLI). Cundinamarca: Bogotá D.C., enredadera procedente de Timbío Cauca, cultivada, 2,550 m (4.66788 N; 74.09977 W), 16 August 2013, *G. Morales 3630* (JBB). ECUADOR. Rio Jamboya, 2,000 m, 1882, A. Mille 223 (US); Pichincha: Quito, *L. Sodiro s.n* (P); Tunguragua: Baños, 1,850 m (introduced), 3 June 1921, *W. Popenoe 1271* (US, type); EL Oro, 24 January 1995, 1,400 m, *V. Eynden 218* (MO), Piñas, Sambotambo, cultivada, 2 September 1997, *V. Eynden 927* (QCA).

DISCUSSION

A shorter list of 33 quantitative and 10 qualitative traits showed a high variability according to a morphological characterization analysis (Table 3). This analysis supports the classification of *P. gustaviana* as a new species of *Passiflora*, subg. *Passiflora*, supersect. *Laurifolia*, series *Laurifoliae* (Ocampo et al. 2011). *Passiflora gustaviana* is distinguishable from other highland *Laurifoliae* species that occur in the Andean region in Colombia

(>1,000 m.a.s.l.) such as *P. ambigua*, *P. pergrandis* Holm-Nielsen & Lawesson, and *P. tolimana* Harms by the position (on the middle) and shape (round) of the petiole glands, large and slender peduncles (10.5–12.8 cm long), corona filaments in five series, operculum margin with short fimbriate filaments (purplish), and distinct size of the flowers (2.8–3.0 cm long x 6–7.2 cm wide) and fruits (8.1–8.5 cm long x 6.5–6.7 cm diameter). Additionally, the new species was compared to its putative closest relative *P. popenovii*, using information gathered from specimens that were recorded during collection trips and herbaria visits, as well as found within the literature (Killip 1938, 1960; Holm-Nielsen et al. 1988; Ulmer and MacDougal 2004). *Passiflora gustaviana* is related to *P. popenovii*, but differs by its stem color (mature branch, purple vs. green); stipule length (8–13 mm vs. 10–17 mm); leaf size (12.5–16.5 cm long × 5.0–7.9 cm wide vs. 10.0–12.5 cm long × 3.9–5.1 cm wide); petiole glands (one pair vs. glandless); pedicel length (8–10 mm vs. 5–8 mm); bract, sepal and petal size (see Table 3); bract color (light-green vs. reddish-purple), grands (glandless vs. 3–4 pairs); corona filaments (5-series vs. 6-series), outermost longest filament length (3.6–3.9 cm vs. 3.0–4.4 cm), inner longest filament length (3–4 mm vs. 4.0–5.5 mm), shape of the inner filament (minute-filiform vs. capillary) and color (purplish vs. white and purplish-blue at apex); also in its operculum margin (fimbriated and purplish vs. entire and white); staminal filaments length (9.0–10.0 mm vs. 6.8–8 mm); ovary (glabrous vs. pubescent); color of mature fruits (yellow, mottled with irregular white dots vs. yellow-orange); percentage of total soluble solids content in fruit juice (13.5–14.3 % vs. 14.8–16.8 %); and flavor (slightly sweet-acidic vs. sweet).

Passiflora gustaviana has only been encountered in the Department of Cundinamarca in Colombia on the Eastern flank of Cordillera Oriental in the Andean region between 1,900

to 2,309 m above sea level, along roadsides, in secondary forest margins and climbing onto trees found in thickets. *Passiflora popenovii* was proposed as a new species by Killip in 1922 based on a plant cultivated in the municipality of Baños at 1,850 m.a.s.l. (Tungurahua, Ecuador), with seeds brought from the Eastern slopes of the Andes in Ecuador by W. Popenoe (*W. Popenoe 1271*, US, type), but there is no record on whether these seeds came from wild or cultivated plants. This species has only been found cultivated in home gardens in the south-western part of Colombia (Cauca and Nariño Departments) and Ecuador (El Oro, Loja, Pichincha and Tungurahua Provinces) under the vernacular names of Curubejo, granadilla de Quijos or granadilla Caucana, and where it is regularly propagated by cuttings (National Research Council 1989). Currently, its origin is unknown and no wild representative of *P. popenovii* has been reported, so some authors consider it extinct outside of cultivation (Ocampo et al. 2007; Yockteng et al. 2011).

The discovery of this new rare endemic species increases to 12 the number of species (Table 4) belonging to the series *Laurifoliae* reported in Colombia (Ocampo et al. 2007, 2010, 2011), and suggests that this country concenters the highest species diversity, followed by Brazil. However, Colombia might still harbor many more unknown species, given the low level of exploration in various zones of the Andes, the Caribbean, the Amazon, the Orinoquia and the Pacific (Ocampo et al. 2007, 2010, 2015). Additionally, the discovery of this new species in Colombian territory brings into question the putative Ecuadorian origin of *P. popenovii* due to its morphological proximity and similar ecological habitat to *P. gustaviana*. We here hypothesize that *P. popenovii* may be an undiscovered species of Colombia that could be found growing on the slopes of high mountains of the Colombian Andes.

