A charity fostering scientific research into the biology and cultivation of the Australian flora

Research Matters

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President’s Report 2020

Delivered by Assoc. Prof. Charles Morris at the AGM, November 2020

This year has been different for all of us because of the pandemic; the main effect on the Foundation’s operations has been that Council meetings have shifted online. This has worked well and will most likely be maintained into the future. One side benefit of online meetings is that it makes participation in Council meetings possible at a national level. The Foundation was established in 1981, based in NSW, and this had continued until now. But with online Council meetings, anyone from anywhere in the country can participate.

Next year will see large changes to the Foundation, as it receives the bequest from former President Malcolm Reed. The funds available for research will increase approximately four-fold, and this will enable changes to the granting scheme. Council is considering options for the expanded research budget at this November meeting. One consequence of an expanded research budget will be an increase in the number of grant applications, and this will have implications for the workload on the Scientific Committee (who peer-review the applications). If members would like to contribute to the work of the Foundation, either on Council or on the Scientific Committee, enquiries will be warmly welcomed. Next year (2021) will be the 40th year of the Foundation’s operation, and the current position of the Foundation and the expansion next year fully justifies the foresight of the Founders in establishing it.

For the round of Grants commencing in 2021, the successful applicants were Miriam Muñoz-Rojas (University of New South Wales), working on native microbes for restoration of threatened ecological communities; David Watson (Charles Sturt University) working on the status of Australian Sandalwood populations; Diego Guevara (University of Adelaide) working on soil microbial populations and restoration in South Australia; Chris O’Brien working on cryobiotechnology methods for conserving the endangered Sweet Myrtle; and Thomas Le Breton (University of New South Wales) working on the link between fire season and post-dispersal predation of serotinous seeds.

Final Reports for earlier grants received in 2020 were from: Edward Tsen (2013); Marco Duretto (awarded to Nathalie Nagalingun) 2014; Susanne Schmidt (2014); Geoff Burrows (2016); Ed Biffin (2017); and Laura Skates (2017).

Thanks are also due to the hard working members of Council who keep the granting program and administration of the Foundation going. Ian Cox is a capable and competent Secretary; Peter Goodwin runs the administration for the granting program; Michelle Leishman heads the Scientific Committee, Tina Bell organises the excellent Newsletter, and Jennifer Firn oversees the Foundation’s web page. Thanks are due to Council members, ordinary members and our donors, all of whom allow the Foundation to function and support plant research.

E. Charles Morris
President
20 November 2020

AFF Grants Awarded

Five grants were awarded for research to begin in December 2020:

The effects of soil microbial community on grassland restoration techniques in South Australian Mediterranean-type climate region

Diego Guevara, University of Adelaide

Soil biota can strongly affect the establishment, diversity and successional replacement of plant species, influencing terrestrial ecosystems. Thus, soil biota is key for the re-establishment of native vegetation communities. In South Australia, the restoration of tussock grasslands represents a challenge, especially in former croplands. Glasshouse experiments have shown promising results for soil microbial inoculation. This 1-year project aims to better understand how soil biota can help to overcome soil legacies and invasive species in former croplands. Soil inoculum from two origins (remnant native grasslands and former croplands) combined with topsoil removal (a restoration technique that removes soil biota along with other legacies that exists in the topsoil layer) will be used. The results from this project will improve our understanding of the soil microbiota in grasslands of South Australia and the world.

Effect of fire seasonality on post-dispersal seed predation of serotinous seeds

Tom Le Breton, University of New South Wales

Serotinous species, such as *Banksia*, which retain their seeds in the canopy and release them after fires, may be sensitive to the timing of fires if they result in seeds being released during unfavourable conditions for germination. Seeds released too early are exposed to seed predators for longer periods of time as they wait for the next germination season. Fires at different times of year may therefore lead to reduced recruitment success and have long term impacts on species populations and demographics. For species which rely on canopy-stored seed bank for post-fire regeneration, failure to recruit from released seeds can result in the local extinction of populations.

Fire seasons are changing globally and conflicts with timing of life-history stages of plants may increase extinction risk. To conserve plant species, it is crucial to understand the threats that they face, however, our understanding of how fire regimes threaten species has largely been limited to fire frequency, while fire seasonality is comparatively understudied. Increased exposure to post-dispersal seed predation is one mechanism for this, with species likely at greater threat in more seasonal rainfall regions. This 1-year study will compare seasonal variance in levels of post-fire, post-dispersal seed predation for serotinous Proteaceae across seasonal and aseasonal rainfall regions. This will improve our understanding of how seed predation and fire/rainfall seasonality interact, the significance for serotinous Proteaceae, and how best to conserve the Proteaceae, one of Australia's most diverse and ecologically significant families.

Native microbes for promoting conservation and restoration of threatened ecological communities

Miriam Muñoz-Rojas, University of New South Wales

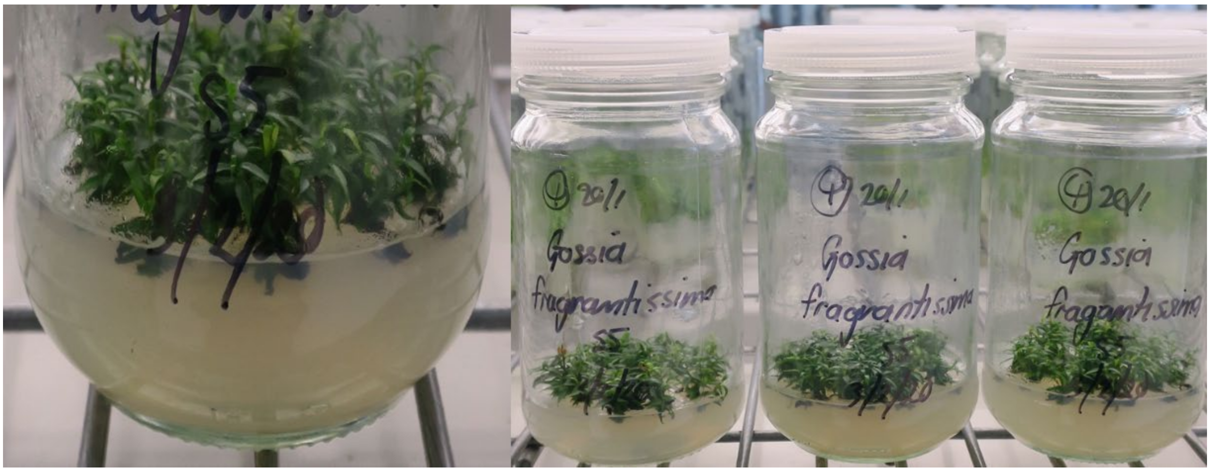
Current challenges in conservation and restoration programs are poor recruitment and establishment of threatened plants both *in*- and *ex-situ*. Finding innovative nature-based solutions for increasing the capacity of native plants to survive and grow after disturbance is key for the success of these programs. In this 1-year project, soil microbial communities and related functional properties linked to key plant communities in threatened ecosystems will be identified. From this information, targeted microbial-based bioinoculants for promoting germination and plant establishment will be developed. This project will use the threatened Brigalow bioregion as a study area, an ecological community that has undergone a severe decline.

