The Invasive Fireweed (Senecio madagascariensis Poir)

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Senecio madagascariensis originates from southern Africa but it has been introduced to several other countries including Australia. Climatic suitability suggests that there are large areas around the world suitable for the weed's growth where it is currently not present. The weed poses a major threat to livestock industries in these countries through its ability to reduce pasture production and poison animals. A range of control techniques has been used to try and manage *S. madagascariensis*. Besides using traditional approaches, the use of competitive pastures and more tolerant livestock (such as sheep and goats) are some of the other options recommended as part of an integrated approach.

Keywords: CLIMEX ; ecology ; herbicides ; fireweed ; Senecio

1. Introduction

Senecio madagascariensis Poir. (fireweed), a native herbaceous plant from southern Africa [1] has been introduced to several countries including Australia, the United States of America (USA; Hawaii), Japan, Brazil, Argentina, Columbia, Uruguay, and Kenya [2]. *Senecio madagascariensis* plants contain pyrrolizidine alkaloids (PAs) and when eaten by some domestic livestock (particularly cattle and horses) it can lead to liver toxicity [3]. *Senecio madagascariensis* has an ability to spread into different habitats quickly through high seed production and multiple dispersal mechanisms, particularly by wind. In some cases, effective *S. madagascariensis* management can be achieved using herbicides, but maintaining a healthy and competitive pasture and implementing multi-species grazing practices are also recommended for long-term control [4]. Nevertheless, the development of integrated management strategies that incorporate a range of options will be the most effective approach to reduce the impact of *S. madagascariensis* [5].

2. Biology and Ecology of *S. madagascariensis*

2.1. Taxonomy

Senecio madagascariensis Poir. was first described by JLM Poiret in Madagascar in 1817 [6]. It belongs to the Tracheophytes, in the class Magnoliopsida, order Asterales, and family Asteraceae with synonyms of *Senecio bakeri* S. Elliot, *Senecio incognitus* Cabrera, and *Senecio ruderalis* Hary [7]. In South Africa, it is called *S. ruderalis* Harv. or *S. junodianus* O.Hoffm, whereas cytological studies in Australia have confirmed it as *S. madagascariensis* [8]. Its name is derived from Latin, senex meaning 'old man' referring to its pappus appearing like a white beard and *madagascariensis* meaning 'from Madagascar' [9].

2.2. Species Description

Senecio madagascariensis is an erect, herbaceous, short-lived perennial plant *ca.* 10 to 50 cm tall (occasionally up to 70 cm). It forms a single stem or occasionally multiple stems which arise from a central crown at its base [10]. Its stems are multi branched, especially towards the top of the plant. Leaves are typically lanceolate with tips that are acute with denticulate margins [11] and sessile or sub-sessile [10]. Individual plants possess a branched tap root which grows 10 to 20 cm deep, with numerous fibrous roots [11].

3. Potential Spread and Future Distribution of *S. madagascariensis*

To assess the climatic suitability of *S. madagascariensis* around the world, a process-based model CLIMEX (version 3) has been used [12]. The CLIMEX model compares the response of a species to long-term averages of climate for different locations. A series of growth and stress indices are inferred based on climates of known occurrences of a species. The annual growth index, GI, describes a species response to temperature and soil moisture, while stress indices (cold, wet, hot, dry, cold-wet, cold-dry, hot-wet, and hot-dry) exclude it from unfavorable locations. By combining these growth and stress indices, an Ecoclimatic Index (EI), ranging from 1–100 is calculated, which provides an overall measure of the suitability of a given location.

The CLIMEX model, run under the current climate scenario, satisfies the present geographic range of *S. madagascariensis* around the world (**Figure 1**). All occurrences of *S. madagascariensis* matched well within the projection created by this model. For South America, the model suggests that most of the southern parts of Brazil, the whole of Uruguay, and northeastern Argentina are highly suitable for *S. madagascariensis* (**Figure 1**).

