HOW NOT TO OVERWATER A RHEOPHYTE: SUCCESSFUL CULTIVATION OF 'DIFFICULT' TROPICAL RAINFOREST PLANTS USING INORGANIC COMPOST MEDIA

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ABSTRACT

Many herbaceous plants native to Malesian perhumid tropical forests are difficult to cultivate long term in traditional (peat, coir and bark) compost mixes. As a result, many appear to be under-represented in *ex situ* living plant collections. Under the leaf-litter, lowland rainforest soils are typically surprisingly low in organic content (< 2%) and many of the smaller forest-floor-dwelling plants exist mainly on steep slopes of bare mineral soils with limited leaf-litter cover. By adopting purely inorganic compost media and placing pots in trays of water the wet mineral soils of their natural habitats are replicated and the plants can be cultivated long term with notable ease. The use of wholly inorganic media reduces the incidence of root rot to such an extent that it is suggested that they should be used more often for the cultivation of slow-growing taxa from other regions which are often considered to be 'difficult'.

INTRODUCTION

In 2013, several plant taxa were collected under licence from forest reserves in Brunei Darussalam, northern Borneo, for growth under controlled conditions in order to fulfil one of the aims of an ongoing research project. The plants were small, forest-floor-dwelling herbs which grew in the deep shade of permanently wet primary rainforest and all were taxa which can exhibit blue-leaf iridescence.

The trip was organised because the ground flora of the lowland forests of the Malesian region (from Peninsular Malaysia and Sumatra, east to New Guinea and north to the Philippines) is not well represented in living collections in botanic gardens. A search of the Botanic Gardens Conservation International (2017) plant database of 1,145 participating institutions reveals a surprisingly tiny number of some of the region's most interesting and spectacular lowland understorey plants in cultivation. Only five botanic gardens grow the spectacular *Alocasia robusta* with one of the largest undivided leaf blades in the world. Only six grow the spectacular and rare small Bornean understorey palm *Licuala cordata* with its perfectly circular glossy leaves. Just three have *Pinanga veitchii*, another very desirable small palm from the region. Three list *Mapania caudata*

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– a sedge with beautiful iridescent blue leaves – and the same number grow *Phyllagathis rotundifolia*, a common understorey herb in Peninsular Malaysia with large and particularly attractive iridescent blue leaves: see Fig. 1 for examples. In addition, only three botanic gardens grow any *Argostemma* species; these are attractive and relatively common elements in the regional flora. This is clearly a truncated and horticulturally biased list but represents a few of the most spectacular and interesting lowland plants of one of the most species-rich areas of the world, which will inevitably have been collected and introduced into cultivation many times and lost. The loss of plant material from botanic garden collections is very much normal (Cronk, 2001) but the lack of understorey plants from the wet Malesian lowlands in cultivation is noticeable, particularly when so many of these taxa are potential 'charismatic' species whose inclusion in living collections could significantly enhance interest for the visiting public. Indeed, the successful cultivation of potentially iconic plants such as *Alocasia robusta* under well-controlled conditions (a mineral substrate and absolutely no root disturbance (Boyce, 2009)) might even draw crowds in the manner of *Amorphophallus titanum* if record-breaking leaves can be grown. Alas, the true species is barely known in cultivation.

The background of the senior author (Clive Lundquist) in botanic garden horticulture has provided insight into the factor that shortens the life of plants in nurseries, namely overwatering. Overwatering plants from such permanently inundated habitats, including rheophytes (which can be defined as aquatic to semi-aquatic plants that grow in fast-flowing water (van Steenis, 1981)), can only make sense when it is understood that the plants are not being grown in the most appropriate growing medium. Clearly the plant is tolerant of permanent wetness; it is the compost that kills the plant if *it* remains too wet.

Not all rainforests are as wet as the Malesian forests, which are described as perhumid (ever-wet), with little seasonality in this regard (New *et al*., 2002). Consequently, many of its understorey plants have very high water needs – higher than plants from many other tropical forests, but given the necessary frequent watering even very open compost mixes cause root rot. Subsequent plant decline or death is common. To illustrate the point, the rheophytic aroid genus *Bucephalandra* has been described as intolerant of standing in water in cultivation (when grown in a mix of coarse bark, grit, clay pebbles and coir pieces) despite the constant presence of water in its natural habitat, as 'swift deterioration of the plant' will result (Boyce, 1995).