Cryo-biotechnology for conservation of endangered Sweet Myrtle (*Gossia fragrantissima*)

Chris O'Brien, Queensland Alliance for Agriculture and Food Innovation and The University of Queensland

This 2-year project aims to develop cryopreservation techniques for germplasm conservation of *Gossia fragrantissima* (F.Muell. ex Benth) N.Snow & Guymer, a nationally endangered species which cannot be conserved as seed. *Gossia fragrantissima* (Sweet Myrtle or Small-leaved Myrtle), is a slow-growing dry sub-tropical and riverine rainforest tree. It is endemic to eastern Australia and occurs in restricted pockets of basalt-derived soils, with a few fragmented populations extending from north-eastern New South Wales to south-eastern Queensland. The natural habitat of this species has suffered significant loss due to land clearing for urbanisation and agriculture. As a member of the Myrtaceae, it is also threatened by the invasive myrtle rust, *Austropuccinia psidii*.

The proposed research has potential for translation to other endangered species of *Gossia* and addresses an urgent need for new conservation methods to focus on the impacts of climate change, land degradation and emerging diseases. The ultimate outcome of this research will be to support a National Conservation Plan for this endangered species through novel germplasm capture and cryobanking at the Australian PlantBank.



Left and right: Examples of tissue culture of *Gossia fragrantissima* (Sweet Myrtle). Photos courtesy of K Sommerville.

The status of populations of Australian Sandalwood (*Santalum spicatum*) in Australia's western rangelands

David Watson, Charles Sturt University

One of Australia's most iconic tree species – Australian Sandalwood (*Santalum spicatum*) – is slowly becoming extinct in the wild across its distributional range in Australia. Numerous studies have reported the decline of populations due primarily to a recruitment failure associated with a range of key threats. This 1-year study will measure the population structure, status, and threat intensity of 10 populations of Sandalwood at 10 different locations in a transect across Australia's western rangelands. Information gained from the sites, all with variations in tenure and land management history, will provide valuable information to guide land managers in the preservation and management of this species.

Young Scientist Awards

The Australian Flora Foundation awards prizes annually to encourage young scientists to continue studying the flora of Australia.

At the annual conference of the Ecological Society of Australia (ESA), held online in December 2020, the Foundation's prizes were presented to the following students.

Outstanding spoken presentation on the biology or cultivation of an Australian plant

Seed and soil microbiomes for natural ecosystem restoration
Allison Merton, Research Centre for Ecosystem Resilience, Royal Botanic Gardens and Domain Trust, Sydney, NSW; School of Biosciences, University of Melbourne, Victoria

Abstract: Microbes such as fungi and bacteria can be endophytes of seeds and are major functional players in the soil existing as free-living entities, as well as being associated with seed germination and plant root development. These microbial species play an important role in maintaining ecosystem function and resilience, although they are rarely integrated into ecosystem restoration projects. When microbial communities are utilised in restoration, often the aim is to restore the functioning of the soil microbial community using microbial inoculations or soil amendments at the restoration site. Sometimes the microbial community is used as an 'indicator' for measuring restoration success. These approaches have varying levels of success and do not take into consideration the interacting role that soil microbes, seed endophytes and seed exudates may play in regulating the microbiome of the developing plant. Here we present current knowledge of the field and suggest how understanding the diversity and interactions of both soil and seed microorganisms in natural ecosystems can be used to inform restoration practice. We also address how knowledge of the interactions between soil and seed microbiomes can be applied to managing and assessing the effectiveness of the restoration of natural ecosystems.

Allison is in the first year of her PhD jointly with the University of Melbourne and the Royal Botanic Gardens, Sydney. Throughout her PhD, Allison will use Next Generation Sequencing, microfluidics and greenhouse experiments to describe the hidden microbial diversity of native Australian plants from natural and restored ecosystems. She is interested in understanding whether microbes within the seed interact with soil microbiomes to influence the early microbiome of seedlings. She is particularly interested in applying this knowledge to improving the outcomes of restoration programmes.

Left: PhD student Allison Merton collecting *Themeda triandra* seed from Khancoban in December 2020 for her ongoing research. Photos courtesy of Allison Merton. Right: PhD student Ruby E Stephens at a site in the Grose Valley, Blue Mountains, looking at a *Xanthorrhoea* sp. flower while investigating possible sites for her upcoming floral traits fieldwork. Photo courtesy of Katy Wilkins.

Outstanding poster presentation on the biology or cultivation of an Australian plant

Functional biogeography of floral traits in Australian plant communities

Ruby E Stephens, Macquarie University, NSW; Royal Botanic Gardens and Domain Trust, Sydney, NSW

Abstract: Plant traits vary in predictable ways along environmental gradients. Floral traits, such as the size, shape or colour of flowers, affect plant reproductive success and the interaction of flowering plants with pollinators and floral visitors. Despite this, floral traits have rarely been considered in studies of traits' geographic distribution, or functional biogeography. Our project examines how floral traits vary across the Australian landscape by targeting two key floral traits: (i) duration of flowering; and (ii) flower symmetry. We combine plant composition and abundance data from 758 TERN AusPlots sites across Australia with data on species symmetry and flowering duration. We then assess whether environmental variables such as temperature, rainfall and soil impact the distribution of flowering duration or floral symmetry across Australia. We predict a relationship between site resource availability, which may affect the availability of pollinators in the landscape, and flowering duration. Further, we hypothesise a functional relationship between flowering duration and symmetry, whereby bilaterally symmetric flowers, which typically experience more efficient pollen transfer, may open for a shorter

duration than less specialised flowers. This project will be the first to examine the environmental drivers of floral traits at a community and continental scale and provide insights into patterns of flowering across the Australian landscape.

