

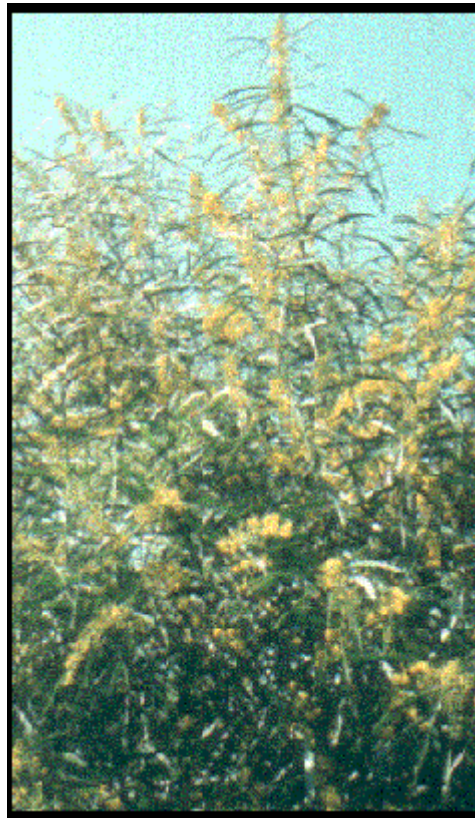


## **The Invasion of South African Fynbos by an Australian Immigrant:**

### **The story of *Acacia saligna***

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In the late 18<sup>th</sup> Century, European settlement on the southern and southwestern tip of South Africa was rapidly expanding. Farming and ranching expanded to the limits of the arable land. Overstocking and overgrazing occurred on the already thin soils and the native vegetation slowly became less diverse. In order to stabilize the disturbed land a desert-adapted, fast-growing tree species was introduced from Australia. Southwestern Australia and southwestern Africa both have nutrient-poor soils and a mediterranean climate characterized by cool wet winters and hot dry summers. Southwestern Africa's position on a major trade route between Europe and Australia also facilitated the introduction. (Witkowski 1991, Deacon 1992). And so, *Acacia saligna* (Port Jackson willow, blue leaf wattle) made its debut on the shifting sands of the lowland fynbos.



*A. saligna*

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## Biology, Geography and Impacted Ecosystems

The fynbos is a unique ecosystem situated within the highly endemic Cape Floristic Region of South Africa. This region, which represents one of six floristic regions worldwide, has the highest recorded plant species density for any temperate or tropical region in the world (Holmes and Cowling 1997). Within this 89,000 km<sup>2</sup> region, 73% of plant species are endemic (Willis et al. 1996). The fynbos ecosystem occurs on the Cape Folded Belt Mountains and the adjacent coastal strip in the southern and southwestern Cape Province of South Africa (Richardson et al. 1989). The soils of the fynbos are nutrient-poor and support mainly shrubs and grasses. This ecosystem, however, provides an essential function as a water catchment in the Mediterranean climate of South Africa where droughts are a seasonal occurrence (van Wilgen and Richardson 1985).

Lowland fynbos, the main habitat of *A. saligna*, occurs between the mountains of the Cape Folded Belt and the coast (Musil 1993). On the coast, lowland fynbos is characterized by shifting sand dunes, while in the interior, lowland fynbos ecosystems are confined to riparian zones. In both locations, periodic low-intensity fires play an integral role in nutrient cycling and germination of native fynbos vegetation. Lowland fynbos is an especially threatened ecosystem because its shifting sand dunes are being stabilized, and fire intensities and frequencies are being altered by the invasion of *A. saligna* (WBFC 2000). The need for restoration of this ecosystem is heightened by the fact that only 3.3% of lowland fynbos remains protected in 289 km<sup>2</sup> state-owned or private nature preserves (Milton et al. 1999).

There is nothing endemic about acacias, however. They are found worldwide both naturally and imported. In many places, acacias have been brought in to control shifting sands and to beautify desert landscapes. Southwestern United States has advocated the use of acacias to reduce desertification and green its landscapes. Several other acacias have been found to be invasive on the islands of the western Pacific (PIER 2000). *A. saligna*, however, is only known to be invasive in South Africa. In fact, 17-24% of the remnant natural areas of the Cape region have been invaded by acacias (Musil 1993). So why is *A. saligna* such a good invader of the lowland fynbos?

