Identification of Seeds and Seedlings of Different Species of Plants Found in Universiti Brunei Darussalam

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Abstract

Identification tools for fruits, seeds, or seedlings can greatly aid biodiversity rehabilitation projects. Since morphological and pictorial data are usually lacking, especially in species-rich tropical regions, this study aims to provide such data for Brunei. To accomplish this, fruits and seeds of different plant species were collected from forested areas inside Universiti Brunei Darussalam campus and described and photographed in a standardised way. The same was done for the seedlings that germinated from the collected seeds. A total of 21 species from 15 families were described although two species remained unidentified. Seedling descriptions are only provided for 17 species since not all the seeds were successfully germinated. For the two unknown species, fruit descriptions were not given since the fruits were not known. Furthermore, only the fruits from eight species were described based on direct observations while 11 were based on existing literature due to the unavailability of fruits on site. While the data from this study are useful for the public to identify fruits, seeds and seedlings, more studies are needed to document the many plant species of Brunei Darussalam not yet included in this study.

Index Terms: Brunei, description, fruit, heath, identification, photographs, seed, seedling

1. Introduction

The importance of forests for mitigating climate change was emphasised when more than 100 country leaders signed an agreement to end deforestation and to recover degraded lands by 2030 during the 2021 United Nations Climate Change Conference.[1-3] This is not surprising since forests offer countless benefits to mankind such as filtering air, sequestering carbon, removing greenhouse gases, providing clean water and cooling environments.[4-6] However, despite the agreements, the destruction of old-growth forests has continued to make way for infrastructural and agricultural development.[7-10] In 2020 alone, at least 4 million hectares of tropical primary forests were lost.[11] Hence, rehabilitating unused degraded lands becomes increasingly important for minimising the negative effects of deforestation. This in turn makes any study that can facilitate land rehabilitation of utmost importance.

Among all global forest types, tropical rainforests stand out for their extraordinary biodiversity.[12-14] Despite covering only 7% of the Earth's land surface, half of the world's terrestrial species can be found there.[14] One hectare of tropical rainforest can harbour up to 1,813 different species of plants and up to 42,000 different species of insects.[13] In fact, it is estimated that up to 90% of the world's tree species can be found in the tropics or sub-tropics.[12] Thus, the extraordinary level of biodiversity makes tropical rainforests a treasure trove for the discovery of medicinal drugs.[15,16] Hence, it is important to conserve and restore tropical forest since losing it means losing innumerable numbers of species, which equates to losing undiscovered opportunities for human development and welfare.

Knowledge of the species of fruits, seeds and seedlings is critical for assisting land restoration.

Seedlings can look very different from their adult form, so there is a need to identify the seedlings. By knowing which seedlings are native and which ones are invasive, the physical removal of only the invasive species from a restoration site is feasible; though it might be challenging if the seedlings are widespread and numerous (on top of other restoration challenges[17,18]). This example also applies to fruits and seeds. Removal would slow down or prevent the establishment of invasive species on that site, giving more chance to native species.[19-21] Additionally, fruits and seeds dispersed by animals such as birds can be a mixture of native as well as invasive species.[22,23] So, being able to differentiate the fruits, seeds and seedlings would allow a person to take and grow only the native plants while at the same time dispose of the invasive ones.

Unfortunately, there is still a lack of publications on identification of tropical rainforest plant species based on their fruits, seeds and seedlings, and there are no specific publications regarding Brunei Darussalam. Therefore, our aim here is to provide the first step in producing a database of plant species with information and pictures on their fruit, seeds and seedlings. Universiti Brunei Darussalam (UBD) campus was chosen as the study site. This is because in and around UBD we can find a mixture of heath and dipterocarp forest species, as well as several pioneer species that can be useful for reforestation purposes. Additionally, UBD has a botanical garden and shade-house facilities available which greatly helps in identifying, germinating and growing the plants collected. Moreover, UBD is located in coastal heath forest which is a highly threatened type of forest in the country.[24-26] This makes UBD a uniquely important place to study fruits, seeds and seedlings due to the presence of the diverse plant species and due to the highly threatened status of the coastal heath forest.[24-26]

2. Material and Methods

2.1 Fruit and seed collection

Different sites were surveyed to collect fruits and seeds: UBD campus, Jerudong Beach, Kampung Masin and BRUN compound. Locations were chosen mainly due to ease of access and the abundance of native plants. Seeds and fruits found on the ground during surveys were collected. Ripe fruits seen on trees were also collected if they were reachable. The seeds and fruits were put inside plastic bags and brought to the lab for documentation and germination treatment on the same day. If documentation and germination treatment had to be postponed, samples were put inside open plastic containers at room temperature to prevent mold growth: the constant air flow was meant to dry fruits and seeds if they were wet.

2.2 Fruit and seed identification

Seeds and fruits collected from or under a parent tree were identified by identification of the parent tree; herbarium vouchers were made from the parent tree if possible. If seeds or fruits were collected from the ground, i.e., no parent tree known, they were germinated and identification was based on the seedling characteristics. If seedlings could not be identified, they were allowed to grow into saplings in the hope that they could be identified when they were more mature. Identification was done by verification from botanists at Universiti Brunei Darussalam Herbarium (UBDH) and Brunei National Herbarium (BRUN), followed by cross-checking with herbarium specimens and information on websites [Plants of the World Online (POWO): https://powo.science.kew.org/ and Global Biodiversity Information Facility (GBIF): https://www.gbif.org/]. If, after all these steps, the name of the species remained unknown, the species was given a morpho-species name under the "unknown species section". All seedlings were eventually stored as herbarium vouchers at UBDH for future reference.

2.3 Seed germination

If the seeds were still inside the fruits, the flesh of the fruits was completely removed to reveal the seeds. Seeds with easy-to-remove seed coats were scarified by removing the outer coating of the seed, either partially or fully, depending on how easy it was to remove the coating (see ***Table 1***). The scarification process involved chipping the outer coating with a pruner or a nail clipper or by simply removing it with bare hands,

whichever was convenient. The procedure was done to facilitate germination.[27-29]

Table 1. Seed treatments before germination.

Family	Species	Scarification
Anacardiaceae	*Buchanania arborescens*	No, to avoid damaging the seeds since they are small
Araceae	*Alocasia macrorrhizos*	No, seed coat was not detected
Arecaceae	*Elaeis guineensis*	No, endocarp too tough
	Ptychosperma macarthurii	Yes
Calophyllaceae	*Calophyllum inophyllum*	Yes
	Calophyllum obliquinervium	Yes
Chrysobalanaceae	*Parastemon urophyllus*	Yes
Combretaceae	*Terminalia catappa*	No, fruit husk very tough to remove
Euphorbiaceae	*Endospermum diadenum*	No, to avoid damaging the seeds since they are small
Fabaceae	*Pterocarpus indicus*	No, to avoid damaging the seeds since seed coat is thin
Lauraceae	*Litsea elliptica*	Yes
Moraceae	*Ficus benjamina*	No, to avoid damaging the seeds since they are small
Myrtaceae	*Syzygium grande*	No to avoid damaging the seeds since seed coat is thin
	Syzygium malaccense	No, same reason as *S. grande*
	Tristaniopsis obovata	No, to avoid damaging the seed since it was small
Primulaceae	*Ardisia elliptica*	No, there is already an opening on the seed
Rubiaceae	*Gardenia jasminoides*	No, seed coat not detected
Sapotaceae	*Planchonella obovata*	No, seed coat too slippery
Symplocaceae	*Symplocos polyandra*	No, it was hard to separate seed from endocarp without damaging the seeds
Unidentified species	Bird's Beak	Yes
	Golden Hair	Yes

The scarified seeds were kept inside closed square petri dishes with dimension 12 x 12 x 1.5 cm (see ***Figure 1A***), or for larger seeds, inside plastic containers with dimensions 17.3 x 17.3 x 9.8 cm (see ***Figure 1B***), at room temperature in the presence of light until their radicles started to emerge. To keep the moisture inside the containers high, moist tissues were laid inside them (see ***Figure 1A*** and ***1B***). Seeds of different species were put inside different containers and arranged randomly but without the seeds touching each other (see ***Figure 1C***). After the radicles emerged, the seeds were transplanted into nursery containers with potting soil (see

Figure 1D). Seeds that were small, i.e., seeds with length or width or height less than 2 cm, were put in small pots (pot size 4-5 cm in height and 6 cm in diameter), while big seeds, i.e., seeds with length or width or height more than 2 cm, were put in polybags (dimension 7.8 x 7.8 x 14 cm) (see ***Figure 1D***).

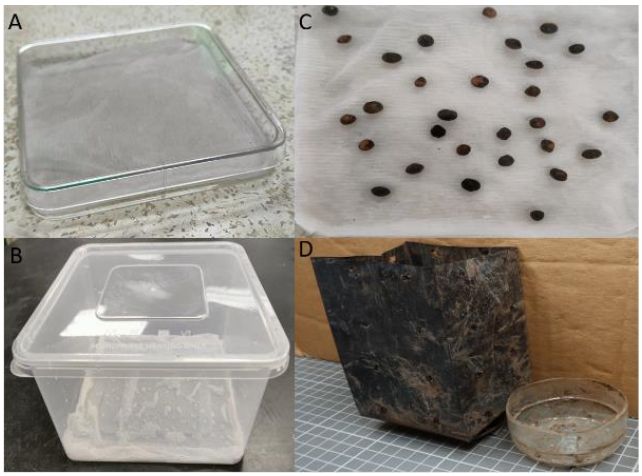

Figure 1. A: a square petri dish with dimensions 12 x 12 x 1.5 cm; ***B***: a plastic container with dimensions 17.3 x 17.3 x 9.8 cm; ***C***: example of random seed arrangement placed on wet tissue; ***D***: on the left is the polybag with dimensions 7.8 x 7.8 x 14 cm while on the right is the pot with dimensions 4.0-5.0 cm in height and 6.0 cm in diameter.

2.4 Seedling growth

Transplanted, germinated seeds were grown inside a shade house at ambient temperature. The shade house was a large metal cage covered with garden shade cloth to provide shade to all plants. Lighting was provided with sunlight (see ***Figure 2A*** and ***2B***). The pots and polybags were arranged close together to maximise space usage since shade house space was limited (see ***Figure 2C***). Samples were watered twice a day with tap water via a water sprinkler system, once in the morning and once in the afternoon (see ***Figure 2D***). If a species had more than three seedlings but was not yet identified, three seedlings were left to grow until they could be identified, while the additional seedlings were used to make herbarium vouchers after the second true leaf had fully developed. If the number of individuals was exactly three or less, then all seedlings would be grown until they could be identified. These individuals were collected as herbarium specimens as soon as they were identified and they had fully developed their second true leaf.