A range of flowers illustrating the wide variety of floral traits found across Australian plant species, including *Styphelia triflora* (Ericaceae), *Melaleuca nodosa* (Myrtaceae), *Brachyscome* sp. (Asteraceae), *Hibbertia spanantha* (Dilleniaceae), *Portulaca pilosa* (Portulacaceae), *Banksia ericifolia* (Proteaceae), *Scaevola ramosissima* (Goodeniaceae), *Dillwynia retorta* (Fabaceae), *Corybas fimbriatus* (Orchidaceae), and *Telopea speciosissima* (Proteaceae). Phots courtesy of Ruby E Stephens.

Ruby E Stephens is a first year PhD student in the Plant Conservation and Ecology Group at Macquarie University and Australian Institute of Botanical Science, Sydney. Prior to starting her PhD Ruby completed honours research in native bee ecology at The University of Sydney and has worked for several years as a consultant plant ecologist. This project will form the first chapter of Ruby's PhD research into the drivers of floral trait variation in Australian plant communities. In the near future, Ruby hopes to follow these analyses up with field measurements of floral traits across environmental gradients and an investigation of the relationship between floral traits and pollinator communities.

Different effects of *Cassytha pubescens*, a native vine parasite, on native and invasive plants: a tipoff for its possible use as biological control

Evelina Facelli*
Laboratory of Terrestrial Plant Ecology, School of Biological Sciences, University of Adelaide, SA

A bit of history

In the early 2000s, members of the then Animal and Plant Control Commission of South Australia observed that in the Adelaide Hills weeds covered by the native parasite *Cassytha pubescens* R.Br. were dying whereas, close by, native plants were seemingly unaffected by the parasite. They thought that perhaps the parasite could be used as a biological control agent and contacted researchers from the University of Adelaide to initiate a collaborative research project to investigate this possibility. To this end, the Terrestrial Ecology and Ecophysiology groups in the School of Biological Sciences, directed by Dr José M. Facelli and Dr Jennifer Watling respectively, have been studying the biology of the parasite to elucidate how environmental factors affect its interaction with different hosts, and how the parasite affects different components of the ecosystem. Understanding the mechanisms and processes involved in these interactions is providing evidence to support informed decisions about the use of the native parasite to control introduced weeds.

Plant parasites

Parasitic plants depend on other plants for water and nutrients. Some can complete their life cycle independent of a host (facultative parasites), while others depend entirely on their host (obligate parasites). They connect to their hosts via haustoria and, through these, can access resources. Some parasites attach to the roots of their hosts, others to the stems. Some are completely parasitic (holoparasites) and derive all their fixed carbon from the host as they commonly lack chlorophyll. As a result, they are always obligate parasites. For example, Dodder (*Cuscuta* sp.) is a stem holoparasite and Broomrape (*Orobanche* sp.) is a root holoparasite.

Plant hemiparasites obtain water and mineral nutrients from the host plant; some obtain at least part of their organic nutrients from the host as well. Hemiparasites can be obligate stem (e.g. mistletoe, *Amyema* sp.) or root parasites (e.g. Native Cherry, *Exocarpus cupressiformis*), or facultative root parasites (e.g. Desert Quandong, *Santalum acuminatum*).

Left: Haustoria of stem parasite *Cassytha pubescens* on host plant *Leptospermum myrsinoides* (Facelli *et al*. 2020). Photo courtesy of David Hollingworth. Right: Developing haustoria of shoot hemiparasite, *Amyema* sp. on branch of host plant. Photo courtesy of John Pate.

An important characteristic of plant parasites from the point of view of their potential use as biological control of introduced weeds is the host range – the number of potential host species the parasitic plant can infect. Most plant parasites are generalists and have a broad range of hosts, but some show a degree of preference for particular hosts. In this two-way interaction, it is also crucial to consider the response of the host to the parasite infection. This also varies with different plant species; some can impede the attachment of the parasite entirely (resistance); others rely on their own growth traits to reduce the effects of the parasite on their fitness (tolerance). Both preference and response are modulated by abiotic factors such as light, nutrients and water (Facelli *et al*. 2020 and references therein).

Cassytha pubescens and its hosts

Cassytha pubescens (Cassytha) is a perennial, rootless, hemiparasitic vine native to southern Australia. It must attach to a host within 6 weeks of germination to survive (i.e. is an obligate parasite). The leaves of this species are reduced to scales, but stems contain chlorophyll making the plant capable of photosynthesis. Cassytha spreads mostly through vegetative growth, growing across branches within a host and spreading to neighbouring plants. Hence, it is often connected to several individuals of different species making it a generalist parasite.

Noriko Wynn and Jane Prider surveyed the distribution of Cassytha and its host preference extensively in several areas of the Mt Lofty Ranges (Prider *et al*. 2009; Facelli *et al*. 2020). They determined that it appears not to have a strong preference for particular hosts (lack of specificity), but they found it growing relatively more abundantly on, and firmly attached to several native (e.g. Myrtle Wattle (*Acacia myrtifolia*) and Heath Tea-tree (*Leptospermum myrsinoides*)) and invasive species (e.g. Broom (*Cytisus scoparius*) and Gorse (*Ulex europaeus*)).

Ecophysiology of the interaction

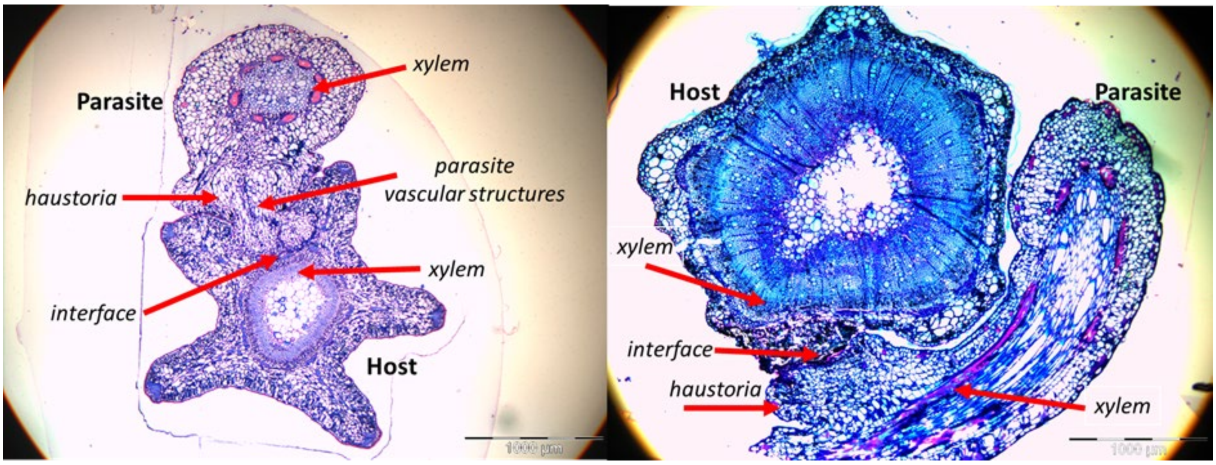
Hao Shen, Jane Prider and Rob Cirocco studied the impact of Cassytha on the ecophysiology of the parasite and its various hosts (mainly *L*. *myrsinoides*, *U*. *europaeus* and *C*. *scoparius*) in several field and glasshouse experiments. Their overarching hypothesis was that the parasitic plant would have a greater impact on introduced host plants than on native hosts. In these studies, photosynthesis, nutrient uptake, growth and survival of hosts and parasite were examined. Cassytha was consistently shown to have strong negative effects on the growth of Broom and Gorse but not on native Heath Tea-tree (Prider *et al*. 2009; Shen *et al*. 2010; Cirocco *et al*. 2020 and references therein).

