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Seed Germination Ecology in Southwestern Western Australia

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Abstract

Germination responses of species from the native plant communities of southwestern Western Australia can be related to syndromes of life history, fire response, and seed storage, and also to factors related to environmental stress. The Mediterranean-type climate of the region with periodic drought and recurrent fires affects the production of viable seeds in plants of limited stature and rooting depth. Fire response ephemerals and species cued to flower by fire tend to produce viable, readily germinable seeds, but there are instances where seed production is aborted in these predominantly herbaceous life forms. Clonal, rhizomatous species often produce mainly inviable seeds. Production of viable seeds in woody species of these highly diverse communities may also be restricted by limitations to cross pollination. Obligate post-fire seeding species tend to produce a greater proportion of viable seeds than species which are capable of resprouting following fire. Serotinous species, whether post-fire re-seeders or post-fire resprouting species, produce mainly viable seeds, which germinate readily once freed from protective fruits. Species of the legume families and a few others of the soil seed bank produce innately dormant seeds which can be germinated following heat shock treatments which simulate the effects of fire. Heat shock in these species appears mainly as a mechanism to crack the hard seed coats, but the effect of heat to denature seed coat inhibitors has not been eliminated. Western Australian species do not seem to break dormancy when exposed to leachates from burned wood as has been observed in comparable habitats in California and South Africa, but further research is advised. Germination in many native southwestern Australian species is cued by temperatures that correspond to the winter rainfall period. There are also indications that an after-ripening period of warm, dry storage increases percentage of germinable seeds. Stimulation of germination by hormones is almost unresearched in Western Australia, but germination percentages have been increased in a small number of species of horticultural potential. Stimulation of germination by soil nutrient concentrations is almost unresearched in Western Australia, except for the inhibitory effect of excess sodium chloride levels in *Eucalyptus* and *Melaleuca*. These species only germinate when osmotic effects are reduced to lower levels as would occur when winter rains dilute soil salts. Application of research on seed germination has already enhanced the establishment of seedlings in the restoration of mine sites and is becoming important in aspects of the breeding and selection of native plants for the cut flower, bedding plant and essential oil industries.

Abstrakt

Das Keimverhalten von Arten der nativen Pflanzengesellschaften aus dem Südwesten Westaustraliens kann mit Syndromen ihrer Entwicklung, dem Verhalten gegen Waldbrände, der Speicherung in Samen und auch mit Umwelt-Sressfaktoren in Verbindung gebracht werden. Das mediterrane Klima dieser Region mit regelmäßiger Trockenheit und wiederholt auftretenden Bränden beeinflußt die Produktion keimfähiger Samen bei kleineren Pflanzen mit geringer Wurzeltiefe. Wadbrand-Ephemere und Arten, die nach Feuer blühen, produzieren im allgemeinen rasch keimende Samen, jedoch kann die Samenproduktion unter Umständen bei diesen vorwiegend krautigen Lebensformen fehlschlagen. Klonbildende Arten mit Rhizomen erzeugen im wesentlichen nicht keimfähige Samen. Bei holzigen Arten dieser enorm mannigfaltigen Pflanzengesellschaften kann die Produktion keimfähiger Samen auch durch Erfordernis einer Fremdbestäubung begrenzt sein. Obligat nach Feuer aussamende Arten tragen tendenziell einen größeren Anteil keimfähiger Samen als Arten, die nach Feuer regenerieren können. Serotine (bradykarpe) Arten mit langsam öffnenden Früchten, seien es nach Feuer aus Samen keimende 'reseeders' oder regenierende 'resprouters,' produzieren im wesentlichen keimfähige Samen, die rasch, sobald sie aus den schützenden Früchten befreit sind, keimen. Leguminosenarten und einige andere produzieren von Natur aus ruhende Samen, die nach einer die Wirkung von Feuer simulierenden Hitzeschockbehandlung zum Keimen gebracht weren können. Bei diesen Arten scheint Hitzeschock vor allem ein Mechanismus zu sein, der die harte Testa sprengt, aber eine Auswirkung von Hitze auf eine Denaturierung von Keimungshemmern konnte nicht ausgeschlossen werden. Bei westaustralischen Arten scheint die Keimruhe nicht durch eine Wirkung von Eluaten aus verbranntem Holz gebrochen zu werden, wie dies auf vergleichbaren Standorten in Kalifornien und Südafrika beobachtet wurde; weitere Untersuchungen sind freilich erforderlich. Die Samenkeimung vieler in Südwestaustralien einheimischer Arten wird durch Temperaturen ausgelöst, die der Winterregenperiode entsprechen. Es gibt auch Hinweise, daß eine Nachreifeperiode mit warmer, trockener Lagerung die prozentuale Keimfähigkeit erhöht. Eine hormonelle Keimförderung ist bislang fast nicht in Westaustralien untersucht worden, aber bei einer kleinen Anzahl von gartenbaulich interessierenden Arten konnte die Keimfähigkeit erhöht werden. Auch eine Keimförderung durch Bodennährstoffkonzentrationen ist in Westaustralien so gut wie nicht untersucht, abgesehen von hemmender Wirkung exzessiver Natriumchloridkonzentrationen bei *Eucalyptus* und *Melaleuca.* Samen dieser Arten keimen nur, wenn die osmotischen Bedingungen soweit erniedrigt werden, wie es geschieht, wenn Winterregen Bodensalze verdünnen. Die Anwendung der Untersuchungen der Samenkeimung hat bereits das erfolgreiche Anwachsen von Sämlingen bei der Wiederbegrünung ehemaliger Gruben verbessert und wird ein wichtiger Aspekt bei Zucht und Auslese einheimischer Pflanzen zur Nutzung als Schnittblumen, Gartenpflanzen und beim Anbau für die Nutzung ätherischer Öle sein.

I. Introduction

The vegetation of southwestern Western Australia is predominantly woody with shrublands (kwongan), woodlands (coastal *Banksia* woodlands and the inland transitional eucalypt woodlands) and forests (dry and wet sclerophyll forests) (Beard, 1990). Perennials predominate with shrubs the most common life form. Trees are common in more moist situations and ephemeral annuals appear in numbers only in occasional habitats. The southwest of Western Australia has a Mediterranean-type climate, a range of soil types, often with severe nutritional deficiencies, and is subject to periodic fires.

Seed germination is a critical process in the ecology of species of this Mediterranean-type climate. This review endeavors to describe the adaptations of native species of this region which enable them to suitably time their emergence from quiescent propagules into a habitat subjected to periodic drought, temperature extremes and fire.

II. Life History Syndromes

The vegetation of southwest Western Australia contains species with a wide range of successful adaptations to cope with environmental stresses, but it is possible to group species with common ecological syndromes. Syndromes are ecological life history responses that are correlated to environmental regimes and are shared by a group of species (Stebbins, 1974). Species can be grouped in relation to the stress of periodic fire as ephemerals, obligate seeders or resprouters (Bell et al., 1984). Ephemerals tend to avoid the direct impact of fire, either by being quiescent during the summer and autumn fire season as underground perennating organ species or annuals. The parent individuals of obligate seeder species are killed by complete fire scorch and must re-establish from seed to maintain the species in the post-fire environment. Resprouting species recover from fire from epicormic buds buried under thick bark or in underground lignotubers, corms, bulbs, rhizomes or roots.

A. EPHEMERALS

Fire ephemerals (or fire weeds) are short-lived species which appear in the first years following a fire and usually complete their life cycle well before a second fire occurs (Bell et al., 1984). Much of the annual photosynthetic reserve of ephemerals is ultimately channelled into reproduction (Fig. 1). Both monocarpic and polycarpic ephemerals have been recognized in the vegetation of southwestern Western Australia. Monocarpic ephemerals are strictly therophytic, germinating with the winter rains and completing the production of seeds in the first year. Growth and reproduction are the primary competing processes for photosynthetic reserves in the monocarpic ephemeral, with energy for maintenance only required to carry the plant to completion of seed set in late spring or early summer. Typical of this life form would be *Athrixia asteroides, Podotheca gnaphalioides, Waitzia paniculata* (all Asteraceae), *Calandrinia corrigioloides* (Portulacaceae), *Isotoma hypocrateriformis* (Lobeliaceae), *Macarthuria apetala* (Aizoaceae), *Stipa elegantissima* (Poaceae) and *Trachymene anisocarpa* (Apiaceae). Monocarpic fire ephemerals of the northern sandplain kwongan were studied by Pate et al. (1985), who found that they tended to produce smaller seeds and exhibited greater seed output per unit biomass and higher harvest indices for dry matter and minerals than polycarpic species.

In Western Australia, polycarpic ephemerals pass the initial season vegetatively and then reproduce in at least two and usually further seasons before the parent plant dies. Representatives of this life form include *Alyogyne hakefolia* and *Anthocercis littorea* (both Solanaceae), *Codonocarpus cotinifolius, Gyrostemon ramulosus* and *Tersonia cyathiflora* (all Gyrostemonaceae) and *Scaevola phlebopetala* (Goodeniaceae). *Tersonia cyathiflora* is typical with a rapid growth vegetative phase in the first

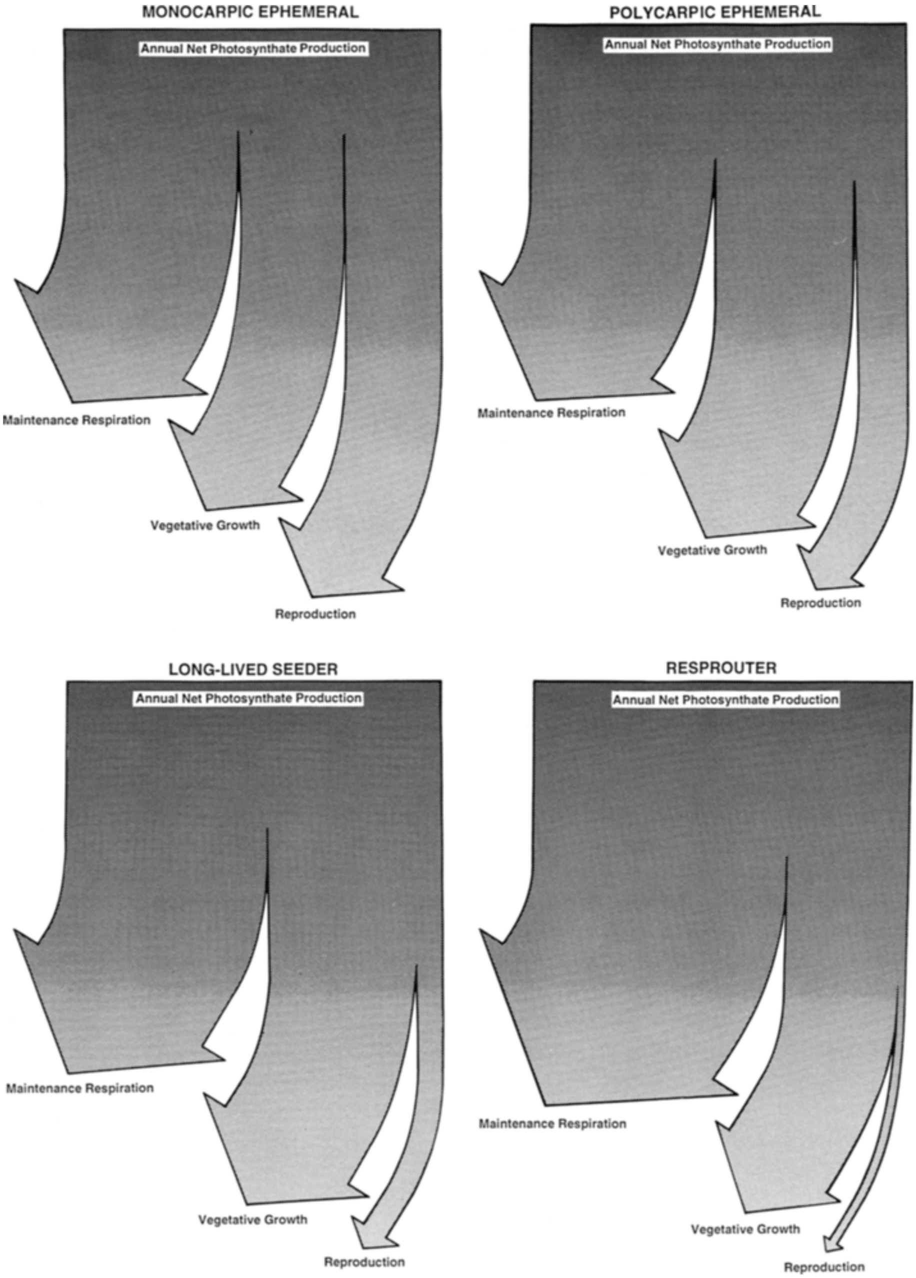

Fig. 1. Diagrammatic representation of the relative partitioning of annual photosynthate production into maintenance respiration, growth and reproduction for monocarpic and polycarpic ephemeral-, long-lived seeder- and resprouters-fire response syndrome species.

growing season, reproduction occurring in years 2 through 4 or 5 and then death of the parent plant. The polycarpic ephemerals are short-lived compared to the obligate re-seeding species, but share the characteristic that parent plants are killed when the above ground parts are completely scorched by fire (Bell et al., 1984).

