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Cover: Coromandal Sacred Langur *Semnopithecus priam* - made with acrylic paint. © P. Kritika.

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COMMUNICATION

Morpho-anatomy and habitat characteristics of *Xanthostemon verdugonianus* Náves ex Fern.-Vill. (Myrtaceae), a threatened and endemic species in the Philippines

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Abstract: This study provided insights into the morpho-anatomy of *Xanthostemon verdugonianus* Náves ex Fern.-Vill., a threatened species endemic to the Philippines. Sampling was conducted in its natural habitat with the presence of dominant vegetation and rehabilitated sites of the species. Quadrats were established to study the population size and document associated species & soil particle characteristics. The leaves are alternate in arrangement, reddish when young, and are hypostomatic with paracytic stomata. The distinctly thick cuticle and the compact spongy layer could be an adaptation to tropical island conditions. The stem and roots contain tissues manifesting secondary growth with secondary xylem and outer bark formation. The inflorescence is a corymb, and the flowers are bright red, with a prominent cup-shaped hypanthium, persistent lobe-shaped calyx, and a superior ovary. Fruit is a globular capsule round-ovoid in shape with a woody texture. Placental seeds are visible upon splitting matured fruits which are flattened and deltoid to semicircular shape. Twenty-nine species of plants belonging to 19 families were found to be associated with *X. verdugonianus*, with a mean abundance of eight species per plot. The ultramafic substrate was dominantly composed of medium sand particles, and the reddish color indicated the oxidation of metallic elements in the soil. Analyzing the morpho-anatomical features can help explain endemicity, survival, and adaptation to climate change.

Keywords: Associated flora, Dinagat Island, diversity, habitat, Ironwood, lowland forest, ornamental, soil types, ultramafic.

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Author contributions: The topic for research investigation, study design, workflow, and editing were performed by Dr. Jess H. Jumawan. The species collection of Xanthostemon verdugonianus and associated species were assessed by Arlyn Jane M. Sinogbuhan, Angie A. Abucayon and Princess Ansie T. Taperla. Morphoanatomical sectioning of plant samples, leaf section was performed by Arlyn Jane M. Sinogbuhan. Stem and root sectioning were conducted by Princess Ansie A. Taperla and Angie A. Abucayon. Data analysis including statistical analysis was performed by the second author. The manuscript was drafted initially by Arlyn Jane M. Sinogbuhan, Angie A. Abucayon and Princess Ansie T. Taperla under the guidance of the primary author.

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INTRODUCTION

The genus *Xanthostemon* F.Muell. (Myrtaceae) comprises approximately of 50 species of trees and shrubs (Ruales & Jumawan 2023) distributed in Australia, Malaysia, Indonesia, New Guinea, and the Philippines (Nazarudin et al. 2012; Nazarudin 2020). *Xanthostemon* species are grown as ornamental plants in parks and roadsides due to their colorful flowers that bloom throughout the year in the tropics (Nazarudin & Tsan 2018). Essential oils are present in the leaves of many *Xanthostemon* species found in Australia (Brophy et al. 2006). Oils can also be present in other plant organs, which could be the basis for many species used as medicinal plants (Nazarudin et al. 2015). In the Philippines, six species of *Xanthostemon* occur in the wild, of which five species are endemic and one introduced to the country (Ruales & Jumawan 2023). These are *X. verdugonianus* Náves ex Fern.-Vill., *X. speciosus* Merr., *X. fruticosus* Peter G. Wilson & Co, *X. bracteatus* Merr., *X. philippinensis* Merr., and *X. chrysanthus* (F.Muell.) Benth.. These species are collectively known as Philippine ironwood.

Xanthostemon verdugonianus is a dominant species in Dinagat Island, forming a distinct vegetation community compared to other species. This unique characteristic was observed in evaluating forest habitat types of Dinagat Island, Philippines (Lillo et al. 2019). *X. verdugonianus* can also be found in Surigao del Norte, Agusan del Norte, Tinago, Samar, Leyte, and Dinagat (Ocon et al. 2018; Sarmiento 2020). The common features of these areas are the ultramafic rocks and soils that are rich in heavy metals (Fernando et al. 2008; Malabrigo & Gibe 2020). It is a hardwood species used as timber posts for houses and materials for furniture. The reddish inflorescence in terminal branches blooms in an open canopy during dry seasons. The attractive reddish flowers are preferred as ornamental plants and are commonly planted in parks and along roadsides outside their natural habitat (Flora Fauna Web).

Xanthostemon verdugonianus is considered a threatened species and is assigned 'Vulnerable' status (DENR DAO 2017; Energy Department Corporation 2018), making this plant a conservation priority. Mining activities in Surigao province threaten its natural habitat. In particular, Dinagat Islands is a Mineral Reserve under Republic Act No. 391 issued in 1939 by the Department of Environment and Natural Resources (DENR) because of its rich mineral resources, metallic and non-metallic deposits in aluminous laterite, phosphate, limestone, siliceous, and gold depositions (Sarmiento 2018). There are few studies conducted to understand the morpho-anatomical traits of *X. verdugonianus*. Studying the anatomy of this species can help better understand its growth, development, cultivation, and economic importance. An essential application of the anatomical studies on plants and trees will be to identify which type of tissues help plants survive different stresses in their environment (Lubis et al. 2022). Understanding the anatomical features of endemic plants in their natural habitats can help project the extreme effects of global warming and climate change (Lynch et al. 2021). Thus, this study aimed to examine the morpho-anatomical description of *X. verdugonianus*, including its associated flora, species richness, abundance, and soil particle characterization.

MATERIALS AND METHODS

The study was conducted in two sites within Barangay Liberty, Gibusong Island Loreto, Dinagat Islands positioned at 10.424829°N, 125.492350°E (Site 1), 10.4377°N, 125.493517°E (Site 2) (Figure 1), with an annual temperature of 27.66 °C, humidity of 79.67%, and precipitation of 16.66 mm for the year 2022 (Visual Crossing Corporation 2022). Site 1 is approximately 700 m away from the shore at 105 m, while site 2 is around 400 m away from the shore and at 45 m (Image 1). The sampling areas are located on the east side facing the Pacific Ocean.

Study Area

This study was conducted on two sites. The first site was located in Purok 3, Sun-ok and the second site was located in Purok 1, Lu-ok (Figure 2). It was observed that Site 1 comprises naturally grown *X. verdugonianus* bearing fruits and flowers associated with taller trees and other vegetation. Site 2 is a habitat with rehabilitated *X. verdugonianus* associated with fewer trees and vegetation. Following the study of Lillo et al. (2019), the present study area falls within the lowland forest type, which was categorized into lowland tall forest (Site 1) and shrub forest (Site 2).