Left: Infection front of *Cassytha pubescens* moving over a thicket of *Ulex europaeus* in the Mt Lofty Ranges, leaving dead *U*. *europaeus* in its wake. Photo courtesy of Robert Cirocco. Right: *Cassytha pubescens* growing on *Leptospermum myrsinoides*. Photos courtesy of José M. Facelli.

To compare the growth of infected native (*A. myrtifolia* and *L. myrsinoides*) and invasive (*C. scoparius* and *U. europaeus*) species, Noriko Wynn set up an experiment in which the target hosts were infected using Cassytha already established on a host (the donor) to another plant (the target). Once the parasite had established on the target hosts, the connections to the parasite of the donor host were severed, thus enabling the measurement of growth in target hosts that were detached from or connected to the donor host. Haustoria were firmly attached to all hosts and all were smaller when connected via Cassytha to the donor host than when the connection was severed. All hosts supported abundant growth of Cassytha in relation to their size. However, the abundant growth on *A. myrtifolia* happened only when this native was connected to the donor host. This suggests that the parasite relied mostly on resources from the donor host and questioned the functionality of the haustoria firmly attached to *A. myrtifolia* (Facelli *et al*. 2020).

Anatomy and functionality of haustoria

To follow this up, Noriko Wynn studied the anatomy of the haustoria formed on the four hosts and found that they were fully developed on the two invasive species and on *L. myrsinoides* but not on *A. myrtifolia*. To confirm the lack of functionality, Hong Tsang and Evelina Facelli compared the transfer of the radioisotope 32P between pairs of hosts (*A. myrtifolia* and *C. scoparius*) connected by Cassytha. They found that there was effective transfer from the invasive host to the parasite but not from *A. myrtifolia* (Tsang 2010; Facelli *et al*. 2020).



Left: Section of haustoria of *Cassytha pubescens* on *Ulex europaeus*. The parasite penetrates host tissue, develops vascular structures and contact with the host xylem. Right: Section of haustoria of *C. pubescens* on *Acacia myrtifolia*. The parasite is prevented from entering host tissue, there is a barrier (thick dark host tissue) at the interface between host and parasite, vascular structures did not form in the haustoria (modified from Facelli *et al*. 2020).

Overall implications of research

Our results highlight that although Cassytha can be observed growing abundantly on *A. myrtifolia*, it does not form functional haustoria and relies on resources from other hosts that it is connected to. This pattern complicates the identification of resistant or tolerant species in the field where native species, such as *A. myrtifolia*, which could be considered to be a 'pseudo host', may only provide physical support for the parasite as it grows between gaps of suitable hosts.

Our studies confirm that Cassytha does not selectively utilise invasive species over natives. A generalist strategy allows the parasite to become established on host species with which it has not coevolved. However, introduced hosts differ in the way they are affected by the parasite, which is the basis of the potential use of Cassytha as biological control. We could speculate that native hosts have evolved in the presence of the parasite and, over time, have developed suitable and different, mechanisms to resist or tolerate infection (Biotic Resistance Hypothesis, Těšitel *et al*. 2020 and references therein). *Acacia myrtifolia* resists penetration by the haustoria whereas *L. myrsinoides* can tolerate infection probably due to its adaptation to low availability of water and nutrients, characteristic of plants in the sclerophyll woodlands of South Australia. In contrast, the two invasive hosts, which were introduced to Australia less than 200 years ago, have not evolved defence mechanisms capable of resisting infection by a novel adversary.

Instead of introducing a specific non-native biological agent (as it is the general strategy for biological control) we propose the use by augmentation of this native parasite as a novel way to aid in control of introduced species. Based on the species tested so far in glasshouse experiments and field trials, it is expected that the used of Cassytha as a biological control agent will have little or no significant effects on native species within the system.

Current research in the Terrestrial Plant Ecology Group

Our group continues to investigate the biology of Cassytha and how the presence of the parasite affects other components of the ecosystem. For example, Elizabeth Maciunas is examining how Cassytha disperses and its population genetics, response to fire and interaction with one of its invasive hosts, *Rubus fruticosus* (Blackberry). Bernardo O'Connor is studying how the parasite changes soil under infected plants and if this gives native plants an advantage over invasive plants. He is also investigating how infection affects the ability of the host plant (native or invasive) to compete with other plants and if more insects feed on infected plants. In field trials, Robert Cirocco has successfully established Cassytha on several major invasive weeds at various sites in the Mt Lofty Ranges. Initial results suggest this is a viable option for situations where more traditional weed management practices (e.g. herbicides, slashing) are not desirable.

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*About the author

Dr Evelina Facelli is an Adjunct Lecturer in the School of Biological Sciences at The University of Adelaide. She completed her PhD in 1999 with an investigation of the role of arbuscular mycorrhizal symbiosis in plant population dynamics. More recently she has been studying the importance of plant-soil feedbacks in restoration of plant communities. She can be contacted by email at evelina.facelli@adelaide.edu.au.

The commercial potential of a tropical native plant, Kakadu Plum

Julian Gorman*
Charles Darwin University, Northern Territory and School of People Planning and Environment, Massey University, Manawatu, New Zealand

Globally, there is a large and increasing commercial demand for 'functional foods' – products which have a positive effect on health above their nutritional value. Many Australian native bushfood products are in this category and represent an important commercial opportunity (Whitehead *et al*. 2006; Clarke 2012). Indigenous ecological knowledge and Australia's unique plant genetic resources are important assets underpinning natural resource-based enterprises (Chapman 2009). Managed the right way, this represents commercial potential that could benefit landscapes, livelihoods and culture.