B. SEEDERS

Adult individuals of obligate re-seeding species are killed by intense fire and must establish seedlings to maintain a role in the post-fire environment (Bell et al., 1984; Keeley & Zedler, 1978). Obligate seeders make up approximately a third of the species of the fire prone kwongan and sclerophyll forest communities in Western Australia (Bell, 1985; Bell et al., 1984). Seeders can be herbaceous perennials [e.g., *Johnsonia pubescens, Thysanotus multiflorus* and *Laxmannia grandiflora*) (all Anthericaceae)], suffrutescent shrubs [e.g., *Leucopogon conostephioides* (Epacridaceae), *Opercularia echinocephala* (Rubiaceae), *Velleia trinervis* (Goodeniaceae)], shrubs [e.g., *Acacia pulchella* (Mimosaceae), *Beaufortia elegans* (Myrtaceae), *Hakea obliqua* (Proteaceae)] or trees [e.g., *Banksia prionotes, B. seminuda* (Proteaceae)] (van der Moezel et al., 1987). Obligate re-seeding species tend to grow vertically initially, then distribute biomass disproportionately toward the upper part of the stem to produce plants with a distinct "umbrella shape" (Delfs et al., 1987). This distinct shape fills available post-fire resource space between resprouting species, which tend to have multiple basal sprouting branches and more of an "urn-shape." Seed regenerating species also tend to have shallow and fibrous roots compared to the woody, deep roots of resprouters (Dodd et al., 1984). Contrasting shoot and root morphologies allow obligate re-seeding and resprouting species to coexist successfully for many years of a post-fire interval (Delfs et al., 1987), but species diversity tends to decline as fire interval length increases due to the loss of re-seeding species (Bell & Koch, 1980). Annual reproductive output in seeders is generally higher than in resprouting species (Fig. 1) (Hansen et al., 1992), and some seeders produce few, but large seeds (e.g., *Hakea obliqua* of the Proteaceae), while others produce numerous small seeds (e.g., *Beaufortia elegans* of the Myrtaceae) (Bell et al., 1987a). The large seed-producing species appear to be maximizing survival of individual seedlings in the post-fire habitat, while the small-seeded species survive by satiating seed harvesting predators and exploiting nutrient rich ash bed locations following fire-cued seed release.

C. RESPROUTERS

Nearly two-thirds of the species of plant communities in southwestern Western Australian plant communities survive severe fires by resprouting from protected buds under bark of above-ground organs, from buds of underground basal lignotubers, or from other underground perennating tissue (Bell & Koch, 1980; Bell et al., 1984; Christensen & Kimber, 1975). Some resprouting species, for example *Jacksonia densiflora* (Papilionaceae), *Bossiaea ornata* (Papilionaceae), *Dryandra bipinnatifida* (Proteaceae) and several *Eucalyptus* (Myrtaceae), also regenerate freely from seed, thus sharing attributes with both the re-seeding post-fire response syndrome and species of long-lived resprouting species that regenerate only rarely from seed (Delfs et al., 1987, van der Moezel et al., 1987). Resprouting species can be trees [e.g., *Eucalyptus marginata* (Myrtaceae), *Banksia grandis* (Proteaceae), *Allocasuarina fraseriana* (Casuarinaceae)], woody shrubs [e.g., *Hibbertia hypericoides* (Dilleniaceae), *Hypocalymma xanthopetalum* (Myrtaceae), *Hakea lissocarpha* (Proteaceae)] or herbaceous perennials [e.g., *Anigozanthos manglesii* (Haemodoraceae), *Conostylis setosa* (Haemodoraceae), *Lyginia barbata* (Restionaceae)] (Bell et al., 1984; van der Moezel et al., 1987). Most set viable seed only rarely and seedlings are uncommon even in the years immediately following fires (Fig. 1).

III. Seed Storage Syndromes

In addition to fire-response syndromes, the species of southwest Western Australia can also be grouped depending on their mode of seed storage. Many species of Western Australia have topsoil seed banks (Bellairs, 1992; Vlahos & Bell, 1986). The seed that is matured annually is broadcast from the parent plant to the soil surface. Southwest Western Australia also has species which store seed in the canopy (Bellairs & Bell, 1990a; Lamont et al., 1991). These serotinous species retain their annual production of seed in woody, protective capsules on the plant and only disperse the seed after considerable time. Seed release may occur with the death of the branches supporting the fruits, but release of serotinous seeds may also require heating (Gill, 1976; Lamont & Cowling, 1984) or charring (Gill, 1981a, 1981b) and/or soaking (Cowling & Lamont, 1985a).

A. SOIL BORNE SEEDS

The soils of the jarrah forest average approximately 750 seeds m^{-2} (Vlahos & Bell, 1986). Although the vegetation is dominated by shrubs, the seeds of the soil are predominantly annual ephemerals (35%) and short-lived polycarpic sub-shrubs (24%), while only 16% are the seed of longer-lived shrubs, which dominate the living structure of the forest. Of the shrub seeds, the top seven species recorded by Vlahos and Bell (1986) were re-seeding fire response syndrome species: *Trymalium ledifolium* (Rhamnaceae), *Thomasia pauciflora* (Sterculiaceae), *Gompholobium marginatum*, *G. capitatum*, *Kennedia coccinea* and *K. prostrata* (all Papilionaceae), and *Acacia pulchella* (Mimosaceae). The sub-shrubs and annuals which make up the majority of soil borne seeds of the jarrah forest are the species previously described as fire syndrome ephemerals. The most prolific seed producers of the sub-shrubs were *Xanthosia atkinsoniana* (Apiaceae), *Stylidium brunonianum* (Stylidiaceae), *Boronia viminea* (Rutaceae) and *Platysace compressa* (Apiaceae). The most common monocarpic ephemerals of the jarrah forest soil seed bank included *Stylidium calcaratum* (Stylidiaceae), *Waitzia paniculata* (Asteraceae), *Hydrocotyle callicarpa* (Apiaceae) and *Levenhookia pusilla* (Stylidiaceae). A most notable feature of the soil seed bank of the jarrah forest was the near absence of seed of the dominant tree, *Eucalyptus marginata* (Myrtaceae), and major species of the understorey tree and shrub strata. The lack of a soil seed store has been noted in other eucalypt forests (Ashton, 1970). A feature of dry sclerophyll forests like the jarrah forest is a reliance on a suppressed seedling bank to fill canopy gaps. Ants harvest the majority of canopy species seed (Abbott & van Heurck, 1985), but an occasional seed germinates quickly enough to develop a surviving lignotuberous seedling. Once a disturbance opens the habitat, the suppressed seedling is able to take advantage of the increased nutrient or light availability and to grow rapidly (Wallace, 1966). Further north in the sandplain kwongan near Eneabba, the soil seed bank is even more reduced with an average of less than 200 seeds m^{-2} (Bellairs, 1992). Important species of the Eneabba kwongan soil seed bank were also annuals and the obligate re-seeding species, rather than the dominant woody resprouting species.

B. CANOPY BORNE SEEDS

In addition to the soil seed bank, southwestern Western Australia has a second major source of seeds. Particular species of the Proteaceae, Myrtaceae and Casuarinaceae carry seed reserves in protective fruits on the plant itself (Lamont et al., 1991). The jarrah forest carries only a limited number of canopy seed storage or serotinous seed species. Bellairs and Bell (1990a) estimate 7 seeds m^{-2} for the jarrah forest, but in kwongan communities of drier regions in Western Australia, the canopy stored seed component of the vegetation can total more than 1100 seeds m^{-2}. Canopy seed store species can be both obligatory re-seeding species and resprouting fire response syndrome species. Lamont and co-workers (1991) estimate there are in excess of 350 serotinous species in Western Australia. The proportion of on-plant seed storage species tends to increase with decreasing average annual rainfall in southwest Western Australia (Bellairs & Bell, 1990a), but particular soil types do not seem to influence this form of seed store. As with the general trend between fire re-seeding and resprouting species, the obligate re-seeding, serotinous species tend to produce greater numbers of seeds per plant than serotinous species, which are capable of resprouting following severe fire (Bellairs & Bell, 1990a).

IV. Viability

A. ENVIRONMENTAL STRESS

Conditions of seasonal drought and poor soil nutrient availability in many southwestern Western Australian habitats often restrict plants from having sufficient photosynthetic reserves to complete the reproduction process each year. Information on seed viability and germination percentage with and without a heat shock pretreatment has been collected from a range of sources for 443 Western Australian species (Appendix I). Tetrazolium chloride has been used to assess the viability of only 73 species. A mean of 51% for this sample indicates that seed in Western Australia species is often aborted (Table I). To increase the sample size by also using the highest value of the germination measures to indicate viability and grouping the species by ecological syndrome indicates no difference in viability depending on fire response type, but a major difference between the viability of seed from species annually depositing seed into the soil and those retaining seed in the canopy (Table I). Apparent from these calculations is that species which produce protective fruit structures to restrain and protect seed for on-plant storage generally insure that the seeds produced are viable. Species without this adaptation apparently tend to abort a greater proportion of seeds in each annual cohort. Often among those species with low viability (or germinability) are smaller statured species. Sub-shrubs often have shallow root systems and periods of water deficit develop during late spring and summer when surface soil moisture is depleted (Dodd & Bell, 1993). Limited water availability during the period of seed maturation could reduce the proportion of viable seed produced.

Table I

Viability of Western Australian seeds. The number, mean ± standard error of species collated in Appendix I. Comparison of fire response and seed storage syndromes by one-way ANOVA and Fisher's Least Significant Difference

Characteristic	n	Range	Mean ± SE	Sig. Diff.
Viability[1]	73	0–100%	51.2 ± 4.2	
Viability[2]	443	0–100%	32.1 ± 1.7	
Viability of reseeders	123	0–100%	36.2 ± 3.0	
Viability of resprouters	292	0–100%	37.6 ± 2.1	N.S.
Viability of soil borne seeds	278	0–98%	20.5 ± 1.7	
Viability of serotinous seeds	164	0–100%	62.4 ± 2.5	$P < 0.001$

[1] "Viability" determined by tetrazolium chloride treatment test.

[2] "Viability" determined as the highest value determined by tetrazolium chloride test, germination percentage without pretrial treatment or germination percentage with a boiling heat shock treatment before provision of moisture and moderate temperature germination conditions.

B. INBREEDING AND OUTCROSSING

Production of inviable seeds due to inbreeding is a process not well researched but apparent in some rhizomatous species of the Cyperaceae and Restionaceae. These species often reproduce asexually creating large areas containing plants of a common clone, which do not produce any viable seed. The Western Australian flora is extremely rich and diverse (Lamont et al., 1984) with species showing a range of isolation mechanisms (James & Hopper, 1981). Many Western Australian species are self-incompatible, for example, *Banksia menziesii* is protandrous and probably aborts pollen germination tubes before fertilization in self-pollen transfers (Lewis & Bell, 1981; Ramsey & Vaugton, 1991). Very low flower to fruit and seed to ovule ratios have been shown for eastern states species in the Proteaceae (Ayer & Whelan, 1989). Low values of realized female fertility appear to be common in woody perennials and outbreeding perennials have lower values than inbreeders (Charlesworth, 1989). Coupled with the inherent patchiness of the vegetation (Bell & Koch, 1980; Bell & Loneragan, 1985), species requirements for cross-pollination and pollinator limitation could also lead to restricted production of viable seed.

Self-incompatibility may be conditioned by factors which act after fertilization as well as pre-fertilization (James, 1978). Post-zygotic seed abortion systems characterize most perennial species of *Stylidium* (Stylidiaceae) (James, 1979; Burbidge & James, 1991), the complex hybrid populations of *Isotoma petraea* (Lobeliaceae) (James et al., 1992) and many of the Western Australian *Drosera* (Droseraceae) species (James and Chen, pers. comm.). Post-zygotic seed abortion systems are common in the Myrtaceae (Rye, 1980) and such systems which discriminate against genetic homozygotes and amplify the frequency of outcrossed products in the surviving seed have been demonstrated in *Eucalyptus camaldulensis* (James and Kennington, pers. comm.). This system of concentrating outcrossed genotypes in eucalypts is probably universal, rendering them highly outbreeding in so far as their seed production is concerned although they are mainly self-pollinating and self-compatible. It is highly probable that genetic factors acting late in seed development or in the seedling and juvenile stages of the life cycle, rather than early seed abortion, contribute to the inherent inviability of seeds in many Australian hermaphroditic, self-compatible and mainly self-pollinating plant species.

As in most environments, many species produce seeds which do not germinate directly after dispersal when provided with moisture and moderate temperatures. Embryos may be immature and require a period of 'after-ripening' to develop the ability to germinate. Other species produce viable seeds, which are innately dormant and require particular cues before germination can occur.

V. After-ripening and Stratification

A low temperature storage (or 'cold stratification') requirement delays germination until late in winter or early in spring, thereby preventing germination when the chance of freezing conditions could affect establishment of germinating seed (Baskin & Baskin, 1987; Meyer et al., 1990). In temperate southeastern Australia, eucalypt species germination can be enhanced by cold stratification, scarification, leaching and treatment with gibberellic acid (Bachelard, 1967; Boden, 1957; Pryor, 1954). Low temperature stratification has also been employed to reduce the duration of a required after-ripening period. In Australia, hastened germination responses of imbibed seeds following cold stratification is common in many species from higher altitudes of more temperate regions (Carroll & Ashton, 1965; Cunningham, 1960; Grose & Zimmer, 1957; Hagon, 1976; Howard & Ashton, 1967; Pryor, 1954; Willis & Groves, 1991). In the Mediterranean-climate southwestern Australia, however, frosts are rare, and it would appear that a requirement for cold stratification would delay germination to a point where the time period is available for growth of roots would be sufficient to insure survival across the summer drought period. A cold stratification requirement under these circumstances, therefore, would be a disadvantage rather than a form of dormancy maintenance cueing germination to the period of the year best suited for the chances of long-term survival.