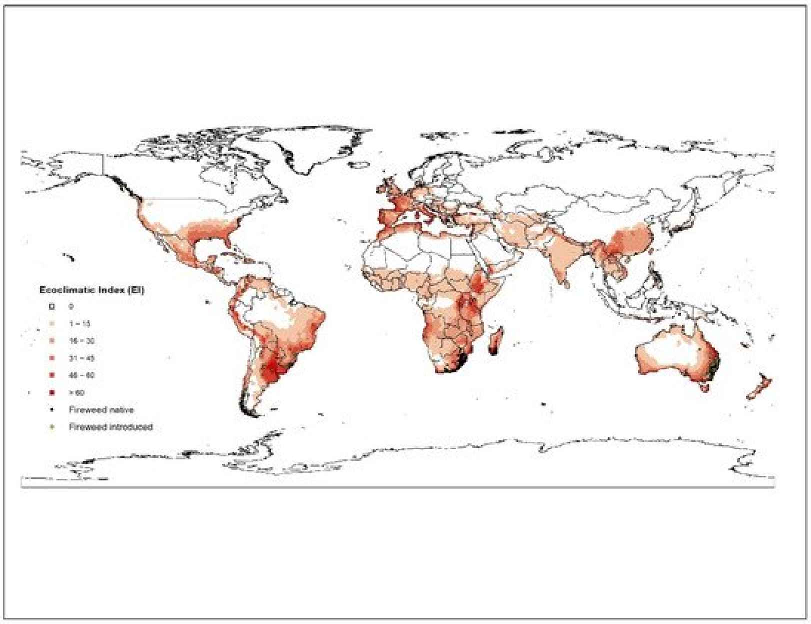

Figure 1. Current distribution (native—green dots; introduced—black dots) and the climatic suitability for fireweed under the current climate modeled using CLIMEX.

3.1. Preferred Habitat

Senecio madagascariensis can develop different growth habits, with different leaf shapes on different soil types and in different locations [13]. *Senecio madagascariensis* is an opportunistic weed and it can adapt and spread into new areas rapidly [8]. The preferred habitat of *S. madagascariensis* in the invaded range includes roadsides, livestock feeding areas, and areas around dams and other wet areas [14]. It can also be found in improved grasslands, in meadows, and along riverbanks [15]. *Senecio madagascariensis* prefers well-drained, non-compact, high fertility soil, but it can grow on a wide range of soils including sands and limed soil [8][9].

3.2. Climatic Requirements

Senecio madagascariensis prefers a humid, maritime, and sub-tropical climate. It is found at similar latitudes on the eastern coast of the three continents of the southern hemisphere with an annual rainfall of between 500 to 1000 mm [9]. An annual mean temperature of 12.4 to 20.1 °C favors the establishment of *S. madagascariensis* in most locations where it has invaded [9]. However, young seedlings are sensitive to frost while older plants show tolerance [16], but frost can reduce their vigour [17]. This may lead to its absence in areas with a high frost rate [16]. *Senecio madagascariensis* can grow at altitudes of up to 2,800 m above sea level in the tropical environments of Kenya and Columbia suggesting that the warmer altitudinal temperatures in these countries may allow it to grow at higher altitudes than would normally be seen in more temperate countries [17].

3.3. Growth and Development

Senecio madagascariensis is a short-lived perennial, however, it often grows as an annual. Most plants finish their life cycle at the end of their first year [9]. However, a few plants will remain, continue to grow, and reproduce vigorously throughout their second year and therefore under these circumstances, it is regarded to be a perennial. It can exhibit high plasticity with the ability to change its life cycle depending upon local conditions [9].

3.4. Reproduction and Seed Dynamics

Senecio madagascariensis reproduces primarily by seeds (i.e., achenes), although vegetative reproduction has been observed under certain conditions [8][18]. When its stems are trampled and contact moist soil, roots and shoots can sprout from the stem's nodes, resulting in new, self-supporting plants [18].

Flowering can take place throughout the year in some countries [19] however, in Australia, it is typically from late autumn (May) through to mid-summer (January). If conditions are favourable, some plants flower until late summer (February). Generally, plants flower 42 to 70 days after seedling emergence. Flowers are pollinated by insects such as European honeybees and hoverflies [9]. Generally, the plants undergo senescence and die after flowering as this is an important part of the life cycle.

3.5. Seed Dispersal

Human aided dispersal has been responsible for the introduction of *S. madagascariensis* into at least eight countries outside of its native range. Once in a new environment, the seeds can be dispersed from local populations through multiple mechanisms including wind, by attaching to animals and vehicles, or in contaminated agricultural produce [20]. The wind has been attributed to the rapid spread and expansion of *S. madagascariensis* in parts of several countries, including Australia, Argentina, Brazil, and the USA (i.e., Hawaii) [21][15][22]. It was hypothesized that the spread of *S. madagascariensis* by wind might have been enhanced through the rapid evolution of superior dispersal traits at the invasion front (i.e., range edge populations) [15], as has been reported for *S. inaequidens* in Europe [23]. However, after comparing key features of the propagules of *S. madagascariensis* plants (i.e., pappus size, achene size, and the ratio of pappus size to achene size) growing on the edge and from within the established range, no differences in dispersal potential were found, which is advantageous from a management perspective.