First of all, *A. saligna* not only invades quickly but also transforms the quality of the soil structure, soil chemistry, and hydrology to better suit its own needs (Richardson et al. 1997). As nitrogen fixers, acacias have a competitive advantage over native plants in the nutrient poor soils of the fynbos (Witkowski 1991). Because of its large above-ground biomass, *A. saligna* creates a large amount litterfall. The litter decomposition rates are accelerated because of greater soil nutrient availability in acacia-invaded stands. Speedy decomposition alters the spatial distribution of nutrients by increasing mineral enrichment and input of organic matter to the soil (Cowling 1992). The native fynbos species, however, are unable to take advantage of the increased nutrient availability in the soil. Native fynbos tree species lack mycorrhizal associates and therefore are less efficient at nutrient uptake. Also, native plants are tropical species with fleshy fruit, a trait that is not well-adapted to nutrient poor soils (Cowling 1992). Plants from infertile sites usually have low growth rates, low nutrient absorption rates, and are unresponsive to changes in nutrient availability (Musil 1993). Because *A. saligna* trees can use the greater nutrient availability to be more successful and native plants cannot, acacias essentially give

themselves a competitive advantage (Holmes and Cowling 1997). *A. saligna* also outcompetes local plants by overtopping them, growing to a height of 3 to 10 meters (Witkowski 1991). Since native plants are shade-intolerant, they typically do not fare well in Acacia-infested habitats. With their large canopy and high transpiration rates, acacias also reduce soil water availability (Musil 1993). Unfortunately, water is a limiting factor in the dry sandy soils of the fynbos and native plants lose out in the arena of water resource competition as well.

Soil stored seeds are another tactic of a successful invader. *A. saligna* seed may stay dormant in soil for up to 50 years. Forty-five percent of the seeds decay in the first year but this rate slows at a near log-linear pace over time (Holmes 1989). The seeds are hard-coated and water-impermeable. Germination is cued by dry heat, which makes *A. saligna* good at germinating after fire. *A. saligna* seed banks also benefit from indigenous ants which collect fallen seed and protect them from rat predation. The seeds are safe until they germinate in the next fire. However, rat predation is only a threat to seed dispersal in sparse stands of *A. saligna*. As stand density increases, enough *A. saligna* seeds are produced to sustain seed predators and enhance the seed bank at the same time (Cowling 1992). In densely invaded stands, *A. saligna* seed density ranges from 24,000 – 34,000 per square meter (Holmes 1992).

Because of its preference for permanently moist sites, *A. saligna* is commonly associated with riparian lands, lowlands, agricultural and transformed lands, and dunes (Cowling 1992). Riparian habitats are particularly sensitive to invasion. They provide easy access to moisture and periodic disturbances such as floods which disperse seed, prepare them for germination, provide a seed bed, and remove competing plants. The harvesting of trees adjacent to riparian zones is another source of disturbance to soil and vegetation. Plantation managers in South Africa avoid planting trees in riparian areas because they suspect trees growing in riparian zones use proportionally more water than those further away from the stream (Dye and Poulter 1995). Thus, with plenty of disturbance and little competition, *A. saligna* rapidly and heavily invades waterways (Cowling 1992). The densest *A. saligna* stands may contain up to 300 seedlings per square meter (Jeffrey et al. 1988). *A. saligna* is well-suited for riparian invasions because its seeds are primarily adapted for dispersal by water (Richardson et al. 1997).

Acacias are better at regenerating after a fire than are native fynbos species (Musil 1993). *A. saligna* has a large soil-stored seed bank with high levels of seed viability. It also has a short juvenile period, less than five years, which means the seed bank will be restored soon after a disturbance. *A. saligna* trees that survive fire may also resprout from epicormic buds near the soil surface (Holmes and Cowling 1997). Thus, after each fire, *A. saligna* density dramatically increases (Holmes and Cowling 1997). Native fynbos plants, on the other hand, have lowered post-fire regeneration in acacia invaded stands. Because of soil nutrient enrichment and shading by acacias, native species suffer from reduced inflorescence and seed production. Dense litter layers under acacias also prevent native seed contact with the soil. Some host-specific ant species may avoid shaded stands during nest establishment and thus not remove native seeds from the reach of seed predators (Musil 1993). With a smaller proportion of seeds in the seed bank, native species regenerate poorly after a fire in comparison to *A. saligna*.



