MEDIA RELEASE

Evolution and speciation[1] patterns of the world's largest tree genus *Syzygium* *identified after a two-year study involving over 60 local and international collaborators*

- *Understanding the origin and relationships within this diverse tree genus will guide conservation and management efforts of the region's rain forests*

London, United Kingdom, 12 September 2022 - A study has confirmed the evolutionary relationships and speciation patterns of the world's largest tree genus *Syzygium.* Native and widespread in tropical and subtropical rain forests, studying the origins and drivers of this hyperdiverse woody tree genus contributes to understanding of how plant species have emerged in the past in response to environmental changes. This knowledge, in turn, is valuable for predicting how plants might respond to environmental changes brought forth by climate change and thus guide conservation and management efforts for plant communities.

This study, published online in the journal Nature Communications[2] on 12 September 2022, was led by the Singapore Botanic Gardens of Singapore's National Parks Board (NParks) in collaboration with 26 local and international research institutions including Nanyang Technological University in Singapore, the Royal Botanic Gardens, Kew in the United Kingdom, the University of Aberdeen in the United Kingdom and the University at Buffalo in the United States of America.

For more information on the Singapore Botanic Gardens and its role in understanding plant diversity, please refer to Annex A.
For list of research institutions involved, please refer to Annex B.

The significance of *Syzygium*

Syzygium, also known as the clove genus, is a hyperdiverse tree genus with about 1,200 named species and many more new species yet to be formally described by botanists. Among forest trees, *Syzygium* is one of the most important species-rich genera, and its diversity is

[1] A slow and gradual process in which a new plant or animal species is formed.
[2] Article title: Genomic insights into rapid speciation within the world's largest tree genus *Syzygium* https://www.nature.com/articles/s41467-022-32637-x DOI: 10.1038/s41467-022-32637-x

highest in the Southeast Asian forests. For example, *Syzygium* is the most diverse tree genus in Singapore, with 54 species recorded from a variety of habitats and found mainly in nature reserves.

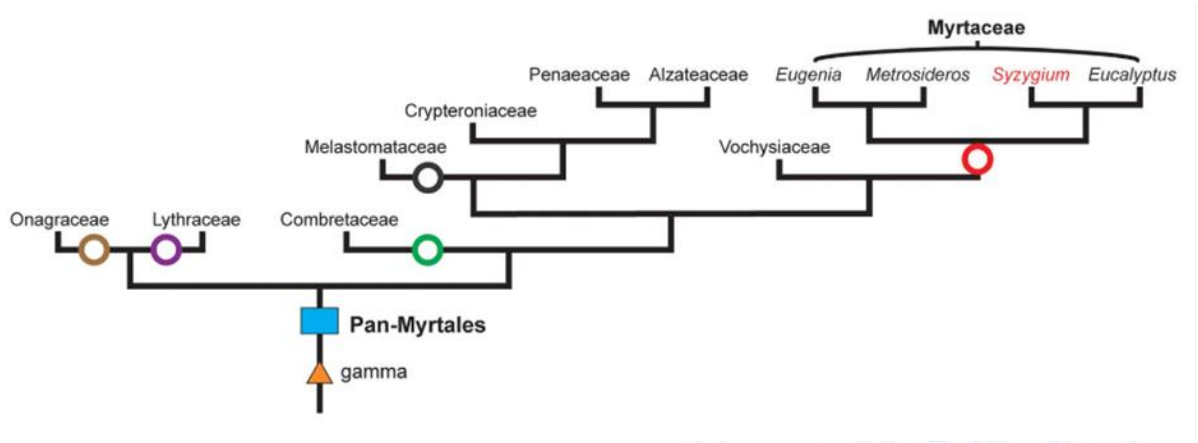
Syzygium species may be found growing together with other trees within the understorey and canopy layers of forests. Because of its large diversity, they play an inordinate role in the functioning of forest ecosystems. Many *Syzygium* species are also cultivated in tropical countries for their large edible fruits (Water Apple [*Syzygium aqueum*], Java Plum [*S. cumini*], Rose Apple [*S. jambos*], Malay Apple [*S. malaccense*] and Java Apple [*S. samarangense*]) and spices (clove [*Syzygium aromaticum*] and Indonesian bay leaf [*Syzygium polyanthum*]). Understanding how *Syzygium* species have evolved will help to advance our knowledge of the highly complex species-environment relationships in forest ecosystems and anticipate forest ecosystem changes under the impacts of climate change. This study has made two key discoveries that contribute to this.