INORGANIC SOLUTIONS

Plants of this genus grown in the author's research collection have their roots in a range of purely inorganic media sitting in water permanently, and they thrive (Fig. 2). The solution is in the compost.

The main issue here is that horticulturists are trained to believe that the lifeblood of any soil is its organic component. For temperate soils it provides a suite of extremely desirable characteristics – increased water holding, cation exchange capacity plus

Fig. 1 Potentially exciting species for cultivation in botanic gardens worldwide that are constrained by being ‘difficult’ in conventional composts. (a) *Alocasia robusta*, an old plant growing at the Kuala Belalong Field Studies Centre, Brunei. Younger specimens can have leaf blades of over 2.75m^2, but are almost never seen in cultivation. Success has been achieved with inorganic compost media. (b) *Licuala orbicularis* at Kubah National Park, Sarawak, is more common than its close relative *L. cordata* but still very rare in cultivation due to the high mortality rates of these slow-growing plants in conventional composts. (c) *Pinanga veitchii* is rarely cultivated despite its extraordinary brown camouflaged leaves. Success has been achieved by growing it in granitic (lime-free) sand and in deep shade. This wild plant is at the Kuala Belalong Field Studies Centre, Brunei. (d) *Phyllagathis rotundifolia* is an iridescent taxon from Peninsular Malaysia and Sumatra which goes blue in cultivation rather easily and should be grown more often. Inorganic compost media allow it to be watered frequently enough to keep it in good health without rotting the roots. This plant is in a rockwool and horticultural foam mix. Photos: Clive Lundquist.

Fig. 2 Plants in the wild (left) and the same species growing in various inorganic media in cultivation (right). (a) *Antrophyum callifolium*, (b) *Cyclopeltis crenata*, (c) *Lindsaea borneensis*, (d) *Lindsaea doryphora*, (e) *Begonia cyanescens*, (f) *Bucephalandra* sp., (g) *Mapania caudata.* Note the visible clay under thin leaf litter with no humic horizon in (b), (d), (e) & (g). Plants have been regularly pruned to keep them small enough to accommodate in a near-closed plastic container, as well as being experimentally subjected to extended periods of near-fatally low light levels, hence the constrained growth and reduced sizes for many taxa. Photos: Clive Lundquist.

Fig. 2 (*continued*)

the ability to aggregate soil particles to improve drainage, regardless of soil type (Adams *et al.*, 2005). In addition, small pot plants are typically grown in media largely comprising lightweight organic material such as coir, peat and milled or composted bark. This is often because it is considered to be the best medium available, although cheap freight and ease of handling are perhaps of equal importance for the horticulture industry.

It is widely known that these principles crumble when applied to plants of different climates; organic-rich mixes are unsuitable for plants from arid and alpine regions as they hold too much moisture. What is less well understood is that they are also not suitable for plants from permanently very wet lowland forests which are not adapted to soils with a high organic component. In these very warm and wet and conditions fallen leaves quickly decompose on the soil surface leaving the soil very largely mineral (Ashton, 2014). On initial excursions to Malaysia the author was quite confounded to see rainforest plants growing luxuriantly in what appeared to be appalling soils – near pure clay or sand in different sites across the country – a far cry from the rich, dark, crumbly medium found in many temperate forests. Astonishingly, underneath the leaf-litter-rich top few centimetres, measured organic components of lowland tropical soils of perhumid regions (not including poorly drained or podsolised soils) are generally less than 2 per cent (Kalpagé, 1976; Mohr, 1930; Sanchez & Logan, 1992), decreasing with higher rainfall (Kalpagé, 1976). Baillie (1984) reports a higher 2.4 per cent organic matter for one site in Sarawak but this may be due to recent logging. Since much of the diversity of the smaller understorey plants is found on mineral soil slopes where potentially smothering fallen leaves cannot accumulate (Fig. 2), levels of organic matter in their root zone will be even lower than those stated above.