Passiflora is considered as a biodiversity indicator in Colombia as its species have multiple ecological interactions with many types of organisms (Ocampo et al. 2010), as such, it can be considered to indirectly provide an ecosystem service through the regulation of populations of other species. However, the species distributions have been drastically affected mainly by the deforestation of rain and cloud forests in the Andean, Amazon, and Pacific regions. This has occurred mainly due to extensive livestock production (pasturing), plantations of illicit crops, hydroelectric dams, illegal gold mines, and agricultural practices that currently support extensive coffee, sugar cane, rice, banana, and potato plantations (Ocampo et al. 2007, 2010).

Indeed, the disappearance of *Passiflora* species from the ecosystem would entail the loss of other organisms that depend on these, such as butterflies (*Heliconius* species) and many nectar feeding insects, mammals (bats), and birds (Yockteng et al. 2011). In this context, not only the species of the genus *Passiflora*, but also most of the Colombian Passifloraceae (71%) are under some degree of threat according to the IUCN criteria (Ocampo et al. 2007). The discovery of *P. gustaviana* during field surveys growing on road edges in severely fragmented habitats, as well as the fact that it has been classified as a probably threatened species within the Endangered (ED, B2a, D) status, emphasizes the need for conservation. *Ex situ* conservation techniques at botanical gardens and seed banks (e.g. cryopreservation) are strategies that must be implemented in case critical habitats are destroyed. These strategies have already begun to be implemented by the Botanical Garden

of Bogotá “José Celestino Mutis”, where individuals of the new species are under cultivation.

In conclusion, statistical analysis allowed for the classification and determination of a new species of *Passiflora* from 41 discriminant morphological descriptors, as well as its fruit properties, *P. gustaviana* constitutes a promising new genetic resource and ecosystem service as a wild relative useful for the improvement of cultivated *Passiflora* species.

ACKNOWLEDGEMENTS. The authors wish to thank the curators of the herbaria that provided specimens for this study, as well as the Botanical Garden of Bogotá “José Celestino Mutis” for its generosity and assistance with the cultivation of *P. gustaviana*. The first author gratefully acknowledges the financial support of the Gines-Mera Fellowship Foundation (CIAT-CBN). This author would also especially like to thank Grupo de Investigaciones en Recursos Fitogenéticos Neotropicales (GIRFIN/UNAL Palmira) for their persistent and inspirational efforts to use and value our plant resources. Our most grateful appreciation and thanks to Hernán Dario Bernal and Jorge Julián Restrepo for their assistance during some collection trips carried out in Cundinamarca and Antioquia, respectively. We also thank our anonymous reviewers, James Smith (our chief editor) and Natalie Orentlicher (for copy editing) for their contributions to the last version of the manuscript.

LITERATURED CITED

392 Bachman, S., J. Moat, A. Hill, J. de la Torre, and B. Scott. 2011. Supporting red list threat
393 assessments with GeoCAT: Geospatial conservation assessment tool. *Zookeys* 150:
394 117–126.
395
396 Feuillet, C. and J. M. MacDougal. 2003 [2004]. A new infrageneric classification of
397 *Passiflora* L. (Passifloraceae). *Passiflora* 13: 34–38.
398
399 Hernández, A., P. M. Jørgensen, and M. M. Arbo. 2015. in Catálogo de plantas y líquenes
400 de Colombia. eds. R. Bernal, S. R. Gradstein, and M. Celis. Bogotá: Instituto de
401 Ciencias Naturales, Universidad Nacional de Colombia.
402 http://catalogoplantasdecolombia.unal.edu.co. Last accessed January 1, 2017.
403
404 Holm-Nielsen, L. B., P. M. Jørgensen, and J. E. Lawesson. 1988. *Passifloraceae.* Pp. 1-130
405 in Flora of Ecuador 31, eds. G. Harling and B. Sparre. Göteborg and Stockholm:
406 University of Göteborg and Swedish Museum of Natural History.
407
408 Ideam - Instituto de Hidrología, Meteorología y Estudios Ambientales. 2016. Atlas
409 climatológico y de radiación solar de Colombia. Ministerio de Ambiente y Desarrollo
410 Sostenible de Colombia [online]. Available from
411 www.atlas.ideam.gov.co/presentacion/ [accessed 3 October 2016].
412
413 IUCN. 2014. Guidelines for using the IUCN red list categories and Criteria. Version 11.
414 Gland, Switzerland and Cambridge, U. K.: IUCN.