*A. saligna*

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The extreme invasiveness of *A. saligna* in the lowland fynbos ecosystem poses several threats to the endemic plant community. *A. saligna* invasions cause a reduction in the species richness, reduction in native species cover, and drastic changes in community structure when acacia canopy cover exceeds 50%. After canopy closure, species richness decreases with time with the more sensitive species being eliminated first. In fact, 70% of the native flora is gone after two fire cycles. Fire cycles in the fynbos occur every 5-40 years, and after each fire the ecosystem takes a further step towards loss of diversity (Holmes and Cowling 1997, Richardson et al. 1989, van Wilgen and Richardson 1985).

Problems caused by the invasion by acacia are not only threatening the biology of southwestern South Africa, but also threatening human settlements. For example, dense *A. saligna* stands increase risks of fire hazard with their high biomass and decreased accessibility. In riparian areas, dense stands of *A. saligna* can alter catchment hydrology, reducing runoff and converting perennial streams to seasonal ones. This could have a detrimental effect on the water supply of any downstream communities including the Greater Cape Town Metropolitan Area (Richardson et al. 1997). The presence of *A. saligna* may also reduce the aesthetic and recreational quality of the fynbos. For example, the fynbos is known for its beautiful ericaceous flowers which attract tourists and nature photographers (Richardson 1998).

Because acacias are so widespread in the lowland fynbos, prospects of successful restorations seem too expensive and time-consuming to many people in the local communities. In urban areas, such as the Cape Peninsula, real estate values are high and the presence of invasives may justify rezoning of land, rather than promoting an expensive alien clearing program (Holmes and Cowling 1997). Public perception is that development is inevitable and that indigenous plants can be saved by translocation. Protected areas can serve as "life boats" for unprotected areas that will soon be developed (Milton et al. 1999). In the Western Cape region of South Africa, rapid urban expansion is destroying remnant habitat and is forcing managers to make rapid decisions

about translocating plants into protected areas (Milton et al. 1999). But outside urban areas, restoration of lowland fynbos is a viable option.

## **Techniques Used to Control the Species**

Several methods have been developed to control the spread of *Acacia saligna* and clear the invasive from the lowland fynbos ecosystem. Biological control, chemical control, mechanical clearing, and burning have all been used with varying results. Each method has been successful but nearly all require follow-up control. The most successful clearing projects have included an integrated approach to account for the initial clearing and continued management. The various methods used to clear *A. saligna*-invaded stands are described below.

### *Mechanical clearing*

The most common means for removing invasive acacias from the fynbos is by mechanical clearing. This is typically done by individuals pulling up *A. saligna* seedlings by the roots and by chopping down the larger trees. Mechanical clearing is the primary method of restoration used by the Working for Water project. This project was developed by the South African National Parks in 1998 to clear acacias from water catchment areas. Such mechanical clearing is time-consuming and expensive. Though in projects like this one, costs can be justified, with taxpayers and global environmental funds taking the burden of financing the project (Stephen 1998). The removal of dense thickets of invasives from riparian zones would increase streamflow, and in turn reduce risk of drought and improve water supply to downstream rural communities (Dye and Poulter 1995). Areas cleared of dense stands recover more slowly than lightly infested areas. Likewise, the older the stand, the slower the recovery. Yet, even where dense *A. saligna* stands existed for 15-40 years, unaided species richness recovery of the fynbos occurred after clearing (Richardson et al. 1989). Due to the thickness of its seed-coat, only 1% of *A. saligna* seed in the seed bank germinated after a stand clearing (Holmes 1988). Native fynbos plants may be better adapted to germinating in cleared sites because their thinner seed coats allow them to germinate more easily with low dry heat or multiple heat treatments from exposed soil surfaces (Jeffrey et al. 1988).

Several issues with the mechanical clearing of *A. saligna* must be addressed before it can be adopted as a viable method of control. If alien plants are cut and left at the site, the large amount of dead biomass may result in more intense fires killing indigenous plant seed banks (Holmes and Cowling 1997). *A. saligna* are also effective at vegetatively resprouting after being slashed. According to Stephens (1998), as many as seven stems can sprout from each stump. Furthermore, viable *A. saligna* seed can persist in soil for up to 50 years. Thus, for a clearing operation to be successful, it must incorporate a program of periodic follow-up control (Holmes 1989).