Morpho-Anatomical Description of *X. verdugonianus* Samples

Morphological measurements of the leaves, flowers, fruits, and seeds of *X. verdugonianus* were done following the method of Berghetti et al. (2019) with some modifications. Twenty samples of leaves were measured using the caliper to get the mean leaf

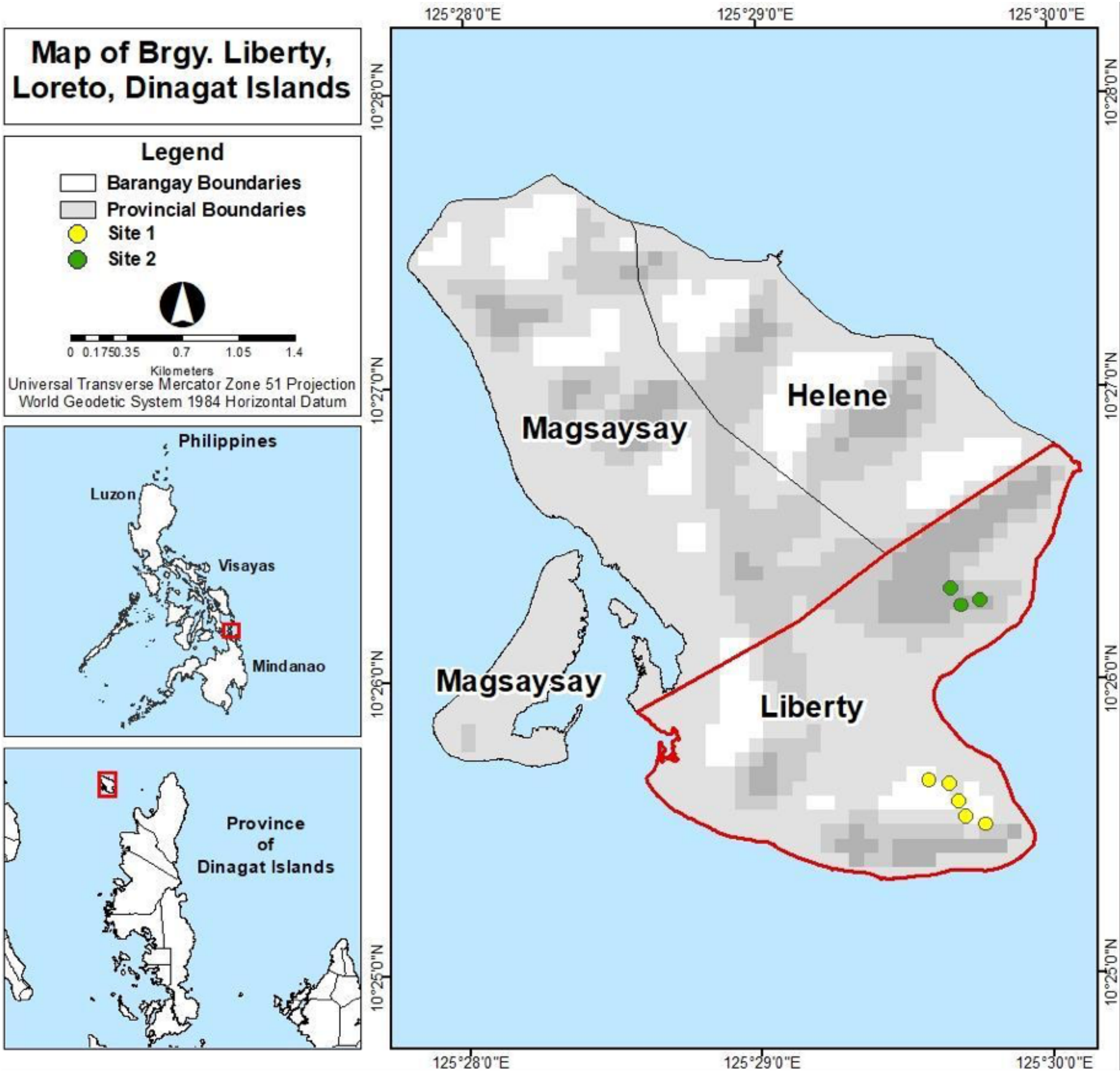

Figure 1. Map of Barangay Liberty, Gibusong Island Loreto, Dinagat Island, Philippines.

length (LL) and leaf width (LW). Randomly selected trees of *X. verdugonianus* were measured in terms of tree height using a tree pole and stem diameter using a tape measure. Photographs depicting the morphological features of the plant were taken using a Canon SX70 digital camera. Tree characteristics were measured in situ and expressed in metric units. Fruits, flowers, and seeds samples were collected, preserved in glycerine, and brought to the Biology Laboratory at Caraga State University for analysis. Flower and seed samples were measured using a digital caliper (mm) and dissecting microscope (KOPPACE) in the laboratory. The samples were collected in November 2022, and photographs of the plants were taken to aid an accurate description.

The fresh samples of *X. verdugonianus* were subjected to anatomical characterization following the method of Dubowsky (2009) and Sultana & Rahman (2020) with some modifications. The adopted procedure utilized stains, but in this study fresh plant samples showed the best results. A handheld microtome instrument (AYM brand Student Hand Microtome) was used for anatomical sectioning, and cross-sections were prepared from the stems, leaves, and roots. It was done by cutting into thin sections with a razor, mounting them on a glass slide, and observing under the microscope. The anatomical structures of some significant parts,

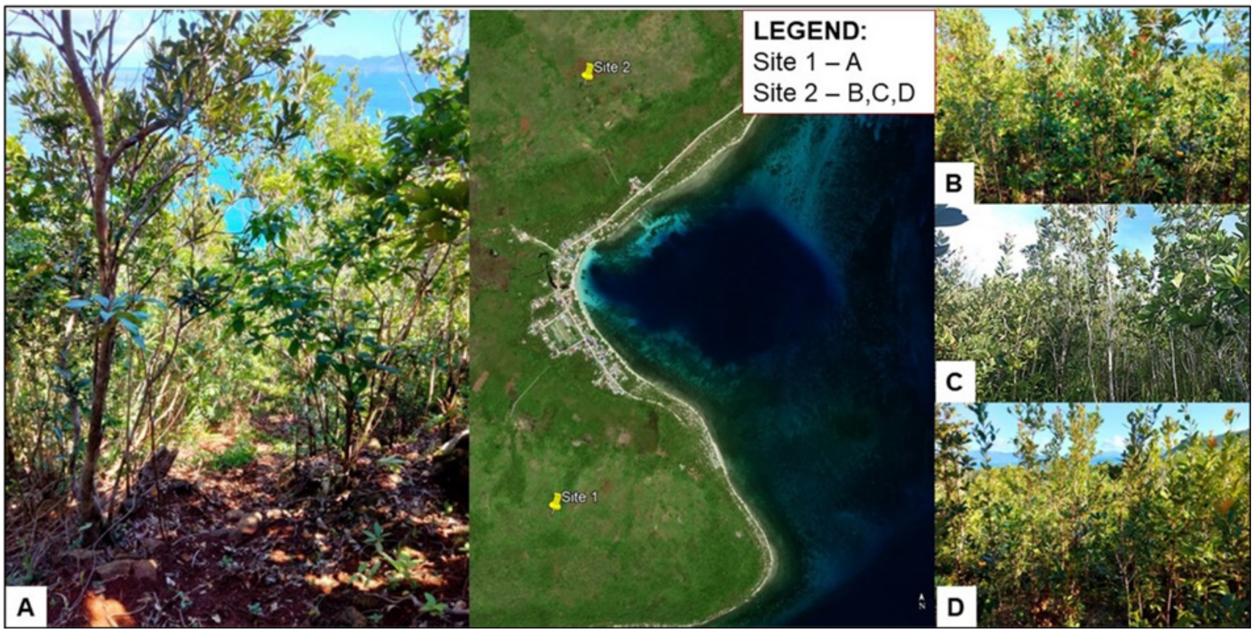

Image 1. Sampling sites showing naturally grown and rehabilitated *Xanthostemon verdugonianus*. © Arlyn Jane Sinogbuhan for 1A&B, Angie A. Abucayon for 1C and Vivian R. Badlis for 1D.

including the leaf, stem, and root of *X. verdugonianus*, were viewed, described, and photographed using the KERN compound microscope.