Commercialisation of native plants requires a multi-disciplinary approach which considers the diversity of genetic resources, ecological and cultural factors, and business and social impacts of harvest. This article provides a short introduction to the commercial potential of *Terminalia ferdinandiana* Exell. (Kakadu Plum) and some of the diverse areas of research and development that need consideration to grow the industry for this species. The research presented is part of my PhD study titled '*Exploring Indigenous enterprise development and the commercial potential of* Terminalia ferdinandiana *(Kakadu Plum) as an Indigenous agribusiness across northern Australia*'. The overall objective of my project was to provide new knowledge about aspects of the Australian Aboriginal bushfood industry and the development of Aboriginal enterprises based on wild harvest of native plant products.

Kakadu Plum is an Australian endemic plant with exceptional commercial potential. This fruit possesses a range of sought-after antioxidants such as anthocyanins and polyphenolics (including gallic and ellagic acids) and it has the highest concentrations of ascorbic acid of any fruit worldwide (Mohanty and Cock 2012; Williams 2014). Kakadu Plum is a small to moderately sized semi-deciduous tree, and one of 24 species or subspecies of *Terminalia* occurring across tropical Australia (Pedley 1995). Its range is largely restricted to the wet-dry tropics of the Northern Territory and the Kimberley region of Western Australia (Pedley 1995; Cunningham *et al*. 2009). It is a mid- to understorey tree and is often associated with open woodlands dominated by *Eucalyptus tetradonta* and *E*. *miniata* (Woods 1995), although it is also found as stands at extremely high densities in areas fringing coastal wetlands on a variety of soils types. This species has a long history of Aboriginal use and cultural connection and, because of its exceptional fruit properties, has an existing market demand (Gorman *et al*. 2006; Whitehead *et al*. 2006).

Left and middle: Kakadu Plum (*Terminalia ferdinandiana*) tree and fruit. Right: Distribution of Kakadu Plum in northern Australia plotted using collection records sourced from Atlas of Living Australia (2019).

Several factors clearly point to future growth of successful agribusiness based on Kakadu Plum. These include the unique characteristics of the fruit as a commercial plant product, the Indigenous people who have cultural connections with this species and the landscapes in which it grows (Gorman *et al*. 2020b). There are several Indigenous organisations across northern Australia that wild harvest Kakadu Plum, others are growing small plantations through enrichment planting of natural populations or by conventional horticultural practice. There are also some non-Indigenous groups involved in growing Kakadu Plum, mainly through traditional horticulture (Gorman *et al*. 2019). The fruit collected by all of these enterprises is sold to a wide variety of commercial entities in raw or powdered form and used for its nutritional, medicinal and anti-microbial properties.

However, important knowledge gaps have recently been identified and need to be addressed for the industry to progress (Gorman *et al*. 2019). For the species itself these include (i) an improved understanding of the taxonomy of Kakadu Plum and clearer definition of the different varieties over its range, (ii) better understanding of the factors impacting density and distribution of plants, (3) floral biology and aspects of pollination, and (iv) drivers of the variability in the nutritional properties of leaves and fruit across its distribution. For commercial purposes we need (v) a better understanding of the aspirations of Aboriginal suppliers for participation in the agribusiness supply chain, and (vi) product development, market signals and specific supply chain models that suit Aboriginal suppliers of *T. ferdinandiana* to service a range of potential national and international markets.

An important aspect for developing a commercial supply of Kakadu Plum is knowledge of its reproductive biology and the factors that impact on fruit production. Despite extensive commercialisation of other species of *Terminalia* worldwide (French 2013), there has been little research on their reproductive biology (Raju *et al*. 2012) and the pollination biology of *T. ferdinandiana* is still largely undocumented. There is considerable variability in fruit production (e.g. timing of flowering, fruit size, yield and chemical properties) of Kakadu Plum and this is a key limiting factor in its commercialisation.

Pollination biology is one aspect of reproductive biology that could be contributing to variation of fruit yields and, to fill this research gap, a study was done in native bush at the Charles Darwin University, Casuarina Campus, Darwin to document this. Anthesis, pollen compatibility and pollinator activity were the most likely factors contributing to variability in fruit yield (Gorman *et al*. 2020a). Anthesis was observed and recorded, pollen compatibility was identified by artificial pollination and exclusion experiments, and pollinators were observed, identified, and collected. It was found that *T*. *ferdinandiana* is andromonoecious and self-incompatible and relies on cross-pollination for successful fruit production (Gorman *et al*. 2020a).

Wild stocks of this species are pollen-limited, likely caused by pollinator satiation in dense, synchronously flowering stands. These findings indicate that enhanced fruit production may require supplementation of suitable pollinators in wild stands. Future studies are required to determine the rewards (nectar or pollen) that pollinators are provided with. If the main reward is pollen and not nectar, an intercropping approach should be considered to ensure pollinators have both pollen and nectar available. This information is important in designing plantations of *T*. *ferdinandiana* in the future to maximise flower pollination.

Left and middle: The flowers of Kakadu Plum are bisexual and self-incompatible and must rely on cross-pollination for fruit production. Right: The racemes are andromonoecious.

Northern Australia is very fortunate to have vast areas of undeveloped land with relatively intact landscapes and important natural and cultural heritage values. Models of plant domestication that promote community participation and local benefit and that protect the natural genetic diversity of a species across its landscape should be prioritised. There are already many species being harvested for customary purposes by Australian Aboriginal people that may have commercial potential (Gorman *et al*. 2006; 2008). This is an ideal time to prevent loss of important landscape multifunctionality by taking an integrated and holistic approach to land management and economic development in northern Australia (Pearson 2013). There is currently an opportunity for a new alternative agricultural paradigm involving a scaling up of customarily harvested products, such as Kakadu Plum, to meet high value niche market demands and contribute to global food security by broadening the base of food species used and valued. The natural and cultural richness of northern Australia are assets worth protecting and it is important to identify land uses which compliment these values rather than degrade them.

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Fires in eastern Australia: where do we stand today?

Tina Bell*
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Just over a year ago, southern and eastern Australia was experiencing one of the worst bushfire seasons since European settlement. The Black Summer fires started in September 2019 and continued through to March 2020, stretching from far North Queensland, along the east coast down to Tasmania and westwards across the continent. Post-fire assessments tallied direct loss of life of 34 people, destruction of nearly 6,000 buildings, and an area of 18.6 million hectares burnt. Estimates of native fauna deaths numbered in the billions. It was calculated that 306 million tons of CO_2 were released into the atmosphere during the months-long bushfires. Direct economic losses were estimated at more than $10 billion and indirect losses have been calculated to be 10-fold greater. One of the most tragic and alarming indirect losses has been attribution of the death of more than 400 people from smoke-related illnesses (Johnston *et al*. 2020). This is not entirely unexpected as air quality on some days during the Black Summer was 23 times above hazardous levels.

