

Chapter 1

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Thesis Overview

This thesis examines the life history strategies, and notably seed germination, of Australian species in the genus *Frankenia*. It focuses on the strategies that enable *Frankenia* to survive in the harsh salt- and water-stressed conditions of the semi-arid and arid regions of Australia. Variations in temperature requirements, seed mass, salt tolerance, and soil characteristics for germination and seedling establishment are examined. This research is significant given global patterns of aridification, and a poor understanding of arid zone plant ecology in general. This research on *Frankenia* germination ecology will inform the development of theoretical arid zone ecology. The research outcomes also have practical applications for revegetation using *Frankenia* because of its salt and drought tolerance.

Description of the genus *Frankenia*

Plants of the genus *Frankenia* are salt tolerant herbs, shrubs or sub-shrubs, and are found in habitats such as coastal cliffs, the margins of salt lakes, dry creek beds and salt pans, at the base of stony hills or sand-hills, and in depressions (gilgai) on gibber plains (Summerhayes 1930; Barnsley 1982; Whalen 1987). The largest fraction of the world's diversity of *Frankenia* occurs in Australia. Currently in Australia, 47 species are recognized and only one (*F. pulverulenta*) is not endemic. (See Appendix B for the list of *Frankenia* species, with authorities, included in this study). *Frankenia* is renowned as a genus in which it is difficult to determine specimens to species level (Barnsley 1982). It is suspected that many species are morphological variants of a single species complex (Whalen 1986). All of the species occurring in Australia are perennial with the exception of *F. annua* and *F. pulverulenta*, which are annuals.

Many species of *Frankenia* are superficially similar in floral, fruit, and seed structure. They can only be distinguished by close examination of floral characteristics, notably ovule number and attachment (Barnsley 1982; Whalen 1987). The leaves are described as simple and opposite, sessile or petiolate, with leaf blades flattened to terete, and leaf margins loosely to tightly under-rolled. Leaves are often encrusted or dotted with salt extruded from salt-glands. The flowers are described as actinomorphic and bisexual, with (usually) five petals (except in *F. sessilis* and *F. tetrapetala*) which are free, spatulate, clawed or sometimes ribbon-like (e.g. *F. setosa*), and coloured white, pink or pale purple. The androecium comprises (usually) five stamens (except in *F. sessilis* and *F. tetrapetala*). The gynoecium comprises superior ovaries, with the ovules either basally attached and few per placenta, or parietally attached with many per placenta. The calyx is (usually) five-lobed. Seeds are ovoid or oblong. (For discussion of infrageneric classification, see Niedenzu 1925; Summerhayes 1930; Black 1964).

Taxonomic history

The species *Frankenia* –named after Johan Frankenius, a 17th century Swedish professor of botany and anatomy – was first described by Linnaeus in 1737. The family Frankeniaceae was proposed by Saint-Hillaire (1815) based on the genus *Frankenia*. The first Australian *Frankenia* species described was *F. tetrapetala*, (a Western Australian species), by

Labillardiere in 1805. Two further Western Australian species, *F. pauciflora* and *F. fruticulosa*, were described in 1824. The first eastern Australia species were described by Lindley in 1848. Bentham in 1863 recognized seven Australian species but grouped a large number of previously separated species under the polymorphic *F. pauciflora*. Revisions of *Frankenia* from two states were published in 1918; Ostenfeld described Western Australian species, while Black described South Australian species. The first revision that included all Australian *Frankenia* was undertaken by Summerhayes in 1930, with a further revision by Barnsley in 1982. Whalen provided a comprehensive revision of South Australia *Frankenia* species in 1987. Taxonomic revision of this complex genus continues (see Craigie 2007).

Geographical distribution

In Australia, *Frankenia* are found south of the latitude 17°S in Mediterranean, arid, and semi-arid zones. *Frankenia pauciflora* has the widest distribution, extending along the coast from the Dampier Archipelago in north-western Western Australia to approximately 250 km east of Melbourne, Victoria, and on islands north of Tasmania (Summerhayes 1930).

Frankenia often occurs in isolated, disjunct pockets along water drainage channels, for example on the sides of dry creek beds, ephemeral lakes, and shallow depressions (gilgais), or on the sides of roads. The reasons for their limited and isolated distribution have not been investigated. Populations generally cover only several square metres. Sometimes only one or two bushes are found (Badman 1999; personal observation). Populations of species, notably those from the *F. serpyllifolia* complex, appear unstable. I have revisited several population sites along the Oodnadatta Track in South Australia within a five year time period and found that the populations no longer exist. However there are large, permanent populations of *F. foliosa* around the mound springs of the Great Artesian Basin, and of *F. pauciflora* and *F. sessilis* in coastal salt marshes. *Frankenia* at these sites comprises the dominant vegetation.

