Post-fire regeneration and growth of *Senecio garlandii* (Asteraceae) — a vulnerable plant of the South Western Slopes, NSW

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Burrows, G.E. (Ron Potter Centre, Charles Sturt University – Riverina, PO Box 588, Wagga Wagga, New South Wales, Australia, 2678) 1995. Post-fire regeneration and growth of Senecio garlandii *(Asteraceae) — a vulnerable plant of the South Western Slopes, NSW.* Cunninghamia *4(1): 35–44. Senecio garlandii* F. Muell. ex Belcher (Asteraceae) is a perennial subshrub that has been recorded from less than 10 sites, mostly on the South Western Slopes of NSW. In conservation terms *S. garlandii* is currently classified as vulnerable. Its site of greatest abundance is The Rock Nature Reserve (340 ha), 30 km south east of Wagga Wagga. In March 1991 the first major fire in 40 years burnt more than 90% of the reserve and less than 5% of the original *Senecio* population remained in leaf. Over the next 3 years post-fire regeneration was assessed in a permanent quadrat (4 x 5 m) located in an area of pre-fire *Senecio* abundance. Following above-average rainfall during winter 1991, 453 *Senecio* seedlings were recorded in September 1991, ranging in density from 4–45 seedlings/m^2. After 4 months of below-average rainfall, seedling numbers declined to 171 by February 1992. In comparison to this 62% mortality (average of 2.23 deaths/day), the other 35 species of annuals and herbaceous perennials present in the quadrat had either died or had died back to a rootstock or similar organ at least two months previously. After February 1992 there was a low constant mortality (average 0.07 deaths/day) for the remaining 22 months of the study. By their first summer *S. garlandii* seedlings consisted of a single shoot 8–15 cm height. By the second summer this shoot had senesced to be replaced by 1–5 shoots (mean = 2.2, average height 65 cm) and by the third summer these shoots also senesced to be replaced by 1–12 shoots (mean = 3.9, average height 92 cm). No seedlings of *S. garlandii* flowered in their first summer, while 44% of the surviving 143 seedlings flowered in their second year and over 95% of the surviving 122 plants flowered in their third year. A small number of plants survived the fire and resprouted from rootstocks. This study indicates that the conservation status of *S. garlandii* has not been harmed by the fire.

Introduction

Senecio garlandii F. Muell. ex Belcher (Asteraceae) is a perennial subshrub, usually up to one metre in height. The stems and lower leaf surfaces are densely lanate, which explains the common name of 'Woolly Ragwort'. The first known collection of *S. garlandii* was made in 1890 by J. R. Garland who sent his material to Ferdinand von Mueller. Mueller prepared a manuscript description of this material under the specific epithet 'garlandii' but never published this species name. The name was formally published almost 100 hundred years later (Belcher 1986).

Belcher (1986) describes the distribution of *S. garlandii* as 'Very local along the 147° E. meridian on the western slopes of the Dividing Range between West Wyalong and Albury.' Belcher lists five localities for the herbarium specimens he examined: i) The Rock Hill, ii) Tabletop Range, iii) a site '15 miles' ESE of The Rock, iv) Gidginbung and v) 'near Albury'. In addition, *S. garlandii* has been recorded at Flowerpot Hill (4 km S of The Rock), Ulandra Nature Reserve (7 km SE of Bethungra) and Benambra State Forest (20 km W of Holbrook)(personal observation). *Senecio garlandii* is classified as a 3V (vulnerable) species (Endangered Flora Network for the Australian & New Zealand Environment and Conservation Council 1993) as its range is greater than 100 km but it only occurs in small populations that are mostly restricted to highly specific habitats.

At only 340 ha, The Rock Nature Reserve (lat. 35° 16' S, long. 147° 05' E) is a small island of remnant native vegetation, surrounded by extensive agricultural lands. The Rock Nature Reserve is an important area for the protection of *S. garlandii* as it supports the largest known population of the species (personal observation) and is one of the few formally protected areas within which the species grows. While *S. garlandii* has a restricted geographical distribution, it also has a restricted distribution within The Rock Nature Reserve. It occurs almost exclusively on the exposed upper slopes and ridges of the reserve and thus occupies only a small percentage of a small reserve. The same habitat requirements are evident at Tabletop and Ulandra Nature Reserves and Benambra State Forest.