Killip, E. P. 1922. Botany. Three new species from Ecuador and Venezuela. *Journal of the Washington Academy Sciences* 12: 330–332.

Killip, E. P. 1938. The American species of Passiforaceae. *Publications of the Field Museum of Natural History. Botanical Series* 19: 1–613.

Killip, E. P. 1960. Supplemental notes to the American species of *Passiflora* with descriptions of new species. *Contributions from the U.S. National Herbarium* 35: 361–362.

Krosnick, S. E., A. J. Ford, and J. V. Freudenstein. 2009. Taxonomic revision of *Passiflora* subgenus *Tetrapathea* including the monotypic genera *Hollrungia* and *Tetrapathea* (Passifloraceae), and a new species of *Passiflora*. *Systematic Botany* 34: 375–385. doi: 10.1600/036364409788606343.

MacDougal, J. M. and C. Feuillet. 2004. Systematics. Pp. 27–31 in *Passiflora*: *Passionflowers of the world*, eds. T. Ulmer and J. M. MacDougal. Portland, Oregon: Timber Press.

National Research Council. 1989. Part V, Fruits, Passionfruits. Pp. 287-295 in *Lost crops of the Incas: Little-known of the Andes with promise for worldwide cultivation*. Washington, D.C.: National Academy Press. doi:10.1525/jlca.1992.4.1.41.1

Ocampo, J., G. Coppens d'Eeckenbrugge, M. Restrepo, A. Jarvis, M. Salazar, and C. Caetano. 2007. Diversity of Colombian Passifloraceae: Biogeography and an updated list for conservation. *Biota Colombiana* 8: 1–45. doi: http://www.redalyc.org/pdf/491/49180101.pdf

Ocampo, J., G. Coppens d'Eeckenbrugge, and A. Jarvis. 2010. Distribution of the genus *Passiflora* L. diversity in Colombia and its potential as an indicator for biodiversity management in the Coffee growing zone. *Diversity* 2: 1158–1180. doi: 10.3390/d2111158.

Ocampo, J., M. Molinari, and Y. Kuethe. 2011. Diversidad y distribución de las especies de la serie *Laurifoliae* (*Passiflora* L.) en el Neotrópico. Cali, Colombia: Memorias VI Congreso Colombiano de Botánica.

Ocampo, J., J. J. Restrepo, and W. Giraldo. 2015. Rediscovery of *Passiflora danielii* Killip, 1960 (subgenus *Passiflora*): a threatened narrow endemic species of Colombia. *Check List* 11: 1589. doi: http://dx.doi.org/10.15560/11.2.1589.

Ocampo, J. and G. Coppens d'Eeckenbrugge. 2017. Morphological characterization in the genus *Passiflora* L.: An approach to understanding its complex variability. *Plant Systematics and Evolution* 303: 531-558. doi: 10.1007/s00606-017-1390-2

Pardo, C. E. and P. C. del Campo. 2007. Combinación de métodos factoriales y de análisis de conglomerados en *R*: el paquete *FactoClass*. *Revista Colombiana de Estadística* 30: 231–245.

Rome, M. and G. Coppens d'Eeckenbrugge. 2017. Delimitation of the series *Laurifoliae* in the genus *Passiflora* (Passifloraceae). Phytotaxa 308: 245–252.

The Royal Horticultural Society - R.H.S. 2001. Royal Horticultural Society colour chart (named A, B, C and D). London, U. K.: Royal Horticultural Society.

Tillett, S. 1988. Passionis Passifloris II. Terminología. *Ernstia* 48:1–40.

Ulmer, T. and J. M. MacDougal. 2004. *Passiflora*: *Passionflowers of the world.* Portland, Oregon: Timber Press.

Vásquez, R. 1998. Las especies de *Passiflora* subgénero *Granadilla* series *Laurifoliae* (Passifloraceae) en Bolivia. *Revista de la Sociedad Boliviana de Botánica* 2: 36–45.

Verborgh, R., and M. de Wilde. 2013. Using *OpenRefine*. Birmingham, U.K.: Packt Publishing Ltd. http://openrefine.org/

Snow, N., and J. M. MacDougal. 1993. New chromosme reports in *Passiflora* (Passifloraceae). Systematic Botany 18:261–273.

Yockteng, R., G. Coppens d'Eeckenbrugge, and T. Souza-Chies. 2011. *Passiflora*. Pp. 129-171 in *Wild crop relatives: Genomic and breeding resources. Tropical and subtropical fruits*. ed. K. Chittaranjan. Berlin: Springer Verlag.