Two key theories have been proposed to explain the geographical distribution of *Frankenia* in Australia. The first theory proposes that *Frankenia*, along with other Australian arid zone flora (Eremean flora), spread from Western Australia eastwards (Summerhayes 1930; Barlow 1971; Martin 2006). Two characteristic patterns support this hypothesis; (1) the morphological characteristics of Western Australian species are very diverse, while species in South Australia and eastwards are of more uniform type, and (2) the majority of the species in the eastern states have a limited number of basally attached ovules as opposed to the presence

of multiple parietally attached ovules. The presence of the limited number of basally attached ovules is thought to represent the more advanced stage (i.e. derived state) in floral development than the presence of many parietally attached ovules (Summerhayes 1930). In Australia, 23 *Frankenia* species have a reduction in the number of ovules per fruit with attachment towards the base of the placenta. Outside of Australia, only three species of *Frankenia* with basally attached ovules are found; *F. palmeri* Watson and *F. jamesii* Torr. from western USA, and *F. fischeri* Hicken from Argentina (Summerhayes 1930; Whalen 1987).

Summerhayes (1930) considered that a group which includes *F. setosa*, *F. glomerata*, *F. bracteata* and *F. georgii* (*Glomeratae sensu* Summerhayes) represented the most derived *Frankenia* species as they have basally attached ovules, aggregation of flowers, a reduction in the number of floral parts, and a clear differentiation between foliage leaves and bracts. Conversely, *F. pauciflora* was considered the plesiomorphic species, having multiple parietally attached ovules, flowers in a loose dichasia, and a wide geographic distribution. *Frankenia pauciflora* is also morphologically similar to other species occurring throughout the world (Summerhayes 1930), notably *F. laevis* L., to which species *F. pauciflora* was originally designated.

The second hypothesis, championed by Burbridge (1960), suggested that much of Eremean flora (including *Frankenia*) evolved from coastal ancestors that stranded in the interior of the continent at the end of ‘past marine incursions’, for example the sea level changes and the associated increase in aridity post-Miocene, or more recently after the cyclic glacial and interglacial periods of the Pleistocene.

Randall (1970) noted that studies of adaptations in reproductive systems in Australian arid zone species may be a useful contribution to a more detailed knowledge of patterns of evolution in the Eremean flora.

Ecology

Frankenia are halophytes with characteristics that allow them to live and reproduce successfully in saline, calcareous or gypseous soils, and in arid environments. This suggests that *Frankenia* have mechanisms in their life histories, especially at the less tolerant seed germination and seedling stages, to cope with both comparatively high levels of salinity and prolonged water shortage. The mechanisms that enable them to survive in these conditions at

seed germination and seedling stages are little known. There are three mechanisms that mature halophytic plants may possess to enable them to tolerate salinity. 'Salt-enduring' halophytes tolerate a high level of salt in their cells. 'Salt-evading' halophytes either do not absorb salts from the soil, or salts are not transported to the leaves. 'Salt-excluding' halophytes secrete salt from glands, or are succulent (Ungar 1987). *Frankenia* are 'salt-excluding' halophytes. They have well-developed salt excreting glands on their stems, leaves and calices (Whalen 1986). However, *Frankenia* can grow successfully in non-saline soils, thus they are non-obligate halophytes. They grow primarily in saline areas because this habitat prevents establishment of salt-sensitive plants that would out-compete *Frankenia* in non-saline habitats (Ungar 1987).

Limited research has been published in reference to the ecology of *Frankenia*. Most studies that include *Frankenia* do not directly relate to *Frankenia* as a taxon but include *Frankenia* species in larger studies. A synopsis of the types of studies that incorporate *Frankenia* species include investigations into: (1) salinity tolerance (Barbour 1968), (2) plant species for reclamation and revegetation (Semple & Waterhouse 1994; Allison 1995; Ladero *et al.* 1998), (3) saltmarsh plant ecology (Brightmore 1979; St Omer 1994; Brochmann *et al.* 1995; Allison 1996), (4) desert vegetation (Melzer & Begants 1991; Jager 1992; Hoffmann & Teillier 1992), (5) pollination (Woodell 1974; Gomez *et al.* 1996), and (6) salt glands (Campbell & Thomson 1976a, 1976b; Balsamo & Thomson 1993). To date, studies of Australian *Frankenia* have primarily focused on taxonomic relationships. (More comprehensive reference lists of studies including *Frankenia* are given in the relevant chapters of this thesis.)