Figure 2. A: exterior view of the shade house; ***B***: interior view of the shade house, the plants shown are not part of this study; ***C***: the compact arrangement of the seedlings used in this study; *D*: water sprinkler system inside the shade house.

2.5 Fruit, seed and seedling measurements and descriptions

The length of fruits was measured from the base (part attached to the fruit-stalk) to the tip of the fruit (see ***Figure 3A***). The width was measured perpendicular to the length, representing the widest part of the fruit (see ***Figure 3A***). The height of the fruit was measured perpendicular to the length and width, representing the narrowest part of the fruit (see ***Figure 3B***). We also described the fruit type, overall shape, colour, fruit surface and presence of hairs. The same method was applied to the seeds (see ***Figure 3C*** and ***3D***). Note that seed coat and endocarp are treated as the seed surface in this study.

We also noted the type of germination, i.e., seed and cotyledons staying underground (hypogeal), or seed with cotyledons appearing aboveground (epigeal). When epigeal germination occurred, we measured and described the cotyledons, i.e., length of the cotyledon from base (attachment to stem) to tip, and width perpendicular to the length along the blade surface (see ***Figure 4C***). Cotyledon petiole length was measured from the stem to blade attachment. Description for cotyledons included the presence of hairs,

attachment to the stem, overall cotyledon shape, cotyledon base, cotyledon margin, cotyledon tip, surface of cotyledon, cotyledon colour and venation.

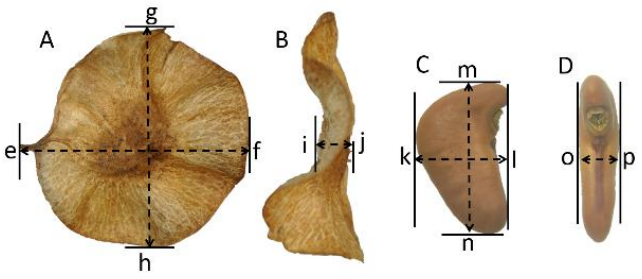

Figure 3. Pterocarpus indicus as an example of how fruits and seeds were measured in this study. ***A*** is the **fruit** viewed from the side. Point "**e**" is the base of the fruit (fruit-stalk attachment) while point "**f**" is the tip of the fruit (the point furthest away from the base), so the line **e-f** represents the length of the fruit. Line **g-h** is the widest distance perpendicular to the length (**e-f**) and represents the **width** of the fruit. ***B*** is the fruit viewed from the tip, with line **i-j** representing the **height** of the fruit (widest point perpendicular to lines **e-f** and **g-h**). ***C*** is the side-view of the **seed**. Point "**x**" is the base of the seed (determined by the presence of the hilum) while point "**k**" is the tip of the seed (longest distance from the base of the seed), so the line **k-l** represents the **length** of the seed. Line **m-n** is the **width** of the seed. ***D*** is the base view of the seed. Line **o-p** represents the **height** of the seed.

We described and measured the true leaves on the first and second node above the cotyledons (epigeal germination) or the first and second node aboveground (hypogeal germination) because the first node often displays different shaped and arranged leaves compared to the leaves on higher nodes (see ***Figure 4***). We first noted leaf arrangement (alternate, opposite, whorled) and presence of stipules for each node and then proceeded with the following leaf measurements: venation types up to tertiary veins, presence of hair, petiole length, overall leaf shape, leaf base, leaf margin, leaf tip, surface of leaf, leaf length, leaf width, leaf colour. Leaf length was measured from the blade base to the tip, width was measured perpendicular to the midrib for the widest point of the blade, petiole length would be measured from the point of attachment of the petiole to the stem to the point of attachment of the petiole to the leaf.

Measurements for V-shaped or pinnate compound leaves, as found in palms (see ***Figure 4B*** and ***4F***), were based on individual leaflets. Leaflet length was measured from the rachis to the tip of the leaflet; width was measured perpendicular to the midrib for the widest point of the leaflet. For leaves with a basal lamina that extended beyond the petiole-leaf attachment point or with petiole attached to the centre of leaf blade, leaf length was measured from the tip of leaf to the furthest point of extension beyond the petiole-leaf attachment point (see ***Figure 4E***). For species where the petiole also serves as part of the stem during seedling-hood (sheathing), such as in many monocots, the petiole was measured directly from the base of the stem (see ***Figure 4A*** and ***4B***).

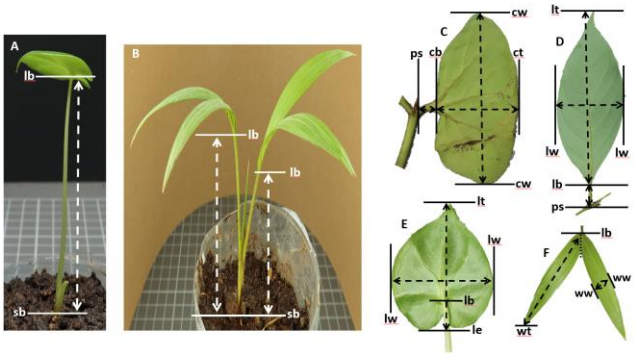

Figure 4. ***A*** and ***B***: Examples of a seedlings with sheathing petioles, the **petiole length** is **sb** (base of stem) to **lb** (attachment of petiole to leaf blade, i.e., leaf base). ***C***: Cotyledon measurements: **petiole length** is line **ps** (attachment of stem to petiole) to **cb** (attachment of petiole to cotyledon blade, i.e., cotyledon base), **cotyledon length** is line **cb** to **ct** (the tip of the cotyledon, i.e., the point furthest away from the cotyledon base), **cotyledon width** is line **cw-cw** (widest distance perpendicular to the cotyledon length). ***D*:** Standard leaf measurements: **petiole length** is line **ps** to **lb**, **leaf length** is line **lb** to **lt** (the tip of the leaf, i.e., the point furthest away from the leaf base), **leaf width** is line **lw-lw** (widest distance perpendicular to the leaf length). ***E***: Leaf measurements when the leaf blade extends **beyond** the petiole-leaf attachment (**lb**) or when the petiole is attached to the centre of the leaf blade: **leaf length** is line **le** (the furthest point of extension beyond the petiole-leaf attachment (**lb**)) to **lt**, **leaf width** is line **lw-lw**. ***F***: Compound leaf measurement: **leaflet length** is line **lb** to **wt** (the tip of the leaflet, i.e., the point furthest away from the leaflet base), **leaflet width** is line **ww-ww** (widest distance perpendicular to the leaflet length).

3. Results

A total of 21 species were recorded in the study, of which 19 could be identified to species. The identified species came from 15 families. However, only the seedlings of 17 species could be described due to failed germination of 4 species. As for the fruits, only 8 out of the 21 species were described based on direct observation while 11 were described from literature. The species are treated in alphabetical order of family, and within family by species names.

ANACARDIACEAE

Buchanania arborescens* (Blume) Blume** (see ***Figure 5)

Fruit: a drupe, length 0.6-0.9 cm, width 0.6-0.7 cm, height 0.6-0.7 cm, single-seeded, as fruit ripens it changes colour from green to red to dark red, surface smooth, overripe fruit is black and crumpled, seed shape round to almost round, hairless, a very small needle-like structure can be present at the tip of fruit.

Seed: length 0.5-0.7 cm, width 0.5-0.7 cm, height 0.4-0.5 cm; light brown to brown to dark brown, hairless, surface of seed covered by vein-like structures, shape is compressed globular from base-tip view, shape almost round from top-bottom view, there is a ridge spanning along the width of the seed.

Cotyledon: opposite, length 0.4-0.7 cm, width 0.4-0.5 cm, green, fleshy but quickly shrivelled and dropped, upper surface greener than lower surface, venation not visible, petiole hairy 0.1-0.3 cm, overall shape is an inverted compressed dome: base asymmetrical, margin smooth, tip indented.

First leaf: opposite, crosswise with cotyledons, length 1.4-2.3 cm, width 0.8-1.2 cm, petiole 0.2-0.3 cm, stipule absent, glands scattered, upper leaf greener than lower leaf, hairless. Venation feather-like, visible up to tertiary veins, secondary veins looped, slightly sunken on upper surface, slightly raised on lower surface, tertiary veins netted and only visible when intense light is directly shone through the leaf. Overall shape is egg-shaped: base wide to slightly tapered, margin smooth to slightly toothed, tip bluntly pointy.

Second leaf: same description as first leaf except alternate, length 1.9-2.4 cm, width 1.2-1.6 cm, petiole 0.3-0.4 cm, overall shape is oval-like: base of leaf more obviously tapered than the first true leaf.

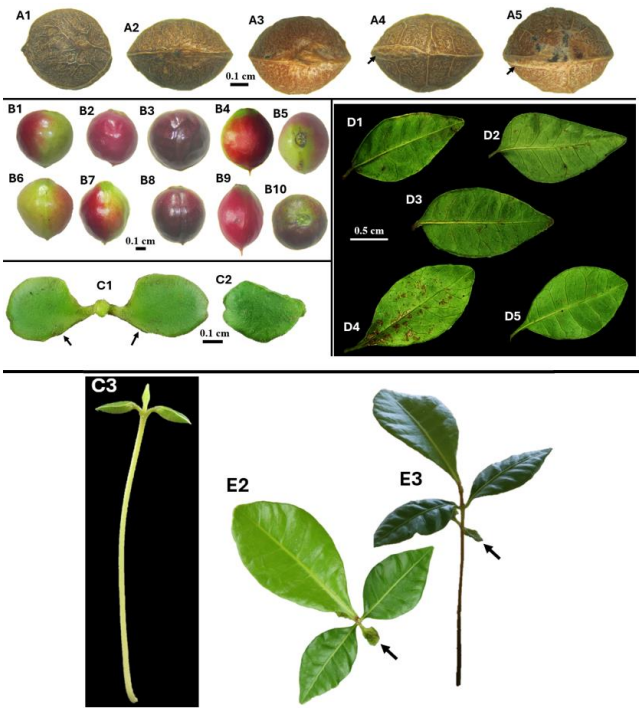

Figure 5. The above pictures are of *B. arborescens*. ***A1-A5*** are the seeds: ***A1*** viewed from the side of the seed, ***A2*** and ***A3*** from the base, ***A4*** and ***A5*** from the tip. The arrow in ***A4*** and ***A5*** indicates the ridge. ***B1-B4*** and ***B6-B9*** are the fruit from the side while ***B5*** and ***B10*** are the fruit from the base. ***C1*** shows a seedling with cotyledons (arrowed). ***C2*** is another cotyledon with different overall shape. ***C3*** is the seedling viewed from the side. ***D1-D5*** are the leaves viewed from the lower side: ***D1-D3*** are the first true leaves while ***D4*** and ***D5*** are the second true leaves. ***E2*** and ***E3*** are seedlings with cotyledons (arrowed) viewed from the top and side respectively.