Yotoko, SC., M. C. Dornelas, P. D. Togni, T. C. Fonseca, F. M. Salzano, S. L. Bonatto, and F. B. Freitas. 2011. Does variation in genome sizes reflect adaptive or neutral processes? new clues from *Passiflora*. *PLoS ONE* 6: e18212. doi:10.1371/journal.pone.0018212.t001

TABLE 1. List of 93 morphological descriptors evaluated in this study. Scales for qualitative characteristics: B (binary), O (Ordinal), and N (Nominal).

Organ	Qualitative characters (51)	Quantitative characters (42)
Stem	Pubescence (N) Color (N)	Internode length (mm)
Tendril	Pubescence (N) Color (N) Anthocyanin (O)	
Stipule	Permanence (B) Color (N) Pubescence (N) Shape (N) Margin (N) Anthocyanin (O) Color (N)	Length (mm) Width (mm)
Leaf	Margin (N) Base shape (N) Apex shape (N) Presence of acumen (B) Pubescence – adaxial (N) Pubescence – abaxial (N) Anthocyanin – lamina (O) Anthocyanin – nerves (O) Color – adaxial (N) Presence of laminar nectaries (B)	Petiole length (mm) Petiole nectaries (number) Lobe length (mm) Lobe width (mm) Margin nectaries (number)
Peduncle	Pubescence (N) Color (N) Anthocyanin (O)	Length (mm) Diameter (mm) Pedicel length (mm)
Bract	Permanence (B) Pubescence (N) Color (N)	Length (mm) Width (mm) Margin nectaries (number)

	Anthocyanin (O) Shape (N)	
Flower	Color sepals (N) Sepal awn (B) Color petals (N) Color filaments at base (N) Color of filaments at apex (N) Color hypanthium (N) Hypanthium pubescence (N) Color androgynophore (N) Color staminal filaments (N) Color of ovary (N) Ovary pubescence (N) Color of styles (N) Color operculum (N) Color operculum margin (N)	Length (mm) Width (mm) Sepal length (mm) Sepal width (mm) Petal length (mm) Petal width (mm) Outer filaments series of corona - radii (number) Outer longest filament of corona length (mm) Inner filaments series of corona – pali (number) Inner longest filament of corona length (mm) Hypanthium length (mm) Hypanthium diameter at base (mm) Hypanthium diameter at above (mm) Nectary chamber length (mm) Nectary chamber diameter (mm) Operculum length (mm) Androgynophore length (mm) Gynophore length (mm) Staminal filaments length (mm) Ovary length (mm) Styles length (mm)
Fruit	Shape (N) Color fruit immature (N) Color fruit mature (N) Pubescence (N) Color aril (N)	Weight (g) Length (mm) Diameter (mm) Seeds per fruit (number) Total soluble solids (˚Brix %)
Seed	Shape seed (N) Color seed (N)	Length (mm) Width (mm)

495

496 TABLE 2. Factor loadings from the principal component analysis (*varimax normalized* rotation) carried out on

497 37 quantitative descriptors. Bold values (Eigenvalues) contribute most to proportion of variance explained

Descriptors	**Components**		
	1	**2**	**3**
Internodes length	**0.870**	-0.144	0.427
Stipule length	**-0.826**	-0.437	0.329
Lobe length	**0.888**	0.387	-0.009
Lobe width	**0.926**	0.276	0.069
Petiole length	0.688	0.633	0.337
Petiole nectaries	**0.999**	-0.014	0.027
Penduncle length	0.392	-0.678	-0.606
Pedicel length	0.005	**0.809**	0.580
Bract length	**0.962**	-0.265	-0.058
Bract width	**0.948**	-0.307	0.024
Flower length	**-0.729**	-0.192	0.588
Flower width	0.097	-0.626	0.418
Outermost filament of corona length	-0.175	**0.928**	-0.095
Inner filaments series of corona	**-0.998**	-0.012	0.039

Inner longest filament of corona length	**-0.999**	0.014	-0.027
Petal length	0.346	**0.918**	0.175
Petal width	**0.849**	0.470	0.229
Sepal length	**0.905**	0.400	0.093
Sepal width	0.232	**0.917**	0.323
Nectary chamber length	**0.815**	0.105	0.561
Nectary chamber diameter	**0.944**	-0.327	-0.013
Hypanthium length	0.179	**0.940**	-0.100
Hypanthium diameter at base	**0.960**	-0.271	-0.017
Hypanthium diameter above	**0.984**	-0.156	-0.049
Operculum length	0.348	0.365	**0.845**
Androgynophore length	**0.782**	0.464	0.403
Staminal filaments length	**-0.999**	0.014	-0.027
Ovary length	**-0.869**	-0.461	-0.042
Styles length	-0.204	**0.949**	0.232
Fruit weigth	**0.999**	0.023	0.011
Fruit length	**0.924**	0.215	0.080
Fruit diameter	**0.936**	0.301	0.041
Number seeds per fruit	-0.650	-0.067	-0.395
Total solid solubles content (˚Brix)	**-0.898**	0.015	-0.275
Seed length	**0.986**	-0.113	0.068
% Total variance	62.425	25.964	7.740
Eigenvalue	23.097	9.607	2.864

498

499 TABLE 3.Summary and comparison of morphological characters between *P. gustaviana* (*Pg*) and *P. popenovii*

500 (*Pp*).