Life history and reproductive strategies

A plant's reproductive success can be determined by its number of offspring to reach maturity (Baskin & Baskin 1988). Investigations into life history strategies reveal how each stage of a plant life cycle contributes to its overall reproductive success. Life history strategies are influenced by the impact of abiotic factors (e.g. drought, nutrient availability, salinity, extremes in temperature) on reproductive success. Reproductive strategies may signify trade-offs between selection pressures that determine optimal resource allocation, for example seed size/number, seed size/dormancy, seed size/dispersal, pollen quality/quantity (Baskin & Baskin 1988). The life history strategies of halophytes in general are still poorly understood

(Adams 1990). In Australia in particular, germination in endemic halophyte species and its relationship to environmental factors – and consequently species distribution – has received limited attention (Groves *et al.* 1982). However, interest in the germination and establishment of arid zone plants is increasing due to their potential use as drought tolerant garden plants, and in reclamation projects associated with salinity problems and in mine-site rehabilitation.

Australian deserts generally have high summer and low winter temperatures, and sporadic, unpredictable rainfall. Thus, life history and reproductive strategies of arid zone, halophytic plants must be well adapted to avoid excessive advances in reproductive activity under impending or prevailing conditions of drought or temperature extremes. The reproductive strategies of species are described in terms of breeding systems, seed size and number, seed dispersal mechanisms, and seedling establishment. Lovett Doust (1989) described ‘reproductive strategy’ as an evolved complex of traits which includes the frequency and timing in the life cycle of reproductive events, size (or age) to maturity, the numbers, arrangements and qualities of sexual structures, and the proportionate distribution of resources to gamete production and embryo maturation. The evolution of different reproductive strategies has been considered as either selection for genetic systems that optimize the rate of expression of genetic variability, or as selection for plastic reproductive responses to ensure success in a variety of environments (Lawrence 1985).

The significance of seed size (mass)

Studies on seed characteristics are of interest when investigating life histories because seeds provide the main opportunity for a species to disperse to new habitats and to escape from adverse conditions in time and space (Lord *et al.* 1995). Seed characteristics include variations in mass, germination rates, and dormancy. The life history and reproductive strategies involving allocation of resources for optimal seed size, or more specifically seed mass, for successful germination and seedling establishment underpin this thesis. Seed mass is theoretically proportional to the amount of resources invested in an individual offspring by the parent plant. It is thought to evolve as a compromise between selection to produce more offspring and selection favouring greater allocation of maternal resources to each offspring (Harper *et al.* 1970; Westoby *et al.* 1992). Studies by Leishman and Westoby (1994a, 1994b) demonstrated that two weeks after germination, hypocotyl length, leaf area and seedling dry

weight of seedlings of large-seeded and small-seeded species from Australian arid zones were all linearly related to seed mass. Seedlings grew larger proportionally to seed mass.

Wiens (1984) described plants as most resembling animals that lay eggs and leave them unattended, and that large seeds were analogous to an increase of parental care. Many studies interpret large seed mass as being adaptive under a variety of hazards. Large seeds are thought to increase the probability of successful seedling establishment when faced with competitors, drought, shading, or defoliation (e.g. Westoby *et al.* 1992; Armstrong & Westoby 1993). Comparative studies have demonstrated that plants in xeric habitats do have larger seeds (reviewed in Moles & Westoby 2004). For example in Australian *Eremophila*, the larger-seeded species of the genus occur in the arid zones (Lawrence 1985). Also, studies such as Salisbury (1974) in Britain, and Baker (1972) in California found a tendency for species occurring in drought-prone environments such as coastal dunes and deserts to have larger seeds than species occurring in open canopy vegetation ecosystems.

Large seeds contain greater nutrient reserves which theoretically assist seedlings growing in soils that are nutrient poor and/or low in moisture (Mustart & Cowling 1992). Larger seeds also theoretically produce seedlings that have a faster rate of root extension to follow rapidly the receding soil-water in drying soil (Westoby *et al.* 1992; but see Jurado & Westoby 1992b). Small seedlings from small seeds that develop roots more slowly would be disadvantaged by not extending rapidly enough to stay in contact with the receding soil-water. Comparisons of arid dune-crest species in the Simpson Desert demonstrated that seedlings from the larger-seeded species did have lower post-emergence mortality (Buckley 1982).