Of more likely ecological advantage to Western Australian habitats would be a seed dormancy broken by storage in hot, dry conditions rather than a stratification in cold, wet conditions. Newly shed seed of *Aristida contorta* (Poaceae), a summer germinating grass of the arid interior, requires a period of after-ripening before germinating. The time period before germination can be initiated is reduced by storage at high temperatures (Mott, 1972). Mott (1972) also found that the after-ripening period of two winter-germinating composites, *Helichrysum cassinianum* and *Helipterum craspedioides,* was shortened by dry heat storage. Apparently these winter annuals from the arid interior of Australia require several months of dry heat before the majority of seeds are ready to germinate, thus restricting the possibility of germination following short, summer thundershowers. The paucity of research on after-ripening and the influence of various storage regimes on seed germination is seriously lacking in the knowledge of germination ecology of Western Australian species.

VI. Readily Germinable Seeds

A. GERMINATION OF SEROTINOUS SEEDS

In addition to serotinous species producing more viable seeds than species which annually release seed to the soil for storage, the seeds of serotinous species generally show no form of germination dormancy once released from the protective fruits. A comparison of values of germination percentage without heat shock pretreatment of the species of Appendix I indicates that the 278 values for soil-borne seed species averaged only 20.5 ± 1.7% compared to 62.4 ± 1.7% for the 164 serotinous seed species (Table I). The protective fruits prevent extensive seed herbivory and shield the seed from the intense heat of the fires, and in some *Banksia* species, also prevent dispersal until a series of wetting and drying events opens the follicles and the seed separator works free (Cowling & Lamont, 1985a). However, serotinous seeds, once freed, are temperature sensitive and germinate only at temperatures coincident with the winter rains (Bell & Bellairs, 1992). Seeds of the heavily protected *Banksia* and *Hakea* species are sensitive to a heat shock treatment, but seeds of *Dryandra,* a genus where the follicles appear to be more exposed, are capable of withstanding intense heat (Bell et al., 1987a).

Although serotiny is not normally considered a form of primary seed dormancy, the protection of seed in woody fruits until release (usually post-fire) prevents the viable and easily germinable seed from falling into habitats where mature vegetation would generally outcompete establishing seedlings. Synchronous release of seed also saturates the seed consuming ant populations and further enhances the chance of establishment (Gill, 1981b). The degree of serotiny is usually strongest in habitats where summer drought stress is also high. Cowling and Lamont (1985b) illustrated a cline of *Banksia* species which retained seed for many years in the driest habitats, but seed release was nearly every year in more moderate habitats where mild summer conditions may allow the establishment of seedlings in the interval between fires. *Banksia seminuda,* a forest species of moist stream banks, releases seeds annually following a delay in dehiscence of only a few months (Baird, 1988).

Serotinous fynbos species from South Africa also germinate readily following fire induced release from the woody fruits, germinating best at temperatures < 15°C (Brits, 1986; Deall & Brown, 1981; Mitchell et al., 1986). Seeds of the serotinous species of *Cupressus* and *Pinus* from California also appear to germinate freely following release from cone, producing even-age stands in the first year following fire (Vogl et al., 1977; Zedler, 1977). Studies of the few Mediterranean Basin serotinous species of pines, e.g., *Pinus bruita,* indicate that seed dormancy is induced by the cones and once freed, the seeds germinate easily at moderate temperatures (Thanos & Skordilis, 1987).

B. SEEDS OF FIRE STIMULATED FLOWERING SPECIES

A group of species that also produce viable, easily germinable seeds are species of *Xanthorrhoea* (Xanthorrhoeaceae) and *Haemodorum* (Haemodoraceae) (Appendix I). These monocotyledonous species resprout after fire and tend to flower prolifically in the growing season following the fire (Bell et al., 1989). The seeds produced are thus released into a habitat still reasonably rich in soil nutrients, light and moisture. Seedling survival following germination in the second winter following the fire is, therefore, expected to be greater than seeds germinating at other times in the interfire period. Baird (1977) also noted that *Haemodorum paniculatum* and *H. spicatum* flowered abundantly only after fire.

Fire-stimulated flowering appears to be a common feature in the fynbos with representatives in the Iridaceae, Orchidaceae, Liliaceae, Amaryllidaceae, Poaceae and Restionaceae (Frost, 1984; Kruger, 1983), but characteristics regarding the seed viability and germination of these fire response monocotyledons is limited. *Watsonia* *pyramidata* (Iridaceae) establishes seedlings in the second growing season after fire (Kruger, 1977) and seeds are reported to germinate readily at cool temperatures, but remain dormant at temperatures above 25°C (Esterhuizen et al., 1986). Chaparral geophytes and certain sub-shrubs flower prolifically in the first post-fire year and have readily germinable seeds (Keeley & Keeley, 1984). Chaparral species which flower mainly in the first few years following a fire also appear to produce seeds which are susceptible to intense heat (Keeley, 1991), as were certain species of the jarrah forest which release their seeds into a habitat which is rarely capable of carrying a second fire.

C. GERMINATION OF SEEDS OF EPHEMERALS

A third group of species producing seeds which germinate readily once provided with adequate moisture and moderate temperature conditions are several of the therophytes. These included *Helichrysum bracteatum, Lagenifera heugelii* and *Podotheca gnaphalioides* of the Asteraceae and *Stylidium calcaratum* of the Stylidiaceae. Annuals are not a common feature of the southwestern Australian flora, but some ephemerals appear to have the capacity to produce readily germinable seeds in a short season of adequate moisture and low soil nutrients. The low viability and germination percentages of other annuals, such as *Helipterum cotula* and *Waitzia suaveolens* (both Asteraceae) and *Isotoma hypocrateriformis* (Lobeliaceae), however, indicate that environmental stress may also limit seed production in this life form.

VII. Seeds with Innate Dormancy

The seeds of numerous species of the Western Australian flora do not germinate easily once provided with moisture, moderate temperatures and an atmosphere of normal composition under laboratory conditions. Dormancy is typically understood to be a condition which delays germination until conditions are more likely to ensure survival and continued reproduction of the genome (Mayer & Poljakoff-Mayer, 1989). In Western Australia, the recurrent fires provide a periodic situation of an open environment, with enhanced conditions of moisture, light and nutrients; conditions normally favoring the survival of germinated seeds. Seeds with a hard integument, which prevents germination until cued by a fire, appear common in the Western Australian flora, especially in the legume families, but research on other soil-borne seed species is limited.

A. HEAT SHOCK RESPONSE SPECIES

Heat shock response species are able to germinate due to the fracturing of the hard seed coat allowing penetration of water, exchange of gases and/or freeing the embryo from a mechanical constraint from the testa (Mott & Groves, 1981; Rolston, 1978; Villiers, 1972). Short exposures to the high temperatures reached in soil during fires greatly increase germination percentages (Floyd, 1966; 1976; Jones, 1963; McCaw, 1988; Monk et al., 1981; Portlock et al., 1990; Purdie, 1977). Exposure to boiling water (Farrell & Ashton, 1978; Glossop, 1980; Jones, 1963; Myers, 1936), dry heat (Jones, 1963; Portlock et al., 1989) or mechanical scarification and acid treatments (Auld, 1986; Aveyard, 1968; Clemens et al., 1977; Jones, 1963; Larsen, 1964) also result in increased germination percentages of hard-seeded species.

Heat shock responsive seeds are predominantly legumes, but seeds of other species also respond to short exposures to high temperatures (Bell et al., 1987a). For example, germination percentages of *Conostylis setosa* of the Haemodoraceae and *Trymalium ledifolium* and *T. floribunda* of the Rhamnaceae are also increased by heat treatments. The heat shock response insures seeds remain dormant until a fire provides a better chance of seedling survival. Boiling treatment is commonly applied for the legume species provided in broadcast seed mixes in the reclamation of bauxite mines in the jarrah forest (Glossop, 1980). Considerable research has gone into the duration of the boiling heat shock treatment to maximize subsequent germination of these seed. Of 58 Western Australian legume species tested only nine did not show a marked increase in percentage germination following boiling treatments (Table II). Of these, four (*Acacia obovata, Bossiaea ornata, Hovea chorizemifolia* and *Labichea punctata*) were resprouting species, which may gain some evolutionary advantage by establishing seedlings during interfire periods. Three *Gompholobium* species (*G. capitatum, G. marginatum* and *G. tomentosum*) also showed high germination percentages and no increase following the heat shock treatments. In fact these species tended to be sensitive to the longer durations of the boiling treatments. An observation concerning *Gompholobium tomentosum* is that the legume pod in this species is small and almost round and falls from the plant without splitting to release the seed (D. T. Bell, unpubl.). It may be that the *Gompholobium* pod provides the same protection from fire as is provided in the serotinous species, but the fruit is actually dehisced from the plant. The final two species not stimulated toward increased germination percentages following boiling treatment were species of *Kennedia* (*K. carinata* and *K. prostrata*). As in *Gompholobium*, both were adversely affected by the boiling treatments.

Variance in tolerance to heat shock intensity has been related to fire response syndrome in California. *Ceanothus greggii*, an obligate seeder, was more tolerant of intensive heat shock than was a facultative seeder-resprouter (*Adenostoma fasciculatum*) (Moreno & Oechel, 1991). Also, within congeneric species of *Ceanothus*, seeders were more tolerant of intense heat than resprouters (Barro & Poth, 1988). Comparisons of the duration data from the Western Australian species indicated that 300 seconds tended to reduce germination percentages in most of the species (Table II). Within the Western Australian data, there are examples of seeders with no significant germination percentage reduction at 300 seconds (e.g., *Acacia alata, A. browniana, A. celastrifolia, A. pulchella* and *Paraserianthes lophantha*), but *Acacia lateriticola* is a resprouting legume without a depression of germination percentage following 300 seconds of boiling treatment. The advantages of greater heat shock tolerance do, however, appear to reside with the obligate re-seeding legumes.

The release from dormancy following heat shock treatments has also been attributed to the effect of heat denaturing seed coat inhibitors (Auld, 1986; Mayer & Poljakoff, 1989). Thirty-one species of the Western Australian legumes in the boiling duration trials also received a scarification treatment (Table II). If seed coat inhibitors prevent germination, the scarification process should show similar percentage germination values as control conditions. If the seed coat acts as a barrier, then scarification will show percentage germination values comparable to those achieved following boiling. The Western Australian trials show examples of both scenarios. A range of species (e.g., *Acacia nervosa, Bossiaea eriocarpa, Gompholobium knightianum, G. polymorphum, Hovea pungens, H. trisperma, Jacksonia furcellata* and *Sphaerolobium vimineum*) showed scarification treatment germination percentages similar to the post-boiling treatment germination percentages. Others (e.g., *Acacia divergens, A.*

Table II

Percentage germination of Western Australian native legume species subjected to no pre-treatment, to scarification and to boiling heat shock treatment of 30, 60, 120 and 300 seconds duration

Species	No pre-treatment control	Seed scarified	Boiling period (seconds)			
			30	60	120	300
Acacia alata	20		69	75	73	68
Acacia browniana	12		78	78	79	82
Acacia celastrifolia	8		91	90	90	85
Acacia cyclops	12	72		20	23	
Acacia divergens	11	28	90	87	83	
Acacia drummondii	10		92	90	86	79
Acacia drummondii var. *candolleana*	6	18	77	77	74	
Acacia drummondii var. *drummondii*	8	16	56	43	53	
Acacia extensa	4		60	54	45	38
Acacia horridula	8		84	72	70	74
Acacia lasiocarpa	20	30	82	82	66	
Acacia lateriticola	11		81	74	76	78
Acacia microbotrya	14		58	66	50	45
Acacia myrtifolia	13		86	84	76	81
Acacia nervosa	16	66	72	70	70	
Acacia obovata	54	40	42	53	56	
Acacia pulchella	10		76	82	76	73
Acacia pulchella var. *glaberrima*	4	13	91	86	82	
Acacia saligna	39		62	56	56	49
Acacia urophylla	21		74	70	69	68
Bossiaea aquifolium	23		52	42	30	34
Bossiaea eriocarpa	2	40	55	49	38	
Bossiaea ornata	42		46	42	42	36
Bossiaea pulchella	18		92	92	82	72
Chorizema dicksonii	10		79	77	55	40
Chorizema ilicifolium	39		69	58	54	42
Chorizema rhombeum	1	5	10	10	23	
Daviesia cordata	17	71	39	17	12	
Daviesia horrida	3	28	83	42	36	
Daviesia physodes	9	78	92	81	32	
Daviesia preissii	0	55	58	18	10	
Gastrolobium calycinum	5	15	5	5	5	
Gastrolobium spinosum	16	35	78	66	74	
Gompholobium capitatum	58		48	38	28	22
Gompholobium knightianum	6	51	61	86	67	
Gompholobium marginatum	83		70	57	8	0
Gompholobium polymorphum	15	53	68	67	51	
Gompholobium tomentosum	73	67	2	3	0	
Hardenbergia comptoniana	56		94	90	78	61
Hovea chorizemifolia	39	46	56	55	44	36
Hovea pungens	19	72	42	26	12	
Hovea trisperma	17	55	78	42	57	
Jacksonia furcellata	18	44	32	30	26	
Kennedia carinata	18	13	0	1	0	
Kennedia coccinea	16		94	90	88	10
Kennedia prostrata	51	55	26	24	20	12
Labichea lanceolata	33	31	79	68	80	
Labichea punctata	55	66	52	37	18	
Mirbelia diliatata	33		76	66	66	54
Oxylobium cuneatum	4	22	45	39	14	

Table II
Continued

Species	No pre-treatment control	Seed scarified	Boiling period (seconds)			
			30	60	120	300
Oxylobium lanceolatum	8	63	87	83	74	
Paraserianthes lophantha	2		40	45	42	51
Sphaerolobium medium	12	36	52	44	28	
Sphaerolobium vimineum	12	41	27	35	24	
Viminaria juncea	25	32	72	64	64	

drummondii, A. lasiocarpa and *Viminaria juncea*) did not respond to the scarification treatment with increased germination percentages despite evidence for seed imbibition. Research by Walker and Pate (1986) on *Viminaria juncea* indicated that germination was achieved only after a H_2O_2 treatment followed by 24 hours of leaching by running water. The leaching treatment stimulus could indicate the removal of a water soluble inhibitor, but it is also likely that the H_2O_2 treatment weakened the seed coat to the point where imbibition could occur. A detailed anatomical study on the impact of boiling on *Paraserianthes lophantha* (formerly *Albizia lophantha*) by Dell (1980) indicated that boiling cracked the cuticular layer and also opened a region referred to as the "strophiolar plug" to allow the entry of water. Although further research is required, heat shock cracking of seed coat barriers appears to be more common than the denaturing effect of heat on seed coat inhibitors in Western Australian species.