ARACEAE

Alocasia macrorrhizos* (L.) G.Don.** (see ***Figure 6)

Fruit: a berry, length 0.8-1.0 cm, width 0.6-1.2 cm, height 0.6-1.1 cm, can contain from one to five seeds, fruit reddish orange to bright red when ripe, overall shape somewhat cuboidal to trapezoidal, there is an opening at the base of the fruit when detached and there is a dot-like structure at the tip of the fruit, surface smooth, shiny, hairless, fruit gives out orangish liquid when crushed (see ***Figure 6, A1-A12***).

Seed: length 0.5-0.6 cm, width 0.4-0.6 cm, height 0.4-0.6 cm, overall shape egg-shaped to almost globular to globular-flattened to disk-like to dome-like; fresh seeds have protrusion at the base (see ***Figure 6, B1*** and ***B6***). Surface of seed is smooth, hairless, glossy, slippery. Fresh seeds are unevenly creamish-brown to yellowish-brown: some areas are browner while some areas are yellower, older seeds are greyish black (see ***Figure 6, B1-B15***).

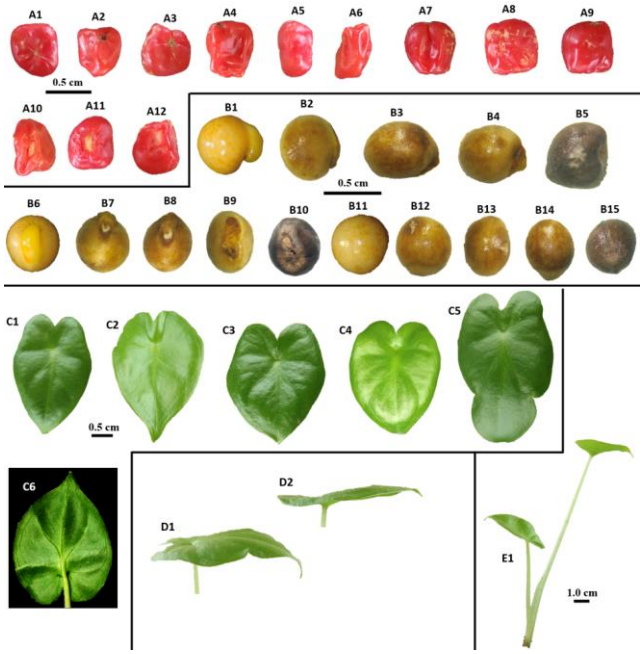

Figure 6. *A. macrorrhizos*. ***A1-A4*** different shapes of the fruit when viewed from the base while ***A5-A9*** when viewed from the side and ***A10-A12*** from the base. ***B1-B5*** shows different shapes of the seeds when viewed from the side while ***B6-B10*** when viewed from the base and ***B11-B15*** from the tip. ***C1-C6*** different shapes of the leaf: ***C6*** shows lower leaf surface to show the venation. ***D1*** and ***D2*** are examples of the leaf viewed from the side: notice the drooping tip. ***E1*** is an example of the seedling at second leaf stage.

Cotyledon: not observed due to hypogeal germination.

First true leaf: simple, alternate, 2.7-5.0 cm in length, 1.7-3.2 cm in width, peltate (petiole attached to centre of leaf), petiole 4.8-12.3 cm, overall leaf shape is cordate (heart-shaped) with drooping pointy tip. Leaf surface is smooth, hairless, glossy with smooth margin, upper surface is greener than lower surface. Venation is palmate, visible up to secondary veins, more obvious on lower surface, main veins are interconnected with other main veins to form loops, inside the loops are netlike secondary veins, there is an additional vein line near the leaf margin surrounding the main veins (see ***Figure 6, C1-C6, D1, D2*** and ***E1***).

Second true leaf: same description as first except length 5.0-5.4 cm, width 2.7-3.6 cm, petiole 5.5-9.0 cm (see ***Figure 6, C1-C6, D1, D2*** and ***E1*)**.

ARECACEAE

Elaeis guineensis* Jacq.** (see ***Figure 7)

Fruit: a drupe, length 2.0-5.5 cm, width 2.0-3.0 cm, somewhat ovoid to somewhat oblong, slightly asymmetrical, colour orange to red to bright red with black tip but ripe fruit is black with red base.[30-32]

Seed: length 1.6-3.5 cm, width 1.4-2.6 cm, height 1.0-2.2 cm, fibrous, appressed extending from base to tip, clustered at tip, overall shape can be somewhat globular to somewhat oval to somewhat cuboidal to somewhat trapezoidal, three near-base pores can be seen on seeds with completely removed flesh, fruit flesh is hard to remove (see ***Figure 7***).

Seeds failed to germinate.

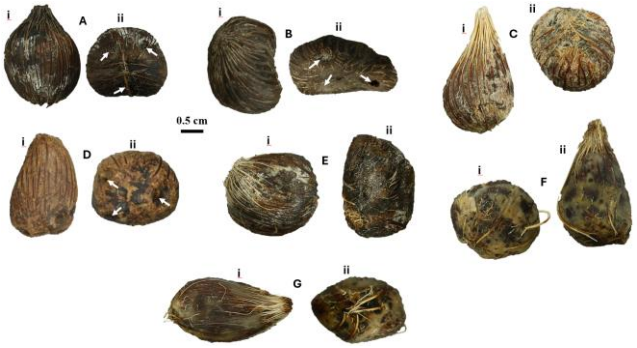

Figure 7. *E. guineensis* seeds with different appearances. Pictures annotated with "**i**" are viewed from the side while "**ii**" are viewed from the base. The white arrows indicate the pores. Picture ***A-E*** seeds without the fruit flesh, ***F-G*** are covered lightly with fruit flesh.

Ptychosperma macarthurii* (H.Wendl. ex H.J.Veitch) H.Wendl. ex Hook.f.** (see ***Figure 8)

Fruit: a drupe, length 1.2-2.5 cm, diameter 0.7-1.2 cm, somewhat globular to somewhat ovoid, colour red when ripe, fleshy, wrinkles as it dries.[32-38]

Seed: length 1.3-1.5 cm, width 0.6-0.7 cm, height 0.6-0.7 cm; hair fibrous, appressed, extending

from base to tip; surface of seed uneven due to the presence of five deep grooves and five obvious ridges: one ridge is bigger than the rest; overall shape is like a balloon whisk: base bluntly pointy (see ***Figure 8, B1-B3***).
Cotyledon: not observed due to hypogeal germination.
First leaf: compound with 2 terminal, opposite leaflets, alternate, leaflet length 4.6-5.0 cm, leaflet width 0.6-0.9 cm, hairless, green, glossy, surface smooth; leaf petiole length 3.3-4.8 cm; stipule absent; glands absent. Leaflet venation parallel, raised on upper surface, base tapered, margin smooth, tip pointy (see ***Figure 8, A1-A3***).
Second true leaf: same description as first leaf except leaflet length 5.2-5.4 cm, width 0.7-1.0 cm, leaf petiole length 4.4-4.5 cm.

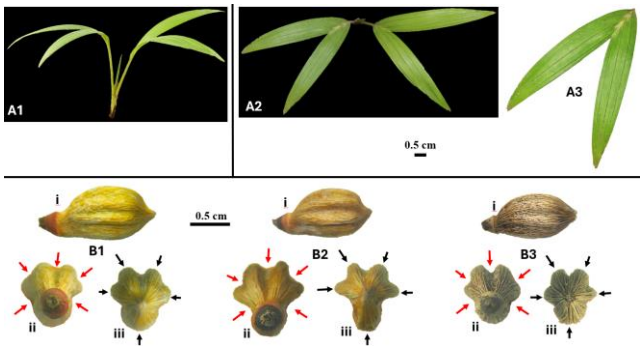

Figure 8. *P. macarthurii*. ***A1***: side-view of a seedling at second leaf stage; the pointy middle part is a developing third leaf. ***A2***: top view of the seedling. ***A3***: the compound leaf displaying its V-shaped leaflets with parallel venation. ***B1***, ***B2*** and ***B3*** are different examples of the seeds viewed at different angles: the annotation ***i***, ***ii*** and ***iii*** means it is viewed from the side, base, and tip respectively. The ***red arrows*** indicate the grooves (depression) on the seeds while the ***black arrows*** indicate the ridges.

CALOPHYLLACEAE

Calophyllum inophyllum* L.** (see ***Figure 9)
Fruit: a drupe, length 2.3-3.4 cm, width 2.2-3.3 cm, height 2.2-3.3 cm, single-seeded, round, hairless, initially fruit surface smooth but eventually becoming crumpled as it ripens, fruit colour turns from green to yellowish to purplish to brownish as it ripens, small white-cream dots can be seen scattered on fruit skin but eventually disappear as fruit ripens, there is a very small pointy needle-like structure at the tip of the fruit but the structure can be absent due to breakage. Fruits can be found partially eaten by animals (see ***Figure 9, A1-G***).
Seed: 1.9-2.7 cm in length, 1.5-2.5 cm in width, 1.5-2.5 cm in height, round, appressed light brown fibrous hairs can cover the seed extending from base of seed towards the tip of seed. Seeds can be found partially covered by the fruit flesh (see ***Figure 9, H-K***).
Cotyledon: not observed due to hypogeal germination.
First true leaf: opposite, 2.8-4.8 cm length, 1.5-2.5 cm width, petiole 0.5-0.7 cm; hairless, smooth, glossy, upper surface greener than lower surface, stipule absent. Overall shape is oval: base tapered, margin smooth, tip rounded. Venation featherlike, visible up to secondary veins, secondary veins placed very close together, reaching the margin, midrib significantly more obvious on lower surface (see ***Figure 9L***).
Second true leaf: same description as the first leaf pair except length 4.2-6.1 cm, width 2.0-3.5 cm, petiole 0.6-0.8 cm.