After less than 75 mm of rain during November 1990 to March 1991 (average 208 mm for this period) the first major fire (15–17 March 1991) in 40 years burnt more than 90% of The Rock Nature Reserve (personal observation). Personal estimates indicated that pre-fire there were several thousand *S. garlandii* plants in the reserve but post-fire there were probably less than 100 plants in leaf and these were confined to inaccessible rock ledges on the eastern cliff.

Given: i) the restricted distribution of *S. garlandii*, ii) the importance of The Rock Nature Reserve to this species' formal protection and iii) the major reduction in plant numbers in the reserve due to the March 1991 fire, it was considered useful to study the post-fire regeneration and subsequent growth of *S. garlandii*. In addition two other aspects of the biology of *S. garlandii* were investigated to help understand seedling establishment and survival. Firstly, *S. garlandii* possesses large leaves of mesophytic appearance while all other perennial species at The Rock Nature Reserve that stay in leaf during summer have smaller xerophytic leaves. Thus leaf anatomy was studied to better understand seedling survival during summer. Secondly, a study of seed viability was conducted as prior tests indicated that a period of dry heat was needed to overcome dormancy. A similar response has only been described in a small number of native species (Bell et al. 1993).

Materials and methods

An area 50 m to the east of the main cliff was selected for the establishment of a permanent quadrat, 4 x 5 m. This area was chosen as it supported, excluding the herbaceous stratum, an almost monospecific stand of *S. garlandii* prior to the fire and thus was considered favourable for regeneration. The quadrat was 250 m above the surrounding plains and was on the easterly facing scree slopes of a north–south ridge. The quadrat had a slope of 30° and consisted of about 80% bare soil and 20% rock and was divided into 20 1 x 1 m contiguous sub-quadrats. The site was well-drained and was shaded from the early afternoon onwards by a 100 m high cliff to the west. Rainfall and temperature data were obtained from the Bureau of Meteorology's station at Forest Hill, Wagga Wagga, about 35 km NE of the study site.

The quadrat was assessed for a total of 28 months, usually at six-weekly intervals. At each trip the following parameters were assessed: i) number of seedlings and rootstocks of *S. garlandii*/m^2, ii) average height and number of basal shoots of seedlings and rootstocks of *S. garlandii*, iii) reproductive stage of seedlings and rootstocks of *S. garlandii* and iv) presence/absence and reproductive stage of species other than *S. garlandii*.

Mature seed of *S. garlandii* was collected from plants that recovered from rootstocks and 30 month old plants in late December 1993 and stored dry at ambient temperature. Seed viability was tested (3 replicates of 50 seeds) at about one month intervals by direct germination on filter paper supported on moistened vermiculite in petri dishes subject to a 16 hr photoperiod (45 μmol/m^2/sec) at 23° C and 8 hrs dark at 20° C. For light microscopy leaves were fixed in glutaraldehyde, processed using standard procedures for plastic embedding and transverse sectioned at 1–2 μm and stained with toluidine blue (O'Brien & McCully 1981).

Results

Seed germination

The seeds were roughly cylindrical (about 2.5 mm length, 0.6 mm diameter), averaged 0.29 mg in weight and had a thin seed coat. Immediately upon wetting the acheneal hairs released several intertwined spiral bodies and within 24 hrs the seeds were surrounded by a mucilaginous sheath. Seed tested within one week of collection exhibited low (< 6%) germination. After 1.5, 2.5 and 3.5 months dry storage at ambient temperatures average germination percentages of 69, 90 and 92%, respectively, were recorded.

Leaf anatomy

In cross-section the leaves showed typical dorsiventral anatomy with a layer of palisade mesophyll, a layer of spongy mesophyll and a layer of mesophyll intermediate between the palisade and the spongy mesophyll in position and cell arrangement (Fig. 1). A large proportion of the leaf was intercellular air space and little or no sclerenchyma was present. Xerophytic modifications to this basically mesophytic structure included: i) the large diameter upper epidermal cells possessed a thick (10–15 μm) outer cell wall, with a thin cuticle, ii) all stomata were restricted to the lower leaf surface, and iii) the lower surface had numerous single-celled trichomes that formed a dense mat about 200 μm thick (Fig. 1).