Variation in soil moisture status during fires can also be influential in the heat shock response of hard-seeded species (Gill, 1981a). In *Acacia pulchella* stimulation patterns with high soil moisture were different from those when soils were dry (Portlock et al., 1990). Thermal diffusion rate increases in a curvilinear fashion with increasing soil moisture (Nakshabandi & Kohnke, 1965). Aston and Gill (1976) also studied the interrelations of soil moisture and the temperatures produced during fire conditions. Temperatures on the soil surface can be lethal to seed yet thermal diffusion to depth may be insufficient to crack seed coats below 6 to 8 cm (Portlock et al., 1990). Burial by ants is maximized near 4 cm for *Acacia pulchella* (Shea et al., 1979) and the interaction of heat penetration during fires and the heat required to break dormancy appears to converge near 4 cm as well (Portlock et al., 1990). Differential response to intense heat and variation in soil moisture may also be responsible for the purely seasonal effects recorded for fires (Baird, 1977).

Some species of *Acacia* are only slightly tolerant of intense heat treatments. *Acacia cyclops,* a species of coastal sand dune, germinates without heat shock treatment and is killed when soil temperatures during fires rise above 100°C for durations exceeding 10 minutes (Christensen et al., 1981; Jeffery et al., 1988). *Acacia saligna,* also a species of coastal habitats, tends to survive mild fires but intense heat kills seed (Jones, 1963; Jeffery et al., 1988). Also, fire may not be the only stimulus to break the dormancy caused by hard seed coats. Low temperature imbibition and subsequent drying of seed of the hard-seeded species, *Acacia blakelyi, A. pulchella* and *Kennedia prostrata,* increased the proportion of seeds that germinated following re-irrigation in a study by Bellairs and Bell (1990b). Presumably the drying process cracked the seed coat in a manner similar to that observed by Lush and co-workers (1984) for *Clematis microphylla.*

Fire-stimulated germination is common in the Californian chaparral and the South African fynbos, but is less a feature in the maquis of the Mediterranean Basin or the matorral of central Chile (Kruger, 1983; LeMaitre & Midgley, 1992; Trabaud, 1981). Seeds of the chaparral shrub genus *Ceanothus* of the Rhamnaceae tend to have hard seeds that germinate only after exposure to intense heat (Keeley, 1991). Other chaparral shrubs stimulated to germinate by heat shock are *Rhus ovata, R. integrifolia* and *Melosma laurina* of the Rhamnaceae (Keeley, 1991; Stone & Juhren, 1951) and several species of *Fremontia* (Sterculiaceae) (Keeley, 1991). The chaparral also has a number of short-lived legumes (e.g., *Lotus scoparius, L. salsuginosus, L. strigosus* and *Lupinus excubitus*) (all Papilionaceae), with heat shock responsive germination. The South African fynbos has numerous heat shock responsive seed species. In addition to species in the legume families (e.g., *Podalyria calyptrata* and *Virgilia oroboides* (Papilionaceae) (Jeffrey et al., 1988), there are South African hard-seeded species in the Rutaceae (*Agathosma* spp.) (Blommaert, 1972), the Ericaceae (*Erica hebecalyx*) (Van de Venter & Esterhuizen, 1988) and Proteaceae (*Leucodendron* spp.) (Brown & Dix, 1985; Williams, 1972). The number of species with this form of post-fire germination cue are not as common in Europe. There are, however, examples of heat responsive legume species in the genus *Cistus* (Papilionaceae) from the region of the Mediterranean Sea. *Cistus albidus, C. ladanifer, C. laurifolius, C. monspeliensis* and *C. salvifolius* have impermeable seed coats that prevent germination without pretreatment. Scarification, heat shock and long leaching times have been successful in breaking dormancy in these European legumes (Corral et al., 1990). Heat-stimulated germination appears to be a common adaptive feature in habitats with the potential for intense fires, and therefore, the vegetation of California, South Africa and Western Australia has greater numbers of species successfully developing this germination cue compared to the vegetation of Chile and southern Europe, where intense fire events are less common.

B. INFLUENCE OF INCUBATION TEMPERATURES

Extremes of high and low temperature prevent germination of all seeds, but in many seeds germination is cued by incubation temperatures that best suit the subsequent survival of seedlings (Lodge, 1981; Lodge & Whalley, 1981; Young et al., 1973). In a study of 28 species from the Western Australian jarrah (*Eucalyptus marginata*) forest, highest germination percentages were achieved at temperatures of 10–15°C, temperatures most likely to occur during the winter rainfall period (Bell & Bellairs, 1992). Species growing in microhabitats where moisture was likely to be available in warmer seasons tended to have germination maxima at higher temperatures. A cline of germination temperature maxima was observed in three common species of *Eucalyptus*. In *Eucalyptus rudis,* a species of river margins near the coast where moisture would be available well into the summer period, germination percentages peaked at between 20°C and 30°C. In *Eucalyptus wandoo,* a species of lower slopes and inland river margins where precipitation and soil moisture regimes would be more limiting, the germination percentage maxima occurred in the range of 15–20°C. In *Eucalyptus oleosa,* an inland species of upland situations where soil moisture conditions would be conducive for germination only during the midwinter rainfall period, germination percentage maxima occurred in the 10–20°C range.

Species native to the more northern sandplain kwongan region near Eneabba have optimum germination percentages between 15°C and 20°C (Bellairs & Bell, 1990b). Eneabba has a more severe seasonal moisture regime than the jarrah forest region, but temperatures during winter tend to be higher in this more northerly habitat. In both studies, germination tended to be best at temperatures which correspond to the period of the year when continuous moisture would be available. The rather low temperature optima of these Western Australian Mediterranean-type climate species contrasts with the optimum germination temperatures of the subtropical Australian species, *Stylosanthes humilis* and several grasses, reported to be between 24°C and 35°C (Hagon, 1976; McKeon, 1985; Mott, 1978; Ross, 1976; Tothill, 1977). Species of grasses and forbs that germinate in summer in Victoria and New South Wales also tend to have higher optimum germination temperatures (Morgan & Myers, 1989; Watt & Whalley, 1982; Willis & Groves, 1991). A study of three eastern Australian *Banksia* species by Sonia and Heslehurst (1978) found that the germination response to temperature also reflected field temperature during establishment periods. *Banksia aemula,* a species with a more northern distribution, had higher optimum germination temperatures than *B. integrifolia* or *B. serrata.*

The response of hydrated seeds to other than optimal temperatures can be different, depending on whether temperatures are above or below the optima (Roberts, 1988). Low temperatures may induce dormancy in some circumstances, but in many species they are stimulatory (stratification response). High temperatures generally reinforce dormancy or may even induce it. Western Australian species, incubated at suboptimum but not freezing temperatures, germinate once placed in warmer conditions (Bell & Bellairs, 1992). A range of species incubated at temperatures of 35°C, however, failed to germinate when moved into conditions of 15°C (Bellairs & Bell, 1990b; Bell & Bellairs, 1992). An exception was the large-seeded species, *Xanthorrhoea gracilis* (Xanthorrhoeaceae), which was not adversely affected by 3 weeks of moist incubation at 35°C. Further study is required to determine whether the 35°C conditions induced further dormancy or killed seeds. Maintenance of dormancy under high temperatures is important for species of southwestern Australia as summer thundershowers can occur, but rarely produce sufficient amounts of soil moisture to carry developing seedlings into the winter period of regular rainfall events.

It might be expected that a requirement for alternating temperatures would be a more sensitive assessment of the environment than a mean daily temperature (Mott & Groves, 1981), but in several studies of Australian species there appears to be no positive effect of alternating temperatures per se with the diurnal temperature regime adequately represented by the mean (Burbidge, 1945; Myers, 1942; Ross, 1976). However, alternating temperatures have a positive influence in the germination of *Spinifex hirsutus* (Harty & McDonald, 1972) and *Aristida armata* (Brown, 1987). The enhancement of germination by alternating temperatures has been interpreted as inhibiting germination of buried seed and promoting germination of seed at or near the soil surface (Thompson, 1974; Thompson et al., 1977).

C. INFLUENCE OF LIGHT

Phytochrome reaction of far red and red light to break seed dormancy and interactions between light and temperature are known for some species (Borthwick et al., 1952; Toole et al., 1955). Light requirements for germination of Western Australian species have not been widely researched, but such a cue to germination appears of limited significance to species in this environment. Clifford (1953) in trials on 41 species of eastern Australian eucalypts found only two that required light for germination. Also, germination of a number of central Australia grass species had comparable germination percentages in regimes of light or dark conditions (Hagon, 1976). Inhibition of germination by light, however, has been documented for *Spinifex hirsutus*, a beach foredune species that germinates only when buried and in darkness (Harty & McDonald, 1972). The potential ecological significance of the response to variation of light is difficult to understand in the high light environment of southwestern Western Australia. Light may influence embryo development and, therefore, indirectly influence rates of germination. In Western Australia, only *Juncus pallidus* (Juncaceae) has been shown to be responsive to a phytochrome induction system (D. T. Bell, unpubl.). *Juncus pallidus* is a species of pond margins. The very light seeds float, are easily dispersed to the edges of the pond, and germinate readily on the surface of the soil or when only lightly buried once the water levels begin to drop in late spring. Dormancy in this species is maintained in the dark or in far red monochromatic light conditions.

D. INFLUENCE OF NUTRIENTS

Enhanced germination percentages under conditions of elevated nitrate have been observed in temperate grassland species (Hilhorst & Karssen, 1989; Pons, 1989). Nitrates are particularly low in Western Australian soils, more so in the first years following fire (Hansen et al., 1987). A specific possibility in the post-fire environment in Western Australia, however, could be an influence of 1) high post-fire soil solution concentrations of bicarbonate, calcium or phosphorus; 2) low post-fire soil solution concentrations of nitrates; or 3) high pH per se. The addition of ash to the soil surface following fire supplements the soil solution temporarily, especially in calcium which is the primary cause of increased pH levels measured following fire (Humphreys & Craig, 1981). Soil solutions would also be high in concentrations of phosphorus, one of the elements most limiting in the habitats of Western Australia (Ward et al., 1985). In a study on the pyrophilic fungus, *Polyporus tumulosus*, Wills and Hilton (1984) found fruiting bodies only in recently burned forest sites and generally only where fire intensity was high. The ability of post-fire dispersed spores to germinate in alkaline pH substrates in this species suggests an adaptive trait as this species generally requires the acid substrates normally measured in these ancient soils during the interfire period (Merrill, 1970). Some pyrophilous fungi fruit after fertilization of forest soil with lime (Hora, 1959; Petersen, 1970), as well as after fire. Although germination in higher plant propagules has not been similarly tested, drastic changes in the concentration of soil nutrients could be an effective cue to break primary dormancy at a time when seedling survival would be expected to be enhanced. At present no information on the stimulator influence of soil solutions for Western Australia exists, but Siddiqi et al. (1976) showed germination percentages of three eastern states *Banksia* species were not significantly altered through a range of nutrient regimes.

The influence of excess soil solution ions on Western Australian species has been investigated in relation to tolerance to salinity (Pearce-Pinto et al., 1990; van der Moezel & Bell, 1987). Inland Western Australian soils have considerable concentrations of salts and with the long vegetative history of the region, it might be expected that species would evolve tolerance to this severe germination condition. The impact of salt solutions from 0 to 200 mM NaCl on the germination of species of *Eucalyptus* (Myrtaceae) shows a reduction in the proportion of seed germinating as salinity levels increased and germination was almost completely suppressed at levels of 200 mM NaCl (Table III). Seeds transferred from high salt conditions to fresh water, however,

Table III

Germination of Western Australian species of *Eucalyptus* (Myrtaceae) under increasing salt concentrations as a percentage of germination achieved with distilled water controls (after Pearce-Pinto et al., 1990; van der Moezel & Bell, 1987)

	Salinity (mM NaCl)			
Species	50	100	150	200
E. eremophila[1]	104	56		42
E. stenanthina[2]	98	27	4	0
E. occidentalis[2]	97	53	4	
E. occidentalis[1]	87	84		40
E. halophila[1]	86	48		4
E. sargentii[2]	86	23	0	0
E. conglobata[1]	84	49		0
E. uncinata[1]	83	48		2
E. leptocalyx[1]	83	34		4
E. rigens[1]	71	14		0
E. forrestiana[1]	69	30		6
E. loxophleba[2]	66	31	6	0
E. angulosa[1]	60	17		0
E. spathulata[2]	48	2	0	1
*E. gonianth*a[1]	46	10		1
E. plenissima[2]	44	7	0	0
E. angustissima[2]	41	4	2	0
E. redunca[1]	35	0		0
E. calycogona[2]	31	13	0	0
E. yilgarnensis[2]	24	10	0	0
E. quadrans[2]	21	2	0	0
E. myriadena[2]	21	1	0	0
E. eremophila[2]	19	4	1	0
E. micranthera[2]	12	0	3	0
E. kondininensis[2]	11	2	0	0
E. kumarlensis[2]	6	4	0	0
E. salicola[2]	4	5	5	0
E. platypus[2]	4	4	1	0

[1] From van der Moezel & Bell, 1987.
[2] From Pearce-Pinto et al., 1990.

readily germinate. Similar tolerances have also been recorded for a range of species of *Melaleuca* (Myrtaceae) (van der Moezel & Bell, 1987). In comparison to some halophytes, such as *Juncus maritimus,* which can germinate in solutions as high as 600 mM NaCl (Rozema, 1975), the inland Western Australian eucalypts and melaleucas would be considered relatively salt sensitive. The ability to remain dormant under high salt solution conditions, however, could be adaptive, preventing emergence following occasional summer showers and delaying germination until mid-winter when the solutions of the surface soils have been diluted sufficiently by the more continuous rains of the Mediterranean-type climate of the region.