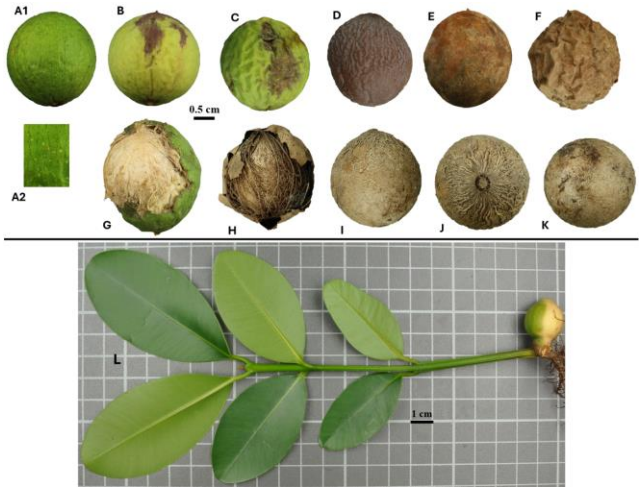

Figure 9. *C. inophyllum*. ***A1, B-F*** show the different stages of ripeness of the fruit: from green to yellowish to purplish to brown and from having smooth skin to crumpled skin. ***A2***: creamish-white dots on the skin. ***G***: partially eaten fruit. ***H***: partially skin-covered seed. ***I***, ***J*** and ***K*** shows a seed viewed from the side, base and tip, respectively. ***L***: a seedling at third leaf stage, the darker green surface is the upper surface while the lighter surface is the lower surface, at the bottom of the seedling is the germinated seed and the roots; each square grid is 1 cm^2.

Calophyllum obliquinervium* Merr.** (see ***Figure 10)

Fruit: a drupe, somewhat globular, surface of fruit smooth when fresh.[32,38]

Seed: length 0.7-0.9 cm, width 0.6-0.7 cm, height 0.6-0.7 cm; hairless, smooth, almost globular to egg-shaped, brown with white patches, the tip has very small needle-like structure which can be hard to see (see ***Figure 10, B1-B3***).

Cotyledon: not observed due to hypogeal germination.

First true leaf pair: opposite or whorled (three-leaved), length 2.0-3.1 cm, width 0.7-1.1 cm, petiole 0.2-0.4 cm; hairless, smooth, glossy, upper surface greener than lower surface, stipule absent. Overall shape is elongated oval: base tapered, margin smooth, tip rounded bluntly pointy. Venation featherlike, visible up to secondary veins, secondary veins placed very close together, reaching the margin (see ***Figure 10, A1-A4***).

Second true leaf pair: same description as the first leaf pair except length 2.0-3.3 cm, width 0.6-1.2 cm, petiole 0.2-0.3 cm.

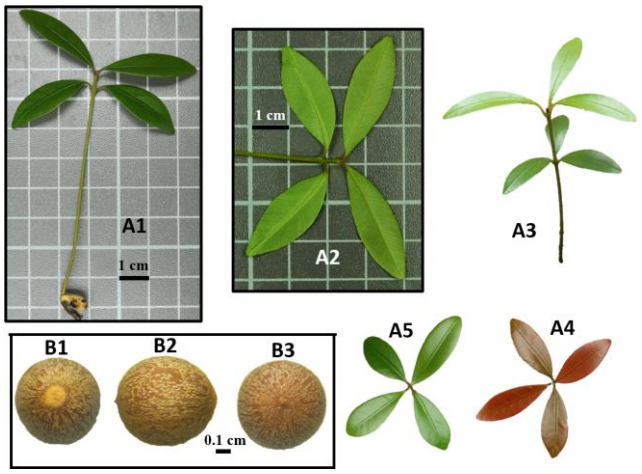

Figure 10. *C. obliquinervium*; each square is 1 cm^2. ***A***: the seedling, ***B***: the seed. ***A1***: the seedling at second leaf stage showing the upper surface of leaves. ***A2***: the seedling showing the lower surface of leaves and venation. ***A3***: a seedling with whorled leaves instead of opposite. ***A4*** and ***A5***: leaf colour before and after maturation respectively. ***B1***, ***B2***, and ***B3***: the seed viewed from base, side and tip, respectively.

CHRYSOBALANACEAE

Parastemon urophyllus* (Wall. ex A.DC.) A.DC.** (see ***Figure 11)

Fruit: a drupe, length 1.0-1.5 cm, width 0.6 cm, somewhat ovoid, surface smooth, immature fruits yellowish but ripe fruits pinkish.[32,37-39]

Seed: length 1.0-1.4 cm, width 0.5-0.8 cm, height 4.6-6.7 mm; light brown to dark brown, overall shape is elongated, flattened, oval: base tapered and bluntly pointy, tip rounded; surface of seed slightly coarse, hairless (see ***Figure 11***, ***A1-A5***).

Cotyledon: opposite, length 1.1-1.3 cm, width 0.5-0.7 cm; fleshy, vein not visible, green but upper surface greener than lower surface, black patches can be present randomly distributed over the cotyledon, hairless, surface smooth, overall shape inverted elongated dome: base can extend beyond the point of attachment of the cotyledon to the stem; margin smooth, tip rounded or protruding and bluntly pointy; withers and falls off eventually (see ***Figure 11, B1-B3***).

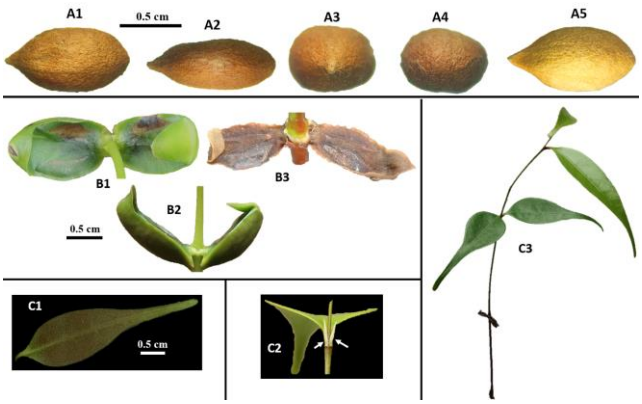

Figure 11. *P. urophyllus*. ***A1***, ***A2***, ***A3*** and ***A4***: examples of a seed viewed from the side (***A1*** and ***A2***) and tip (***A3*** and ***A4***), respectively. ***A5***: an example of a seed with lighter colour. ***B1*** and ***B2*** are examples of fresh cotyledons viewed from the top and side respectively, while ***B3*** is an example of withered cotyledons; the protrusions at the centre are the stem. ***C1*** is an example of the first and second true leaf viewed from the lower surface of leaf: it is brownish because the leaf is still developing. ***C2*** shows the stipules (arrowed). ***C3*** is an example of the seedling viewed from the side.

First leaf: opposite, crosswise with cotyledons, length 3.6-5.5 cm, width 0.9-1.6 cm, petiole 0.1-0.4 cm, petiole brownish, stipules very obvious but eventually fall-off, leaf smooth, hairless, upper surface greener than lower surface, initially lower surface brownish but eventually green,

venation feather-like, visible up to tertiary veins, secondary veins looped, tertiary veins netted, overall shape elongated egg shape: base tapered, margin smooth, tip tapered to a long point and rounded (see ***Figure 11, C1-C3***).
Second leaf: same description as first leaf except that it is alternate, length 4.8-5.6 cm, width 1.1-1.7 cm, petiole 0.2-0.5 cm (see ***Figure 11, C1-C3***).

COMBRETACEAE
Terminalia catappa* L.** (see ***Figure 12)
Fruit: a drupe, length 4.7-6.5 cm, width 2.7-5.6 cm, height 1.9-2.2 cm; overall shape oval with pointy ends, flattened, edge is winged, hairless, surface smooth but eventually becoming coarser due to withering, not glossy (see ***Figure 12, A1-A10***). Fresh fruits are green, older fruits are black to brownish.
Seed: seed was not documented due to difficulties in taking out the seed from the fruit.
Cotyledons: opposite, 2.8-4.3 cm in length, 5.4-7.6 cm in width; upper surface green, lower surface pale green, both surfaces uneven, bumpy, hair is present near the base on upper surface but hair is present from base to centre of leaf along the veins on lower surface; petiole length 0.6-1.3 cm, hairy. Venation is tri-veined, sunken on upper surface but raised on lower surface, venation visible up to secondary veins but tertiary veins become visible when intense light is shone directly from the lower leaf surface, secondary veins looped, tertiary veins net-like, venation more obvious on upper surface than lower surface. Overall shape is lung-shaped, asymmetrical: base very broad, margin wavy and entire but basal margin hairy, tip very wide. The shape of the cotyledon pair does not mirror each other. Glands absent (see ***Figure 12, B1***).
First true leaf: alternate, perpendicular to cotyledons, length 6.8-9.8 cm, width 3.3-5.3 cm; upper surface greener than lower surface, both surfaces uneven, bumpy, hair present on midrib and margin; petiole length 0.6-1.0 cm, hairy. Venation is feather-like, sunken on upper surface but raised on lower surface, venation visible up to tertiary veins, secondary veins looping, tertiary veins net-like. Overall shape is reverse-egg-shaped to elongated reverse-egg-shaped: base tapered, margin slightly wavy, tip bluntly pointy. Glands are present in secondary veins near margin; stipule absent (see ***Figure 12, B2-B4***).
Second leaf: same as first leaf except leaf length 10.3-12.3 cm, width 4.8-6.0 cm; petiole 0.7-1.1 cm.