(1) <u>*Syzygium* genome reveals a single 'pan-Myrtales' event for the order</u>

The study compared the genome of the Sea Apple (*Syzygium grande*) to other species of its plant order, Myrtales, and discovered that all Myrtales (comprising nine families, approximately 400 genera and around 14000 known species) share a single whole genome duplication (WGD) event[3]. This overturns the results of an earlier study in 2019 which had reported the involvement of multiple WGD events. This is a key discovery, as a single WGD will imply that there was a single, major environmental trigger in the past which led to the ancestor of all species in the Myrtales gaining multiple copies of the genome and passing this duplication down through the following generations. It is known that plants can contain several copies of their genome through WGD events. This can result in plants having advantages such as increased resistance to diseases and environmental stress. Scientists believe that WGD can also potentially lead to the formation of new species over time and WGD events are often associated with diversification in flowering plants, including in the Myrtales. Thus, the new discovery of a single WGD event in Myrtales helps scientists to better understand WGD events, a critical but poorly understood natural phenomenon. This, in turn, provides critical evidence

[3] Whole genome duplication (WGD) event - A process where an organism's entire genetic information is copied once or multiple times which can result in divergence and formation of new species over time.

for future studies on possible factors that might have triggered a single WGD, and how we might anticipate the consequences of climate change on species extinction and evolution.



Phylogeny of major lineages of Myrtales, depicting study findings of a single whole genome duplication event, named 'pan-Myrtales'

(2) Genomic analyses confirm the origin of *Syzygium* in Australia-New Guinea, later migrating westward to Southeast Asia multiple times

The study also confirmed that *Syzygium* species originated in Australia-New Guinea and later migrated eastward to the Pacific and westward to Southeast Asia before proceeding onward to India and Africa. The westward migration to Southeast Asia occurred multiple times. These repeated migrations to Southeast Asia correspond with many instances of geographic isolation of *Syzygium* populations. In turn, bursts of *Syzygium* speciation occurred, during which many new species were formed.

This helps us to understand the evolutionary history and complexity of *Syzygium* species, including why some can be distantly related yet morphologically[4] similar when comparing vegetative and floral features. For example, the previous understanding of the Sea Apple (*Syzygium grande*) is that it is one distinct species that can be found in a range of habitats in Southeast Asia, from lowland areas at sea level to the mountains. This assumption was made based on morphological characters and because these populations share similar leaf, fruit and

[4] morphologically – physically

flower characteristics. The study has now discovered that the lowland population occurring naturally in the coastal forests of Singapore is genetically distinct from the population occurring on Mount Kinabalu at 1700 m above sea level in Malaysia. It also found that these two lowland and highland populations descended from different lineages. Such discoveries are important in guiding our conservation efforts and ensuring that we do not lose our biodiversity.

Syzygium is one of the most difficult genera when it comes to distinguishing its species based on morphological characters. Using genomics tools, this study improves our ability to identify individual *Syzygium* species more accurately, thus allowing us to better assess and monitor their population sizes and extinction risk, as well as the factors that drive change in a region. This could enable a better understanding of how plant communities might respond to future climatic scenarios and predict resilience of plant populations in different areas. This is important to ensure that conservation and management efforts of our rain forests are effective in mitigating against the impacts of climate change.

This study's findings were made possible through sampling of nearly 300 *Syzygium* individuals, including species from Africa, Sri Lanka, Malaysia, Singapore, Indonesia, Japan, Australia and the Pacific Islands. To date, this is the most extensive sampling of the genus, involving over 60 researchers from various institutions. It took two years to complete.