Field Sampling and Identification of Associated Species

A total of eight sampling plots were established in the two sites with dimensions of 10 x 10 m each. A purposive sampling was conducted across all sampling plots with identified naturally grown and rehabilitated *X. verdugonianus* in the area. The associated flora was determined in situ, and other species were verified using the identification guides of Fernando (2017) on the flora of Dinagat and Co's Digital Flora of the Philippines (Pelser et al. 2011). The species count data were summarized and used to derive abundance and species richness for biodiversity implications of species associated with *X. verdugonianus*. The PAST software (Hømmer et al. 2001) computed diversity values.

Soil particle characteristics in *X. verdugonianus* habitats.

Soil samples were collected within the established sampling plots for soil particle analysis. At least 300 g of soil samples collected at 10 cm depth (Mullet et al. 2014) were transported to Biology Department Laboratory, Caraga State University. Soil was air-dried in a well-ventilated area for 5–7 days. Completely dried samples were weighed at exactly 300 g each and subjected to soil particle characterization using a sieve (W. S TYLER brand) with the following sizes and descriptions: gravel (2 mm), very coarse sand (850 µm), medium sand (425 µm), fine sand 180 µm, very fine sand (150 µm), and silt or clay (<150 µm) (Jumawan et al. 2015).

RESULTS AND DISCUSSION

Morphological characteristics of *X. verdugonianus*

In its natural habitat, *X. verdugonianus* is a shrub to a tree with a mean height of 5.28 m and a mean stem diameter of 20.27 cm. Most of the individual samples are primarily shrubs, and few are trees, with a height ranging from 14–30 m (Image 2A). As observed, one of the unique character traits of *X. verdugonianus* was the rampant growth of new shoots with bright red regenerated leaves (Image 2D).

The leaves are simple and alternate in young and adult plants, with oval to elliptical lamina, glossy green on the adaxial and white greenish on the abaxial side. The leaf has a mean diameter of 4.5 cm and 8.6 cm in length (Image 2B). Young leaves are bright reddish, showing pinnate venation with visible secondary veins (Image 2E).

The inflorescence is a simple corymb, 3–6 flowered, bright red, found at the terminals of branchlets. Each flower is complete with sepals, petals, androecium, and gynoecium (Image 3A,B). A prominent cup-shaped hypanthium is connected to a sturdy pedicel (Image

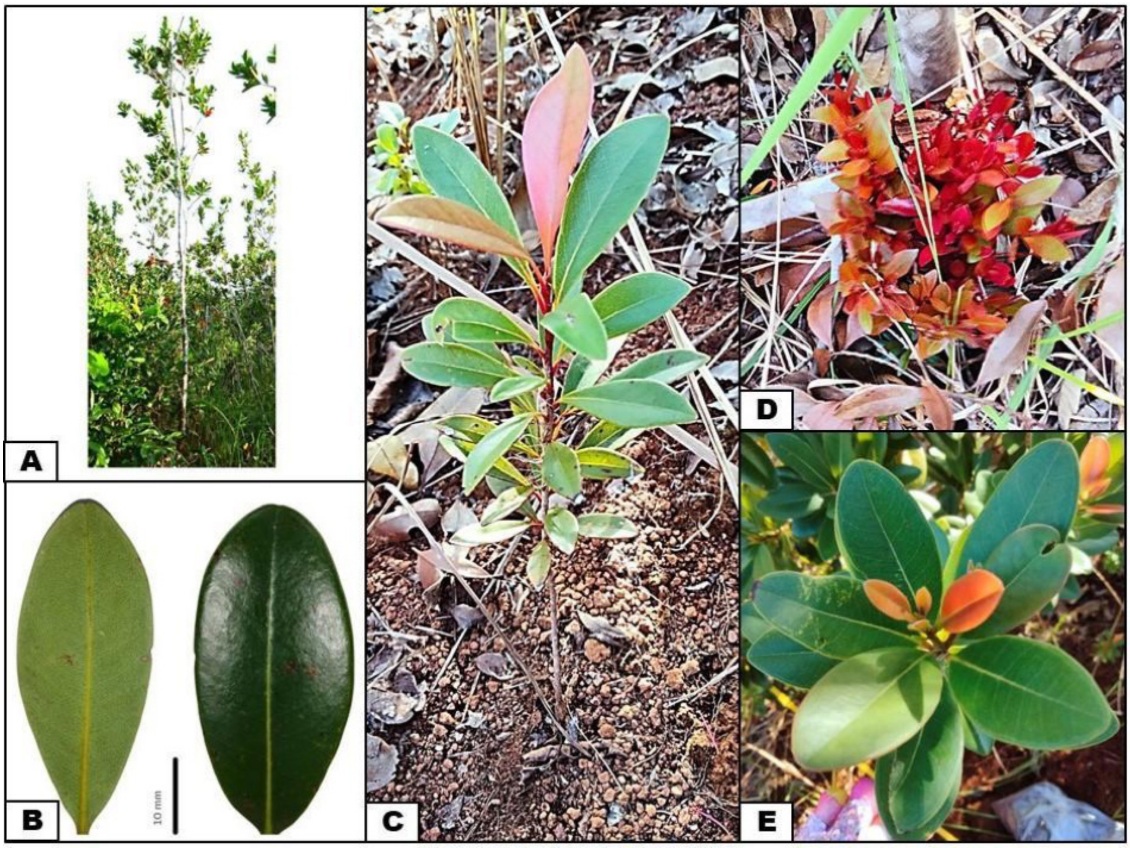

Image 2. Morphological Characterization of *Xanthostemon verdugonianus*: A—Tree | B—Leaves (adaxial and abaxial) | C—Juvenile stage | D—Newly develop branches or young branches | E—Axillary shoot (mature plant). © Angie A. Abucayon for 2A, Jeco Jade Ruales for 2 B and Arlyn Jane M. Sinogbuhan for 2 C-E.