There is no doubt that it will take years for human communities affected by the Black Summer bushfires to recuperate from their personal, economic, and social losses. It will also take time for disturbed forests and woodlands to recover. The affected areas may return to a state that resembles what was present before fire but, equally, they may never completely return to their original pre-fire state. Regeneration of vegetation depends on the condition of the forest or woodland prior to being burnt (Bennett *et al*. 2016), the intensity and extent of the fires and post-fire conditions aiding recovery processes. For example, prolonged drought prior to a landscape-scale fire event may cause widespread tree stress (De Kauwe *et al*. 2020) and will affect how readily plants can respond after being burnt. Vegetation subject to high intensity fires tend to require longer recovery time compared to low intensity fires. Site conditions also dictate post-fire processes. Volkova and colleagues (2019) found that forests located in high rainfall areas (900-950 mm per annum) in eastern Australia had quicker accumulation of fuel (and presumably growth) after both high and low intensity fire than low rainfall areas (600-650 mm per annum).

Immediate post-fire plant recovery

Within months of the Black Summer fires (March 2020) there was evidence of recovery of the vegetation. In moist forest in the Blue Mountains in NSW, the first signs of recovery were resprouting shoots from a range of herbaceous species in the understorey. The brown tips of leaves from Grass Trees (*Xanthorrhoea resinosa*) show the extent to which the heat penetrated the growing tip or caudex of plants. The caudex of this species is typically located at ground level or underground but may grow up to 1 m above ground (Tozer and Keith 2012). In any of these locations, tightly packed leaf bases provide insulation around the growing tip and if the caudex is belowground, soil will provide an additional layer of insulation. Soil is a good insulator against the conductive heat from fire but, if the soil is dry, the insulation capacity is very much reduced.

Bushfire in the Blue Mountains. Left: Often the first green to appear after fire are long thin leaves of Grass Trees; middle and left: resprouts of eucalypts showing differing post-fire form, density, and rate of growth among species. These images were taken in Blackheath NSW in early March 2020, three months after burning in late December 2019.

Bark is also a good insulator from heat (Wesolowski *et al*. 2014). Within a few weeks post-fire, buds protected beneath bark emerged as green and red shoots along trunks of burnt trees. Here they can take advantage of high levels of light with removal of surrounding vegetation. Leaves associated with these epicormic buds have been shown to be thicker and more porous (i.e. increased intercellular airspace) and have very high rates of respiration in the second year after fire (Turnbull *et al*. 2014). Surprisingly, it is not until three or four years after bushfire that leaves produced by epicormic buds have rates of photosynthesis that suggest the tree no longer needs to rely on carbon stores of the tree.

There is often an impressive show of flowers after fire with some species taking advantage of an excess of insect pollinators. Most often these will be herbaceous monocotyledons (Kubiak 2009). *Xanthorrhoea* sp. (Grass Tree) typically flowers profusely after fire with individual flowers on the sunnier north side of the inflorescence opening first. Other plants, mostly woody dicotyledons, will only have vegetative growth post-fire and may not flower for several years after fire. This is often referred to as a 'secondary juvenile period' and will differ among populations of the same species according to soil conditions, nutrient availability, rainfall and length of growing season (Kubiak 2009). Resprouting members of the

Proteaceae tend to have a long secondary juvenile period and, often, have protracted 'primary juvenile periods' (i.e. time from germination to first flowering) ranging from between 5 and 9 years (Myerscough *et al*. 2000). This makes them particularly vulnerable if fires return to the area in the time before seed stores held in the canopy or soil can be replenished.



Left: *Blandfordia cunninghamii*, a tufted perennial herb found near Mount Hay, NSW in November 2020. There were hundreds of individuals flowering in the vicinity. Photo courtesy of Andrew Cox. Middle: *Celmisia longifolia* (Snow Daisy), found near the Newnes Plateau, NSW, the northern extremity of its range, had successfully germinated and flowered after the fire in November 2020. Photo courtesy of Lesley Waite. Right: Post-fire flowering spike of *Xanthorrhoea resinosa* (Grass Tree) with the first creamy flower opening on the northern side of the inflorescence; located near Picton, NSW in June 2020.

Seedlings of many species can also cover the ground, emerging after the first rains of autumn and winter as the soil profile wets up. Some species, including acacias and other legumes, require heat from fires to crack seed coats, others require a chemical stimulus from smoke or solutes released from ash. Other species, including many species of invasive weeds, may not need fire to promote germination but take advantage of reduced competition from other plants either killed or reduced in size by the fire.

One-year recovery of vegetation

A year after the Black Summer bushfires and regeneration of the forest is in full swing. To show this, images of a private property near Cobargo on the south coast of NSW have been provided. Here, trees have resprouted vigorously and lush green grass is a result of good winter rains. Fire weather, typified by high temperatures and low annual rainfall, has been strongly linked with the El Niño Southern Oscillation (e.g. most recently by Harris and Lucas 2019). We are currently at the start of a La Niña phase and the expected wet spring and summer (https://www.abc.net.au/news/2020-09-29/bom-declares-la-nina-wet-conditions-likely-for-eastern-australia/12617528) has provided excellent rain for regrowth of trees and grass alike.

Recovery of vegetation is related to fire intensity, but rates of regeneration are also dependant on forest type and structure. Recent work using satellite remote sensing has reiterated the complexity of landscape-scale recovery of forests with the only clearly discernible patterns being within a single forest type and relatively small patches (36 hectares or 600 x 600 m) (Hislop *et al*. 2019). Fire history (past patterns of bushfires including intensity, size, season and frequency) has a role in shaping the vegetation after a fire event. One study has found that fires even as far back as the mid-Holocene determined current forest structure (Wolfe *et al*. 2014). Of course, fire has been a part of the Australian environment for millennia and maybe for as long as 60 million years (Crisp *et al*. 2011).

Longer-term recovery of vegetation

If allowed to regenerate undisturbed, most forests and woodlands will eventually recover. Over time, the amount of bare ground is reduced, initially with regrowth of herbaceous grasses and forbs and later with regrowth of woody shrubs. Seedlings that germinated after the fire will increase in size, with some species growing at faster rates than others. Epicormic growth of overstorey trees continues to thicken and, as the canopy of these trees is restored, the growth on trunks and lower branches often dies off due to shading and restoration of apical dominance of canopy shoots. Studies using satellite imagery have shown that full 'regreening' of forests and woodlands dominated by resprouting eucalypts can occur within 5-7 years of a bushfire (e.g. Heath *et al*. 2016).