Ovule number and seed mass

This thesis explores the effects of seed mass and number on germination rates and success between *Frankenia* species. Theories on seed mass and number, and the reproductive success, have mostly addressed total seed production per plant (Salisbury 1974; Stephenson 1981). However, seed mass within species is one of the least plastic components of plant life history strategies (Harper *et al.* 1970). Also, seed numbers are dependent on ovule number per fruit and this is largely determined genetically (Wiens 1984). Total seed production per plant is resource limited, although resource limitations are more critical in regulating flower production (Wiens 1984). Flowering plants have (within limits) perpetual growth patterns and

meristems generally continue to grow as long as resources are available and the ambient conditions remain favourable. Thus, resource availability and the ambient environment determine the number of reproductive modules (flowers) produced. An increase in flower production – and a concomitant potential increase in seed number per plant – does not necessarily correlate with a decrease in seed mass. Consequently, the total number of seeds produced per plant will vary enormously depending on conditions from year to year, and not as a function of seed mass.

Concepts of ‘clutch’ and ‘brood’ size in plants are rarely discussed. Wiens (1984) defines brood size (the preferred term for all organisms) in plants as the mean number of seeds maturing per fruit, not per plant. His definition of ‘brood’ permits the study of seed packaging strategies in relation to life histories strategies. Wiens argues that in sessile organisms with multiple reproductive modules, natural selection acts primarily on the individual module (fruit) with respect to packaging of seeds consistent with optimal dispersal or energy investment. Within *Frankenia*, two types of seed packaging (few larger-seeds per fruit and many smaller-seeds per fruit) have evolved, and both types often co-occur in geographical proximity (or habitat), sometimes even within the same population. Thus, I can test the significance of seed mass for germination within a single geographic region to uncover ecological correlates of this seed characteristic that would otherwise be masked by the strong effect of region or habitat differences on seed mass (see Silvertown 1981).

Significance of seed germination and seedling establishment

Germination of seeds of desert plants is a rare event that usually only follows major rainfall, and is often also temperature dependent (Ackerman 1979). Natural selection favours seed germination strategies that coincide with favourable conditions for seedling growth. This is of primary importance in arid zone species where conditions are erratic and capricious for plant growth and survival. Seedlings in semi-arid and arid regions are highly susceptible to mortality from water stress. The combination of suitable conditions firstly for germination and subsequently for successful seedling establishment occurs infrequently. The relatively high levels of dormancy and specific temperature requirements for germination of many arid zone species suggests that germination is restricted to periods when certain environmental criteria are met (Mikhiel *et al.* 1992). Consequently, the rate at which new individuals are added to

natural populations of desert plants is extremely slow. Successful seedling establishment may only occur every five to 10 years (Ackerman 1979).

The effects of rainfall and temperature on germination

Germination starts with seed hydration and ends with the emergence of the radicle. Therefore, the availability of water and the rate of water intake (imbibition) directly affect germination rates and are considered to be limiting factors for germination and seedling establishment in drought prone environments. Arid ecosystems are characterized by highly variable timing and magnitude in annual precipitation. The water necessary for seed germination is often only briefly available following rainfall, which may occur at any time of the year. The extent of soil-water availability for imbibition is dependent on ambient temperature (Flores & Briones 2001). The upper 10 cms of the soil profile can dry out within five days or alternately up to 25 days depending on the post-rainfall temperature (G. Hastwell personal communication). Seeds that take several days to germinate may find themselves in the dry soil conditions of the top few centimetres when only a few days old (Leishman & Westoby 1994b).

Timing germination to correspond with unpredictable favourable conditions is of vital importance to arid zone plants. Hence, opportunistic life history strategies relating to germination are typical of arid zone plant species. Two strategies have evolved to respond to the unpredictable favourable conditions for germination. In some taxa, germination is promoted only after large rainfall events (either heavy or sustained rainfall). These events are more conducive for soil-water storage, keeping the upper soil layers at field capacity for a longer period and enabling developing seedlings to establish before the soil dries (Mott 1972; Aronson & Schmida 1992). In other taxa, seeds germinate quickly after even brief rainfall events. It is hypothesized that seedlings of these species grow extremely rapidly enabling them to establish before the soil dries (Jurado & Westoby 1992a). Seed mass is hypothesized to be a mechanism for triggering suitable timing for germination.