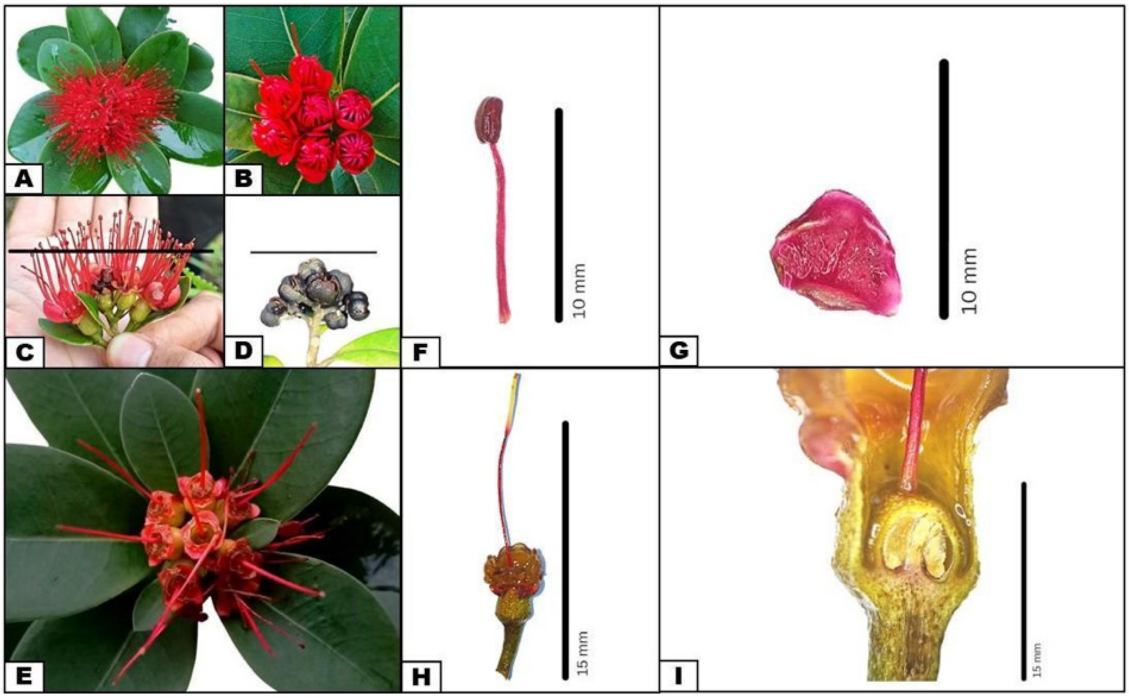

Image 3. *Xanthostemon verdugonianus* flower morphology: A,B—Flower bud | C,D—Flower Inflorescence | E—Complete flower | F—Anther and filament (Stamen) | G—Petals (corolla) | H—Style | I—Ovary. © Angie A. Abucayon for 3 A & D, Arlyn Jane M. Sinogbuhan for B-C & E and Vivian Badlis for 4 F-I.

3C,D). The calyx is persistent (Image 3E). The stamens are 18–25, red, 1.5–1.9 mm long (Image 3F). Petals are 4–8, red, slightly triangular in shape, 4.5–6.7 mm long, 4.3–6.4 mm broad (Image 3G). The style is 6.9–12.6 mm long (Image 3H). The ovary is enclosed in the hypanthium connected to the pedicel. Ovaries are almost superior (Wilson 1990), 2–3 locular, glabrous, 5.4–8.8 mm long, and 5.1–9.5 mm in diameter (Image 3I).

The fruit is an ovoid-globular capsule, measuring 10–12 mm in diameter and 4.4–5 mm long (Image 4A). Seeds are bilaterally flattened and deltoid to semicircular in outline (Image 4C). Mature fruits dehisce open, exposing the seeds (Image 4D). The capsule is woody, 2–4-lobed (Image 4E).

Anatomical Characterization of *X. verdugonianus*

The leaf. The depicted section is the adaxial surface of a leaf covering the lamina and midrib portion. The midrib cross-section has prominent xylem and phloem. The upper and lower epidermis showed similar thickness with distinct cuticle layers (C) (Image 5). The mesophyll consists of a palisade and spongy layer. The mesophyll layer is a conspicuously greenish layer composed mainly of compact palisade box shape cells with no distinct spongy layer of loosely arranged cells observed in the leaf cross-section. The stomata are found in the lower epidermis with a diameter of about 240 µm, hypostomatic with a paracytic type of stomata (Image 6).

The study's leaf anatomy findings are the same observed in the family Myrtaceae. According to Ali et al. (2009), the leaf section of Eucalyptus (family Myrtaceae) from the Faisalabad region showed epidermis and cuticle were similar to the present study. Another similar observation in *Eugenia luschnathiana* (Myrtaceae) was reported by Lemos et al. (2018). Nazarudin et al. (2015) study on the anatomy of *Xanthostemon chrysanthus* treated with PBZ (paclobutrazol) reveals tightly arranged palisade and mesophyll cells on the leaf which is similar to the findings on the *X. verdugonianus*. As Ali et al. (2009) reported, the thicker epidermis and the thick cuticle could be adapted to island conditions in tropical environments. According to Savaldi-Goldstein et al. (2007) and Domínguez et al. (2011), the cuticle mechanically protects plants by reducing the impact of external stresses such as wind or heavy rain and, in conjunction with the epidermis, preventing tissue breaking and participating in the control of organ growth.

The stem. Samples performed for stem anatomy were taken from shoot tips of mature shrubs in their natural habitat. The cross-section of the stem was generally smooth and circular, with an indication of secondary growth. The section of the stem (Image 7) shows the thick periderm (Pr), which later forms the outer bark—followed by the primary phloem (Ph[1]), and secondary