A sound understanding of the recovery of forests and woodlands after bushfire is needed for the most effective post-fire management of forests and woodlands. We need to know when to intervene, for example, for weed control and prevention of erosion, and when we can allow the vegetation to recover more or less undisturbed. At some point, regenerating forests and woodlands will have accumulated enough fuel to support another bushfire. Mangers will need to decide if they intervene to reduce the fuel load using planned controlled fire or to wait until other components of the vegetation have recovered. This includes naturally slow-growing species (long secondary juvenile periods), plants that have recovered from seed stores but are yet to flower (long primary juvenile periods), those that have low seed set or flower infrequently and those that must still replenish their stored energy reserves. Managers must also consider the fauna that rely on recovery of vegetation for food and shelter. It is an even greater vexed situation when people live in and amongst fire-prone vegetation and their health and safety is of paramount importance.

Left top and middle: The effect of bushfire on a property near Cobargo on the south coast of NSW after being burnt on the 23 January 2020 (images taken 24 January 2020). Right top and middle: The same setting after 11 months of forest regeneration (images taken 22 December 2020). Bottom: Restoration of a dam and surrounding vegetation on the property after good spring and early summer rains. Photos courtesy of Sally Anne Gaunt.

Left top and bottom: Early epicormic resprouting of eucalypt trees after a bushfire near Springwood, NSW in November 2013. Bare ground is clearly seen. Right top and bottom: Extent of regrowth of vegetation in the same location by January 2021. Photos courtesy of Sebastian Pfautsch.

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What Research Were We Funding 25 Years Ago?

Note: See http://aff.org.au/results/grant-summaries/ for further details of these and other research projects funded by the AFF.

Seed biology and germination study of *Zieria prostrata*

Nallamilli Prakash, Department of Botany, University of New England, Armidale, NSW
Funded in 1994 for $3,000

Zieria prostrata (Headland Zieria) is an endangered species restricted to four headlands near Coffs Harbour. The main threats to this species are weed invasion and disturbance by visitors to the national park in which it is found. It has small star-shaped flowers arranged in groups of 3 to 7 but sometimes in far greater numbers. The buds are pink and turn white as flowers open. Plants have a prostrate habit growing to a height of 0.5 to 1.0 m. These features, along with being relatively easy to propagate from stem cuttings, offered great horticultural potential when the species was first discovered. However, little was known of the reproductive biology of the species.


Left: Clusters of attractive small star-shaped flowers of *Zieria prostrata* (Heathland Zieria). Right: Prostrate habit of this species. Image from the Australian National Botanic Gardens, http://www.anbg.gov.au/photo.

This study was funded by the AFF at the request of National Parks and Wildlife Service of New South Wales to further develop a management plan for the species. The first recovery plan was written in the early 1990s (Griffith 1991). The most recent recovery plan (2016) is available at: http://www.environment.gov.au/resource/recovery-plan-zieria-prostrata

The study funded by the AFF showed that that reproductive biology of *Zieria prostrata* was similar to other species in the family Rutaceae. There were no indications of pollen or ovule sterility. Unfortunately, nearly half of the seeds tested were predated by insect larvae. The requirements for successful germination were not established as rates of seed germination were low.

Since this time there has been further research to guide management, albeit contained in unpublished reports, investigating the reproductive biology of Heathalnd Zieria (Prakash 1995) and its genetics (Peakall 1994). The horticultural development of this species has resulted in two cultivars; Zieria 'Carpet Star' and Zieria ‘Pink Crystals’, both of which are readily available from native nurseries.

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Identification of *Ptilotus* species (Mulla Mulla) suitable for domestication and breeding for the cut and dried flower trade

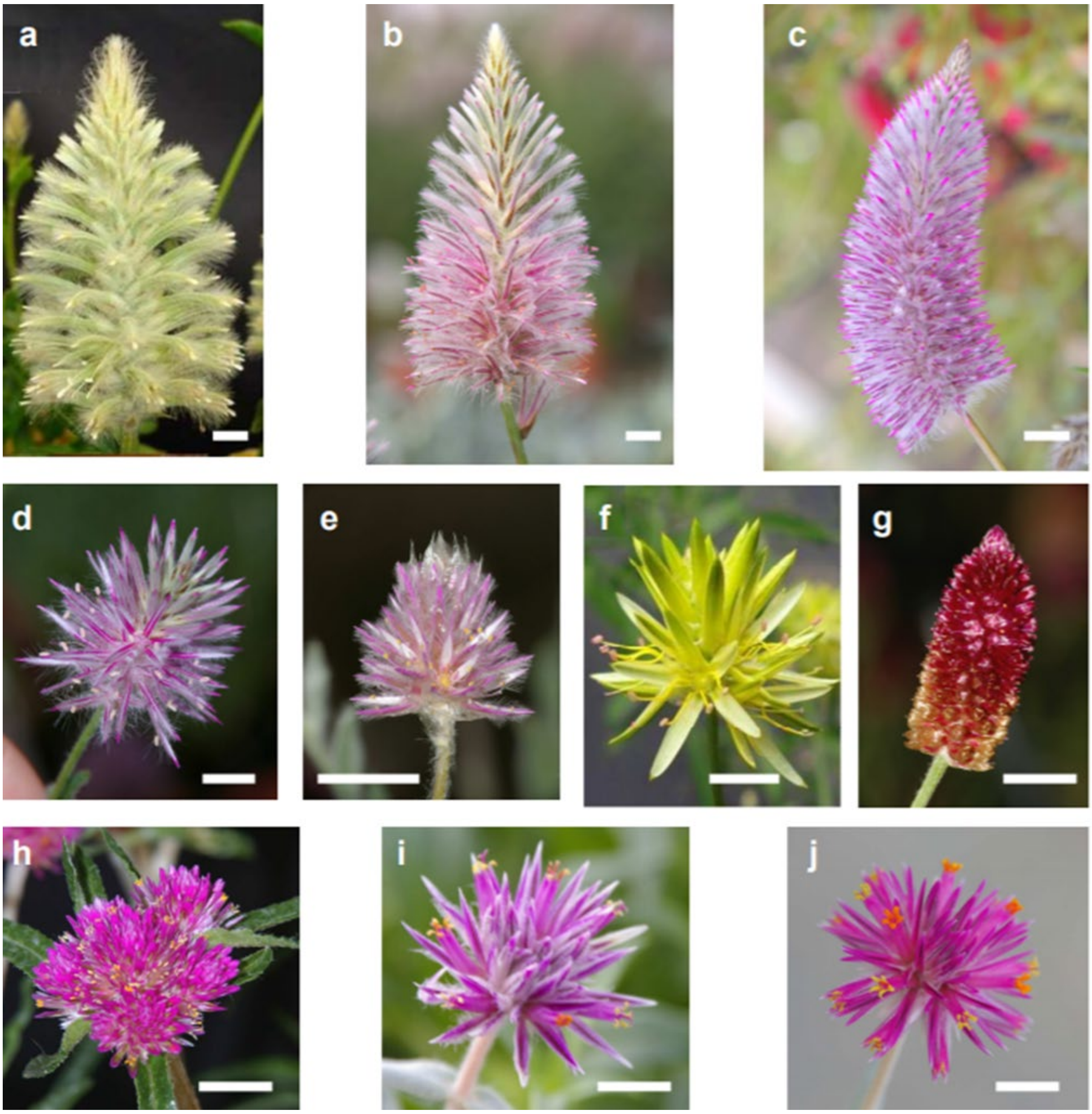
John Oates and Peter Abell, Plant Breeding Institute, The University of Sydney, Cobbitty, NSW
Funded in 1994 for $4,955 and in 1995 for $4,959