Field assessment

i) Species other than *Senecio garlandii*

The overstorey surrounding the quadrat consisted of *Eucalyptus macrorhyncha*, with some *E. polyanthemos*, *E. albens* and *Brachychiton populneus*, but these species were not recorded in the quadrat. A total of 35 species, excluding *S. garlandii*, were recorded in the quadrat over the assessment period. In terms of origin 22 species (63%) were naturalised and 13 (37%) were native species. In terms of life cycle and growth form 26 (74%) were annual herbs and 9 (26%) were perennial herbs.

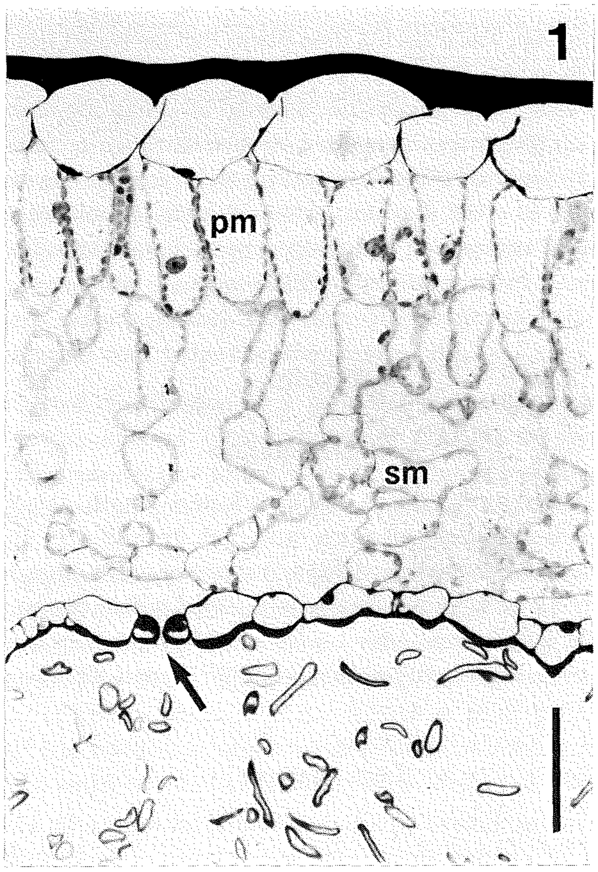

Fig. 1. Transverse section of a mature leaf of *Senecio garlandii*. Note the thick outer epidermal cell walls, the large adaxial epidermal cells, the palisade (pm) and spongy mesophyll (sm) layers, the stoma (arrowed) and the abaxial trichome layer. Scale = 50 μm.

ii) Survival of *Senecio garlandii*

While the fire killed many of the existing *Senecio* plants some survived by resprouting from a rootstock. Survivors could be identified by their greater shoot growth compared with *Senecio* seedlings and often by the presence of the charred stumps of the previous year's growth. By early September 1991 at least 2 rootstocks had not resprouted in the quadrat, 2 rootstocks both had a single shoot 3 cm in height and one rootstock had 7 shoots all about 8 cm high. Six weeks later one of the smaller rootstocks had died, while of the two remaining, one had a shoot 28 cm high and the other five shoots 50–75 cm high, all with flower primordia. This represents a rapid elongation of 1–1.5 cm/day over the intervening 6 weeks for many of the rootstock shoots. These two plants remained alive for the duration of the study.

iii) *Senecio garlandii* seedling establishment and mortality

In early September 1991, 5 months after the fire and with average or above average rainfall in the preceding 3 months (Fig. 2), 453 *S. garlandii* seedlings were recorded in the 20 m^2 quadrat (Fig. 3), ranging from 4–45 seedlings/m^2, at an average of 22.7 seedlings/m^2. The seedlings were no greater than 2 cm in height and most were 1 cm or less. Seedling numbers remained largely unchanged over the next 6 weeks (Fig. 3). Several annual species, e.g. *Carduus tenuiflorus, Daucus glochidiatus, Parietaria debilis, Ranunculus sessiliflorus* and *Stellaria media*, were more abundant and vigorous than the *Senecio* seedlings and tended to smother the smaller individuals. By late November 1991, a relatively small 7.3% reduction in seedling numbers had occurred (Fig. 3), although rainfall had been well below average for October and November (Fig. 2). Seedlings that had germinated in thin, loose ash on the top of boulders had died and many of the smaller individuals appeared to be water-stressed. Well-developed seedlings had 5–8 fully expanded leaves, were 10–15 cm high and did not elongate further. All the annual species that had previously overgrown the smaller, slower growing *Senecio* were dead and the perennial herbs died back to some form of rootstock or bulb by mid-summer. At mid-January 1992 the preceding 6 weeks had been relatively dry with only 31 mm of rainfall recorded. Combined with the excellent drainage and warmer temperatures this resulted in the most rapid rate of seedling mortality during the study (Fig. 3) with a 44% reduction in numbers, at an average of 4 deaths/day. In late February 1992, a further 27% reduction in numbers from the previous assessment period (average of 1.5 deaths/day) was recorded. The second half of summer 1991/1992 was relatively wet (93.4 mm of rainfall) and cool (January and February mean monthly maxima were about 2 degrees below average). These conditions had allowed hundreds of *Carduus tenuiflorus* seedlings to germinate in the quadrat, but a new cohort of *Senecio* seedlings did not germinate. During the winter and spring of 1992 no new *Senecio* seedlings germinated, even in the organic material and soil on top of the rocks where suitable germination conditions occurred without competition from existing plants. In spring 1992, as per the previous year, the *Senecio* seedlings were partially smothered by annuals but given their greater size and greater competitive ability the effects were not as pronounced. After the high mortality rate recorded during summer 1991/1992 seedling mortality was low during the remainder of the study (Fig. 3) even during the summer of

