LUDWIGIA PERUVIANA - DESCRIPTION AND BIOLOGY

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Summary. *Ludwigia peruviana* is an aggressive species introduced from the Americas and invading coastal south-eastern Australia. Its biology and ecology were studied in a series of shallow urban lakes known as the Botany Wetlands and also in glasshouse experiments. The plant produces a profusion of flowers and seeds in summer. Seed production and viability is high; vegetative reproduction from fragments is efficient and the plants thrive in a range of water regimes. Shade, salinity and burying under >2 cm of soil inhibit germination of fresh seed. As the seed ages its germination is less affected by these factors.

INTRODUCTION

The aquatic species *Ludwigia peruviana* (family Onagraceae) has colonised a large part of the Botany Wetlands, an area covering about 45 ha and 11 ponds near Botany Bay, Sydney. The Wetlands drain a densely populated part of Sydney's Eastern Suburbs and the sediments and water are nutrient-enriched. It was first recorded naturalised here in 1970 and recognised as having the potential to become a weed in 1971. The species was cultivated at the Royal Botanic Gardens in 1907. Since 1907 it has been collected from Heathcote (about 40 km south of Sydney), and Gosford (about 80 km north of Sydney). Numerous sightings have been made within 30 km of Sydney.

L. peruviana is a cold-deciduous perennial shrub growing to about 4 m tall, with attractive yellow flowers and hairy lanceolate, mostly alternate, leaves (8,9). Stems are woody, but break easily. The root system is poorly developed and new season's growth is often from fallen stems. The species is native to Central and South America, and considered post-European in the southern United States. It is now naturalised in Asia, Indonesia, India, North America and Australia.

L. peruviana has seldom been reported as a weedy species. In 1977 it was recorded from Malesia without comment and 10 years later (5,6) it was twice recorded as a minor weed in Indonesia. In Florida, USA, both *L. peruviana* and *L. octovalvis* are regarded as invaders of disturbed wet habitats (10); however it is not as aggressive and dominant in central Florida as it is in Sydney, Australia. *L. peruviana* is a declared noxious plant in the Municipality of Botany, Sydney.

Concern over the weed potential of *L. peruviana* has increased in recent years by its behaviour in the Botany Wetlands and the comparatively recent spread of the species from this locality. In areas where it has been established longest, unispecific stands have been formed, native waterplants have been crowded out and bird populations diminished.

Several aspects of the biology of germination and establishment of *L. peruviana* were investigated to aid formulation and implementation of management strategies.

METHODS

Three transects were set up within 2 ponds. The transects were at rightangles to the shore and ran through dense unispecific *L. peruviana* stands. Transects T1 and T2 located in pond 1, were 24 and 20 m long respectively. Transect T3 was 20 m long and in permanent water, whereas in T1 and T2 *L. peruviana* was growing in saturated sand located in an intermittently flooded area. These transects were used as the basis for all sampling, including obtaining seed and soil for seed bank studies, and to determine biomass, standing seed bank, flowering and fruiting phenology, and seed production. Methods as previously described are detailed in (1).

Glasshouse experiments were conducted at the Royal Botanic Gardens Sydney and by the Science Club at St George Girls' High School. Experiments at St George Girls' High School investigated the germination responses of *L. peruviana* to different levels of shading, temperature, salinity, emergence from different depths of soil, and seed longevity. The methods used are documented in (1,4).

Experiments at the Royal Botanic Gardens concentrated on an estimate of the soil seed bank, vegetative growth from different-sized stem fragments, the effect of variable water levels on new shoot growth, buoyancy of seeds, the effect of water turbulence on germination and buoyancy, and theoretical viability using tetrazolium dye. Methods are detailed in (1).

RESULTS AND DISCUSSION

The standing crop consisted of dense erect stems with many side branches. Biomass estimates of above-ground dry weight were about 1500 g/m^2. Stems contributed 83% of the total above ground biomass, and leaves most of the remaining 17%. Regrowth on cleared quadrats was about 74 g/m^2 /week. The number of seeds remaining over winter in old fruits on these stems averaged about 300 000/m^2. The stands were unispecific, dense and, during peak growing season, intercepted 93% of incident light measured at midday. Under the dry conditions of the 1990/91 growing season, most flowering occurred in autumn, Though some flowers were present most of the time, flowers lasted only a day and some petals had often fallen by late afternoon.