The inflorescence of *Ptilotus* consists of persistent bracts surrounding a hairy perianth with five segments. It is usually a terminal cylindrical, ovoid or globose spike that can be up to 150 mm long and 50 mm wide. Flower colour is usually pastel shades of pink, mauve, green, pale yellow and white. Overall floral presentation is often enhanced by long scapes which can vary in length up to 0.5 m depending on the species and environmental conditions.

Extensive characterisation and testing of seed for germination and cuttings for vegetative propagation was achieved in this study. Seed set from wild collections and commercial suppliers were highly variable and resulting seeds had equally variable viability. Germination rates of seeds extracted from flowerheads was greater than when whole flowerheads or bulk seed was used possibly indicating either a physical or chemical barrier of seed in the flower. Soft, herbaceous tip and stem cuttings from cultivated plants worked well with most species. Older woody material was usually more difficult to strike. 'Ex wild' material from central Australia proved difficult to propagate vegetatively, with the best success being from actively growing (herbaceous) tips.

While a considerable body of information was generated by this project, there were more questions raised than were answered. As a result, other research funded by the AFF includes a project titled 'Pollination biology of *Ptilotus axillaris*' awarded in 2007 and 2008 to M Perkins and M Johnston from the Centre for Native Floriculture, School of Land, Crop and Food Sciences, University of Queensland. A year later in 2009, a second research project titled 'Understanding the biochemical basis of flower colour in Australian native *Ptilotus* and *Gomphrena*' was also funded (awarded to DK Harrison, J Kochanek and DC Joyce).

Recent research involving *Ptilotus* has been focused on the taxonomy of the genus. From a propagation perspective, microproagation has been successful for *P*. *exaltatus* and *P*. *nobilis* (Pinker and Czarnowski 2016), particularly with the use of ethylene (Prameswara *et al*. 2009). To aid development of new cultivars, morphological indictors of initiation of flowering have been examined for *P*. *nobilis* (Orzek *et al*. 2012). Ecophysiological research has investigated the hyperaccumulation of phosphorus by species in the genus (Aziz *et al*. 2015; Suriyagoda *et al*. 2016; Hammer *et al*. 2020). The unique physiology of species in the genus Ptilotus may provide knowledge for development of more P-efficient crops (Aziz *et al*. 2015). *Ptilotus* is clearly an iconic genus that has much to offer to horticultural and agricultural industries.



Flowers of species and accessions used in the study funded by the AFF titled 'Understanding the biochemical basis of flower colour in Australian native *Ptilotus* and Gomphrena' by DK Harrison, J Kochanek and DC Joyce. (a) *Ptilotus nobilis* cv. Purity, (b) *P. nobilis* cv. Passion, (c) *P. exaltatus* cv. Joey, (d) *P. exaltatus* var. *semilanatus*, (e) *P. helipteroides*, (f) *P. gaudichaudi*, (g) *P. spicatus*, (h) *Gomphrena flaccida*, (i) *G. leontopodioides* cv. Empress, and (j) *G. leontopodioides* (darkpurple flower).

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Financial Report

This statement is summarised from the Foundation's audited accounts for the year ended 30 June 2020.

	2020	2019
Income	**$**	**$**
Donations	15,570	17,563
Administration contributions	487	520
Grant administration fees	300	305
Membership subscriptions	1,680	1530
Interest	5,688	7,534
Managed fund distributions	27,659	46,978
Sundry income	6	-
Imputation credits refunded	5,279	8,158
Total income	**56,669**	**82,588**
Expenses		
Grants	50,161	45,716
Decrease in market value of investments	41,627	45,322
Accounting and audit fees	2,295	2,245
Website costs	48	87
Postage and printing	183	177
Young Scientist Awards	500	500
Australian Network for Plant Conservation	-	100
Administration	29	(25)
Total expenses	**94,843**	**94,122**
Surplus (deficit) for the year	**(38,174)**	**(11,534)**
Assets		
Investments and bank accounts	948,044	970,632
Debtors	8,948	29,287
Imputation credits receivable	5,279	8,158
GST receivable	5,870	4,378
Total assets	**968,141**	**1,012,455**
Liabilities		
GST payable	183	166
Grant commitments	63,816	69,973
Total liabilities	**63,999**	**70,139**
Net assets	**904,142**	**942,316**
Accumulated funds		
Accumulated funds from last year	942,316	953,850
Current year surplus (deficit)	(38,174)	(11,534)
Total accumulated funds	**904,142**	**942,316**

About the Australian Flora Foundation

The Australian Flora Foundation is an Australian not-for-profit charity dedicated to fostering scientific research into Australia's flora. It is totally independent. All members of the Council and the Scientific Committee give their time freely as volunteers.

Each year the Foundation provides funding for a number of grants for research into the biology and cultivation of the Australian flora. While the grants are not usually large, they are often vital in enabling such projects to be undertaken. Many of the researchers are honours or postgraduate students, and their success with an Australian Flora Foundation grant hopefully stimulates their interest in researching Australia's unique and diverse plants throughout their careers.

This work is only made possible by the generous support of donors and benefactors.

The Foundation is currently calling for applications for projects to commence in December 2021. The Foundation expects to support between two and four projects funded for $5,000-$15,000/year each in 2022 with possible extension into 2023. Typically, projects are funded up to $10,000 per annum for two years or up to $15,000 for one year. See the AFF website for application details (http://aff.org.au/grants/grant-criteria/).

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