1992/1993 when there were 10 consecutive weeks where only 33.4 mm of rainfall was recorded and there were 11 consecutive days with maxima greater than 35° C.

In spring 1991 there were about 450 *Senecio* seedlings in the quadrat, ranging in density from 4–45/m². In December 1993, 28 months later, there were 122 *Senecio* seedlings, ranging in density from 1–14/m². This represents an overall mortality of 73%, ranging from a high of 89–94% in 3 sub-quadrats, to a low of 44% in one sub-quadrat.

iv) Growth form

In their first year of growth the *Senecio* seedlings developed a single upright shoot but by early winter this shoot had usually senesced and axillary buds at its base began to slowly elongate. Rapid elongation of the new basal shoots commenced in mid-August 1992 and by late September most shoots had increased in average height by 8 cm in the preceding 6 weeks. This elongation was greatest during October (about 4.5 cm/week) and began to slow in December when plants reached their average maximum height of 65 cm. Seedlings averaged 2.2 shoots in their second year, and some plants had up to 5 equal-sized shoots. In early May 1993 the shoots produced during the previous spring and summer began to senesce and, as in the previous year, the shoot system was gradually replaced by new shoots which were initiated in the basal leaf axils of the existing shoots. These shoots were often initiated just below ground level and grew horizontally for a short distance before becoming upright, thus giving a single individual the appearance of several plants growing in close proximity. In December 1993 most plants were at full adult-size (average plant height 92 cm), with an average of 3.9 shoots per plant (range 1–12). These main shoots were unbranched for most of their length but near the apex several axillary buds had elongated and initiated flowers to form a corymbose inflorescence.

v) Flowering

In their first year no seedlings in the quadrat flowered or had formed flower primordia, while the two rootstocks had finished flowering by late November but fruits had not been released. In September 1992 many *Senecio* plants had initiated flower primordia and by early November the primordia had developed into large flower buds. In mid-December 1992, 44% of the 143 remaining *Senecio* plants were flowering or had finished flowering and in late January 1993 flowering had finished. However December 1992 was unusually moist (Fig. 2) and cool, and in January 1993 the lower axillary buds in some plants had rapidly elongated and initiated new flower primordia. In mid-March 1993, after a dry finish to summer (Fig. 2), the flower buds that had been initiated in mid-January had been aborted. In December 1993 more than 95% of the 122 plants surviving their third summer had flowered or were flowering.

General observations throughout the reserve revealed that *S. garlandii* had: i) re-established monospecific thickets where they existed pre-fire, ii) increased plant density where previously only scattered plants had been present, and iii) a limited increase in range but was still restricted to the ridge areas.