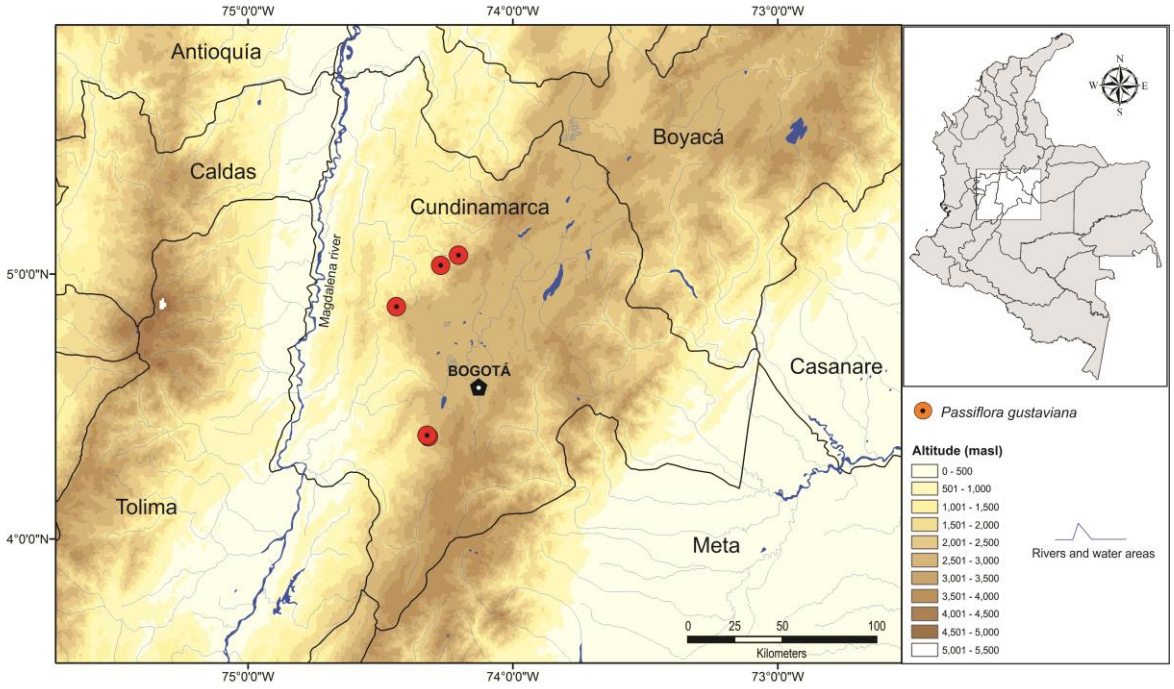
Organs	Descriptors		*Passiflora gustaviana*						*Passiflora popenovii*						Duncan's test (p≤0.05)	
			Minimum		Maximum	Mean	Std.Dev.	Coef.Var.	Minimum		Maximum	Mean	Std.Dev.	Coef.Var.	*Pg*	*Pp*
Stem	Internodes length	mm	32.0	-	80.0	61.6	13.9	22.6	22.0	-	46.0	35.4	5.5	15.6	a	b
	Stem color (mature branch)		purple						green							
Stipules	Stipule length	mm	8.0	-	13.0	10.2	1.4	13.7	10.0	-	17.0	11.9	1.5	12.5	a	b
Leaves	Lobe length	mm	125.0	-	165.0	143.4	15.6	10.9	100.0	-	125.0	116.2	8.1	6.9	a	b
	Lobe width	mm	50.0	-	79.0	63.1	9.3	14.7	39.0	-	51.0	46.1	3.9	8.4	a	b
	Petiolar glands		one pair						absent - (rarely with a scarlike gland near base)							
Pedicel	Pedicel length	mm	8.0		10.0	9.2	0.8	8.3	5.0		9.0	6.9	1.2	18.1	a	b
Flowers	Flower length	mm	28.0	-	30.0	29.0	0.9	3.3	30.0	-	31.0	30.5	0.5	1.7	a	b
	Flower width	mm	60.0		72.0	65.5	4.3	6.5	60.0		80.0	71.7	7.1	9.9	a	b
	Bract length	mm	35.0	-	40.0	37.2	1.3	3.5	20.0	-	30.0	23.4	2.7	11.7	a	b
	Bract width	mm	20.0	-	24.0	21.9	1.2	5.4	11.0	-	18.0	14.8	1.9	12.9	a	b
	Bract glands		glandless						glandular							
	Color bract		light-green						reddish-purple							
	Petal length	mm	38.0		41.0	39.1	1.0	2.5	25.0		44.0	36.0	5.5	15.2	a	b
	Petal width	mm	14.0	-	18.0	15.8	1.1	7.0	10.0	-	15.0	11.8	1.7	14.3	a	b
	Sepal length	mm	40.0	-	45.0	43.0	1.3	3.1	36.0	-	42.0	40.0	1.7	4.2	a	b
	Sepal width	mm	20.0		23.0	21.8	0.9	4.1	16.0		24.0	20.6	3.2	15.4	a	b
	Outer longest filament of corona length	mm	36.0		39.0	37.8	0.9	2.4	30.0		44.0	39.0	4.2	10.8	a	b
	Inner filaments series of corona		3-seriate						4-seriate							
	Inner longest filament of corona length	mm	3.0		4.0	3.4	0.5	13.6	4.0		5.5	4.5	0.5	12.3	a	b
	Shape inner filaments		minute-filiform						capillary							
	Color of inner filaments		purplish						white and purplish-blue at apex							
	Hypanthium length	mm	12.4		14.0	13.1	0.5	3.8	8.2		11.5	9.9	1.2	11.8	a	b
	Hypanthium diameter at base	mm	20.0	-	21.0	20.7	0.4	2.2	12.0	-	16.0	13.5	1.4	10.3	a	b
	Hypanthium diameter above	mm	22.0	-	24.0	23.1	0.7	3.1	14.0	-	19.0	15.9	1.4	8.6	a	b
	Nectary chamber length	mm	7.0	-	9.0	8.2	0.6	7.0	3.0	-	5.6	4.4	0.6	14.1	a	b
	Nectary chamber diameter	mm	20.0	-	21.0	20.7	0.4	2.2	12.0	-	17.0	14.3	1.6	10.9	a	b
	Operculum length	mm	3.6		4.3	4.1	0.2	5.6	3.0		5.0	3.9	0.6	14.4	a	b
	Operculum margin		fimbriated-purplish						entire-white							
	Color operculum margin		purplish						white							
	Androgynophore length	mm	16.0	-	17.0	16.6	0.3	2.0	9.0	-	16.0	12.5	2.1	16.8	a	b
	Staminal filaments length	mm	6.8	-	7.1	6.9	0.1	1.3	6.0	-	9.9	8.4	1.2	14.5	a	b
	Ovary length	mm	5.0	-	6.0	5.7	0.3	5.4	6.0	-	7.8	6.8	0.9	12.3	a	b
	Ovary pubescense		glabrous						pubescent							
	Styles length	mm	6.0		7.0	6.3	0.3	5.1	5.0		9.0	6.9	1.6	22.9	a	b
Fruits	Fruit weigth	g	199.0	-	210.0	203.3	3.1	1.5	78.0	-	120.0	100.4	12.7	12.7	a	b
	Fruit length	mm	81.0	-	85.0	82.8	1.2	1.5	63.0	-	88.0	69.9	5.6	8.0	a	b
	Fruit diameter	mm	65.0	-	67.0	66.3	0.6	0.9	50.0	-	63.0	54.3	3.2	5.9	a	b
	Color mature fruits		yellow mottled with irregular white dots						yellow-orange							
Seeds	Seeds per fruit	#	78.0	-	84.0	80.1	1.6	2.0	74.0	-	117.0	97.9	13.4	13.7	a	b
	Seed length	mm	9.0		10.0	9.3	2.2	1.6	7.0		8.0	7.2	4.8	5.1	a	b
Aril	Total soluble solids	°Brix	13.5	-	14.3	14.0	0.2	1.8	14.8	-	16.8	15.4	0.5	3.2	a	b