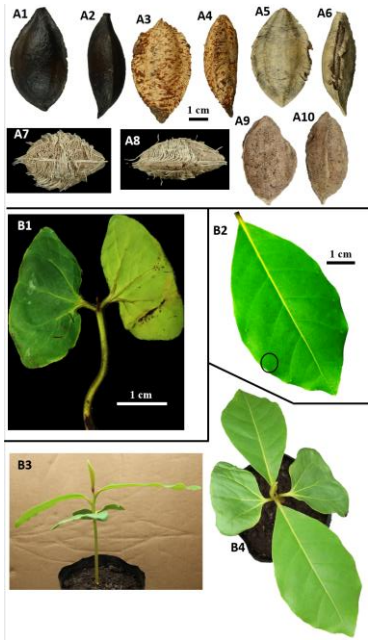

Figure 12. *T. catappa*. ***A***: the fruits at different stages of withering with ***A1*** and ***A2*** being the least withered while ***A9*** and ***A10*** being the most withered. ***B***: the seedling and its parts. ***B1***: seedling with its cotyledons: the greener one shows the upper surface of the cotyledon while the paler one shows the lower surface. ***B2***: the leaf displaying its shape and glands (circled). ***B3***: side-view of a seedling. ***B4***: top view of a seedling.

EUPHORBIACEAE
Endospermum diadenum* (Miq.) Airy Shaw.** (see ***Figure 13)
Fruit: a capsule, usually double seeded, can be triple seeded but with one underdeveloped seed, length 0.6-0.7 cm, width 0.6-0.9 cm, height 0.6-0.7 cm, hairless, green but yellowish green to yellowish when mature, initially surface smooth but eventually wrinkled as fruit dries, overall shape somewhat oblong but triple seeded fruit is triangular (with curved edges): remnants of stigma persistent at tip of fruit (see ***Figure 13, E-L***).
Seed: length 0.4-0.5 cm, width 0.4-0.5 cm, height 0.3-0.4 cm; surface hairless, smooth; overall shape almost globular to dome-like; colour white

except base of seed, there is an opening at the base of seed (see ***Figure 13, A-D***).
Seeds failed to germinate.

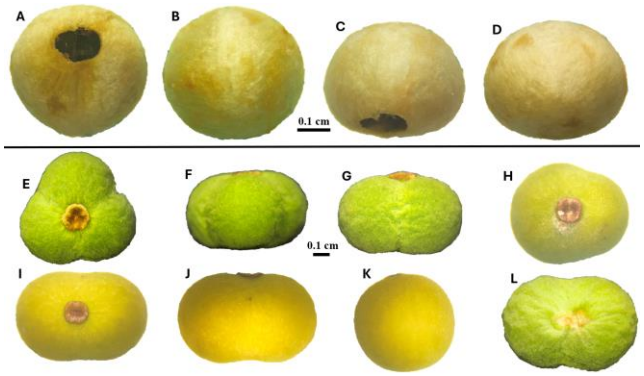

Figure 13. *E. diadenum*. ***A***, ***B***, ***C*** and ***D***: seeds viewed from the base, tip, and side, respectively. ***E***, ***F*** and ***G***: examples of a fruit containing three seeds viewed from the tip and side, respectively. ***H*** is an example of a fruit with one underdeveloped seed. ***K***, ***I***, ***J***, and ***L*** are examples of a fruit with two developed seeds viewed from the tip, side and base.

FABACEAE

Pterocarpus indicus* Willd.** (see ***Figure 14)

Fruit: a samara, length 4.2-6.3 cm, width 3.7-6.2 cm, height 4.4-7.4 mm, thin, flat, disk-like, almost circular, initially green eventually brown, centre is the thickest part of the fruit, centre spiky and very coarse, margin smooth and very wavy, base of fruit protrudes from the fruit, netted-vein-like structure can be seen extending from the centre to margin (see ***Figure 14, B1-B5***).

Seed: length 0.4-0.6 cm, width 0.7-0.9 cm, height 1.8-2.3 mm; light brown to brown, flattened, kidney shaped to ear shaped to boomerang shaped; base of seed located at the side, there is a circular opening at the base of the seed, the opening is lined by a yellowish-brown structure (see ***Figure 14, C1-C4***).

Cotyledons: opposite, length 2.0-2.8 cm, width 1-1.3 cm, petiole 0.1-0.2 cm and clasping; the whole cotyledon is hairless and smooth, the upper surface is green, lower surface pale green. Venation inconspicuous but becomes obvious when light is shone directly through the cotyledons, midrib is always obvious, venation visible up to tertiary veins, the secondary veins are looped, tertiary veins netted. Overall shape is elongated oval: base very wide but asymmetrical, margin entire, tip broadly rounded (see ***Figure 14, A1-A2***).

First true leaf: simple, alternate, length 2.0-3.6 cm, width 0.8-2.1 cm; green, hairless and smooth. Overall leaf shape is acuminate or tadpole-shaped: base broadly rounded but sometimes slightly indented, margin smooth, tip tapered to a long point. Venation visible up to tertiary veins, the secondary veins are looped, tertiary veins reticulate, venation more obvious on lower surface; stipules obvious, needle-like; glands absent; petiole 0.8 – 1.6 cm, pulvinus present on both petiolar ends (see ***Figure 14, A1-A2***).

Second leaf: same description as first leaf except length 0.9-3.8 cm, width 0.5-2.3 cm; petiole 0.7-1.5 cm (see ***Figure 14, A1-A2***).

Additional information: it was accidentally found that seed germination can be facilitated through submersion in water, i.e., leave the seeds submerged in water until they germinate. It was also observed that the compound leaf started to appear earliest at the fifth leaf stage.

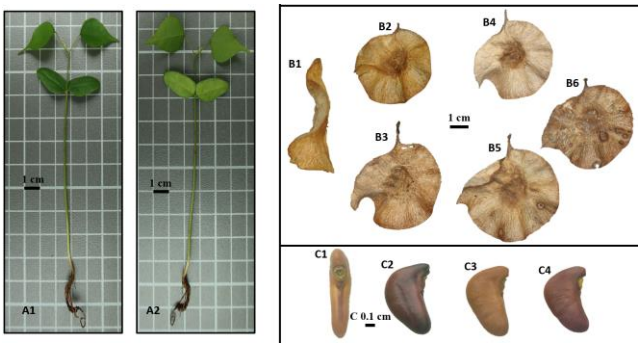

Figure 14. *P. indicus*. The grid square is 1 cm^2 each. ***A***: the seedling, ***B***: the fruits, **C**: the seeds. ***A1*** is the seedling showing the upper side of leaves and cotyledons while ***A2*** shows the lower leaf surfaces. ***B1***: the fruit viewed from tip-base, ***B2-B6***: side-view of the fruits showing that their shapes can be slightly different from each other. ***C1***: the fruit viewed from base, ***C2-C4***: the seeds viewed from the side.

LAURACEAE

Litsea elliptica* Blume.** (see ***Figure 15)

Fruit: a drupe, length 0.7-1.2 cm, red when mature, somewhat globular to somewhat ovoid, base surrounded by a cupule.[37,40]

Seed: length 0.6-0.7 cm, width 0.6-0.7 cm, height 0.6-0.7 cm, hairless, smooth, almost globular,

blackish orange, orange colour is strongest at the base, there is a very small protruding opening at the base (see ***Figure 15***).
Leaf and cotyledon were not observed due to failed germination.

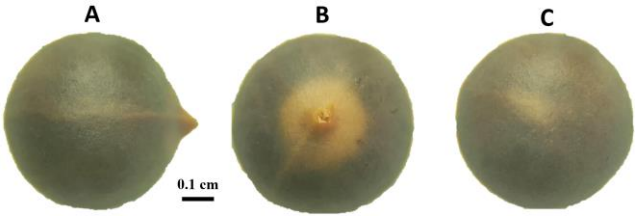

Figure 15. *L. elliptica*. ***A***: side-view of the seed, ***B***: base-view of the seed showing a strong orange colouration and a small opening at the centre, ***C***: tip-view of the seed.

MORACEAE

Ficus benjamina* L.** (see ***Figure 16)
Fruit: a fig (synconium), length 0.7-1.7 cm, width 0.5-1.4 cm, height 0.5-1.4 cm, contains countless seeds, colour yellow to orange to red to dark red, surface smooth but eventually becoming crumpled as fruit ripens, spotted to faintly spotted, overall shape is somewhat globular to oval-like, a very small opening can be found on fruit tip (see ***Figure 16, A1-A11***, ***B1-B10***, ***C1-C8***).
Seed: somewhat round to oval-like, very small, maximum size ~0.1 cm, colour white to creamish-white (see ***Figure 16, D1*** and ***D2***).
Cotyledon: opposite, length 0.1-0.6 cm, width 0.1-0.6 cm, petiole length less than 0.1 to 0.2 cm, green, hairless, surface smooth, glands scattered, cotyledon glittered when light was shone through it; venation two-veined, hardly visible; overall shape almost round: base round, margin smooth, tip indented (see ***Figure 16, E2, E3*** and ***F***).
First true leaf: opposite, length 0.4-1.9 cm, width 0.5-0.9 cm, petiole 0.2-0.4 cm, crosswise with cotyledons, stipules present, glands scattered, leaf green, upper surface greener than lower surface, hairless, surface smooth, leaf glittered when light was shone through it; venation three-veined to featherlike, visible up to tertiary veins but tertiary veins very hard to see, secondary veins looped, tertiary veins net-like; overall shape is elongated egg-shaped: base rounded to wide to tapered and sometimes slightly indented, margin slightly toothed, tip slightly indented (see ***Figure 16, E1, E2, G1-G4***).
Second true leaf: same description as first true leaf except alternate, length 0.9-2.1 cm, width 0.6-1.3 cm, petiole 0.2-0.7 cm, overall shape slightly heart-shaped: base slightly indented, margin slightly toothed, tip slightly indented (see ***Figure 16, E1, E2, H1-H3***).