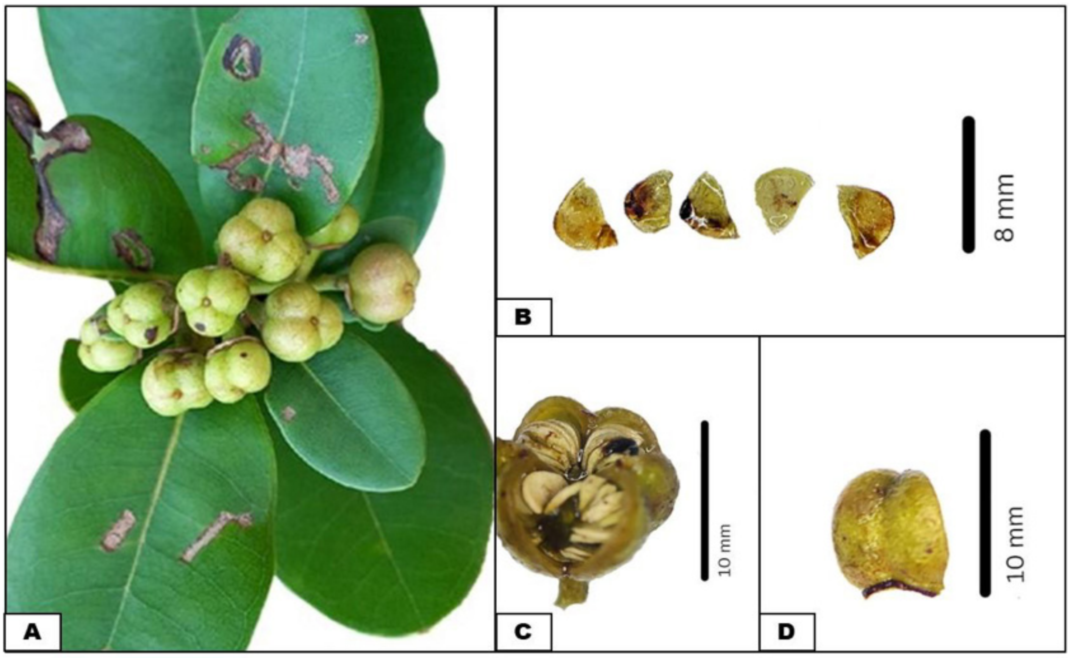

Image 4. Fruit morphology of *Xanthostemon verdugonianus*: A—Fruiting twig | B—Seeds | C—Dehisced fruit showing the seeds | D—A valve of the fruit shell. © Angie A. Abucayon for 4 A and Vivian Badlis for 4 B-D.

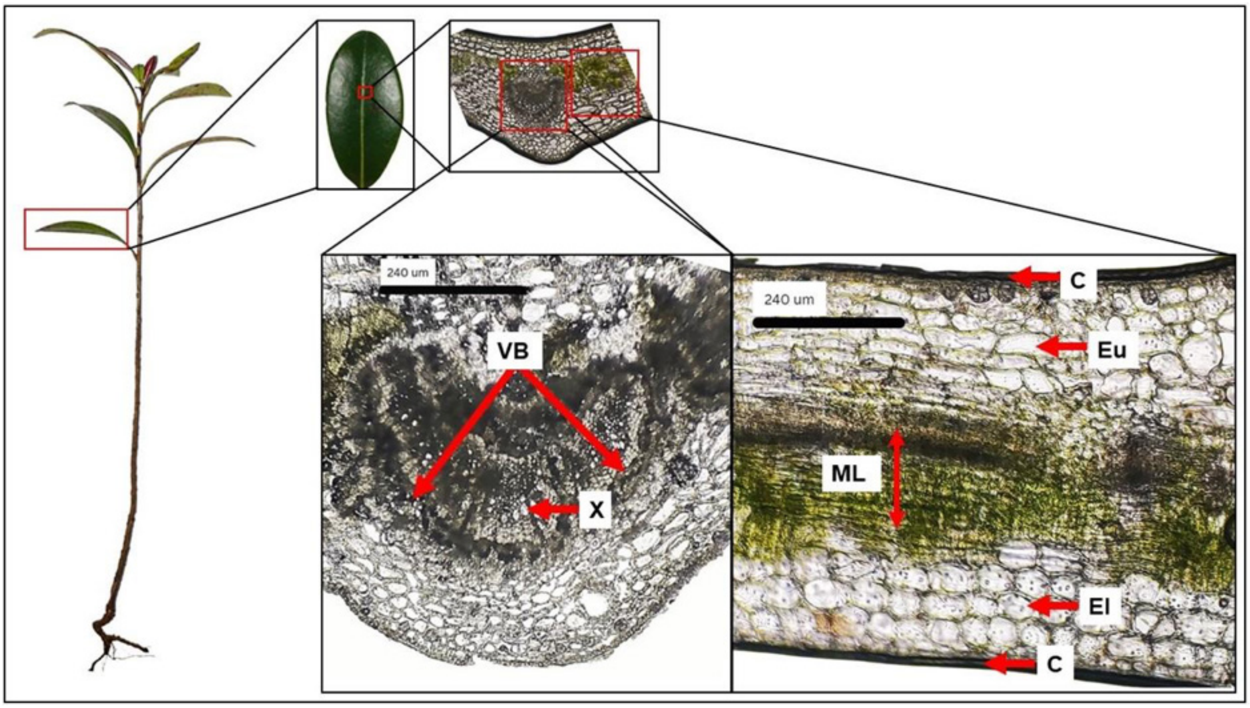

Image 5. Leaf anatomy of *Xanthostemon verdugonianus* showing the various tissues: VB—Vascular bundle | X—Xylem | C—Cuticle | Eu—Upper epidermis | ML—Mesophyll layer | EI—Lower epidermis. © Arlyn Jane M. Sinogbuhan.

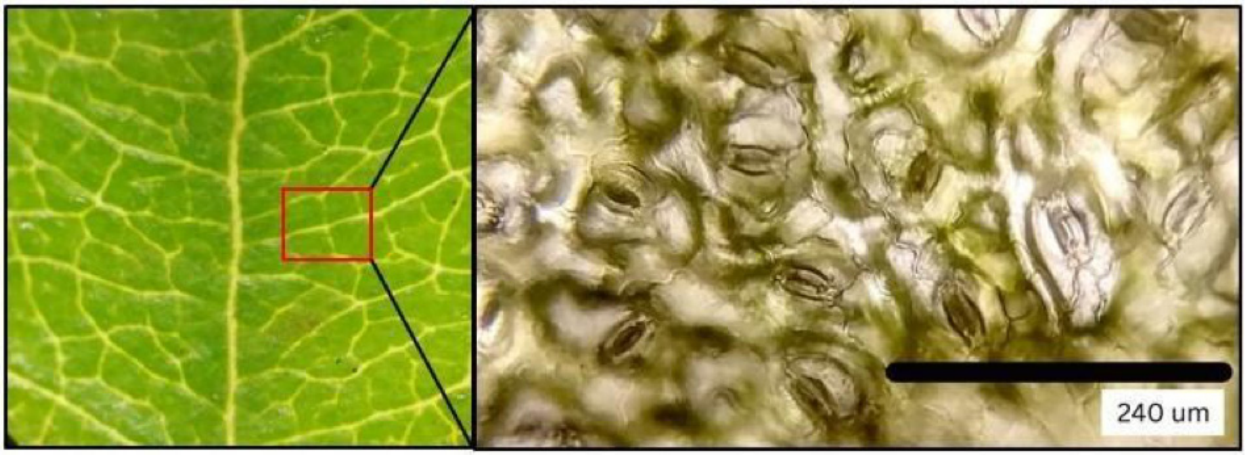

Image 6. Leaf lower epidermis of *Xanthostemon verdugonianus*: Stomata- paracytic. © Arlyn Jane M. Sinogbuhan.

phloem (Ph²). These tissues are undifferentiated due to their similar composition. The vascular cambium (Vc) is sandwiched between the phloem and the xylem. Xylem rays (Xr) appear as dark lines and vessel elements (V) emerge as distinct solitary-circular cells dispersed within the premises of the secondary xylem (X²). The less intact primary xylem (X¹) is noticeable as it shows small-circular compacted cells near the pith. The pith (P), which is positioned at the innermost part of the stem composed of irregular parenchyma cells showing a less clearly stellate shape (Image 7).