TABLE 4. List of *Laurifoliae* species inventoried in Colombia according to Ocampo et al. (2007, 2010, 2011).

Species	Elevation m.a.s.l.	Distribution in the Biogeographic regions	Observations
P. ambigua Hemsl, 1902	10 – 1,500	Andean, Caribbean, Orinoquian, Pacific	Edible fruit
P. sp. nov.	1,800 – 1,880	Andean	Endemic, *D. Sánchez et al. 1378 and L. K. Escob F. J. Roldán 8662* (COL, CUVC, HUA, MEDEL
P. gleasonii Killip, 1924	130 – 172	Amazonian	Unknown fruit, endemic
P. guazumaefolia Juss., 1805	6 – 70	Caribbean, Orinoquian	Edible fruit, synonymous *P. theobromifolia* DC.
P. gustaviana Ocampo & Molinari, 2017	1,924 – 2,309	Andean	Edible fruit, endemic
P. killipiana Cuatr., 1960	216	Amazonian, Orinoquian	Edible fruit, endemic
P. laurifolia L., 1753	79 – 237	Amazonian, Orinoquian	Edible fruit, synonymous *P. tinifolia* Juss.
P. nitida HBK., 1817	0 – 826	Amazonia, Andean, Orinoquian, Pacific	Edible fruit, synonymous *P. nymphaeoides* H. Ka
P. pergrandis Holm-Niels. & Lawesson, 1987	1,020 – 1,417	Andean	Edible fruit
P. popenovii Killip, 1938	1,500 – 1,900	Andean	Edible fruit, cultivated in home gardens
P. riparia Mart ex. Mast., 1872	180 – 300	Amazonian, Orinoquian	Edible fruit
P. tolimana Harms, 1894	250 – 1,800	Andean, Orinoquian	Edible fruit, synonymous *P. metae* M. Bonilla, C. Aguirre & C. Caetano