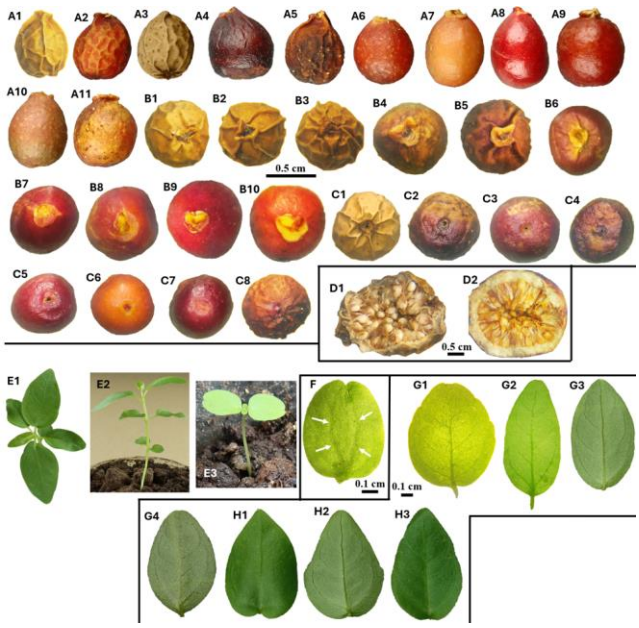

Figure 16. *F. benjamina*. ***A1-A11*** are fruits viewed from the side. ***B1-B10*** are fruits viewed from the base. ***C1-C8*** are fruits viewed from the tip. ***D1*** and ***D2*** show seeds clustered inside the fruits. ***E1*** and ***E2*** are seedlings at the stage of developing the 4th true leaf with cotyledons still intact: they are viewed from the top and the side respectively. ***E3*** shows a seedling with well-developed cotyledons: at the centre is the first true leaf pair still undergoing development. ***F*** shows the overall shape of the cotyledon and the dual main veins extending from the base to the tip (arrowed): image contrast is increased by 48% to increase venation clarity. ***G1-G4*** are examples of the first true leaf viewed from the lower side of the leaf: image brightness of ***G1*** is increased by 20% while image contrast of ***G2*** is increased by 26% both to increase venation clarity. ***H1-H3*** are examples of the second true leaf: ***H1*** and ***H3*** are viewed from the upper surface while ***H2*** from the lower surface.

MYRTACEAE

Syzygium grande* (Wight) Walp.** (see ***Figure 17)
It was observed that scale leaves appeared first before the appearance of normal-looking-leaves. Stem initially red eventually brown; lower stem eventually flaky brown (see ***Figure 17H***).

Fruit: a berry, single-seeded, length 2.7-4.0 cm, width 1.8-2.7 cm, height 1.7-2.6 cm, ripe fruits are green, overripe fruits are brown to dark brown, there are ridges extending from the base to the tip of the fruit but they become less obvious as the fruit ripens: the ridges cause the fruit to appear striped, remains of flower can be found on tip of fruits, overall shape is elongated oval: fruit tip hollow (see ***Figure 17, A1-A8, B1, B2, C1*** and ***C2***).

Seed: length 2.0-2.7 cm, width 1.6-2.5 cm, height 1.6-2.2 cm, surface rough, colour light brown to brown, overall shape is somewhat globular to elongated oval: base can be slightly indented to bluntly pointy, always wider towards the tip. A groove or a distinct stripe extending from the base towards the centre or tip of seed can be present (see ***Figure 17, D1-D4, E1-E4, F1, F2, FS, G1-G3*)**

Cotyledon: not observed due to hypogeal germination.

Scale-leaves: opposite to subopposite to alternate, length 0.1-0.6 cm, width < 0.1-0.2 cm, petiole absent, primary vein can be obvious but not the other veins.

First true leaf: opposite to subopposite to alternate, length 2.2-9.6 cm, width 1.9-5.6 cm, petiole green 0.3-0.8 cm; upper surface greener than lower surface, glossy smooth; leaf glands scattered. Venation is feather-like, venation visible up to tertiary veins, secondary veins looping, sunken on upper surface but raised on lower surface, tertiary veins net-like and only visible when intense light was shone through the leaf. Overall shape is almost round to oval-like: base tapered, margin smooth to very slightly toothed, tip tapered, bluntly pointy to pointy, symmetrical to slightly asymmetrical (see ***Figure 17, i1-i3, J1-J8***).

Second true leaf: same description as first leaf except length 5.6-10.7 cm, width 3.0-6.2 cm, petiole 0.5-0.9 cm, overall shape the same but never almost round, if opposite the leaves are crosswise with first leaf pair. (see ***Figure 17, i1-i3, J2-J8***).

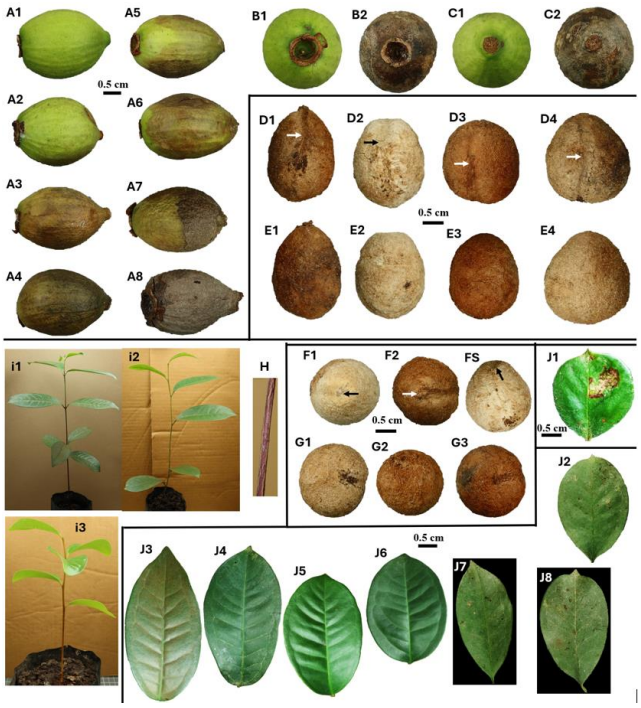

Figure 17. *S. grande*. ***A1-A8*** are the fruits viewed from the side, ***B1*** and ***B2*** from the tip while ***C1*** and ***C2*** from the base. ***D1-D4*** are the seeds viewed from the side: ***D1*** with a distinct stripe while ***D2*** with a groove extending until the centre, ***D3*** and ***D4*** with a groove extending towards the tip (arrowed). ***E1-E4*** are the seeds viewed from the side without the groove or stripe. ***F1*** and ***F2*** are the seeds viewed from the base: ***F1*** indented while ***F2*** pointy (arrowed). ***FS*** is a seed viewed in a way that shows the indentation of the base more clearly. ***G1-G3*** are the seeds viewed from the **tip**. ***H*** is a picture of the flaky brown lower stem. ***i1-i3*** are the seedlings viewed from the side. ***J1-J8*** are examples of the first and second true leaves: ***J1*** is applicable only for the first leaf while ***J2-J8*** are applicable for both leaves.

Syzygium malaccense* (L.) Merr. & L.M.Perry.** (see ***Figure 18)

It was observed that scale-leaves appeared first before the appearance of normal-looking-leaves. Up to 10 alternate or subopposite or opposite scale-leaves can appear before the appearance of true leaf and scale leaves can continue to appear after the appearance of the first true leaf **(see *Figure 18, A2*)**. Up to five scale-leaf pairs can appear before the appearance of normal-looking-leaves.

Fruit: a berry, length 2.5-10 cm, width 2.5-8.0 cm, single-seeded, fleshy, juicy, colour reddish or pinkish or whitish with whitish or pinkish or reddish stripes, surface of fruit smooth, glossy;

overall shape somewhat bell-shaped to somewhat globular to somewhat ovoid to somewhat oblong.[32,37,38,41,42]

Seed: length 1.6-3.0 cm, width 2.0-4.0 cm, height 1.6-3.1 cm, dark brown to brown to light brown, hairless, surface slightly rough, overall shape somewhat cuboidal to somewhat globular, base slightly indented to indented and hilum can be obvious or not, tip wide to very wide, faint veinlike structures can be found surrounding the seed, seed can be found slightly cracked or cracked **(**see ***Figure 18, B-D*****)**.

Cotyledon: not observed (hypogeal germination).

Scale-leaves: opposite to almost opposite to alternate, every pair is crosswise with another pair, length 0.1-1.2 cm, width 0.1-0.2 cm; petiole absent; colour creamish white to creamish green; leaf surface smooth, hairless, not shiny; venation feather-like, midrib is always visible but secondary veins can be slightly visible starting from third scale-leaf pair; overall shape scale-like: base clasping, margin smooth, tip pointy. The scale-leaves dies off very early and leave behind scars **(**see ***Figure 18, A2-A3*****)**.

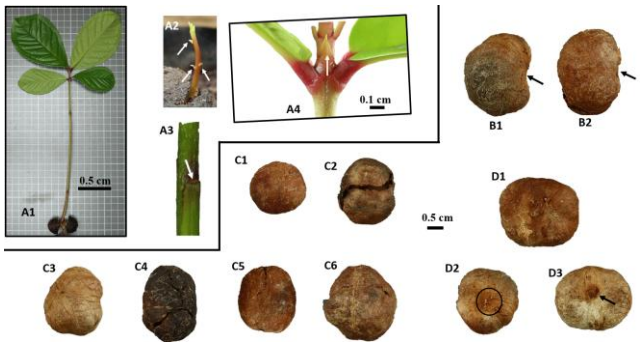

Figure 18. *S. malaccense*. ***A1***: seedling at second leaf stage showing upper and lower surface of leaves against 1 cm^2 grid boxes; the two bulging parts at the bottom are the remains of the seed. ***A2***: a seedling showing its scale leaves (arrowed). ***A3***: scale-leaf scar (arrowed). ***A4***: a scale-leaf appeared in between the nodes of the second leaf pair (arrowed). ***B***: seeds viewed from the side to show different indentation of the base of the seeds, ***B1*** indented, ***B2*** slightly indented. ***C1-C6***: seeds viewed from tip to show the different shapes of the seeds. ***D***: seeds viewed from base to show different funicle scar (hilum), ***D1*** not obvious, ***D2*** less obvious (circled), ***D3*** obvious (arrowed).

First normal-looking-leaf: opposite to almost opposite, crosswise with previous scale-leaf pair, hairless, glossy, length 4.5-9.6 cm, width 1.7-4.2 cm; upper surface greener than lower surface, both surfaces uneven, bumpy; petiole reddish 0.2-0.9 cm; leaf glands scattered. Venation is feather-like, sunken on upper surface but raised on lower surface, venation visible up to tertiary veins, secondary veins looping, tertiary veins net-like. Overall shape is oval-like to reverse-egg-shaped: base tapered, margin smooth to very slightly toothed to slightly wavy, tip broad and minutely indented to tapered to a long point without indentation and asymmetrical **(**see ***Figure 18, A1*****)**.

Second normal-looking-leaf: same description as first normal-looking-leaf except opposite, length 5.1-11.5 cm, width 2.6-7.0 cm, petiole 0.2-0.8 cm, scale-leaf can appear in between the nodes of the leaf pair **(**see ***Figure 18, A4*****)**.