The majority of compost mixes for tropical plants in botanic gardens are heavily based on organic ingredients. This spells trouble for many plants when overwatered, even when the mix is free-draining. Careful watering pays dividends for many taxa but this is very difficult to ensure in the long term with the inevitable transient staffing common in botanic institutions. It is also clearly inappropriate for many Malesian understorey plants which in nature rarely even approach dryness and can suffer with this treatment. Clearly the plant itself is well adapted to daily watering as it would frequently receive in nature so, taken in isolation, it is clearly the compost that gets overwatered and not the plant. The standard practice of allowing composts to dry out between waterings can be seen as a way of circumventing the shortcomings of the compost and does not benefit plants of permanently inundated habitats. Since overwatering has always been and will always be a major issue in nurseries it would seem prudent to change the compost ingredients.

The author has found that the plants can be retained in the same entirely inorganic medium for many years and can be kept wet – very wet, in fact. The collection sits permanently in approximately 2cm of water (this is termed 'passive hydroponics' or 'semi-hydroponics') as well as being watered and fed from above three times a week. The plants are kept rather crowded to shade the water tray so that algae are not a problem. The forest floor component of the Malesian flora is not well adapted to the periodic droughts necessary to keep organic composts from causing problems and they thrive when permanently wet, as in their natural habitat. For some taxa even slight dryness at the root can have disastrous consequences. Two taxa have so far been lost due to momentary dryness, but none has been lost to overwatering in several years, even when grown in near-closed plastic containers with little air movement. With no organic component to go stale there is no chance of overwatering the compost, and the cultivation of previously difficult plants, such as the 'extremely difficult to maintain' fern genus *Lindsaea* (Walters, 1986), becomes very easy. The aroid *Amorphophallus pendulus*, also 'difficult in cultivation' (Hettersheid & Ittenbach, 1996), is also very easy to grow in wet perlite or in sand (pers. obs., C. Claudel, pers. comm.). The collection includes many plants of the Malesian forest floor region for which inorganic wet media, low light and very stable temperatures (25–27°C day, 20–22°C night) ensure long-term survival. Plants are grown in a propagator with artificial lighting for ease of performing repeatable growth experiments but otherwise this is not necessary. Genera include *Selaginella*, *Bolbitis*, *Cyclopeltis*, *Diplazium*, *Lindsaea*, *Mapania*, *Bucephalandra*, *Schismatoglottis*, *Begonia* and *Phyllagathis* as well as plants that grow so slowly that they are better grown in these media to minimise chances of irrecoverable root rot, such as epiphytic *Antrophyum* spp. The plants grow very well (Fig. 2).

It must be noted that several of the larger and more spectacular understorey plants of the region are relatively common in botanic institutions and are typically grown in organic-rich composts, especially *Amorphophallus titanum* and several *Alocasia* spp. In most cases these plants are cultivated with a regime in which the composts are partially dried out between waterings, which is unsuitable for many taxa of the region, and/or changed annually, which is quite an undertaking for some species such as the huge *Amorphophallus*. It is also worth noting that the above plants have storage organs by which they can often be saved following collapse from overwatering. In addition, the *Amorphophallus* is not strictly a lowland plant, being found at up to 1,200m a.s.l. (Hettersheid, 1998). At altitudes over 600m organic matter accumulates more readily due to slower breakdown at cooler temperatures (Ashton, 2014; Potts *et al*., 2002) so this taxon should be more resistant to organic matter. However, it is our belief that, where practical, a great many plants from the hyperhumid lowlands could have their long-term survival greatly improved by the use of inorganic composts.

INORGANIC COMPOST MEDIA

This article is primarily intended to highlight the applicability of passive hydroponics as an asset to the maintenance of living collections rather than a practical guide, as much information is available online (First Rays LLC, n.d.). As such, the following is very much an outline.

The ultimate aim of inorganic media is to provide stability and give the roots somewhere to grow – the plants derive no significant nutrients from the medium itself. For this reason it can be seen that the nature of the medium is not necessarily important assuming that it has some wicking properties and the plants are regularly fertilised. Sand, gravel, various expanded clay products, perlite, pumice, rock-wool with horticultural foam and even rocks have been used (Kurth, 2016). The most important factors are safety (dust from dry perlite and rock-wool is hazardous to human health), weight and the size of the individual particles compared to the roots. It is also worth bearing in mind that clay-based products can be expected to have a higher cation exchange capacity and therefore may confer an advantage if separate feeding and watering days are to be implemented. Perlite is predominantly used for the collection although several media have been trialled to equally good effect. Most media can be reused which may save money in the long term (e.g. Hanna, 2005).