3.6. Toxicity

Among the 1,200-worldwide species of *Senecio*, *ca.* 25 species (including *S. brasiliensis, S. heterotrichius, S. cisplatinus, S. selloi, and S. oxyphyllus*) are toxic to certain livestock, such as horses (*Equus caballus* L.) and cattle (*Bos taurus* L., *Bos indicus Brahman*) [3]. According to various studies, some *Senecio* species can be toxic to humans. For example, if milk products containing PAs from *S. madagascariensis* are consumed [24].

4. Management of *S. madagascariensis*

4.1. Legislation

In Australia, *S. madagascariensis* is a declared weed under the relevant legislation of all states and territories. However, the level of declaration and associated requirements vary greatly depending on the perceived level of risk. *Senecio madagascariensis* was added to the Hawaiian State Noxious Weed List by their Department of Agriculture in 1992 [25]. In Japan *S. madagascariensis* has been declared an Invasive Alien Species under the Invasive Alien Species Act (which restricts importation, moving, or growing of species within Japan) [2].

4.2. Physical Control

Senecio madagascariensis seeds are mostly wind dispersed and therefore the physical hand pulling of plants must be completed before the seed is formed if it is to be effective. The pulled plants should then be burnt or deep buried to prevent plants re-growing and producing further seeds. This technique is only practical for isolated plants or small patches and not for large infestations, as it is time consuming and labour intensive [4][14][18].

4.3. Chemical Control

In terms of chemicals, 2,4-D formulations [11][26], dicamba, glyphosate, MCPA, tebuthiuron, triclopyr [26], bromoxynil, fluroxypyr/aminopyralid, metsulfuron-methyl, and triclopyr/picloram/aminopyralid [14][27] are some herbicides that have been found to be effective on one or more growth stages of *S. madagascariensis.* However, which chemicals and rates can be legally applied, may vary between countries and even between jurisdictions within countries.

4.4. Biological Control—Competitive Pastures

In an effective *S. madagascariensis* management program, maintaining a vigorous, competitive pasture through the autumn and winter months is an important step in providing best management practice [9].

4.5. Biological Control—Insects and Pathogens

Although a biocontrol program to control *S. madagascariensis* first commenced in Australia in 1987, only two insects were tested, and neither were released. *Aecidium* sp. is a rust fungus that was imported into quarantine in Australia for detailed studies. This rust was like a naturally occurring Australian isolate of the orange rust *Puccinia lagenophorae* Cooke [28] that is found on the family Asteraceae. The South African rust was less damaging than the Australian isolates of *P. lagenophorae.* These results imply that their introduction would be doubtful to Australia due to its low virulence, which would be expected to translate to poor control of *S. madagascariensis* [28].

4.6. Livestock Grazing

Using cattle as a control strategy for *S. madagascariensis* tends to be unsuccessful, as the reduced competition and improved light conditions that occur once the pasture is grazed down allow new seedlings to grow faster. Cattle also tend to avoid it in heavily grazed paddocks as it is more easily distinguished amongst the grass pasture [9]. In contrast, grazing with sheep or goats is considered an effective method to control *S. madagascariensis*. According to Watson *et al.* sheep and goats are about 20 times more tolerant to *S. madagascariensis* poisoning than horses and cattle [11]. Sheep might ingest and suppress *Senecio* spp. toxin due to their ability to undergo hepatic detoxification. This is related to their ruminal flora populations that can reduce the probability of poisoning [29].

4.7. Integrated Management

Integrated weed management (IWM) is the use of a combination of methods, including cultural, physical, biological, and chemical approaches [30]. For *S. madagascariensis*, some trials to determine the effects of individual treatments have been undertaken, but testing of combinations of treatments is lacking. Despite this, Sindel and Coleman suggest that an effective IWM approach for *S. madagascariensis* control should include the use of perennial competitive pasture species, hand weeding (for isolated plants or small patches), the maintenance of good farm sanitation practices, and the use of herbicides to control the weed [14]. Furthermore, for long-term control of this weed, reduced grazing within a competitive pasture may need to be used by landholders [14]. The integration of livestock that are more tolerant (e.g., sheep and goats) of *S. madagascariensis* should also be considered given the success obtained in reducing its density in some situations [29].

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