Tristaniopsis obovata* (Benn.) Peter G.Wilson & J.T.Waterh.** (see ***Figure 19)

Fruit: a dry capsule that splits open into 3 valves when mature to release many seeds, colour orange to brown when ripe.[32,37]

Seed: length 0.1-0.2 cm, width 0.3-0.5 cm, height < 0.1 cm, golden brown to light brown to dark brown, shape oval-like to suboval, very thin, base very wide, tip very wide to broadly rounded (see ***Figure 19, B1*** and ***B2***).

Cotyledon: opposite, length 0.2-0.4 cm, width 0.4-0.7 cm, petiole 0.1-0.2 cm, upper surface greener than lower surface, smooth, hairless, thin, overall shape is kidney-shaped and asymmetrical: base very wide, margin smooth, tip very wide and slightly indented (see ***Figure 19, A1***).

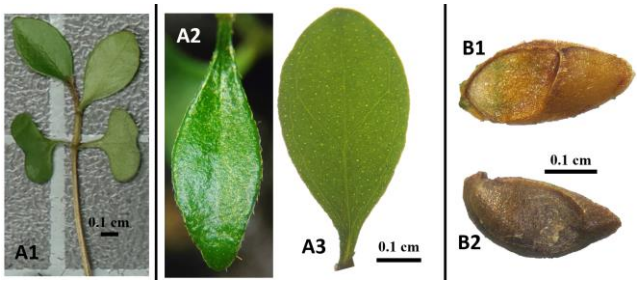

Figure 19. *T. obovata*. ***A1***: seedling showing upper and lower surface of cotyledon and leaf. ***A2***: a closeup of the upper surface of the first leaf showing its glossiness and fine hair along the margin. ***A3***: a closeup of the first leaf showing the scattered glands (white dots) and venation. ***B1-B2***: the seeds viewed from the side.

First leaf: alternate but sometimes opposite, length 0.3-0.9 cm, width 0.2-0.5 cm, petiole 0.1-0.2 cm, margin lined with very fine hair, upper surface greener than lower surface, smooth, glossy, venation featherlike, visible up to tertiary veins, secondary veins looped, tertiary veins netted and less visible, stipule absent, glands scattered, overall shape is oval: base tapered, margin smooth but with very fine hairs, tip rounded to bluntly pointy (see ***Figure 19, A1-A3***).

Second leaf: same description as first leaf except length 0.4-0.9 cm, width 0.2-0.6 cm.

PRIMULACEAE

Ardisia elliptica* Thunb.** (see ***Figure 20)

Fruit: a drupe, length 0.5-0.7 cm, diameter 0.5-1.2 cm, fleshy, compressed globular, colour pinkish to reddish to purplish but mature fruits are purplish black to black and slightly to thoroughly dotted.[36,37,40,43,44]

Seed: length 4.3-4.8 mm, width 5.0-5.6 mm, height 5.0-5.6 mm; almost globular; the base of the seed can have an opening or be covered; seed covered with appressed creamish fibrous hairs which extend from the base to the tip of the seed but the seed itself is brownish (see ***Figure 20, B1-B4***).

Cotyledon: opposite, length 1.7-2.7 cm, width 1.2-1.9 cm, glabrous, smooth, glossy, light green to green, lower surface has purplish patches due to presence of glands; petiole 1.0-2.0 mm. Venation inconspicuous but becomes visible up to tertiary veins when light is shone directly through the cotyledon, venation featherlike, secondary veins looped, tertiary veins net-like. Overall shape is egg-shaped: base rounded and asymmetrical, margin entire, tip indented (see ***Figure 20, A1-A3***).

First true leaf: same description as the cotyledon, alternate, length 1.7-3.5 cm, width 1.0-1.9 cm; petiole green to red, 1.0-4.0 mm; venation description is the same as the cotyledon. Overall shape is oval: base tapered, margin smooth to slightly toothed, tip bluntly pointy but sometimes indented (see ***Figure 20, A1-A4***).

Second leaf: same description as the first leaf except length 2.2-5.5 cm, width 1.1-2.7 cm; petiole 2.0-5.0 mm.

Additional information: a new clone can be grown from detached leaves when the leaves are put in a container filled with water.

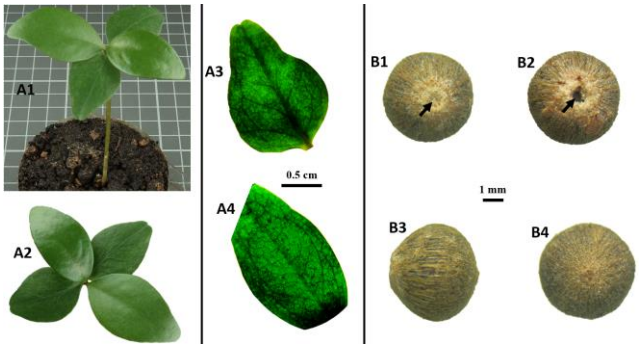

Figure 20. *A. elliptica*. ***A1*** and ***A2***: side view and top view of the seedling, respectively, showing the cotyledons, first, and second leaf. ***A3*** and ***A4***: the cotyledon and the first leaf, respectively, showing the differences in their venation; the brightness of the images is reduced by -23% and -21% respectively while the contrast is increased by 65% and 79% respectively to enhance the appearance of the venation. ***B1*** and ***B2***: base-view of the seed: there can be an opening as in **B2** or sealed as in ***B1*** (arrowed). ***B3*** and ***B4***: side and tip view of the seed, respectively.

RUBIACEAE

Gardenia jasminoides* J. Ellis.** (see ***Figure 21)

Fruit: a berry, length 1.27-7.0 cm, width 1.2-2.0 cm, somewhat ovoid with 5 – 9 ridges extending from base to tip, fleshy, indehiscent, green when unripe but yellowish to yellowish-orange when mature, persistent calyx protrudes from tip measuring up to 0.4 cm.[32,37,38,45]

Seed: length 0.6-0.9 cm, width 0.5-0.8 cm, height 0.2-0.4 cm; shape varies from kite-like to rectangular to trapezoidal to rhomboidal to elongate-elliptical, convex, glabrous, surface bumpy, wrinkly, and uneven, with a marginal groove spanning about three-quarters of the seed length: marginal ridge can be more prominent in one part than the other. Fresh seeds are orange, older seeds brown (see ***Figure 21, B-G***).

Cotyledons: opposite, length 1.0-1.2 cm, width 1.2-1.6 cm, hairless, surface varies from very crumply to almost flat, upper surface greener than lower surface; petiole 1.0-2.0 mm, creamish-green when viewed from the top. Venation palmate, looping, raised on upper surface, visible up to secondary veins, secondary veins netted, primary veins toward the base are green but paler in comparison with the cotyledon

blade. Overall shape is rounded: base wide and rounded, margin smooth to wavy, tip wide and rounded (see ***Figure 21, A2*** and ***A3*****)**.

First true leaf: opposite, placed crosswise with cotyledons, length 0.7-3.1 cm, width 0.5-1.8 cm, glossy, green, upper surface greener than lower surface, very small hairs scattered on upper surface, surface can be uneven and crumply; glands absent, petiole 1.0-2.0 mm. Venation feather-like, visible up to tertiary veins: tertiary veins become more visible when intense light is shone through the leaf; secondary veins looped, sunken on upper surface but raised on lower surface; tertiary veins net-like; midrib sunken on upper surface but raised on lower surface, midrib is green but paler in comparison with the leaf blade. Overall shape oval to egg-shaped: base tapered, margin lined with very small hair, tip pointy. The shape can also be asymmetrical with wavy margin. Stipules absent (see ***Figure 21, A1-A3*****)**.

Second leaf pair: same as first leaf pair but placed crosswise with first leaf pair; length 1.5-4.6 cm, width 0.9-2.2 cm; petiole 1.0-3.0 mm.

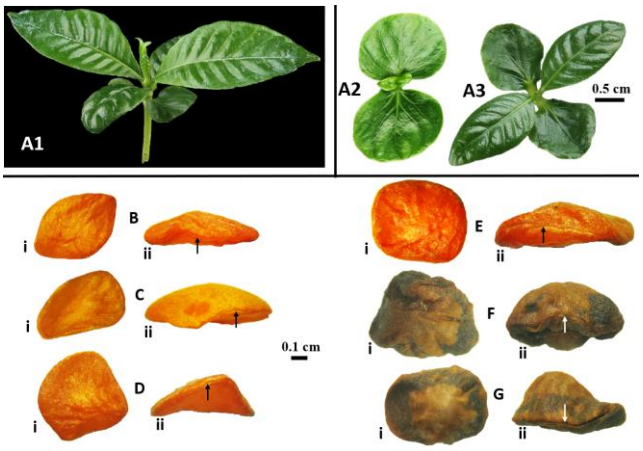

Figure 21. *G. jasminoides*. ***A***: the seedlings, ***B-G*** examples of the seeds. ***A1***: side-view of a seedling with fully developed second pair of leaves; the emerging leaves at the centre are the third leaf pair. ***A2***: the cotyledons showing their venation; at the centre is the first leaf pair. ***A3***: a seedling displaying its first leaf pair and cotyledons. ***B-G*** are different individual seeds: seeds annotated with "**i**" are viewed from top-bottom while those with "**ii**" are viewed from the tip. The "**arrows**" indicate the ridge of each seed.

SAPOTACEAE

Planchonella obovata **(R.Br.) Pierre.** (see ***Figure 22***)

Fruit: a berry containing one to five seeds, length 1.0-1.5 cm, width 1.0-1.5 cm, somewhat globular to somewhat ovoid, hairless, colour eventually changes from green to yellowish or bluish or reddish.[36-38,46]

Seed: length 0.4-0.5 cm, width 0.6-0.7 cm, height 0.3-0.4 mm; colour dark brown to black except for the seed-scar which is whitish grey; seed surface shiny, smooth, slippery, hairless; overall shape is flattened suboval: tip and base very wide (see ***Figure 22, B1-B3***).