E. INFLUENCE OF CHARRED WOOD

Germination cued to the presence of water soluble material in charred wood insures the post-fire emergence of a range of California chaparral species (Keeley, 1987, 1991; Keeley et al., 1985). Chemical factors from charred wood or smoke also cue the germination of *Pharnaceum elongatum* (Aizoaceae), *Nemesia* aff. *lucida* (Scrophulariaceae) and *Audouinis capitata* (Bruniaceae) of the South African fynbos (de Lange & Boucher, 1990; Keeley, 1992). However, the limited number of trials to date have indicated that this phenomenon is not apparent in the Western Australian flora (Bell et al., 1987b). Keeley (1991) hypothesizes that the mode of action of the charred wood compound could be related to 1) triggering a biochemical change in the embryo, 2) inactivating an inhibitor, or 3) chemically breaking the seed coat or membranes beneath. In personal communications with Keeley on our Western Australian trials (Bell et al., 1987b), it was apparent that the charred *Eucalyptus marginata* material was closer to ashed material and with a greater concentration of the singed wood component still available to contribute the active stimulatory ingredient, greater germination enhancement might have been achieved. Further trials should be conducted, especially with those species in which gibberellic acid stimulates germination. In the Californian species, *Romneya coulteri,* Harrington (1975) reported stimulation to 42% germination with 100 ppm GA_3 from 0% for controls in both heating and cold stratification. This compares favorably with a germination stimulation from 0% to 40% in *Romneya coulteri* when incubated with charred wood (Keeley & Keeley, 1987).

F. INHIBITORS

The role of water soluble compounds preventing germination in climates with seasonal rainfall has been studied for therophytes in California. Jain (1982) showed a correlation between the presence of after-ripening requirements and the probability of summer rainfall. Also a number of annual California grassland species are triggered to germinate by autumn rainfall events of greater than 125 mm (Heady, 1956; Young & Evans, 1989), presumably due to a requirement of inhibitor leaching.

Seed coat inhibitors can also be eliminated by ingestion by animals. Noble and Whalley (1978) reported that *Nitraria billardieri* germinated more readily following ingestion by emus, due to the removal of a saline pericarp. Similar observations have been made for the recalcitrant species, *Leucopogon propinquus* and *Styphelia tenuiflora* (Taylor, unpubl.). Ashton and Frankenberg (1976) report that removing the fleshy seed coating of *Acmena smithii* increases germination through elimination of inhibitors. Passage through the gut of vertebrates is also implicated in the breaking of dormancy in *Persoonia elliptica* (Proteaceae) (Abbott & van Heurck, 1988) and the germination of the Western Australian cycad, *Macrozamia reidlei,* is enhanced with removal of the pulpy integument of the sporocarp (Bell, unpubl.).

G. RESPONSE TO PLANT HORMONES

Plant hormones have been commonly used to influence the germination process. Gibberellic acid (GA) appears to be essential for seed germination and almost universally stimulates germination, being frequently associated with mobilization of endosperm reserves and growth of embryonic tissues (Jones & Stoddard, 1977). GA-deficient mutants never germinate without applied GA (Karssen & Groot, 1987). Applied cytokinins overcome dormancy in many seeds. Application of kinetin overcomes dormancy of *Stipa beginiculata,* a central Australian grass species (Hagon, 1976). In particular cytokinins are effective in counteracting the effect of inhibitors (Khan & Tao, 1978). Both gibberellins and cytokinins may function to reduce the after-ripening period by assisting the development of embryos which are only rudimentary at dispersal (Graebe, 1987; Lethame & Palni, 1983).

Ethylene promotes germination in a variety of species, though its effect is not as widespread as the other hormones (Ketring, 1977). Ethylene builds up in waterlogged soil (Smith & Russel, 1969) and is a component of wood smoke, field conditions which may influence seed germination. Inhibitors which prevent embryo growth may be present in the pericarp, seed coat, endosperm or embryo itself. Abscisic acid (ABA) is the most prominent of the germination inhibitors and is essential for the onset of dormancy in several species (Bewley & Black, 1982; Karssen & Groot, 1987). Although endogenous ABA levels have been correlated with the maintenance and breaking of dormancy, for example during stratification of temperate zone species, no consistent pattern for all seeds has emerged (Wareing, 1982). Although ABA is most often a germination inhibitor, in proper amounts it has been successfully used to enhance, advance and synchronize germination in tomato seeds (Finch-Savage & McQuistan, 1991).

Plant hormones are generally associated with other germination promoting factors. In light-requiring seeds, the promotion system is enhanced by red light or sunlight, GA and ethylene, whereas, the dormancy-inducing system responds to far-red light, high temperatures, water stress and ABA. Light and GA promote germination of several *Eucalyptus* species held at 30°C or under conditions of water stress (Zohar et al., 1975). Also GA overcomes the germination requirement for light or stratification in *E. pauciflora,* whereas, kinetin, a cytokinin, further inhibits germination (Bachelard, 1967). GA has also been shown to overcome the requirement for after-ripening in many species of the Poaceae (Don, 1979; Hagon, 1976). Dormancy caused by inhibitors in the embryo in *Protea compacta* and *Leucadendron daphnoides,* two South African Proteaceae, can be partially overcome by the application of gibberellic acid and kinetin (Brown & Van Staden, 1973; Van Staden et al., 1972).

Induction of germination with plant hormones is in its infancy in Western Australia. Enhanced levels of germination, however, have been achieved in *Billardiera bicolor* (Pittosporaceae) and *Boronia fastigiata* (Rutaceae) following soaking in GA_3 (S. K. Taylor, unpubl.). In two other Western Australian species, inbibition is prevented by the seed coat, but once treatment to overcome this inhibition to germination is applied, applications of gibberellins are successful in improving germination percentages. In *Anigozanthos manglesii,* a combination of scarification with KOH to remove a mucilage layer and application of either GA_3 or KNO_3 give complete germination (Sukhvibul, 1991). In *Boronia megastigma,* acid scarification with H_2SO_4 followed by treatment with GA_3 greatly improves germination (B. Bussel, pers. comm.).

H. MULTIPLE MECHANISMS

The multiple mechanisms process to break dormancy in seeds is little appreciated, whether it involves two or more environmental cues in combination or cues presented sequentially, and few published reports exist. In certain Western Australian acacias, there is an initial requirement of a heat shock followed by appropriate germination temperatures before germination percentages are maximized (Bell & Bellairs, 1992). In *Anigozanthus manglesii* both scarification and additions of GA were required to break dormancy (Sukhivibul, 1991). In eastern Australia, *Eucalyptus regnans* and *E. fastigata* require both light and GA for germination (Bachelard, 1967) and in

Acacia melanoxylon germination is improved when a heat shock treatment is followed by cold stratification (de Zwaan, 1978).

VIII. Applied Germination Ecology

It is apparent that numerous mechanisms have evolved in the southwestern Western Australian flora to cue germination to a time when seedling establishment potential is enhanced. In this fire-prone environment, seedling establishment is likely only in the first few seasons following a burn. Once the predominant resprouting species have re-established their aboveground structure and the available soil water and nutrient resources which were maximally available in the first winter are again under severe competition, there is little likelihood that seedlings can establish. Also the summer-dry, winter-wet, Mediterranean-type climate exerts an evolutionary pressure to cue germination to the cool winter rainfall season; early enough to provide the maximum length of time for growth before surface moisture becomes limiting the following summer, but not too early in the rainy season when rainfalls are sporadic and light.

Maximum species diversity in the Western Australian ecosystems occurs about 2 to 5 years following a fire (Bell & Koch, 1980). At this time, the habitat simultaneously harbors resprouting individuals of the longer-lived species, occasional seedlings of the resprouters, the more common seedlings of obligate seeding perennials and the short-lived fire ephemerals of the soil seed store, seedlings of the serotinous species, and fire-stimulated flowering species that have produced seeds which established seedlings in the second or third season following the fire. Understanding the germination ecology of the Western Australian species is allowing the mining industry to maximize the species return to these highly diverse communities once mining has been completed (Bell et al., 1990). Topsoil saved and quickly returned to the reformed, post-mining landscapes returns soil-borne seeds and appropriate mycorrhizal fungi. Provision of a mulch of plant canopies on top of the returned soils in the mining rehabilitation in the northern sandplain kwongan provides seed of the serotinous species. In addition a mix of seed collected by hand and pretreated by boiling where appropriate adds heat shock responsive seed to the post-mining environment. Maximizing the return of as many species as possible in the first post-mining rainy season is a major objective as these Australian ecosystems conform predominantly to the *initial floristic composition* model of community development (*sensu* Noble & Slatyer, 1981). In this model the composition of vegetation in the first few years of reconstruction controls ecosystem function for many years (Bell, 1988; Bell et al., 1990). If inappropriate species are initially established in post-mining habitats, particular organisms of the pre-mining habitat may not be able to survive in the post-mining community. Further research on germination cues will be used to establish nursery stock for interplanting of species which will not germinate from topsoil, canopy mulch or heat stimulus of the broadcast seed. In addition, appearance in the rehabilitation areas of some species, especially species of the Orchidaceae, following 5–10 years, indicates that soil development and possibly the appearance of appropriate vescicular arbuscular or ectotrophic mycorrhizal fungi also influence germination and establishment of some Western Australian species. The importance of an understanding of seed germination ecology has also been expressed by Willis and Groves (1991) in relation to the rehabilitation of conservation reserves in eastern Australia. Further knowledge of germination syndromes will continue to improve the restoration of Australian ecosystems.

A lack in the knowledge of seed germination and dormancy mechanisms in Western Australian species has also limited their introduction to horticultural industries (Windle et al., 1990). For example, several species of *Boronia* are obtained from wild populations for the local and export cut-flower trade, but no breeding and selection trials have been attempted because of poor seed germination rates. *Helichrysum bracteatum, Helipterum roseum* and *Brachycome multifolia* are promising Western Australian bedding plants (Sharman et al., 1989), but their development has been conducted mostly in Europe. The horticultural potential of species from *Hibbertia, Pimelea, Scaevola* and *Lechenaultia* is equally enormous, yet problems in breaking seed dormancy also limit exploitation. The knowledge of seed germination would also enhance the potential of other floriculture, nursery and essential oil plants from the Western Australian native flora.

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Appendix I

Characteristics related to the germination ecology of plants of southwestern Western Australia. Information on seed viability, germination with and without pretreatment of boiling water heat shock and information on fire response syndrome, seed storage syndrome and whether the species is stimulated to flower by fire. References include: 1) Bell, 1988; 2) Glossop, 1980; 3) Bell et al., 1987b; 4) Baird, 1988; 5) Bellairs, 1992; 6) Bell & Bellairs, 1992; 7) Bell, 1991 unpubl. data; 8) Bellairs & Bell, 1990b; 9) Bell et al., 1990; 10) Lamont et al., 1991; 11) van der Moezel & Bell, 1987; 12) Fell & Bell, unpubl. data, 1984; 13) Glossop, unpubl. data, 1984; 14) Abbott & van Heurck, 1988; 15) Pearce-Pinto et al., 1990; 16) Lamont & Baker, 1988; 17) Enright & Lamont, 1989; 18) Taylor, unpubl. data, 1992; 19) Meney & Dixon, 1988

Species	Author	Reference	Via-bility %	% no treat-ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow-ering stimu-lation
Gymnospermae								
Cypressaceae								
Actinostrobus acuminatus	Parl.	5		5		Resprouter	On-Plant	No
Actinostrobus pyramidalis	Miq.	5		45		Seeder	On-Plant	No
Zamiaceae								
Macrozamia reidlei	(Fischer ex Gaudich.) C. Gardner	18		4		Resprouter	Soil	Yes
Angiospermae-Monocotyledonae								
Anthericaceae								
Agrostocrinum scabrum	(R. Br.) Baillon	3, 9, 18	41	2	0	Resprouter	Soil	No
Arthropodium capillipes	Endl.	18		0		Resprouter	Soil	No
Chamaescilla corymbosa	(R. Br.) F. Muell. ex Benth.	18		25		Resprouter	Soil	No
Johnsonia lupulina	R. Br.	18		0		Seeder	Soil	No
Johnsonia pubescens	Lindley	5		0		Seeder	Soil	No
Laxmannia omnifertilis	G. J. Keighery	5		15		Seeder	Soil	No
Sowerbaea laxiflora	Lindley	18		0		Resprouter	Soil	No
Thysanotus brevifolius	N. H. Brittan	5		0		Resprouter	Soil	No
Thysanotus dichotomus	(Labill.) R. Br.	3, 18	0	1	0	Resprouter	Soil	No
Thysanotus multiflorus	R. Br.	3, 18	61	1	0	Resprouter	Soil	No
Thysanotus teretifolius	N. H. Brittan	5		0		Resprouter	Soil	No