The findings of the stem anatomy of *X. verdugonianus* were compared to some studies of the Myrtaceae family. The stem in the present study lacks a secretory cavity similar to *Eugenia pyriformis* Cambess in the study Armstrong et al. (2012). However, the presence of secretory cavities is recorded to be found in stems of some *Eucalyptus* species, such as *E. grandis*, *E. urophylla*, and *Eucalyptus saligna*, measuring 78, 45, and 40–110 µm in diameter, respectively, were included in the study of Saulle et al. (2018) and Brisola & Demarco (2011). The xylem forms inward while the phloem forms outward, as

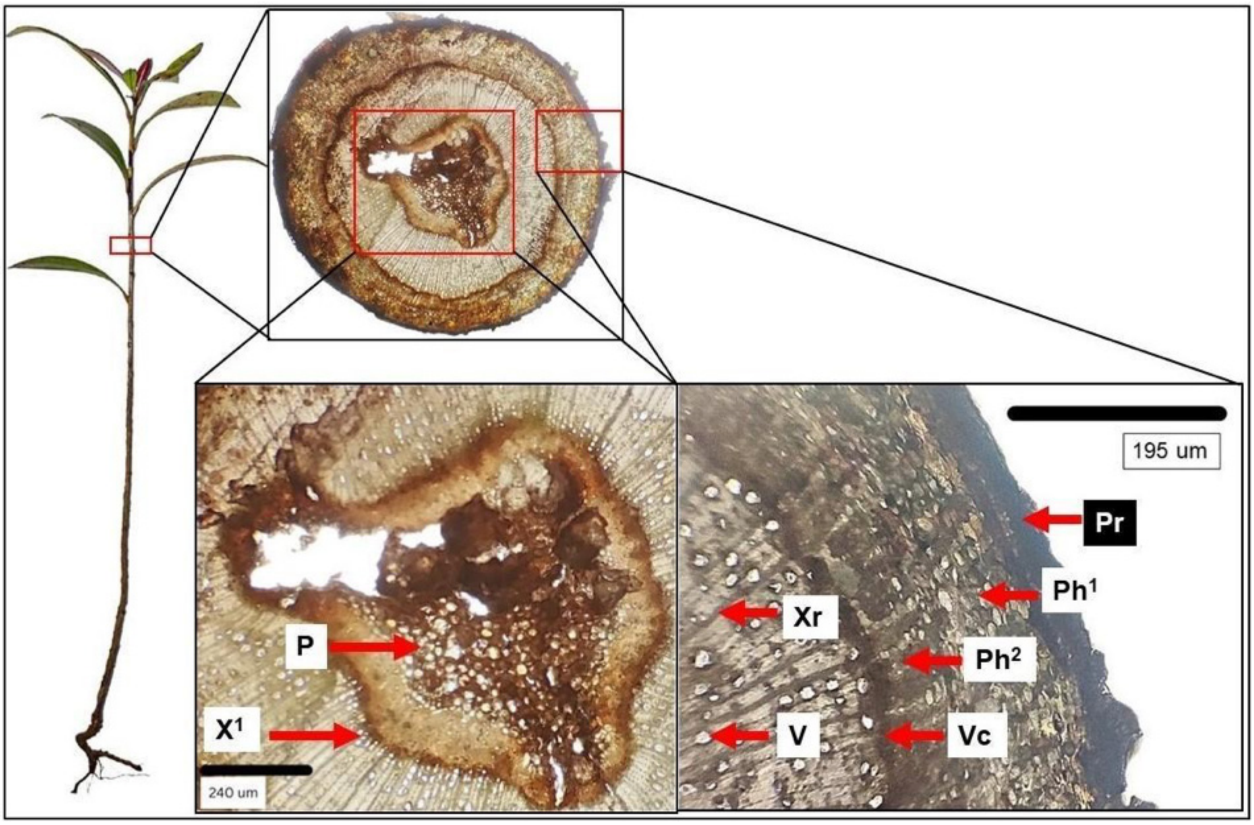

Image 7. Stem anatomy of *Xanthostemon verdugonianus*: P—Pith | X¹—Primary xylem | X²—Secondary xylem | V—Vessel element | Xr—Xylem rays | VC—Vascular cambium | Ph²—Secondary phloem | Ph¹—Primary phloem | Pr—Periderm. © Princess Ansie T. Taperla.

observed in *Eucalyptus cinerea* (Pauzer et al. 2021). The less clearly stellate pith shape observed in this study was similar to the results of *E. microcorys, E. pilularis*, and *E. marginata* Sm. in the study by Bryant & Trueman (2015).

The roots. The woody root of the juvenile *X. verdugonianus* was examined in the study and is found to be positively geotropic. Anatomical features are shown in Image 8 and appear to have a distinct demarcation of epidermal, cortical, and vascular regions. The cross-section shows the unilayered periderm (Pr) consists of thin-walled cutinized cells as the outermost protective layer of the root, followed by the primary phloem (Ph^1) characterized by round and oval shape, clumped (usually 5–10) in a linear manner and secondary phloem (Ph^2) portray a much smaller round and oval cells, also arranged in a linear manner (usually 3–5 in a clump) designated just before the vascular cambium. Dividing the phloem and the xylem is the vascular cambium (Vc) appears to have undistinguished cells. The secondary xylem (X^2) covers a larger part of the root, displaying round to oval vessel elements irregularly scattered and the xylem rays (Xr) display a distinct line along the periphery of the stele. The primary xylem (X^1) encloses the remnants of the pith at the innermost part of the root, which was pushed to the center due to the production or development of the secondary xylem (Evert 2006). The primary and secondary phloem is also pushed in the opposite direction of the primary vascular system, which will later become the woody part of the root and serve as protection along with the periderm (Pr).

There is a limited study on the anatomical structure of *X. verdugonianus* in its natural habitat, and in this study, the noticeable feature found in the root are the phloem fibers (see white arrow in Image 8) along the vascular cambium. This species is endemic and vulnerable in its ecological status and data provided anatomical descriptions as baseline information. Findings such as the solitary vessel elements and the conspicuous xylem rays throughout the length of the secondary xylem were also observed in the root anatomy of *Syzygium* sp. (Rahayu & Husodo 2020) and *Syzygium cumini* Skeels, a vascular plant under the family Myrtaceae (Singh & Misra 2015).