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Highlights of *Syzygium* species sampled

Species	Description
 *Syzygium grande* (Sea Apple) Credit: W.H. Lim	A flowering branch of the Sea Apple, *Syzygium grande*, native to Singapore and occurs naturally in coastal forests. The Sea Apple was one of the pioneer selection of trees planted along roadsides when Singapore's Tree Planting campaign was initiated in 1963. Inset: Fruit of the Sea Apple ripens green and is dispersed by bats.
 *Syzygium aqueum* (Water Apple) Credit: Y.W. Low	Fruits of *Syzygium aqueum*, a tree species that occurs naturally in Southeast Asia and is sometimes cultivated for its large edible fruits.

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 *Syzygium buettnerianum* (New Guinea Satinash) Credit: Y.W. Low	Showy inflorescences of *Syzygium buettnerianum*, a tall rain forest tree encountered at the Cape York Peninsula (Queensland, Australia), that attracts various insect pollinators.
 *Syzygium adelphicum* Credit: Y.W. Low	Close-up of a small inflorescence of *Syzygium adelphicum*, a compact and attractive montane shrub endemic to New Guinea.

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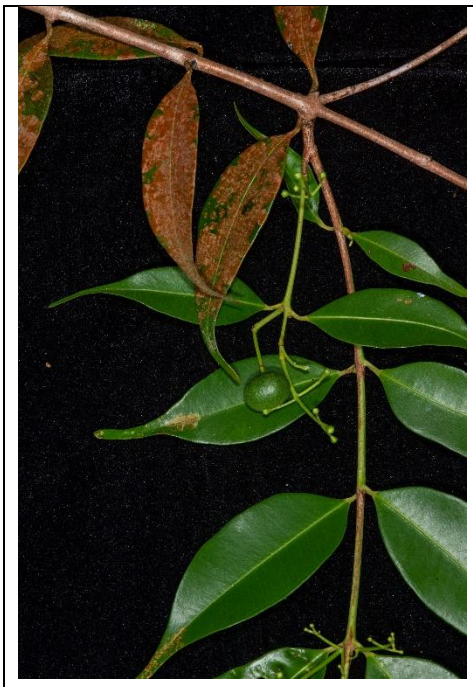 *Syzygium singaporense* Credit: Y.W. Low	Close-up of a flowering and fruiting branchlet of *Syzygium singaporense,* a species native to Singapore and Peninsular Malaysia. Flowers of this peculiar species are only 1mm wide and with 8 stamens; and mature fruit is up to 7mm wide. This species can be found in the Central Catchment Nature Reserve of Singapore.
 *Syzygium singaporense* Credit: Y.W. Low	Close-up of an open flower of *Syzygium singaporense*.

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 *Syzygium cormiflorum* (Bumpy Satinash) Credit: Andrew J. Ford	Trunk of *Syzygium cormiflorum*, a species native to Australia, bearing thousands of flower buds. The Southern Cassowary, a large flightless black rain forest bird native to New Guinea and northeastern Australia, as well as marsupials, feed on the fruits and flowers of this species.

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About Singapore Botanic Gardens (SBG)

Established in 1859, the Singapore Botanic Gardens played an important historical role in the introduction and promotion of many plants of economic value to Southeast Asia, including the Para rubber tree. Over the years, the Gardens has continued to introduce and rejuvenate its horticultural attractions while continuing its mission of connecting plants and people.

Today, the 82-hectare Gardens is a key civic and community space, and an international tourist destination. Attracting an annual visitorship of more than 5 million, it is also an important institution for tropical botanical and horticultural research, education and conservation.

The Gardens showcases the best and most spectacular of tropical flora, including more than 10,000 types of plants and the region's most significant living collection of documented palms, orchids, cycads and gingers. Its historic 19th century garden landscape is well preserved and includes the earliest ornamental designed lake in Singapore. Home to numerous heritage trees and a tract of primary rain forest, the Gardens is less than a 10-minute walk from the shopping belt in Orchard Road. The Gardens was inscribed as Singapore's first UNESCO World Heritage Site in 2015.