Germination and establishment. The minute seeds are hydrophobic, they germinate while afloat and remain afloat indefinitely in still water. However in turbulent water the seeds sink. They can germinate underwater but the seedlings eventually float to the surface. The floating seeds/seedlings allow *L. peruviana* to form floating islands and also line the shores of water bodies.

Under laboratory conditions 80% of seeds germinated. Viability of seeds collected was assessed at 99% using tetrazolium dye. The differences between the germination and tetrazolium dye tests could be explained by at least two possibilities: (i) the difference reflects the problem in attempting to accurately estimate viability using tetrazolium dye (2), or (ii) the difference represents a store of dormant seeds entering the seed bank. The second option is being tested in a series of continuing experiments and early results indicate that this is the most likely explanation. Dormant seeds in the seed bank will greatly affect management options.

Optimum light levels were between 60-75% of incident light with fresh seed, but the effect of shading became less obvious as the seed aged in storage. With old seed only, the highest level of shading inhibited germination.

Increasing salinity decreased germination in fresh seed but in stored seed this result was also ameliorated, and levels of about 0.2 M NaCl were needed to depress germination.

Viability has increased with storage though no figures yet approach the positive tests with tetrazolium dye. There is some indication that dormant seeds may be starting to germinate but not all dormancy appears to be broken after one year. Potential longevity is another factor critical to the management options and studies on this will be continuing.

Seed bank trials are still producing seedlings two years after beginning seed bank studies, though the germination rate is dropping. So far the results are consistent with the germination test percentages and the tetrazolium percentages if the difference is due to hard seeds or dormancy. If this is the case then only low germination would be predicted for the next wetting cycle.

There is some discrepancy between results from germination trials and seed bank studies. In wet soil it is obvious that germination is more extended than under experimental conditions. The continued emergence over several months of seeds in the seedbank trials presumably represents the gradual break down of dormancy of the hard-seed component of the seed bank. The maintained emergence of seedlings at a much slower rate after two wetting and drying cycles can, so far, also be explained by this. The seedbank trials are continuing and the results of these, and the result of longevity in storage, will be critical for the long-term management options.

Soil depth experiments show that very few seeds emerge from a soil cover of >10 mm. Washing out the seeds showed that most non-emerged seeds had germinated and died before reaching the surface. The 1-2% emerging from 20 mm of soil still represents a potential 650 seedlings/m^2.

There was no significant effect of temperature on germination. While there seemed to be a non-significant trend for lower temperatures to depress germination in fresh seed, this disappeared when stored seed was tested. This contradicts field observations where germination is virtually non-existent over winter but the absolute minimum temperatures may be more significant than the mean figures used for the analyses

Vegetative fragments. *L. peruviana* can establish from stem fragments. There is a relationship between shoot frequency of vegetative growth and stem fragment diameter and length. The larger fragments (both diameter and length), always had a higher percentage of shoots. This could reflect the food reserves available to the growing shoots.

Water depths of 10-20 cm had little detrimental effects on the establishment of new plants from new shoots in summer. The strongest of the new shoots were able to survive flooding and grow to become emergent shoots. The percentage of shoots able to reach the water surface was inversely proportional to the water depth. Food reserves in the plant may also have an effect on survival. For flooding to be effective in the control of *L. peruviana,* it may be necessary to submerge the plants by more than 1 m. Nothing is known about the effects of flooding during winter. Cutting underwater in autumn is a technique used to control *Typha* spp. (7) and warrants investigation.

Population maintenance. *L. peruviana* uses both seeds and vegetative growth to maintain its population. The soil seed bank is about 65 000/m^2. The growing season production for 1990/91 was estimated at about 450 000/m^2. Seeds had an average germination of about 80%, with an estimated viability of 99%.

The seed bank is relatively high when compared with seed bank figures for other wetlands (3), and is of the same order of magnitude as that obtained for *Juncus articulatus* in Australia (Brock unpublished data). The numbers fall short of the highest numbers recorded for dryland weed populations of up to 1 000 000/m^2 for *Amaranthus* spp. but are of the same order of magnitude.

Seedlings were only observed under the canopy where there had been some disturbance to the canopy. Seedlings were seen growing on mud away from shade.

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