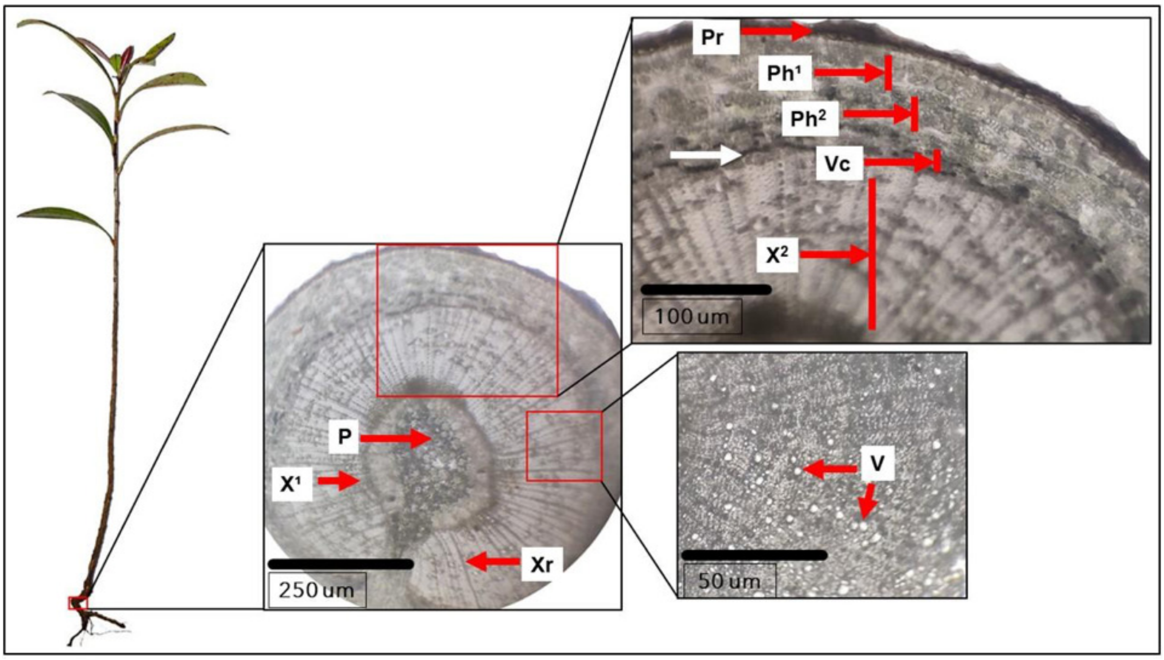

Image 8. Root anatomy of *Xanthostemon verdugonianus*: P—Pith | X¹—Primary xylem | X²—Secondary xylem | V—Vessel element | Xr—Xylem rays | VC—Vascular cambium | Ph²—Secondary phloem | Ph¹—Primary phloem | Pr—Periderm. © Angie A. Abucayon.

Table 1. Plant associations of *Xanthostemon verdugonianus* in Loreto, Dinagat Island.

Family name	Scientific name number of individual	Total number of individual	Present in Site 1	Present in Site 2
Anacardiaceae	*Buchanania arborescens* F. Muell.	7	*	*
	Mangifera indica L.	2		*
Apocynaceae	*Alstonia parvifolia* Merr.	6	*	
	Kibatalia stenopetala Merr.	1		*
	Kibatalia sp.	7		*
Bignoniaceae	*Radermachera pinnata* Seem.	2	*	
Burseraceae	*Canarium euryphyllum* var. *euryphyllum*	5	*	
Calophyllaceae	*Calophyllum inophyllum* L.	1		*
Ebenaceae	*Diospyros* sp.	8	*	
Gnetaceae	*Gnetum gnemon* L.	8	*	*
Melastomataceae	*Medinilla myrtiformis* (Naudin) Triana	6	*	
	Medinilla sp.	1	*	
	Melastoma malabathricum L.	1		*
Meliaceae	*Swietenia mahagoni* (L.) Jacq.	1		*
Myrtaceae	*Tristaniopsis decorticata* (Merr.) Peter G. Wilson & J.T. Waterh.	4	*	*
Moraceae	*Artocarpus pinnatisectus* Merr.	1	*	
Rubiaceae	*Pavetta williamsii* Merr.	1	*	
	Timonius valetonii Elmer	8	*	
Pandanaceae	*Freycinetia* sp.	2	*	
	Pandanus dinagatensis Merr.	2	*	*
	Sararanga philippinensis Merr.	1		*
Pentaphragmataceae	*Pentaphragma* sp.	2		*
Phyllantaceae	*Phyllanthus ramosii* Quisumb. & Merr.	8	*	
	Phyllantus sp. 1	6	*	
	Phyllantus sp. 2	2	*	
Podocarpaceae	*Podocarpus* sp.	7	*	
Sapindaceae	*Guioa diplopetala* (Hassk.) Radlk.	6	*	
	Guioa koelreuteria (Blanco) Merr.	8	*	
Thymelaeaceae	*Wikstroemia indica* (L.) C.A. Mey.	8	*	

*represents the presence of species in the site.

Table 2. Species richness and abundance of plants associated with *Xanthostemon verdugonianus* in Barangay Liberty, Loreto Dinagat Island.

	Site 1					Site 2			Average
	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	
Species richness	11	11	4	10	8	6	6	8	8
Abundance	77	62	44	23	15	35	131	53	55

Table 3. Mean values of Soil Particles Obtained in Barangay Liberty, Loreto, Dinagat Island.

Soil Particle	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Soil obtain (g)	Percentage (%)
Gravel	44	69	124	114	78	107	62	73	671	28.74
Very coarse sand	55	78	57	100	66	109	80	71	616	26.39
Medium sand	40	133	115	85	101	73	132	147	826	35.38
Fine sand	40	10	0.4	77	39	8	18	8	200.4	8.58
Very fine sand	0	0	0	4	6	0	0	0	10	0.43
Silt or clay	0	0	0	0	11	0	0	0	11	0.47

Associated Flora to *X. verdugonianus* in its habitat

Twenty-nine species under 19 families of vascular plants were identified (Table 1) in the study plots of *X. verdugonianus*. The family Phyllantaceae is the most presented with 16 individual species. The least represented families were Meliaceae and Moraceae, each with one species. Phyllantaceae family included *Phyllanthus ramosii* Quisumb. & Merr. and two other unidentified species of *Phyllanthus*. The other associated plants belonging to other families included *Tristaniopsis decorticata* (Merr.) Peter G.Wilson & J.T.Waterh., *Alstonia parvifolia* Merr., *Artocarpus pinnatisectus* Merr., *Pavetta williamsii* Merr., *Timonius valetonii* Elmer, *Buchanania arborescens* F.Muell., *Calophyllum inophyllum* L., *Canarium euryphyllum* G.Perkins var. euryphyllum, *Diospyros* sp., *Freycinetia* sp., *Gnetum gnemon* L., *Guioa diplopetala* (Hassk.) Radlk., *Guioa koelreuteria* (Blanco) Merr., *Kibatalia stenopetala* Merr., *Kibatalia* sp., *Mangifera indica* L., *Medinilla myrtiformis* (Naaudin) Triana, *Melastoma malabathricum* L., *Pandanus dinagatensis* Merr., *Podocarpus* sp., *Radermachera pinnata* Seem., *Swietenia mahagoni* (L.) Jacq., *Wikstroemia indica* (L.) C.A.Mey., and *Sararanga philippinensis* Merr. The sampling was considered a rapid procedure conducted in a short period. By increasing sampling intensity, more species could be associated with *X. verdugonianus* in other areas.