### *Fire*

Since fire is a natural component of the fynbos, it is an obvious choice for controlling alien vegetation. This technique, however, is problematic because fire plays a vital role in the natural regeneration of both *A. saligna* and native fynbos species. Fire is also the main disturbance factor

that creates an "invasion window" that allows alien invasives to establish in the fynbos (Pieterse and Boucher 1997). One fire can shift the balance from a lightly infested stand to one where *A. saligna* is the dominant species (Jeffrey et al. 1988). To use fire to kill *A. saligna* seeds, rather than just germinate them, the fire must be greater than 150 ° C for at least 2 minutes. A fire of less intensity or duration would most likely damage the seedcoat and allow imbibition and germination. A lethal fire, on the other hand, would damage the living tissues of the seed and prevent germination (Jeffrey et al. 1988). Unfortunately, lethal temperatures for native obligate reseeding species are much lower (Jeffrey et al. 1988). Thus, fire temperatures lethal to *A. saligna* seeds also destroy the native flora's seed bank.

The proximity of invaded stands to developed areas is another concern that needs to be addressed when considering fire as an agent of control. The use of fire in riparian zones is risky because of the adjoining forest plantations (Dye and Poulter 1995). Also, dense acacia thickets with their high biomass will cause intense fires that may scorch soil and make the site more susceptible to erosion (Holmes and Cowling 1997). Furthermore, the presence of charred *A. saligna* remains may hamper the control of seedlings especially if the original stand was quite dense (Pieterse and Boucher 1997).

#### *Chemical control*

Chemical control has not been a major means of restoring *A. saligna*-invaded sites for three reasons. First, sprays are generally not used because of the threat they would pose to the rest of the fynbos vegetation. Pesticide applicators that spray new seedlings may also accidentally spray chemicals on nearby native vegetation. Secondly, *A. saligna* tends to grow in riparian zones where herbicides might easily enter the water supply. Poison from sprays may be directly absorbed into the soil or indirectly absorbed through dying vegetation. In either case, chemical toxins in riparian soils threaten the quality of the water table. The use of chemical control is most accepted on dry sites away from the water table and on sites where native vegetation is minimal or absent (Stephen 1998). A third reason for the lack of chemical control is that pesticide applicators must be registered. This excludes most contract workers employed in the manual clearing of acacias from using chemical control (Stephen 1998). If herbicide is deemed an appropriate method of control, Richardson (1989) mentioned the possibility of using the non-selective herbicide "Gramoxone"/paraquat on *A. saligna*. Most chemical control of *A. saligna* is implemented after a stand has been cleared manually or by fire. Typically, poison is applied to stumps after manual clearing and seedlings are sprayed after clearing or burning of stands (Pieterse and Boucher 1997).

#### *Biological control*

Biological control, on the other hand, is widely accepted and is showing positive results. Leaf-eating insects and stem-boring insects have both been considered as biocontrol agents for *A. saligna* but rejected because though they may be mostly host-specific, different species of acacias are so similar that it is foreseeable that an insect strain would spread to economically important acacias (Klein 2000). The biocontrol agent currently used for attacking and killing *A. saligna* is a host-specific fungus, *Uromycladium tepperianum*. *U. tepperianum* is a gall-forming fungus which attacks healthy tissue, reduces plant vigor, and eventually kills it. Like most

biocontrol agents, *U. tepperianum* is slow to establish and spread initially. Within five years, it does create obvious stand dieback (Holmes and Cowling 1997). To inoculate *A. saligna* with the fungus, young growth tips of branches are treated with a suspension of fungal spores. The branches are then covered with a foil-lined plastic bag for 24 hours. Six to eight weeks after inoculation bright red galls are visible on the branches. Once the fungus has become established in an area, it is preferable not to use any other control measures. The fungus will gradually thin out the stands of existing trees, infect all new *A. saligna* seedlings, and allow the natural regeneration of indigenous vegetation. Even where stand dieback is great, a few gall-infested trees should be kept alive so that they can infect any new *A. saligna* recruits that may appear (Klein 2000). Where gall-bearing trees have survived fires, the fungal spores have infected acacia seedling recruits (Holmes and Cowling 1997). Since its inception, *U. tepperianum* has been extending its geographical range. At several sites monitored in the Western Cape Province, the density of living trees was reduced by up to 80 % by the fungus over a six year period between 1991 and 1996 (ARC-PPRI 1997). Despite the positive returns for the use of *U. tepperianum*, Richardson (1997) argues that biological control against *A. saligna* cannot be used because in some places *A. saligna* is grown commercially for tannin, timber, firewood or fodder. It may be more economically sensible to use a host-specific biological control agent, such as seed eating beetles, that targets the non-commercial attributes of acacias. Commercial orchards can use a chemical agent to protect its crop from seed-eating beetles and ensure the production of healthy seeds. No such biological control for *A. saligna* has been developed yet (Richardson et al. 1997).