The Gardens was ranked the number one park in Asia in TripAdvisor's Travellers' Choice Awards for attractions in 2014. In 2012, it clinched the inaugural Garden of the Year Award by the Canadian Garden Tourism Council. In 2008, it was awarded the Michelin three-star rating and selected by Time Magazine as Asia's Best Urban Jungle.

The Singapore Botanic Gardens is managed by the National Parks Board. For more information, visit www.sbg.org.sg and www.facebook.com/singaporebotanicgardens.

About National Parks Board (NParks)

The National Parks Board (NParks) is responsible for enhancing and managing the urban ecosystems of our City in Nature. We are the lead agency for greenery, biodiversity conservation, and wildlife and animal health, welfare and management. We are also working closely with the community to enhance the quality of our living environment.

NParks manages some 400 parks, 3,347 hectares of nature reserves, the Singapore Botanic Gardens, Pulau Ubin and the Sisters' Islands Marine Park. Adding to this is the extensive

network of Nature Ways, and the over 300 km Park Connector Network that links major parks, nature areas and residential estates island-wide. Every year, we run over 3,500 educational and outreach programmes across our various green spaces.

NParks has developed an urban biodiversity conservation model, which aims to conserve representative ecosystems in land-scarce Singapore. NParks also monitors and coordinates measures to enhance the presence of biodiversity in our urban landscape.

NParks is working closely with partners in the landscape, horticulture, veterinary and animal sectors to increase productivity, and provide training for all levels of the workforce. Enhancing competencies of the industry will support Singapore's vision of being a City in Nature.

For more information, visit www.nparks.gov.sg and www.facebook.com/nparksbuzz

About Nanyang Technological University, Singapore

A research-intensive public university, Nanyang Technological University, Singapore (NTU Singapore) has 33,000 undergraduate and postgraduate students in the Engineering, Business, Science, Humanities, Arts, & Social Sciences, and Graduate colleges. It also has a medical school, the Lee Kong Chian School of Medicine, set up jointly with Imperial College London.

NTU is also home to world-class autonomous institutes – the National Institute of Education, S Rajaratnam School of International Studies, Earth Observatory of Singapore, and Singapore Centre for Environmental Life Sciences Engineering – and various leading research centres such as the Nanyang Environment & Water Research Institute (NEWRI) and Energy Research Institute @ NTU (ERI@N).

Ranked amongst the world's top universities by QS, NTU has also been named the world's top young university for the past seven years. The University's main campus is frequently listed among the Top 15 most beautiful university campuses in the world, and it has 57 Green Mark-certified (equivalent to LEED-certified) building projects, of which 95% are certified

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Green Mark Platinum. Apart from its main campus, NTU also has a campus in Singapore's healthcare district.

Under the NTU Smart Campus vision, the University harnesses the power of digital technology and tech-enabled solutions to support better learning and living experiences, the discovery of new knowledge, and the sustainability of resources.

For more information, visit www.ntu.edu.sg

About Kew Science

Kew Science is the driving force behind Royal Botanic Gardens, Kew's mission to understand and protect plants and fungi, for the well-being of people and the future of all life on Earth. Over 300 Kew scientists work with partners in more than 100 countries worldwide to halt biodiversity loss, uncover secrets of the natural world, and to conserve and restore the extraordinary diversity of plants and fungi. Kew's *Science Strategy 2021–2025* lays out five scientific priorities to aid these goals: research into the protection of biodiversity through **Ecosystem Stewardship**, understanding the variety and evolution of traits in plants and fungi through **Trait Diversity and Function**; digitising and sharing tools to analyse Kew's scientific collections through **Digital Revolution**; using new technologies to speed up the naming and characterisation of plants through **Accelerated Taxonomy**; and cultivating new scientific and commercial partnerships in the UK and globally through **Enhanced Partnerships**. One of Kew's greatest international collaborations is the Millennium Seed Bank Partnership, which has to date stored more than 2.4 billion seeds of over 40,000 wild species of plants across the globe. In 2020, Kew scientists estimated in the *State of the World's Plants and Fungi* report that 2 in 5 plants globally are threatened with extinction.