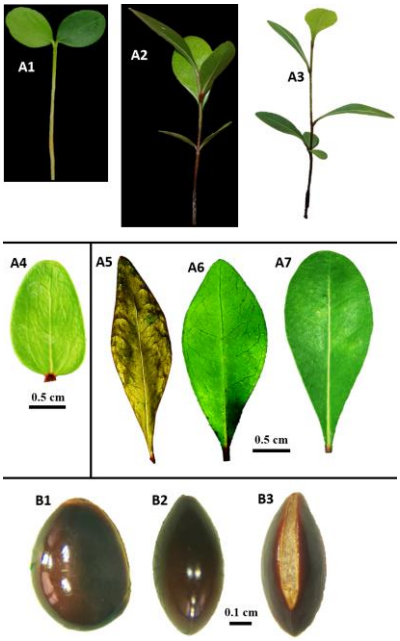

Figure 22. *P. obovata*. ***A1***: seedling displaying both sides of the cotyledons: the greener one is the upper surface while the paler one is the lower surface. ***A2*** and ***A3***: seedlings at third and fourth leaf stage, respectively, both viewed from the side. ***A4***: a closer view of the upper surface of a cotyledon showing its venation; the red part at its base is its petiole. ***A5***, ***A6*** and ***A7***: examples of the shapes of the first and second leaf as well as the venation. ***B1***, ***B2*** and ***B3*** are the seeds viewed from the side, tip, and base respectively.

Cotyledon: opposite, length 1.5-1.6 cm, width 0.7-0.9 cm, petiole 0.1-0.2 cm reddish to brownish; hairless, glossy, green, smooth; venation tri-veined, secondary veins looped, venation raised on upper surface, midrib obvious, midrib creamish-green but becomes green towards the tip; overall shape oval-like: base

tapered, margin smooth, tip rounded to bluntly pointy (see ***Figure 22, A1-A4***).
First leaf: simple, alternate, length 1.1-3.8 cm, width 0.8-1.6 cm, petiole 0.2-0.3 cm reddish to brownish and covered with fine glossy hair; leaf green, upper surface greener than lower surface, upper surface and lower surface of leaf covered very lightly with fine glossy hair which is hard to see, glossy. Venation featherlike, visible up to tertiary veins, secondary veins looped, tertiary veins netted, midrib creamish-green. Overall shape is oval to elongated oval to reverse egg-shaped to elongated reverse egg-shaped: base tapered, margin smooth, tip rounded to bluntly pointy (see ***Figure 22, A2, A3, A5-A7***).
Second leaf: same description as the first leaf except length 2.5-3.9 cm, width 0.9-1.7 cm.

SYMPLOCACEAE
Symplocos polyandra* (Blanco) Brand.** (see ***Figure 23)
Fruit: a drupe, length and width approximately 1.2 cm and 0.7 cm, respectively; hairless to hairy but hair appressed, short, matted; overall shape somewhat cylindrical to ovoidal; colour violet when ripe; persistent fruit calyx present at tip of fruit.[32,38,47]
Seed: length 0.6-1.0 cm, width 0.4-0.6 cm, height 0.4-0.6 cm; urn-shaped, widest at centre, surface uneven due to presence of grooves; grooves extend from near seed base towards seed tip merging at the tip, colour light brown to dark brown but grooves can be whitish grey (see ***Figure 23***).
Seeds: failed to germinate.

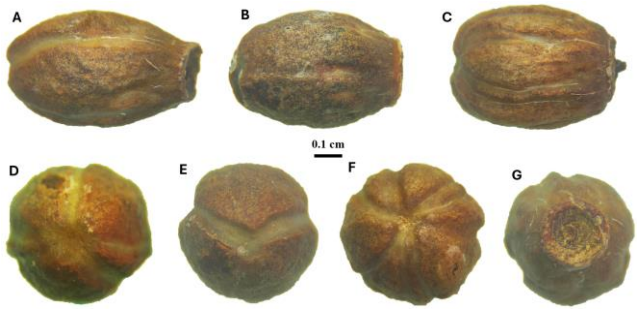

Figure 23. *S. polyandra*. ***A***, ***B*** and ***C***: side view of the seeds. ***D***, ***E*** and ***F***: the seeds viewed from the tip. ***G***: base of seed.

UNKNOWN SPECIES
Bird's Beak (see ***Figure 24***)
Seed: length 0.7-1.0 cm, width 0.9-1.4 cm, height 0.5-0.8 cm; overall shape can be somewhat globular to elongated sub-oval with a ridge spanning about half of the seed length. This ridge covers both sides or only one side of the seed and forms a pointy tip. Surface of seed is smooth, glabrous, glossy, light brown. Remains of its funicle can be found at the bottom of the ridge (see ***Figure 24, C*** and ***D***).
Cotyledons: opposite (see ***Figure 24, A1*** and ***A2***), 2.9-3.6 cm in length, 2.0-2.7 cm in width; the whole cotyledon is hairless and smooth, initially green eventually greenish yellow, the upper surface is greener than the lower surface; petiole 0.5-0.7 cm initially green eventually reddish. Venation netted raised on upper surface, more obvious on the upper surface than the lower surface but the midrib is obvious on both sides, midrib initially creamish on both upper and lower surface but eventually it changes with the upper surface midrib reddish to yellowish towards the tip, while the lower surface midrib turns reddish. Overall shape is egg-shaped: base tapered or rounded, margin smooth but wavy and initially greenish but eventually reddish, tip rounded (see ***Figure 24, B4***).
First true leaves: simple, opposite, placed crosswise with cotyledons (see ***Figure 24, A1*** and ***A2***), 6.2-8.8 cm in length, 1.7-3.2 cm in width; petiole 0.7-1.1 cm, initially green eventually red; leaf is hairy on lower surface but hairless and smooth on upper surface, upper surface green to greenish yellow, lower surface pale green. Venation featherlike, visible up to tertiary veins, more obvious on upper surface but midrib is obvious on both surfaces, secondary veins are looped, tertiary veins netted, midrib initially greenish to creamish on both upper and lower surface but eventually changing to reddish on both sides, although upperside turning yellowish towards the tip; stipules encircling stem (ochrea); glands absent. Overall leaf shape is narrowly elliptic: base tapered, margin smooth and wavy initially greenish eventually reddish, tip can be tapered differently either to a short point or to a long point or tapered asymmetrically but always pointy (see ***Figure 24, B1-B3***).

Second leaf pair: same description as the first leaf pair except length 8.1-9.3 cm, width 2.7-3.4 cm, petiole 0.8-1.2 cm leaves, placed crosswise with previous leaf pair.
Additional information: the plant is a climber, the older plant has very dark green leaves (upper surface, lower surface still pale green).

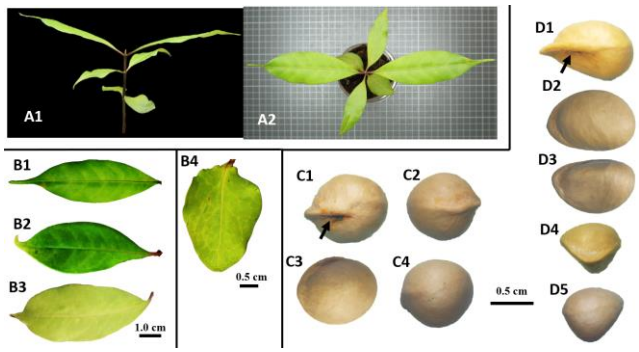

Figure 24. Bird's beak, an unknown climber (perhaps Celastraceae). ***A-B*** are pictures of the seedling and its parts while ***C-D*** are examples of the seeds. ***A1***: side view of the seedling, ***A2***: top view. ***B1***, ***B2*** and ***B3***: different shapes and colours of the leaves but venation pattern is always similar. ***B4***: the cotyledon showing its venation and shape. ***C1*** and ***D1***: base view of the seeds showing the funicle remains (arrowed) and their respective ridges. ***C2*** is the tip view (no funicle). ***C3***, ***D2*** and ***D3*** are the top-bottom view of the seeds. ***C4***, ***D4*** and ***D5*** are the side view of the seeds.

Golden hair (see ***Figure 25***)
Seed: length 1.1-1.5 cm, width 0.7-0.9 cm, height 0.7-0.9 cm, light brown to brown, egg-shaped to elongated egg-shaped, widest near the base, tapered near the tip, tip pointy; hair golden, shiny, appressed, extending from base to tip; there are grooves extending from base to tip, grooves are easier to spot near the base.
Cotyledons: not observed due to hypogeal germination.
First true leaf: opposite, length 4.6-6.4 cm, width 1.3-1.6 cm, hairless, surface smooth, initially greenish brown but eventually green, upper surface greener than lower surface. Venation pinnate, visible up to tertiary veins, secondary veins looping rectangularly, tertiary veins net-like. Overall shape is asymmetrical elongated egg shape: base tapered and asymmetrical to symmetrical, margin entire, tip tapered and pointy. The leaf blade is also slightly curved. Petiole length 0.3-0.5 cm, brownish to reddish; gland absent; stipule encircling stem (see ***Figure 25***).
Second leaf pair: same as first leaf except leaf length 4.5-11.5 cm, width 0.8-2.1 cm; petiole length 0.4-0.5 cm; crosswise with previous leaves; the shape is more elongated.
Additional notes: hard to germinate, took at least 6 months.

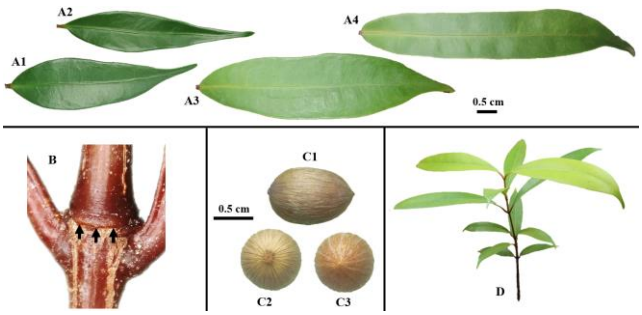

Figure 25. Golden Hair. ***A1-A3*** are different shapes of the first and second true leaf while ***A4*** is the shape that was seen only in second true leaf. ***B***: the arrow indicates the stipule that is encircling the stem. ***C1***, ***C2*** and ***C3*** are the seed viewed from the side, the base and the tip respectively. ***D*** is an example of the seedling at 6th leaf stage viewed from the side.

4. Conclusion

There are still many more species to be documented not just in UBD but also in Brunei Darussalam regarding fruits, seeds and seedlings. While morphological and pictorial data of mature plants are ubiquitous, relative to fruits, seeds, and seedlings, they are still lacking especially from Brunei. It is hoped that this study will serve as a backbone for future studies involving the documentation of fruits, seeds and seedlings of various plant species in Brunei Darussalam.

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