IRRIGATION AND FERTILISER

It is sensible to irrigate from above at least every other day to prevent salt build-up at the surface through evaporation (pers. obs.). Plants cannot be overwatered when grown in these substrates.

The requirement of rainforest plants for a low-salt solution dictates that reverse osmosis, distilled or deionised water must be used. Fertilising needs to be done extremely weakly and therefore regularly for good growth. Since inorganic media provide no nutrition the fertiliser needs to be balanced and complete with trace elements. The author currently uses the low-phosphate 'Rain Mix' orchid fertiliser from Akerne Orchids (based on the MSU formulation) although standard formulations such as diluted Miracle-Gro® Water Soluble Azalea, Camellia, Rhododendron Plant Food have worked well. Nitrates are the recommended main source of nitrogen as other forms may need to be broken down by micro-organisms (Matteson *et al.*, 2009) which will be much reduced or lacking in these media. Feeding with every watering makes sense for plants grown in media with little cation exchange capacity. The media outlined here are generally pH neutral, although some may change in this regard over time (Albiflora, 2017). This does not appear to be a problem for any taxa grown here, despite Malaysian rainforest soils being around pH 4.2–4.8 (Cranbrook, 1988).

ADVANTAGES AND DISADVANTAGES OF USING INORGANIC MEDIA

The main advantage of inorganic media is chiefly that the plants cannot be overwatered – which is the major cause of plant death. There is no need to change the compost because it does not biodegrade as organic-based composts do, and fungus gnats are eliminated because they cannot survive in the inorganic substrate. The plants also have a reduced need for humidity as they have such ready access to water. The disadvantages are chiefly the initial cost of the media, its potentially large carbon footprint and the difficulty of disposal if not reused. Recent innovations using recycled glass as a substrate may well be the way forward. Good-quality water must also be used, for example reverse osmosis water, to avoid calcium precipitation on the surfaces. Plants also need very regular (and very weak) fertiliser. This latter point need not be seen as a disadvantage as the plants can be 'blanket watered' in these composts, saving much time.

WIDER CONSIDERATIONS

There is an increasing trend towards the use of pure (or predominantly) inorganic media to increase the health of several plant groups – notably expensive, rare or long-lived groups such as bonsai and hardy orchids. The health benefits are due to the ability to water more freely together with increased oxygen levels at the roots and greatly reduced incidences of root rot. Ingredients in modern composts for the hardy orchid genus *Cypripedium* are increasingly mainly inorganic; entirely inorganic composts have been suggested as a way for a beginner to try 'difficult' species (Cribb, 1997). The speed of growth of other cold-climate subjects such as *Fritillaria* has been demonstrated to increase significantly by using inorganic media (Cumbleton, 2009) though a water tray is not used for such species from drier climates. Taxa such as *Disa* orchids which dislike salts in the media can be grown in pure washed quartz sand; less stable media apparently cause problems for those with extremely salt-sensitive roots (Albiflora, 2017).

While this paper has focused on the cultivation of plants from the Malesian lowlands, this method of cultivation also works extremely well for plants from the Malesian highlands and permanently wet habitats worldwide including UK natives such as the filmy fern *Trichomanes speciosum* (Fig. 3a). There is no reason to think that this method would not work for difficult plants of seasonally dry habitats by removing the pot from the water tray below to create an appropriate dry season. One fern native to neotropical ridge-top and white-sand forests, the Peruvian *Elaphoglossum metallicum*, did not respond particularly well to it; the need for the densely scaly crown to dry out regularly appeared to be important for this species. Conversely, another fern (*Microsorum thailandicum*) from seasonally dry limestone hills in southern Thailand is very happy in permanently wet clay pebbles (Fig. 3b), so it seems there is much to be discovered.