Appendix I
Continued

Species	Author	Reference	Via- bility %	% no treat- ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow- ering stimu- lation
Thysanotus thyrsoideus	Baker	18		0		Resprouter	Soil	No
Tricoryne elatior	R. Br.	18		0		Resprouter	Soil	No
Byblidaceae								
Byblis gigantea	Lindley	5		0		Seeder	Soil	No
Colchicaceae								
Burchardia multiflora	Lindley	18		0		Resprouter	Soil	No
Burchardia umbellata	R. Br.	3, 5, 18	70	47	0	Resprouter	Soil	No
Cyperaceae								
Gahnia decomposita	(R. Br.) Benth.	18		0		Resprouter	Soil	No
Lepidosperma angustatum	R. Br.	18		0		Resprouter	Soil	No
Lepidosperma tenue	Benth.	18		0		Resprouter	Soil	No
Lepidosperma tetraquetrum	Nees	18		0		Resprouter	Soil	No
Mesomelaena pseudostygia	(Kuek.) K. L. Wilson	5, 19		0		Resprouter	Soil	No
Mesomelaena tetragona	(R. Br.) Benth.	5, 18		0		Resprouter	Soil	No
Ecdeocoleaceae								
Ecdeocolea monostachya	F. Muell.	5, 19		0		Resprouter	Soil	No
Dasypogonaceae								
Dasypogon bromeliifolius	R. Br.	18		0		Resprouter	Soil	Yes
Lomandra nigricans	T. D. Macfarlane	18		0		Resprouter	Soil	Yes
Lomandra preissii	(Endl.) Ewart	5		0		Resprouter	Soil	Yes
Lomandra purpurea	(Endl.) Ewart	5, 18		33		Resprouter	Soil	Yes
Lomandra sonderi	(F. Muell.) Ewart	9, 18	56	1		Resprouter	Soil	Yes
Haemodoraceae								
Anigozanthus manglesii	D. Don	3, 5, 13, 18	0	3	6	Resprouter	Soil	No
Anigozanthus flavidus	DC.	18		7		Resprouter	Soil	No
Anigozanthus humilis	Lindley	18		5		Resprouter	Soil	No
Anigozanthus viridus	Endl.	18		0		Resprouter	Soil	No
Conostylis aculeata	R. Br.	5, 18		0		Seeder	Soil	No

Appendix I
Continued

Species	Author	Reference	Viability %	% no treatment	% after boiling	Fire response syndrome	Seed storage syndrome	Flowering stimulation
Conostylis aurea	Lindley	5		0		Resprouter	Soil	No
Conostylis canescens	Endl.	5		0		Resprouter	Soil	No
Conostylis dielsii	W. Fitzg.	5		6		Resprouter	Soil	No
Conostylis neocymosa	S. D. Hopper	5, 8		9		Seeder	Soil	No
Conostylis serrulata	R. Br.	18		0		Resprouter?	Soil	No
Conostylis setigera	R. Br.	18		0		Resprouter?	Soil	No
Conostylis setosa	Lindley	3, 18		1	53	Resprouter	Soil	No
Haemodorum laxum	R. Br.	18		0		Resprouter	Soil	Yes
Haemodorum paniculatum	Lindley	18		47		Resprouter	Soil	Yes
Haemodorum simulans	F. Muell.	18		7		Resprouter	Soil	Yes
Haemodorum simplex	Lindley	5		90		Resprouter	Soil	Yes
Haemodorum spicatum	R. Br.	5, 18		43		Resprouter	Soil	Yes
Iridaceae								
Orthosanthus laxus var. *laxus*	(Endl.) Benth.	18		6		Resprouter	Soil	No
Orthosanthus laxus var. *gramineus*	(Endl.) Benth.	18		8		Resprouter	Soil	No
Patersonia juncea	Lindley	18		0		Resprouter	Soil	No
Patersonia occidentalis	R. Br.	6, 18		1		Resprouter	Soil	No
Patersonia pygmaea	Lindley	18		0		Resprouter	Soil	No
Patersonia sericea	R. Br.	3	80	16	1	Resprouter	Soil	No
Patersonia umbrosa	Endl.	18		0		Resprouter	Soil	No
Phormiaceae								
Dianella revoluta	R. Br.	3, 9	10	0	0	Resprouter	Soil	No
Poaceae								
Amphipogon turbinatus	R. Br.	5		0		Resprouter	Soil	No
Neurachne alopecuroidea	R. Br.	5, 18		12		Seeder	Soil	No
Tetrarrhena laevis	R. Br.	18		1			Soil	No
Restionaceae								
Lepidobolus chaetocephalus	F. Muell.	5, 19		0		Resprouter	Soil	No

Appendix I
Continued

Species	Author	Reference	Via-bility %	% no treat-ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow-ering stimu-lation
Lyginia barbata	R. Br.	5		0		Resprouter	Soil	No
Restio sphacelatus	R. Br.	5, 19		0		Resprouter	Soil	No
Xanthorrhoeaceae								
Xanthorrhoea drummondii	Harvey	5, 8		98		Resprouter	Soil	Yes
Xanthorrhoea gracilis	Endl.	3, 6, 18	80	63	0	Resprouter	Soil	Yes
Xanthorrhoea preissii	Endl.	3, 18	40	21	0	Resprouter	Soil	Yes
Angiospermae-Dicotyledonae								
Amaranthaceae								
Ptilotus drummondii	(Moq.) F. Muell.	18		8		Seeder	Soil	No
Ptilotus manglesii	(Lindley) F. Muell.	18		0		Seeder	Soil	No
Ptilotus polystachyus	(Gaudich.) F. Muell.	5		5		Seeder	Soil	No
Apiaceae								
Actinotus leucocephalus	Benth.	18		0		Seeder	Soil	No
Pentapeltis peltigera	(Hook.) Bunge	7, 18		1		Resprouter	Soil	No
Platysace compressa	(Labill.) Norman	18		0		Resprouter?	Soil	No
Platysace tenuissima	(Benth.) Norman	9, 18	2	0		Resprouter	Soil	No
Xanthosia atkinsoniana	F. Muell.	3, 6, 9, 18	0	0	0	Resprouter	Soil	No
Xanthosia candida	(Benth.) Steudel	18		0		Resprouter?	Soil	No
Xanthosia huegelii	(Benth.) Steudel	18		0		Resprouter?	Soil	No
Asteraceae								
Helichrysum bracteatum	(Vent.) Andrews	13, 18		94		Seeder	Soil	No
Helipterum cotula	(Benth.) DC.	18		4		Seeder	Soil	No
Lagenifera huegelii	Benth.	18		63		Seeder	Soil	No
Olearia axillaris	(DC.) F. Muell.	7, 18		10		Seeder	Soil	No
Olearia paucidentata	(Streetz) F. Muell.	18		0		Seeder	Soil	No
Podolepis gracilis	Graham	18		8		Seeder	Soil	No
Podotheca gnaphalioides	R. A. Graham	5		42		Seeder	Soil	No

Appendix I
Continued

Species	Author	Reference	Via-bility %	% no treat-ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow-ering stimu-lation
Senecio hispidulus	A. Rich.	18		8		Seeder	Soil	No
Waitzia paniculata	(Streetz) F. Muell.	18		16		Seeder	Soil	No
Waitzia suaveolens	(Benth.) Druce	18		7		Seeder	Soil	No
Caesalpineaceae								
Labichea lanceolata	Benth.	18		33	53	Resprouter	Soil	No
Labichea punctata	Benth.	1, 18	90	53	50	Resprouter	Soil	No
Casuarinaceae								
Allocasuarina fraseriana	(Miq.) L. Johnson	18		34		Resprouter	On-Plant	No
Allocasuarina huegeliana	(Miq.) L. Johnson	18		68		Resprouter	On-Plant	No
Allocasuarina humilis	(Otto & Dietr.) L. Johnson	5, 8, 18		52		Resprouter	On-Plant	No
Allocasuarina microstachya	(Miq.) L. Johnson	5		22		Resprouter	On-Plant	No
Chloanthaceae								
Lachnostachys eriobotrya	(F. Muell.) Druce	5		0		Resprouter	Soil	No
Dilleniaceae								
Hibbertia amplexicaulis	Streudel	18		0		Resprouter	Soil	No
Hibbertia commutata	Streudel	18		1		Resprouter	Soil	No
Hibbertia hypericoides	(DC.) Benth.	9, 18	28	0		Resprouter	Soil	No
Hibbertia lasiopus	Benth.	18		0		Resprouter	Soil	No
Hibbertia montana	Streudel	6, 18		0		Resprouter	Soil	No
Hibbertia rhadinopoda	F. Muell.	18		0		Resprouter	Soil	No
Dioscoreaceae								
Dioscorea hastifolia	Nees	18		62		Resprouter?	Soil	No
Droseraceae								
Drosera erythrorhiza	Lindley	18		0		Resprouter	Soil	Yes
Drosera macrantha	Endl.	18		40		Resprouter	Soil	No?
Epacridaceae								
Andersonia heterophylla	Sonder	5		0		Resprouter	Soil	No

Appendix I
Continued

Species	Author	Reference	Via-bility %	% no treat-ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow-ering stimu-lation
Andersonia involucrata	Sonder	18		0		Resprouter	Soil	No
Andersonia lehmanniana	Sonder	18		0		Resprouter	Soil	No
Astroloma ciliatum	(Lindley) Druce	18		0		Resprouter	Soil	No
Astroloma microdonta	F. Muell.	5		0		Seeder	Soil	No
Astroloma pallidum	R. Br.	5, 18		0		Resprouter	Soil	No
Astroloma xerophyllum	(DC.) Sonder	5		0		Seeder	Soil	No
Leucopogon capitellatus	DC.	18		0		Resprouter	Soil	No
Leucopogon nutans	E. Pritzel	18		0		Resprouter	Soil	No
Leucopogon oxycedrus	Sonder	3, 9, 18	0	0	0	Resprouter	Soil	No
Leucopogon propinquus	R. Br.	18		0		Resprouter	Soil	No
Leucopogon pulchellus	Sonder	18		0		Resprouter	Soil	No
Leucopogon verticillatus	R. Br.	3, 9, 18	0	0	0	Resprouter	Soil	No
Styphelia tenuiflora	Lindley	18		0		Seeder	Soil	No
Euphorbiaceae								
Phyllanthus calycinus	Labill.	3, 9, 18	30	7	0	Resprouter	Soil	No
Poranthera huegelii	Klotzsch	18		0			Soil	No
Goodeniaceae								
Lechenaultia biloba	Lindley	3, 18		1	0	Resprouter	Soil	No
Scaevola calliptera	Benth.	18		0			Soil	No
Scaevola crassifolia	Labill.	7, 18		19		Seeder?	Soil	No
Scaevola fasciculata	Benth.	18		0			Soil	No
Scaevola pilosa	Benth.	18		0			Soil	No
Scaevola striata	R. Br.	18		0			Soil	No
Velleia triverva	Labill.	6, 18		13		Seeder	Soil	No
Gyrostemonaceae								
Tersonia cyathiflora	(Fenzl) A. S. George	5		0		Seeder	Soil	No
Haloragaceae								
Glischrocaryon aureum	(Lindley) Orch.	3, 9, 18	2	0	0	Resprouter	Soil	No

Appendix I
Continued

Species	Author	Reference	Viability %	% no treatment	% after boiling	Fire response syndrome	Seed storage syndrome	Flowering stimulation
Lamiaceae								
Hemiandra pungens	R. Br.	18		6		Resprouter	Soil	No
Hemigenia incana	(Lindley) Benth.	18		4			Soil	No
Hemigenia pritzelii	S. Moore	18		0			Soil	No
Hemigenia ramosissima	Benth.	18		0			Soil	No
Lobeliaceae								
Isotoma hypocrateriformis	(R. Br.) Druce	18		0		Seeder	Soil	No
Lobelia heterophylla	Labill.	18		0		Seeder	Soil	No
Lobelia rhombifolia	Vriese	18		0		Seeder	Soil	No
Loganiaceae								
Logania serpyllifolia	R. Br.	18		0			Soil	No
Loranthaceae								
Nuytsia floribunda	(Labill.) R. Br. ex Fenzl	18		10		Resprouter	Soil	No
Mimosaceae								
Acacia alata	R. Br.	1, 18	76	6	52	Seeder	Soil	No
Acacia aphylla	Maslin	18			47		Soil	No
Acacia blakelyi	Maiden	5, 8		35		Seeder	Soil	No
Acacia browniana	H. L. Wendl.	6, 18		12	78	Seeder	Soil	No
Acacia celestrifolia	Benth.	6, 18		8	63	Seeder	Soil	No
Acacia cyclops	Cunn. ex Don	2, 18		14	27	Seeder	Soil	No
Acacia divergens	Benth.	18		11	60	Seeder	Soil	No
Acacia drummondii var. *candolleana*	Lindley	18		18	48	Seeder	Soil	No
Acacia drummondii var. *drummondii*	Lindley	18		16	63	Seeder	Soil	No
Acacia ericifolia	Benth.	18		0	0	Resprouter?	Soil	No
Acacia extensa	Lindley	7, 18		4	50	Seeder	Soil	No
Acacia hemiteles	Benth.	2		10	69		Soil	No
Acacia horridula	Meissner	18		8	63	Seeder	Soil	No