The effect of salinity on germination

Arid zone soils are often saline. (Note that saline soils are not necessarily dominated by sodium chloride.) Consequent effects of saline soils include a reduction in a plant's ability to extract water from the soil causing wilting and death (Peverill *et al.* 1999). Excess salt can totally inhibit seed germination. Rainfall dilutes salinity levels. Rapid seed germination is hypothesized to be an adaptive strategy to utilize any soil-water with reduced salinity levels, even of short duration (Khan & Ungar 1996). However, if the rainfall is transitory and the post-rainfall temperature is high, the soil will dry quickly exposing young seedlings to a substantial rise in soil salinity concentrations (Glenn & Brown 1998).

Many halophytes have the potential to germinate at any time of the year under favourable conditions. Halophytes are able to maintain seed viability during extended exposure to hypersaline conditions and to initiate germination when salinity stress is reduced to within the species' tolerance limits. This guarantees that seeds will not germinate under extreme salt stress conditions that would expose seedlings to high mortality risk. Rather, a viable seed bank would ensure immediate germination when conditions become favourable (Woodell 1985; Ungar 1991; Gutterman 1994; Khan & Ungar 1996, 1998; Keiffer & Ungar 1997; Tobe *et al.* 2000a, 2000b).

Soil properties and Frankenia distribution

Arid zone soils in general are alkaline ($>pH 7$) and low in organic matter. They can be calcareous or saline/sodic with high electrical conductivity, and gypsum is often present. Soils with $pH > 9$ contain sodium levels that are detrimental to soil structure. Sodium disperses clay and organic matter, thereby degrading soil structure and reducing macropore space. Consequent effects of sodic soil include water-logging, hard setting, poor infiltration, and a reduction in plant available water (Peverill *et al.* 1999). Furthermore, the ratio of sodium, calcium, magnesium and potassium ions in the soils can vary, and species exhibit different tolerances to different ion ratios. The distribution of plant species can depend on the ion ratios of the soil.

Soil texture and soil-water (osmotic) potential affect seed germination and seedling survival. Soil texture refers to the relative proportions of sand, silt and clay in the soil. Arid zone soils have characteristically higher proportions of sand. The soil texture with a high sand

content has low osmotic potential. Temperature, rainfall and soil properties inter-relate in the regulation of water availability for plant use and for germination (Rivas-Arancibia *et al.* 2006). Several *Frankenia* species have been associated with particular soil types (see Badman 1999). However, a comprehensive examination of soil properties from *Frankenia* populations has not been undertaken.

Aims of this thesis

The primary aim of this thesis is to investigate germination in Australian *Frankenia*. The limited published data on germination in Australian *Frankenia* generally refers to its horticultural potential (e.g. Elliot & Jones 1986). Relatively few studies have investigated germination strategies in halophytes in general, especially in Australia. The germination success of seeds plays a major role in the persistence of all plant taxa, especially in arid zone halophytic species. The evolution of germination strategies is a consequence of plant taxa responses to environmental cues (e.g. repetitive rainfall patterns, favourable temperature) (Rivas-Arancibia *et al.* 2006). Arid zone halophytes have evolved under selective pressures whereby they respond to a sequence of environmental cues that indicate periods of relatively high probabilities for survival and establishment of seedlings.

The underpinning aim of this thesis addresses the large-seed versus small-seed paradigm by investigating the advantages and disadvantages of these two alternate reproductive strategies in arid environments. Many hypotheses that have been proposed to explain the advantages of large-seededness, especially in arid zone species, have been inadequately tested (Leishman & Westoby 1994a). Large-seededness has arisen several times in Australian *Frankenia* as a result of evolution towards fewer ovule numbers (and consequently the production of fewer and larger seeds) per flower. Both the larger- and smaller-seeded *Frankenia* species have the same biogeographical distribution. By restricting the analysis of seed mass variation to similar habitats, it is possible to uncover ecological correlates that would otherwise be masked by the strong effect of habitat differences on seed mass.

The differences in both germination success and germination rates between plant taxa reflect their various responses to the diverse combinations of temperature, water availability and substrate characteristics between years due to the variation in environmental conditions

during the germination process (Rivas-Arancibia *et al.* 2006). This affects the survival and divergence of plant species. Geographically peripheral and disjunct populations may occur because individuals experience selective pressures different from those in other populations (Ramsey *et al.* 1994).

Chapter outline

This thesis includes six chapters that examine the various factors that influence germination in Australian species of *Frankenia*. It has been formatted as a series of papers to be submitted to peer reviewed journals.