FIG. 1. Geographical distribution of *P. gustaviana* (red dots) on Eastern Cordillera in the Colombia`s Andean region from herbarium and field collections.

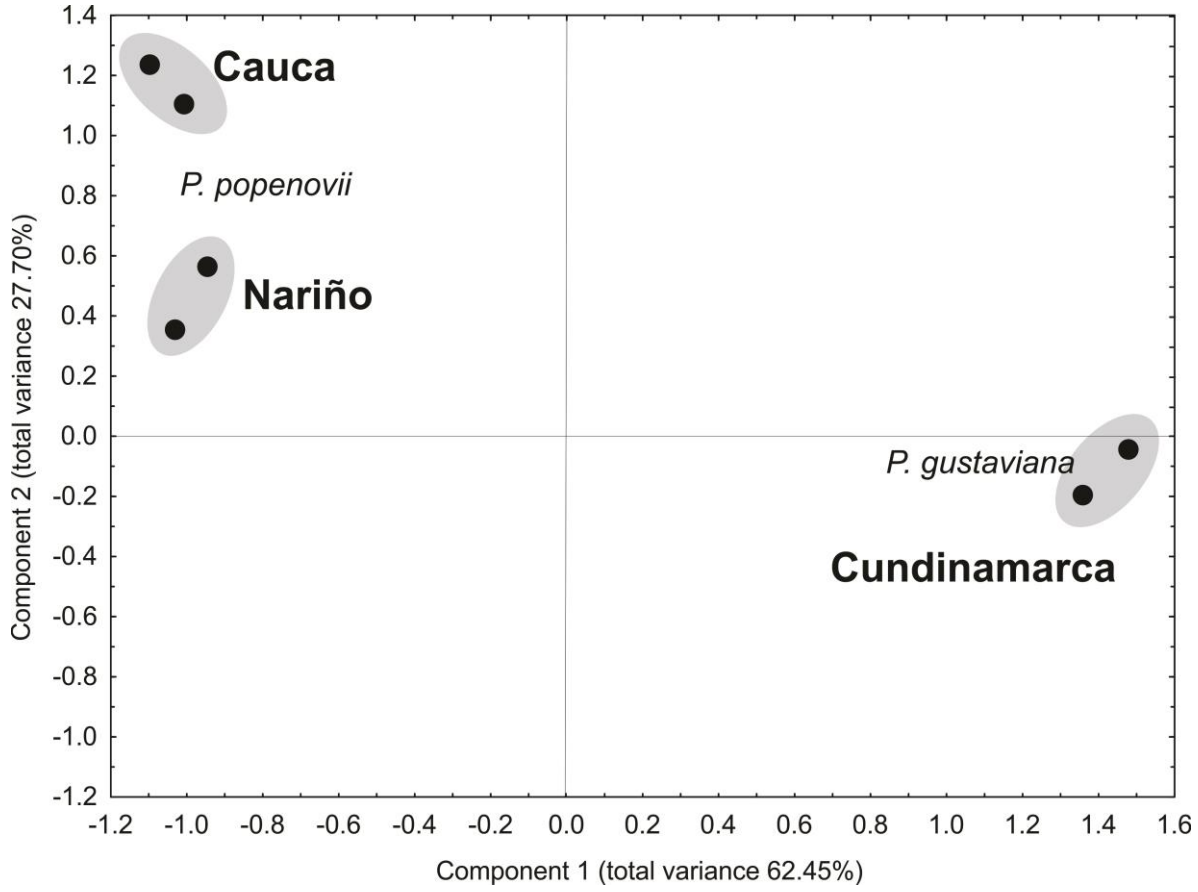
507



508

509 FIG. 2. Plot of the scores obtained by *P. gustaviana* and *P. popenovii* accessions for the principal plane

510 quantitative variation components of the PCA.