### *Combined techniques*

Both clearing and burning techniques can be effective at restoring the fynbos but exhibit limitations when used separately. Several reserve managers have designed a control method that successfully combines the two. Since *A. saligna* germinates more effectively after a fire, its seed bank is depleted by burning the stand to germinate seed, and then by clearing out the *A. saligna* seedlings (Holmes 1989). To implement this method, mature *A. saligna* trees are first clear-cut to reduce biomass in the area. The seeds in the seed bank are then allowed to germinate. Next, fire is introduced to kill the seedlings and germinate more seed. When the next crop of seedlings emerges, another fire is used to kill the seedlings and so on. This method is extremely expensive compared to using a biocontrol agent and accounts for 17% of the total budget for the conservation of the Western Cape (Richardson et al. 1997). The repetitive use of fire may deplete the seed bank of native seeds along with *A. saligna* seeds. A more economically viable variation of this control method involves local harvesters. Using a method described as "integrated control", firewood harvesters come in and harvest out the larger *A. saligna* trees and branches. Fire, which will now be low-intensity, is then used to remove the nitrogen rich litter and twigs. Soil exposure, plus heat and smoke of fire may inspire germination of the remaining native seeds. The biocontrol agent *U. tepperianum* is then used for follow-up control of *A. saligna* (Holmes and Cowling 1997).

### **Author's Comments and Critique**

The most important thing to remember in the restoration of an *A. saligna*-invaded system is that the restoration problem is not only the seed bank, but also the soil nutrient changes and the

above-ground structure of *A. saligna* invaded habitats. Together, these three habitat modifications allow *A. saligna* to outcompete native flora. Secondly, fynbos communities are resilient. Stands that have been invaded for 25 years still have a viable seed bank of native seed. This existing seed bank is of utmost importance to the successful restoration of the lowland fynbos (Holmes and Cowling 1997).

The best solutions to the *A. saligna* invasion problem take into account these three levels at which *A. saligna* outcompetes the native flora. These solutions also seem to use a combination of the different control techniques described above. The most effective combination of control agents will differ between sites. For example, dryer sites may allow for chemical control and urban sites may be limited to non-burning techniques. However, Holmes' (1997) description of integrated control against *A. saligna* provided the most effective use of each control technique against each level of *A. saligna* impact on the fynbos ecosystem. The integrated approach begins with a manual clearing of *A. saligna* and a removal of the biomass from the site. This biomass can be harvested out which would save money on the most expensive aspect of the restoration. The next step is to burn the site. Burning after the biomass is removed ensures a low intensity fire. This fire will burn through that impenetrable litter layer laid down by *A. saligna* and it will also help to volatilize some of the mineral enrichment that *A. saligna* added to the soil. The elimination of the changes to soil nutrient availability and structure will reduce *A. saligna*'s competitive advantage over the native species. Low intensity fires will maximize the number of native seeds that germinate and minimize the number of seeds being killed by lethal fire temperatures. Both native seeds and *A. saligna* seeds will germinate after the fire. The germination of *A. saligna* seeds represents a depletion in the *A. saligna* seed bank, however plenty of dormant seeds will still exist in the soil.

Follow-up control is essential to a successful restoration project dealing with *A. saligna*. Newly germinated *A. saligna* seedlings can be treated as soon as possible with the fungus *U. tepperianum*. Because the fungus takes up to five years to take hold in an *A. saligna* stand, and the juvenile period of *A. saligna* is less than five years it seems risky to depend on the fungus to kill *A. saligna* seedlings before they reach maturity and contribute to the seed bank. Perhaps, before clearing, a select group of acacias can be inoculated with *U. tepperianum*. These trees would not be cleared out and would not die in the low intensity fire. Thus, when the new crop of *A. saligna* seedlings emerge after fire, they will be readily inoculated from spores from the infected trees. As the fungus grows and spreads over the next couple of years it will attack and kill *A. saligna*. *A. saligna* stand die back will allow sunlight to once again reach the native fynbos flora. Within a few years of *A. saligna* removal, the excess nutrients in the soil will leach out and the soil will return to its low nutrient state. And finally, with few seedlings reaching maturity, *A. saligna*'s seed bank will slowly diminish.

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