Appendix I
Continued

Species	Author	Reference	Via-bility %	% no treat-ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow-ering stimu-lation
Acacia incurva	Benth.	18			29		Soil	No
Acacia lasiocarpa	Benth.	18		20	57	Seeder	Soil	No
Acacia lateriticola	Maslin	2, 6, 18		9	57	Resprouter	Soil	No
Acacia latipes	Benth.	5		98		Resprouter	Soil	No
Acacia microbotrya	Benth.	18		14	50	Seeder?	Soil	No
Acacia myrtifolia	(Smith) Willd.	18			65	Seeder	Soil	
Acacia myrtifolia var. *angustifolium*	(Benth.) W. Fitzg.	18			40	Seeder	Soil	
Acacia nervosa	DC.	18		16	55		Soil	No
Acacia obovata	Benth.	18		54	51	Resprouter	Soil	No
Acacia pulchella-Eneabba	R. Br.	5, 8		67		Seeder	Soil	No
Acacia pulchella-Jarrah forest	R. Br.	2, 18		7	48	Seeder	Soil	No
Acacia pulchella var. *glaberrima*	R. Br.	18			59	Seeder	Soil	No
Acacia tetragonophylla	Meissner	18			73		Soil	No
Acacia saligna	(Labill.) H. L. Wendl.	2, 5, 18		28	42	Resprouter	Soil	No
Acacia urophylla	Benth. ex Lindley	2, 6, 18		10	80	Seeder	Soil	No
Paraserianthes lophantha	(Willd.) I. Nielsen	1, 13, 18	80	0	65	Seeder	Soil	No
Myrtaceae								
Agonis linearifolia	(DC.) Schauer	18		4		Resprouter	On-Plant?	No
Agonis flexuosa	(Sprengel) Schauer	5		95		Resprouter	On-Plant	No
Astartea fascicularis	(Labill.) DC.	6, 18		1		Resprouter	On-Plant	No
Baeckea camphorosmae	Endl.	6, 18		0		Resprouter	On-Plant	No
Beaufortia bracteosa	Diels	5, 8		94		Seeder	On-Plant	No
Beaufortia elegans	Schauer	5		97		Seeder	On-Plant	No
Beaufortia squarrosa	Schauer	18		89		Seeder	On-Plant	
Callistemon speciosus	(Sims) DC.	13		5		Resprouter	On-Plant?	No
Calothamnus blepharospermus	F. Muell.	5		3		Resprouter	On-Plant	No
Calothamnus longissimus	F. Muell.	5		90		Resprouter	On-Plant	No
Calothamnus planifolius	Lehm.	18		0		Resprouter	On-Plant	No

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Continued

Species	Author	Reference	Via-bility %	% no treat-ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow-ering stimu-lation
Calothamnus quadrifidus	R. Br.	18		23		Resprouter	On-Plant	No
Calothamnus rupestris	Schauer	6, 18		80		Resprouter	On-Plant	No
Calothamnus sanguineus	Labill.	5, 18		62		Resprouter	On-Plant	No
Calothamnus torulosus	Schauer	5		86		Resprouter	On-Plant	No
Calothamnus villosus	R. Br.	5		21		Resprouter	On-Plant	No
Calytrix depressa	(Trucz.) Benth.	5, 18		0		Resprouter	Soil	No
Calytrix empetroides	(Schauer) Benth.	5		0		Resprouter	Soil	No
Calytrix flavescens	Cunn.	18		0		Resprouter	Soil	No
Calytrix fraseri	Cunn.	18		0		Resprouter	Soil	No
Calytrix oldfieldii	Benth.	18		0		Resprouter	Soil	No
Calytrix superba	C. Gardner & A. S. George	5		0		Resprouter	Soil	No
Darwinia citriodora	(Endl.) Benth.	18		0				No
Eremaea acutifolia	F. Muell.	5		69		Resprouter	On-Plant	No
Eremaea beaufortioides	Benth.	5		79		Resprouter	On-Plant	No
Eremaea violacea	F. Muell.	5		72		Resprouter	On-Plant	No
Eucalyptus accedens	W. Fitzg.	5, 18		92		Resprouter	On-Plant	No
Eucalyptus angustissima	F. Muell.	15		95		Resprouter	On-Plant	No
Eucalyptus angulosa	Schauer	11, 18		82		Resprouter	On-Plant	No
Eucalyptus astringens	(Maiden) Maiden	18		80		Resprouter	On-Plant	No
Eucalyptus calophylla	Lindley	13, 18		49		Resprouter	On-Plant	No
Eucalyptus calycogona	Turcz.	15, 18		89		Resprouter	On-Plant	No
Eucalyptus camaldulensis	Dehnh.	5, 11, 18		99		Resprouter	On-Plant	No
Eucalyptus conglobata	(R. Br. ex Benth.) Maiden	11		67		Resprouter	On-Plant	No
Eucalyptus decipiens	Endl.	18		86		Resprouter	On-Plant	No
Eucalyptus drummondii	Benth.	5, 18		75		Resprouter	On-Plant	No
Eucalyptus eremophila	(Diels) Maiden	11, 15		43		Resprouter	On-Plant	No
Eucalyptus erythrocorys	F. Muell.	7		35		Resprouter	On-Plant	No

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Continued

Species	Author	Reference	Via-bility %	% no treat-ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow-ering stimu-lation
Eucalyptus flocktoniae	(Maiden) Maiden	11, 18		32		Resprouter	On-Plant	No
Eucalyptus foecunda	Schauer	18		86		Resprouter	On-Plant	No
Eucalyptus forrestiana	Diels	11, 18		80		Resprouter	On-Plant	No
Eucalyptus gomphocephala	DC.	18		81		Resprouter	On-Plant	No
Eucalyptus goniantha	Turcz.	11		69		Resprouter	On-Plant	No
Eucalyptus halophila	D. J. Carr & S. G. M. Carr	11, 18		91		Resprouter	On-Plant	No
Eucalyptus jucunda	C. Gardner	5		48		Resprouter	On-Plant	No
Eucalyptus kondininensis	Maiden & Blakely	15, 18		83		Resprouter	On-Plant	No
Eucalyptus kumarlensis	Brooker ms. name	15		13		Resprouter	On-Plant	No
Eucalyptus laeliae	F. D. Podger & Chippendale	18		94		Resprouter	On-Plant	No
Eucalyptus lane-poolei	Maiden	18		90		Resprouter	On-Plant	No
Eucalyptus leptocalyx	Blakely	11		88		Resprouter	On-Plant	No
Eucalyptus loxophleba	Benth.	15, 18		94		Resprouter	On-Plant	No
Eucalyptus macrocarpa	Hook.	5, 18		80		Resprouter	On-Plant	No
Eucalyptus marginata	Donn. ex Sm.	13, 18		28	0	Resprouter	On-Plant	No
Eucalyptus megacarpa	Hook.	18		46		Resprouter	On-Plant	No
Eucalyptus micranthera	F. Muell. ex Benth.	15		57		Resprouter	On-Plant	No
Eucalyptus myriadena	Brooker	15		97		Resprouter	On-Plant	No
Eucalyptus occidentalis	Endl.	11, 15, 18		98		Resprouter	On-Plant	No
Eucalyptus oleosa	F. Muell. ex Miq.	6, 18	100	84		Resprouter	On-Plant	No
Eucalyptus patens	Benth.	18		35		Resprouter	On-Plant	No
Eucalyptus plenissima	(C. Gardner) Brooker	15		99		Resprouter	On-Plant	No
Eucalyptus platypus	Hook.	15, 18		89		Resprouter	On-Plant	No
Eucalyptus quadrans	Brooker ms. name	15		92		Resprouter	On-Plant	No
Eucalyptus redunca	Schauer	11, 18		95		Resprouter	On-Plant	No
Eucalyptus rigens	Brooker ms. name	11		91		Resprouter	On-Plant	No

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Continued

Species	Author	Reference	Via- bility %	% no treat- ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow- ering stimu- lation
Eucalyptus rudis	Endl.	6, 18	95	86		Resprouter	On-Plant	No
Eucalyptus salicola	Brooker ms. name	15		17		Resprouter	On-Plant	No
Eucalyptus sargentii	Maiden	15, 18		99		Resprouter	On-Plant	No
Eucalyptus spathulata	Hook.	15, 18		93		Resprouter	On-Plant	No
Eucalyptus stenanthina	Brooker ms. name	15		99		Resprouter	On-Plant	No
Eucalyptus tetragona	(R. Br.) F. Muell.	5, 8		76		Resprouter	On-Plant	No
Eucalyptus todtiana	F. Muell.	5, 18		57		Resprouter	On-Plant	No
Eucalyptus uncinata	Turcz.	11		94		Resprouter	On-Plant	No
Eucalyptus wandoo	Blakely	6, 18	95	91		Resprouter	On-Plant	No
Eucalyptus vilgarnensis	Diels	15		100		Resprouter	On-Plant	No
Hypocalymma angustifolium	Endl.	3, 18		1	1	Resprouter	Soil	No
Hypocalymma robustum	Endl.	3, 18		8	6	Resprouter	Soil	No
Kunzea ericifolia	(Smith) Heynh.	18		30		Resprouter	On-Plant	No
Kunzea recurva	Schauer	6, 18		41		Resprouter	On-Plant	No
Leptospermum erubescens	Schauer	18		0		Resprouter	On-Plant	No
Leptospermum spinescens	Endl.	5, 8		48		Resprouter	On-Plant	No
Melaleuca acerosa	Schauer	5, 8		98		Resprouter	On-Plant	No
Melaleuca bracteosa	Turcz.	11		96		Resprouter	On-Plant	No
Melaleuca calycina	R. Br.	11		35		Resprouter	On-Plant	No
Melaleuca cardiophylla	F. Muell.	11		98		Resprouter	On-Plant	No
Melaleuca cliffortioides	Diels	11		89		Resprouter	On-Plant	No
Melaleuca cymbifolia	Benth.	11		58		Resprouter	On-Plant	No
Melaleuca glaberrima	F. Muell.	11		86		Resprouter	On-Plant	No
Melaleuca hamulosa	Turcz.	5		54		Resprouter	On-Plant	No
Melaleuca huegelii	Endl.	18		94		Resprouter	On-Plant	No
Melaleuca incana	R. Br.	18		32		Resprouter	On-Plant	No
Melaleuca lateritia	A. Dietr.	18		86		Resprouter	On-Plant	No
Melaleuca nesophila	F. Muell.	11		83		Resprouter	On-Plant	No

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Species	Author	Reference	Via-bility %	% no treat-ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow-ering stimu-lation
Melaleuca preissiana	Schauer	6, 18		21		Resprouter	On-Plant	No
Melaleuca pulchella	R. Br.	11		5		Resprouter	On-Plant	No
Melaleuca aff. quadrifaria	F. Muell.	11		3		Resprouter	On-Plant	No
Melaleuca radula	Lindley	18		0		Resprouter	On-Plant	No
Melaleuca raphiophylla	Schauer	18		29		Resprouter	On-Plant	No
Melaleuca scabra	R. Br.	18		29		Resprouter	On-Plant	No
Melaleuca subtrigona	Schauer	11		58		Resprouter	On-Plant	No
Melaleuca teretifolia	Endl.	18		89		Resprouter	On-Plant	No
Melaleuca thyoides	Turcz.	11, 18		93		Resprouter	On-Plant	No
Melaleuca trichophylla	Lindley	5		98		Resprouter	On-Plant	No
Melaleuca uncinata	R. Br.	5, 18		96		Resprouter	On-Plant	No
Melaleuca viminea	Lindley	18		36		Resprouter	On-Plant	No
Pericalymma ellipticum	Schauer	6		0		Seeder	On-Plant	No
Phymatocarpus maxwellii	F. Muell.	11		75		Resprouter	On-Plant	No
Phymatocarpus porphyrocephalus	F. Muell.	5		63		Seeder	On-Plant	No
Pileanthus filifolius	Meissner	5		0		Seeder	Soil	No
Regelia ciliata	Schauer	6		26		Resprouter?	On-Plant	No
Scholtzia laxifolia	Benth.	5		0		Resprouter	Soil?	No
Verticordia huegelii	Endl.	18		0		Seeder	Soil	No
Verticordia nitens	(Lindley) Endl.	5		0		Seeder	Soil	No
Verticordia pennigera	Endl.	18		0		Seeder	Soil	No
Verticordia serrata	(Lindley) Schauer	18		0		Seeder	Soil	No
Papilionaceae								
Bossiaea aquifolium	Benth.	2, 13, 18		0	33	Seeder	Soil	No
Bossiaea eriocarpa	Benth.	18		2	38	Resprouter	Soil	No
Bossiaea ornata	(Lindley) Benth.	6, 18		42	42	Resprouter	Soil	No
Bossiaea pulchella	Meissner	18		18	71	Resprouter	Soil	No
Chorizema aciculare	(DC.) C. Gardner	18		0		Resprouter?	Soil	No

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Species	Author	Reference	Via-bility %	% no treat-ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow-ering stimu-lation
Chorizema dicksonii	R. A. Graham	1, 18	70	10	69	Resprouter	Soil	No
Chorizema ilicifolium	Labill.	1, 18	92	6	60	Resprouter?	Soil	No
Chorizema rhombeum	R. Br.	1, 18	78	3	48	Resprouter?	Soil	No
Daviesia cordata	Smith	18		17	25	Resprouter?	Soil	No
Daviesia horrida	Preiss ex Meissner	18		3	39	Resprouter	Soil	No
Daviesia longifolia	Benth.	18			3	Resprouter?	Soil	No
Daviesia pectinata	Lindley	18			3	Resprouter	Soil	No
Daviesia physodes	Cunn.	18		9	53	Resprouter	Soil	No
Daviesia preissii	Meissner	18		0	28	Resprouter	Soil	No
Dillwynia sp. A.		18			0		Soil	No
Gastrolobium calycinum	Benth.	18		5	23	Resprouter	Soil	No
Gastrolobium spinosum	Benth.	18		16	44	Seeder	Soil	No
Gompholobium capitatum	Cunn.	1, 18	80	55	34	Seeder	Soil	No
Gompholobium knightianum	Lindley	1, 18	90	2	60	Seeder	Soil	No
Gompholobium marginatum	R. Br.	18		83	22	Seeder	Soil	No
Gompholobium polymorphum	R. Br.	1, 18	66	15	38	Seeder	Soil	No
Gompholobium preissii	Meissner	18			50	Seeder	Soil	No
Gompholobium tomentosum	Labill.	18		73	40	Seeder	Soil	No
Gompholobium venustum	R. Br.	18			30	Seeder	Soil	No
Hardenbergia comptoniana	(Andrews) Benth.	2, 18		3	38	Resprouter	Soil	No
Hovea chorizemifolia	(Sweet) DC.	1, 18		0	26	Resprouter	Soil	No
Hovea pungens	Benth.	18		19	29	Resprouter	Soil	No
Hovea trisperma	Benth.	18		17	45	Resprouter	Soil	No
Jacksonia densiflora	Benth.	5		65		Resprouter	Soil	No
Jacksonia furcellata	(Bonpl.) DC.	18		18	28	Seeder	Soil	No
Jacksonia sternbergiana	Benth.	18			73	Seeder	Soil	No
Kennedia carinata	(Benth.) Domin.	18		7		Seeder?	Soil	No
Kennedia coccinea	Vent.	1, 18		5	37	Seeder?	Soil	No