Chapter 2 compares germination in two species commonly found in geographically abutting areas of the ‘Far North’ of South Australia. In this preliminary study, I test for light and temperature preferences for germination, and how seed age affects seed viability in *F. foliosa*, a smaller-seeded species, and *F. serpyllifolia*, a larger-seeded species. The basic requirements for germination (temperature and light preferences, seed age viability) are thus established for subsequent experiments.

Chapter 3 expands on the seed mass/temperature interaction effects by testing six species for each of the seed mass categories. I investigate whether there are differences in germination rates and/or germination success between larger-seeded and smaller-seeded species, and if so, whether there is any correlation with different temperatures. I hypothesize that larger-seeded species are more successful than smaller-seeded species under all temperature conditions.

Chapter 4 introduces several additional species to investigate differences in germination between 20 of the *Frankenia* species occurring in Australia. I test hypotheses for the cause of interspecific variation in germination rates and germination success across Australian species in the context of the geographical distribution of each individual species. This is important knowledge for predicting species with horticultural and revegetation potential.

Chapter 5 investigates the soil properties from sites of central and southern Australian *Frankenia* populations. I test for correlations between soil properties and seed mass, focusing on soil pH, electrical conductivity (EC), cation exchange capacity (CEC), cation concentration ratios, soil texture, water holding capacity, and the presence of gypsum and/or

carbonates. I test the hypothesis that different soil properties are important for different seed mass categories. This information is relevant to the suitability of *Frankenia* for revegetation projects.

Chapter 6 re-addresses germination outcome following the protocols of Chapter 3, but this time using various water salinity levels to investigate whether there are differences in germination rates and/or germination success between larger-seeded and smaller-seeded species at different salinity levels. I also investigate differences in germination between species, this time in relation to the species' geographical distribution. This information is important to assess which species would be suitable for salinity remediation projects.

Chapter 7 investigates the seed mineral chemical composition to identify mineral nutrient differences between seeds of the larger- and smaller-seeded species to test the hypothesis that large seeds in desert plants have more nutrients available for rapid growth.

Chapter 8 discusses the results of all chapters in the overall context of germination in *Frankenia*. It then addresses findings in lieu of the large seed/small seed paradigm.

Project outcomes

The outcomes of this project will have practical implications for conservation, cultivation and revegetation utilizing *Frankenia*. Firstly, it will lead to a greatly increased understanding of interspecific variation in life history and reproductive strategies of Australian *Frankenia* species, particularly in the significance of seed mass and number. The genus includes species that have limited or disjunct distributions and others about which very little is known. Species of particular conservation significance in South Australia include *F. plicata* – which is considered to be nationally endangered (conservation code 3E) and under the environmental Protection and Biodiversity Conservation Act, *F. confusa* and *F. subteres* (conservation code 3K) for which more information is needed to determine their conservation status, and *F. crispa* because of its isolated populations (Briggs & Leigh 1996).

As well as furthering the knowledge of life histories and reproductive biology of *Frankenia* species and halophytes in general, and assisting with the ongoing taxonomic revision of the genus, this project has three practical applications. In recent years there has been an increase in research activity concerning the ecology of halophytes, which has been stimulated by significant problems caused by increasing soil and water salinity levels.

Research on the life history strategies of *Frankenia* species is particularly important for three major areas:

(1) Identifying the potential use of *Frankenia* in rehabilitation and revegetation projects in areas affected by the growing salinity problems caused by irrigation and land clearance, and for mine site rehabilitation. The unpalatability of *Frankenia* endorses it as a valuable genus in revegetation programs. Efforts to utilize species in revegetation have met with mixed success due in part to a lack of knowledge about specific seed germination requirements (Mikhiel *et al.* 1992). Understanding the environmental cues that trigger germination under laboratory conditions and the variation in germination response between species should make it possible to improve species selection and planting techniques using *Frankenia*. Seed collections from a variety of species and populations within species, compared under a common set of treatment conditions, permits direct evaluation of both intra- and interspecific variation in germination responses and seedling survival;

(2) Developing conservation management plans for the rare species *F. plicata*, *F. drummondii* and *F. georgii*, and the small isolated island-like populations of *F. crispa*, *F. brachyphylla*, *F. parvula*, *F. confusa*, *F. densa* and *F. subteres*; and

(3) Cultivating *Frankenia* for horticulture. Although only a few Australian *Frankenia* species are currently cultivated, many have potential uses in gardens and as container plants (Elliot & Jones 1986). Many species are decorative, having mass displays of white, pink or purple flowers. In particular, *Frankenia* should become popular because of its tolerance of saline soils and drought conditions.

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