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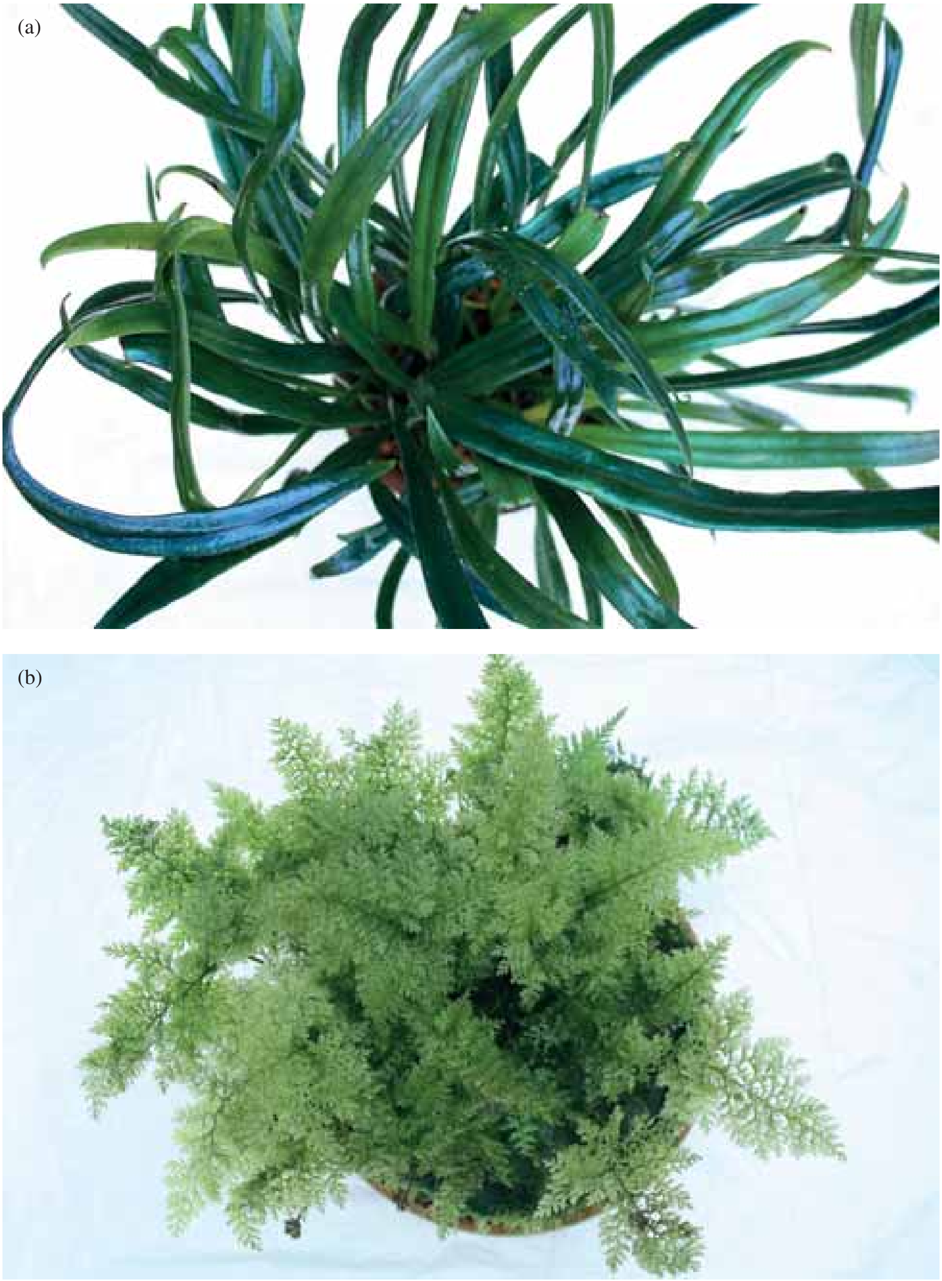

Fig. 3 Plants of different habitats which take well to inorganic wet media. (a) *Microsorum thailandicum* from limestone outcrops in southern Thailand growing in expanded clay granules but in different environmental conditions from the Malesian plants in Fig. 2. (b) *Trichomanes speciosum*, a UK native species grown in perlite in a near-closed case outdoors in the UK in full shade. Photos: Clive Lundquist.

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