Species richness and abundance of associated flora

Species richness, defined as the number of species per unit area, is perhaps the most straightforward measure of biodiversity (Brown 2003). According to Fedor & Zvaríková (2019), species richness presents a measure of the variety of species based simply on a count of the number of species in a particular area. Associated species to *X. verdugonianus* in Barangay Liberty, Loreto, Dinagat Island has an average species richness of 8. It was observed that plants that thrive in this area had developed morphological adaptations to lessen their water intake and water loss (Brady et al. 2005). The abundance of species recorded in plot 1 (45), plot 2 (40), plot 4 (17), plot 7 (16), and plot 8 (13), respectively, where *X. verdugonianus* dominated in the area (Table 2).

Soil Particle Characteristics Sampled from *X. verdugonianus* habitats

As observed in the field, *X. verdugonianus* grow in reddish soils of Surigao del Norte, Philippines. The soil type in the province is derived from serpentinized ultramafic rocks composed of Mg, Fe, Cu, Co, Ni, and Cr elements subjected to weathering of olivine, pyroxene, and chromite minerals (Ocon et al. 2018). The reddish soil coloration is due to oxidized iron minerals resulting in red color commonly referred to as rust (Pérez-Guzmán et al. 2010). Aside from iron, the red soils contain the heavy metals preferred for mining activities (Navarrete & Asio 2011). Similar ultramafic substrate in Palawan Island, Philippines where another species of *Xanthostemon speciosus* was observed (De Castro et al. 2020). Medium sand has the most abundant percent value, 35.38%, followed by gravel (2 mm) which is 28.74%, and very coarse sand (850 µm), with a percent value of 26.39%, respectively (Image 9). The

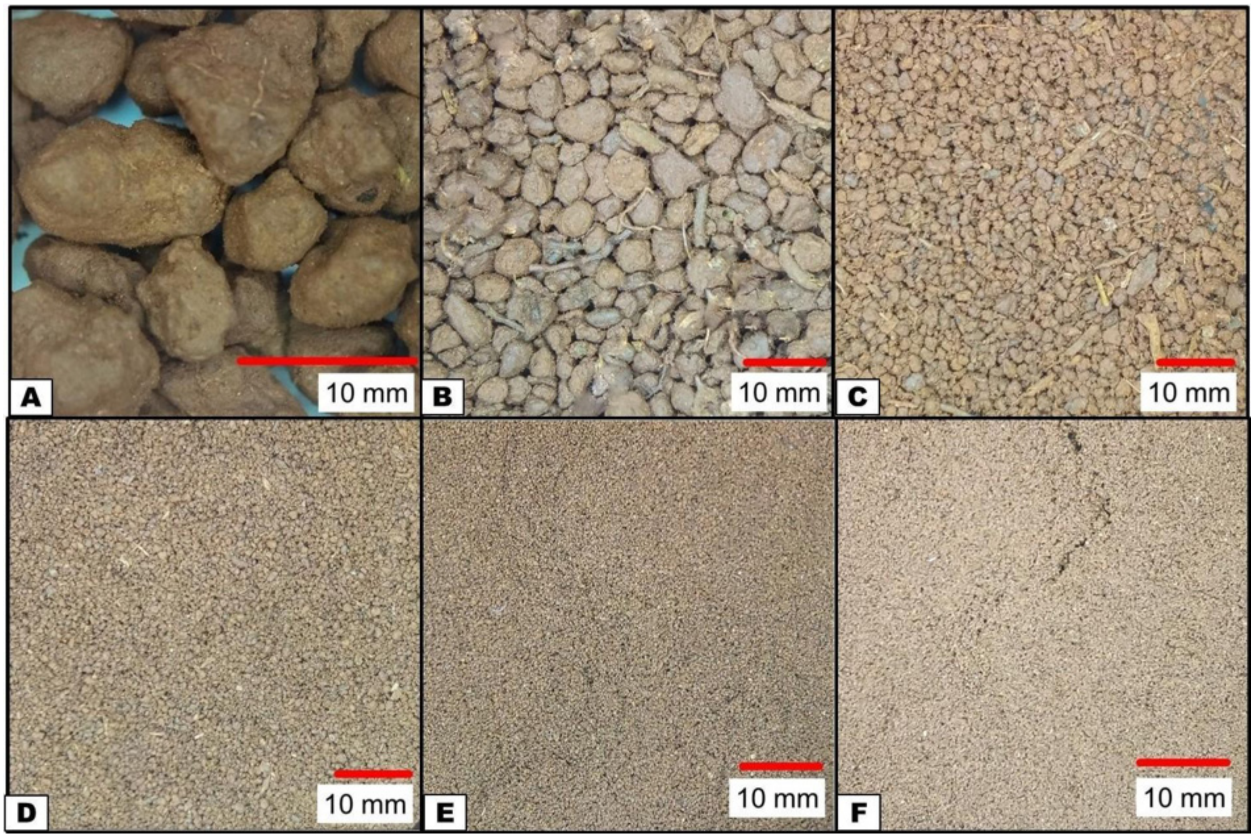

Image 9. The soil type in Barangay Liberty, Loreto, Dinagat Island: A—Gravel | B—Very coarse sand | C—Medium sand | D—Fine sand | E—Very fine sand | F—Silt or clay. © Angie A. Abucayon.

least mean value of all the substrates was very fine sand (150 µm) with a percentage value of 0.43% (Table 3). Few articles described soil particle characteristics that are preferential to the growth and development of *X. verdugonianus*. The study provides baseline information on soil particles of the species in the sampling area. The data suggested that the bigger soil particle size consisting of medium sand, very coarse sand, and gravel is preferable to the growth of *X. verdugonianus.*

CONCLUSION

Xanthostemon verdugonianus is a threatened species endemic to the Philippines. The plants grow in the mineral-rich red soils and are characterized by their reddish young foliage, red flowers arranged in red corymbs in the terminals of branches. The woody, dehiscent capsules are 2–4-lobed and have many flattened seeds. The leaf is arranged alternately in both young and adults. With corymb inflorescence, the complete flower of *X. verdugonianus* possessed a cup-shaped hypanthium and semi-circular calyx. The ovoid-globular fruit consists of a woody covering and the seeds are bilaterally flattened and deltoid to semicircular in shape. The leaf anatomy was observed to have a thick cuticle on the adaxial side that displays the characteristic of plants to adapt to island conditions in tropical environments. The stem shows secondary growth, with a pith arranged in a less clearly stellate shape. Xylem rays and the vessel elements scattered along the length of the secondary xylem are the distinctive features of its stem and root anatomy. Twenty-nine associated plant species belonging to 19 families were recorded in the study area. Soil substrate mainly comprises medium sand particles, and reddish coloration could be due to oxidized metallic elements. Distinct anatomical characteristics of *X. verdugonianus*, such as the compressed palisade and spongy layer of the leaf midrib cross-section and the irregular shape of the pith in the stem cross-section, may be due to environmental stress like the presence of heavy metal in the soil, limited water intake, and temperature fluctuations in the island conditions. To better understand the unique features and adaptations of *X. verdugonianus*, detailed morpho-anatomy studies of the plants growing in the rainforest and island conditions are needed. The effects of heavy metals in the habitats on the plants should also be investigated.

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