About the University of Aberdeen

Established in 1495, the University of Aberdeen is the fifth oldest in the UK and is ranked within the Top 20 universities in the UK in both the 2022 Times and Sunday Times Good University Guide and the 2022 Guardian University Guide. It was ranked 158th in the world in the 2022 THE World University Rankings.

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The University is renowned for its world-leading research in health, energy, food and nutrition and environmental and biological sciences. The University also has an outstanding track-record for arts and humanities research.

With a community of students and staff encompassing 130 nationalities, the University of Aberdeen has a global outlook and reach.

About the University at Buffalo

The University at Buffalo is a premier, research-intensive public university, and it is a flagship institution of the State University of New York. UB's more than 32,000 students pursue their academic interests through more than 500 undergraduate, graduate and professional degree programs. Founded in 1846, the University at Buffalo is a member of the Association of American Universities, which is composed of America's leading research universities. AAU's 65 research universities transform lives through education, research and innovation.

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Annex A

Singapore Botanic Gardens' role in understanding plant diversity

The Singapore Botanic Gardens has played an important role in the documentation of plant diversity in Singapore and the region since its founding in 1859. Today, as a leading tropical botanical institute for plant science and conservation, the Gardens' roles in research and raising awareness on plants and nature also strengthen its Outstanding Universal Value as a World Heritage Site. This includes finding, cataloguing and describing plant diversity; understanding what plants there are and where they occur; as well as understanding changes in plant diversity over time through taxonomic research and in-depth surveys.

In addition to conducting research on plant diversity, the facilities of the Singapore Botanic Gardens strengthen its role in safeguarding Southeast Asia's flora in other ways.

- The Herbarium safeguards our natural heritage by documenting and preserving a valuable record of Singapore and the wider region's flora. This includes a collection of about 750,000 herbarium specimens, as well as a supporting spirit collection, going as far back as the 1790s but beginning in earnest from the 1880s.
- The Seed Bank enables the long-term conservation of the region's plant genetic diversity, with its capacity to store the seeds of 25,000 species, approximately half the total number of plant species in the region. It also supports vital research into the optimisation of storage methods for these seeds.
- The Micropropagation Laboratory enables the conservation of plant diversity by propagation of seed and tissue resources of extremely rare native plant species from Singapore. Similar techniques are also used for seed germination and cloning of novel orchid hybrids and other ornamental and horticulturally important cultivars.

These efforts of the Singapore Botanic Gardens will help to achieve a more ecological and climate resilient Singapore, as part of the City in Nature vision, one of the key pillars of the Singapore Green Plan.

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Annex B

List of Research Institutions:

1. National Parks Board, Singapore (Singapore Botanic Gardens and Conservation Divisions)
2. Nanyang Technological University, Singapore
3. Royal Botanic Gardens, Kew, UK
4. University of Aberdeen, UK
5. University at Buffalo, US
6. Salk Institute for Biological Studies, US
7. New York Botanical Garden, US
8. Australian Tropical Herbarium, Australia
9. Brisbane Botanic Gardens, Australia
10. Northern Territory Herbarium, Australia
11. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
12. Brunei Forestry Department, Brunei Darussalam
13. Universiti Brunei Darussalam, Brunei Darussalam
14. Herbarium Bogoriense, Indonesia
15. Universitas Papua, Indonesia
16. Kebun Raya Bogor, Indonesia
17. BALITBANGDA Papua Barat, Indonesia
18. Universitas Samudra, Indonesia
19. Universitas Jenderal Soedirman, Indonesia
20. University of the Ryukyus, Japan
21. Universiti Malaysia Sabah, Malaysia
22. Sabah Parks, Malaysia
23. Universiti Malaya, Malaysia
24. Universiti Tun Hussein Onn Malaysia, Malaysia
25. University of Colombo, Sri Lanka
26. National Herbarium of Sri Lanka, Sri Lanka
27. National Institute of Fundamental Studies, Sri Lanka