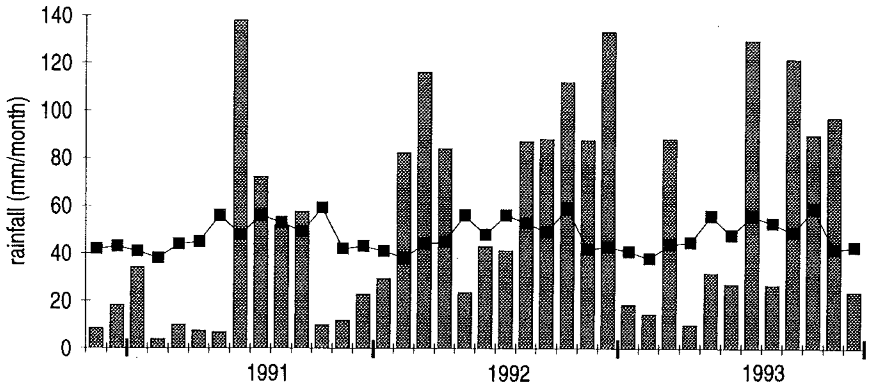

Fig. 2. Monthly rainfall during the study period with long-term average (■ – ■) values. Values are for Forest Hill, Wagga Wagga (35 km NE from site). Arrow indicates time of the fire.

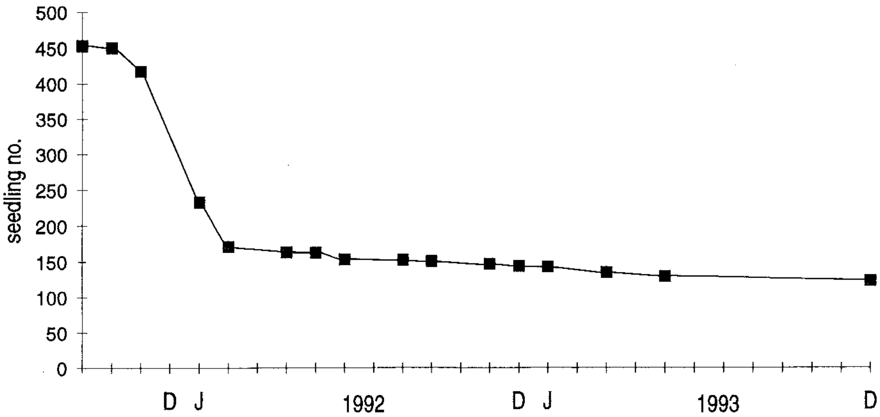

Fig. 3. Number of *Senecio garlandii* seedlings in the permanent quadrat during the study period.

Discussion

The principal finding of this study is that *Senecio garlandii*, a vulnerable species reduced to a few individuals after the 1991 fire at The Rock Nature Reserve, has regenerated successfully from seed and, to a lesser extent, from rootstocks. It has maintained its almost monospecific stands in its areas of pre-fire dominance, has increased in density where previously only scattered individuals existed and has expanded its distribution but is still principally restricted to the upper ridge areas. Several *Senecio* species are known as fire ephemerals or 'fire weeds' (Gill 1993). While *S. garlandii* shares with these species the ability to successfully regenerate after fire it would not be considered a fire weed because: i) seeds do not need a heat treatment to germinate, ii) individual plants appear to be relatively long lived through their annual resprouting habit, i.e. they do not have the short life span of a fire ephemeral, and iii) populations can persist in low fire frequency conditions, e.g. plants on cliff ledges.

Lawrence (1985) investigated the reproductive biology of 32 mainly native species of *Senecio*, with *S. garlandii* listed as *Senecio* species A (Belcher 1986). Lawrence noted, as in the present study, that *S. garlandii* is a perennial, is early flowering, produces lightweight seeds, the seeds produce a mucilaginous sheath upon wetting and that these seeds can have high germination percentages. From observations on pollen-ovule ratios and inflorescence morphology it was possible for Lawrence to deduce that *S. garlandii* was self-incompatible. Lawrence noted that stable environments favour outbreeding perennials but only 5 of the 15 self-incompatible perennials she investigated were usually restricted to comparatively stable environments. Three of the five, including *S. garlandii*, are found on rocky outcrops of drier inland areas.