511

512 FIG. 3. *Passiflora gustaviana* Ocampo & Molinari. Drawing of a mature plant. A. Stipules, young bud, tendril,
513 petiole, petiolar glands and leaf. B. Stipule. C. Flower, pendent. D. Longitudinal section of a flower. E. Fruit,
514 mature. F. Seed. Drawn by Jairo Larrahondo, of the type (*Gustavo Morales 3190*, JBB).

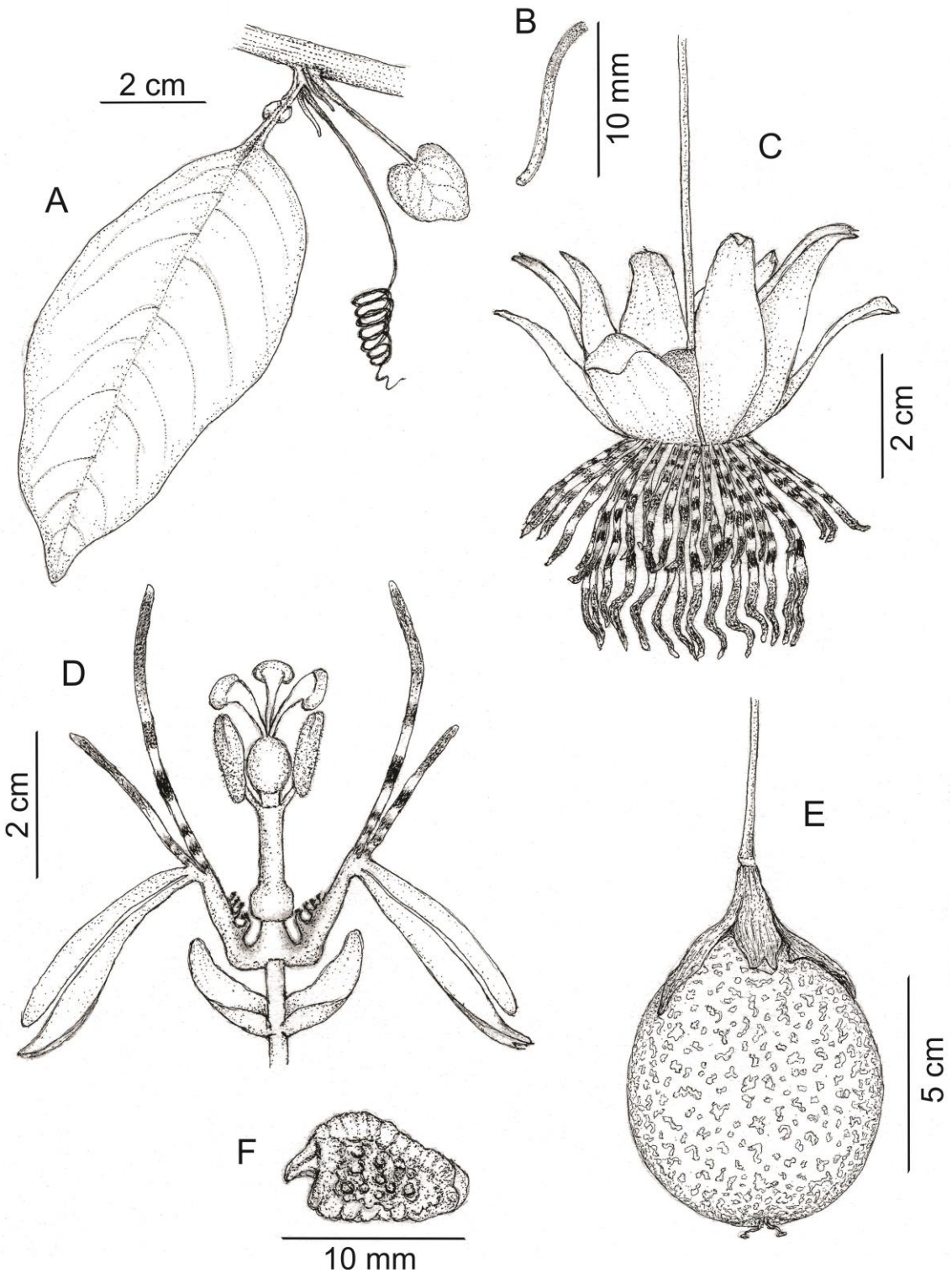


FIG. 4. *Passiflora gustaviana* Ocampo & Molinari. Photographs of a mature plant. **A**, stipules, young bud and tendril. **B**, petiole and petiolar glands. **C**, mature leaf. **D**, terminal branch, **E**, frontal view of a flower. **F**, flower,

pendent. **G**, floral bracts. **H**, longitudinal section of a flower. **I**, fruit, immature. **J**, fruit, becoming mature. **K**, fruit mature, cross section showing mesocarp and pulp. **L**, seeds. Photographs by John Ocampo and Gustavo Morales, of the type (*Gustavo Morales 3190*, JBB).