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Species	Author	Reference	Viability %	% no treatment	% after boiling	Fire response syndrome	Seed storage syndrome	Flowering stimulation
Kennedia prostrata	R. Br.	2, 5, 8, 18		24	21	Seeder	Soil	No
Mirbelia dilatata	R. Br.	1, 18	32	0	39	Seeder	Soil	No
Oxylobium cuneatum	Benth.	18		4	45	Resprouter	Soil	No
Oxylobium lanceolatum	(Vent.) Druce	1, 18	86	3	74		Soil	No
Oxylobium linearifolium	(G. Don) Domin.	1	82	33	34		Soil	No
Oxylobium obovata	Benth.	18			25		Soil	No
Sphaerolobium macranthum	Meissner	18			16	Resprouter	Soil	No
Sphaerolobium medium	R. Br.	18		12	35	Resprouter	Soil	No
Sphaerolobium vimineum	Smith	18		12	25	Resprouter	Soil	No
Templetonia retusa	(Vent.) R. Br.	18			2	Seeder	Soil	No
Viminaria juncea	(Schrader & Wendl.) Hoffsgg.	6, 18		1	39	Seeder	Soil	No
Pittosporaceae								
Billardiera bicolor	(Putterl.) E. M. Bennett	3, 18	10	1	0	Resprouter	Soil	No
Billardiera floribunda	(Putterl.) F. Muell.	3, 18	10	0	0	Resprouter	Soil	No
Billardiera variifolia	DC.	18		0		Resprouter	Soil	No
Pittosporum phylliraeroides	DC.	7, 18		53		Resprouter?	Soil	No
Pronaya fraseri	(Hook.) E. M. Bennett	18		0			Soil	No
Sollya heterophylla	Lindley	3, 9, 18	0	2	0	Resprouter	Soil	No
Proteaceae								
Banksia attenuata	R. Br.	5, 10, 17, 18	75	68		Resprouter	On-Plant	No
Banksia baxteri	R. Br.	10	100			Seeder	On-Plant	No
Banksia burdettii	E. G. Baker	16	32			Seeder	On-Plant	No
Banksia candolleana	Meissner	5, 17	80	84		Resprouter	On-Plant	No
Banksia coccinea	R. Br.	10	100			Seeder	On-Plant	No
Banksia cuneata	A. S. George	10	97			Resprouter	On-Plant	No
Banksia grandis	Willd.	18		92		Resprouter	On-Plant	No

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Species	Author	Reference	Viability %	% no treatment	% after boiling	Fire response syndrome	Seed storage syndrome	Flowering stimulation
Banksia grossa	A. S. George	5		93		Resprouter	On-Plant	No
Banksia hookeriana	Meissner	5, 10, 16	87	85		Seeder	On-Plant	No
Banksia lanata	A. S. George	5		76		Seeder	On-Plant	No
Banksia leptophylla	A. S. George	5, 10, 16, 17	82	94		Seeder	On-Plant	No
Banksia littoralis	R. Br.	18		38		Resprouter	On-Plant	No
Banksia menziesii	R. Br.	5, 10, 17, 18	79	79		Resprouter	On-Plant	No
Banksia prionotes	Lindley	10, 16, 18	53	50		Seeder	On-Plant	No
Banksia seminuda	(A. S. George) B. L. Rye	4	91	83	0	Seeder	On-Plant	No
Banksia speciosa	R. Br.	10	100			Seeder	On-Plant	No
Banksia sphaerocarpa	R. Br.	18		77		Resprouter	On-Plant	No
Banksia tricuspis	Meissner	10	100			Resprouter	On-Plant	No
Conospermum crassinervium	Meissner	5		3		Resprouter	Soil	No
Conospermum incurvum	Lindley	5		0		Resprouter	Soil	No
Conospermum triplinervium	R. Br.	5		0		Resprouter	Soil	No
Dryandra armata	R. Br.	18		57		Seeder	Soil	No
Dryandra carduacea	Lindley	3, 9, 18	64	56	66	Seeder	On-Plant	No
Dryandra carlinoides	Meissner	5		44		Seeder	On-Plant	No
Dryandra aff. falcata	R. Br.	5		78		Seeder	On-Plant	No
Dryandra formosa	R. Br.	3	10	42	28	Seeder	On-Plant	No
Dryandra fraseri	R. Br.	3		38	45	Resprouter	On-Plant	No
Dryandra kippistiana	Meissner	5		65		Seeder	On-Plant	No
Dryandra nivea	(Labill.) R. Br.	3, 5, 9, 18		48	2	Resprouter	On-Plant	No
Dryandra aff. nivea	(Labill.) R. Br.	18		37		Resprouter	On-Plant	No
Dryandra polycephala	Benth.	3, 9	95	80	72	Resprouter	On-Plant	No
Dryandra sessilis	(Knight) Domin.	3, 7, 9	50	82	72	Seeder	On-Plant	No

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Species	Author	Reference	Via- bility %	% no treat- ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow- ering stimu- lation
Dryandra shuttleworthiana	Meissner	5		100		Resprouter	On-Plant	No
Dryandra tridentata	Meissner	5		67		Resprouter	On-Plant	No
Grevillea bipinnatifida	R. Br.	13, 18		2	0	Resprouter?	Soil	No
Grevillea eriostachya	Lindley	5		6		Resprouter	Soil	No
Grevillea pilulifera	(Lindley) Druce	18		0		Resprouter	Soil	No
Grevillea polybotrya	Meissner	5		0		Resprouter	Soil	No
Grevillea quercifolia	R. Br.	9, 18	95	4		Resprouter	Soil	No
Grevillea synapheae	R. Br.	18		2		Resprouter	Soil	No
Grevillea wilsonii	Cunn.	13, 18		1	0	Resprouter	Soil	No
Hakea amplexicaulis	R. Br.	18		71		Resprouter	On-Plant	No
Hakea auriculata	Meissner	5		60		Resprouter	On-Plant	No
Hakea conchifolia	Hook.	5		65		Resprouter	On-Plant	No
Hakea corymbosa	R. Br.	5		55		Resprouter	On-Plant	No
Hakea cyclocarpa	Lindley	18		81		Resprouter	On-Plant	No
Hakea flabellifolia	Meissner	5		89		Resprouter	On-Plant	No
Hakea incrassata	R. Br.	5, 18		88		Resprouter	On-Plant	No
Hakea lissocarpha	R. Br.	3, 7, 18	80	82	0	Resprouter	On-Plant	No
Hakea obliqua	R. Br.	5		62		Seeder	On-Plant	No
Hakea petiolaris	Meissner	18		74		Resprouter	On-Plant	No
Hakea prostrata	R. Br.	18		76		Seeder	On-Plant	No
Hakea smilacifolia	Meissner	5		100		Resprouter	On-Plant	No
Hakes trifurcata	(Smith) R. Br.	3, 6, 9	90	87	0	Seeder	On-Plant	No
Hakea undulata	R. Br.	9, 18	44	74		Seeder	On-Plant	No
Hakea varia	R. Br.	18		68		Seeder	On-Plant	No
Isopogon dubius	(R. Br.) Druce	3, 18	58	19	12	Seeder	On-Plant	No
Isopogon linearis	Meissner	5		18		Resprouter	On-Plant	No
Isopogon sphaerocephalus	Lindley	18		1		Resprouter	On-Plant	No
Isopogon tridens	F. Muell.	5		13		Resprouter	On-Plant	No

Appendix I
Continued

Species	Author	Reference	Viability %	% no treatment	% after boiling	Fire response syndrome	Seed storage syndrome	Flowering stimulation
Lysinema ciliatum	R. Br.	5		0		Seeder	Soil	No
Persoonia elliptica	R. Br.	14, 18	73	0		Resprouter	Soil	No
Persoonia longifolia	R. Br.	18		0		Resprouter	Soil	No
Petrophile biloba	R. Br.	18		30			On-Plant	No
Petrophile brevifolia	Lindley	5		4		Resprouter	On-Plant	No
Petrophile chrysantha	Meissner	5		58		Resprouter	On-Plant	No
Petrophile drummondii	Meissner	5		24		Seeder	On-Plant	No
Petrophile linearis	R. Br.	7, 18		0		Resprouter	On-Plant	No
Petrophile macrostachya	R. Br.	5		2		Resprouter	On-Plant	No
Petrophile media	R. Br.	5		60		Seeder	On-Plant	No
Petrophile striata	R. Br.	18		0			On-Plant	No
Stirlingia latifolia	(R. Br.) Steudel	5, 18		1		Resprouter	Soil	No
Stirlingia simplex	Lindley	18		0		Seeder	Soil	No
Strangea cyanchicarpa	(Meissner) F. Muell.	5		53		Resprouter	On-Plant	No
Xylomelum occidentale	R. Br.	18		76		Resprouter	On-Plant	No
Ranunculaceae								
Clematis pubescens	Huegel ex Endl.	3, 9, 18	16	4	0	Resprouter	Soil	No
Rhamnaceae								
Cryptandra arbutiflora	Fenzl	18		0			Soil	No
Spyridium globulosum	(Labill.) Benth.	18		7		Seeder	Soil	No
Trymalium floribundum	Steudel	3, 9, 11, 18	64	5	36	Seeder	Soil	No
Trymalium ledifolium	Fenzl	3, 9	42	3	37	Seeder	Soil	No
Rubiaceae								
Opercularia echinocephala	Benth.	9, 18	10	1		Resprouter	Soil	No
Rutaceae								
Boronia crenulata var. *gracilis*	Smith	18		0		Resprouter	Soil	No
Boronia fastigiata	Bartling	3, 9, 18	10	0	0	Resprouter	Soil	No
Boronia molloyae	J. Drumm.	3, 9, 18	0	0	0	Resprouter	Soil	No

Appendix I
Continued

Species	Author	Reference	Via-bility %	% no treat-ment	% after boiling	Fire response syndrome	Seed storage syndrome	Flow-ering stimu-lation
Boronia ovata	Lindley	18		0		Resprouter	Soil	No
Boronia spathulata	Lindley	12, 18	20	0		Resprouter	Soil	No
Eriostmon spicatus	A. Rich	9, 18	8	2		Resprouter	Soil	No
Geleznowia verrucosa	Turcz.	5		1		Resprouter	Soil	No
Santalaceae								
Leptomeria cunninghamii	Miq.	9, 18	0	0		Seeder	Soil	No
Sapindaceae								
Dodonaea ceratocarpa	Endl.	18		25		Resprouter	Soil	No
Dodoneae hackettiana	W. Fitzg.	18		3		Resprouter?	Soil	No
Dodoneae viscosa var. *purpurea*	Jacq.	18		29		Resprouter	Soil	No
Dodoneae viscosa var. *viscosa*	Jacq.	18		7		Resprouter	Soil	No
Stackhousiaceae								
Stackhousia heugelii	Endl.	18		0		Seeder?	Soil	No
Stackhousia pubescens	A. Rich	18		0		Seeder?	Soil	No
Tripterococcus brunonis	Endl.	7, 18		0		Seeder?	Soil	No
Sterculiaceae								
Lasiopetalum floribundum	Benth.	18		1		Seeder	Soil	No
Thomasia pauciflora	Lindley	9	13	8		Resprouter	Soil	No
Stylidiacea								
Stylidium affine	Sonder	18		0		Seeder?	Soil	No
Stylidium amoenum	R. Br.	18		1		Seeder	Soil	No
Stylidium bulbiferum	Benth.	13		0		Seeder?	Soil	No
Stylidium calcaratum	R. Br.	18		38		Seeder	Soil	No
Stylidium hispidum	Lindley	18		0		Seeder	Soil	No
Stylidium junceum	R. Br.	18		0		Seeder	Soil	No
Stylidium schoenoides	DC.	18		0		Seeder	Soil	No

Appendix I
Continued

Species	Author	Reference	Viability %	% no treatment	% after boiling	Fire response syndrome	Seed storage syndrome	Flowering stimulation
Thymeliaceae								
Pimelea brevistyla	B. L. Rye	18		0			Soil	No
Pimelea ciliata	B. L. Rye	18		1			Soil	No
Pimelea ferruginea	Labill.	18		0			Soil	No
Pimelea leucantha	Diels	5		0		Seeder	Soil	No
Pimelea rosea	R. Br.	3, 9, 13, 18	2	0	0	Seeder	Soil	No
Pimelea spectabilis	Lindley	3, 9, 18	10	0	0	Seeder	Soil	No
Pimelea suaveolens	Meissner	3, 18	0	0	0	Seeder	Soil	No
Pimelea sylvestris	R. Br.	18		0			Soil	No
Tremandraceae								
Tetratheca hirsuta	Lindley	9, 18	52	2		Seeder	Soil	No
Violaceae								
Hybanthus floribundus	(Lindley) F. Muell.	3, 7, 9, 18	20	0	0	Resprouter	Soil	No