The most common criterion for classifying a species response to fire is whether persistence is by seed ('seeders') or by vegetative means ('sprouters') (Gill & Bradstock 1992). This study indicates that *S. garlandii* is principally a seeder although some plants function as sprouters after a low-intensity fire. Gill & Bradstock (1992) list three categories of seed regeneration: i) from viable canopy-stored seed, ii) from soil-stored seed, and iii) from seed brought in, because no propagules remain on site after fire. In *S. garlandii* the mature achenes are easily dislodged from the head's receptacle with little force, therefore no seed-store exists on the plant. Many species of the Asteraceae have small air-borne fruits and are capable of recolonising burnt areas with seed blown in from unburnt areas (Purdie & Slatyer 1976). However, because the fire eliminated almost the complete *Senecio* population, except for some isolated individuals on cliff ledges, there were no seeds on unburnt plants to be used for recolonisation of burnt areas. In addition, while the achenes of *S. garlandii* have numerous slender pappus bristles they are not persistent (Belcher 1986), and thus long-distance wind dispersal of the fruits would not be expected. Thus it is most probable that the re-establishment of *S. garlandii* was from a seed-store in the soil, as were the 7 composites described by Purdie & Slatyer (1976). Purdie (1977) noted that seeds in litter are often destroyed in fires, while many seeds in the soil survive. Purdie (1977) noted that germination of herbaceous species, including *Senecio quadridentatus* and *Hypochoeris* spp., was lower in burnt than unburnt areas. She suggests that the seed may not be stored for long periods in the soil or are trapped in the litter by their pappus and thus destroyed by fire.

Studies by Hobbs & Atkins (1991) and Purdie & Slatyer (1976) found, as did the present study, that germination of perennial species occurred in the first year after the fire, but not in subsequent years. Hobbs & Atkins (1991) also found that seedlings of perennial species that survived their first summer generally continued to survive or, conversely, mortality is greatest in the seedling phase (Fig. 3).

Bell et al. (1993) noted that obligate re-seeding species tend to grow vertically initially then produce an 'umbrella shape', while resprouting species have more of an 'urn shape'. *Senecio garlandii* combines these two strategies as initially it produces a vertically growing shoot that only branches near the apex; however, after plants have become established they branch from near the base and form a more spreading canopy.

While *S. garlandii* operates as a resprouter in its annual growth cycle, the shoots originate above or close to ground level and a specialised rootstock or similar organ does not appear to be present. Thus fire-induced mortality of mature plants is to be expected. The degree of water-stress experienced by shrubs at and following the time of fire may be an important factor in determining the proportion of shrubs that resprout (Hodgkinson & Griffin 1982). This suggests that a low fire intensity, combined with more than the about 25 mm of rainfall received in the 2.5 months after the March fire (Fig. 2), then more *Senecio* rootstocks may have resprouted.

Over 200 vascular plant species have been recorded at The Rock Nature Reserve (Benson & Melrose 1993) but only about 50 species remain in leaf over summer. Most (> 90%) of these species possess small leaves and/or pronounced xerophytic modifications to their leaf anatomy. Thus it is remarkable that *S. garlandii* has the largest leaves of any species at The Rock Nature Reserve (personal observation) and possesses a mesophytic dorsiventral leaf anatomy that appears unsuited to the semi-arid conditions. The thickening of the outer epidermal cell wall, the restriction of stomata to the abaxial surface and the extremely dense abaxial trichome covering are probably effective in controlling water loss, in both seedlings and adults. This contributes to a relatively low mortality rate for a mesophytic species growing in semi-arid conditions and allows the seedlings a competitive advantage as they are able to continue vegetative and reproductive growth when the other species are dead or dormant. The lack of sclerenchyma results in wilting of leaves during times of pronounced water-stress.

After more than 70 mm of rainfall in early February 1992, combined with 13 consecutive days with temperature maxima below the monthly mean, there was an extensive germination of *Carduus* seedlings but no *Senecio garlandii* seedlings were observed. All the thistle seedlings died of water-stress before flowering. This observation, combined with the germination tests, suggests that the *Senecio garlandii* seeds may possess some mechanism to prevent germination after periods of wet weather in summer. A period of after-ripening, consisting of several months of dry heat has been described for a small number of Australian species of the Asteraceae and Poaceae (Mott & Groves 1981, Bell et al. 1993).

From a conservation viewpoint it is of concern that 22 weed species were present in the quadrat. General observation and the findings of other studies (Purdie & Slatyer 1976, Hobbs & Atkins 1991) indicate that the abundance and diversity of weeds should progressively be reduced as the *S. garlandii* re-establishes. *Senecio garlandii* is able to reach reproductive maturity relatively quickly as shown by 45% of the surviving seedlings flowering in their second summer and greater than 95% flowering in their third summer. This indicates that this species would not be eliminated at this site even if the fire frequency increased, although further study is required to determine what length of time and conditions are required to establish an effective seed-store in the soil. In summary, it appears that *S. garlandii* could tolerate a wide variation in fire frequency and no specific fire management practices are needed to maintain the population at The Rock Nature Reserve.

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