Impact of foliar herbicides on germination and viability of Siam weed (*Chromolaena odorata*) seeds located on plants at the time of application

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Summary
A field study was undertaken to determine the effects of foliar spraying on germination and viability of *Chromolaena odorata* (L.) King and Robinson (Siam weed) seeds at three different stages of maturity. Viability of Siam weed seeds was not significantly affected by herbicide application, irrespective of the stage of seed maturity. However, some inhibition of germination occurred. The application of herbicide reduced germination of intermediate seed by 65% compared with the unsprayed control. These results suggest that effective control will be more likely if plants are sprayed and killed prior to flowering.

Introduction
Chromolaena odorata (L). King and Robinson (Siam weed), a native of the rainforests of central and southern America, currently threatens the 'Wet Tropics' bioregion of northern Queensland, Australia. It was first discovered in 1994 at Bingil Bay (Waterhouse 1994), with additional infestations subsequently found along several kilometres of the banks of the Tully River and a small tributary, Echo Creek (Csurhes and Edwards 1998). The seeds of Siam weed are believed to have originally been imported into Queensland as a contaminant of pasture seed used on a grazing property in the 1960s and 1970s (Csurhes and Edwards 1998, Scott *et al.* 1998).

Siam weed is a branched, perennial shrub capable of forming dense, tangled thickets 2–3 m tall in open land and up to 20 m as a scrambling climber on trees. Several stems develop from the crown and new stems are produced following fire, drought or slashing (Csurhes and Edwards 1998). White to pale-lilac flowers appear from December to July in the tropics (Parsons and Cuthbertson 1992), with a single plant capable of producing as many as 87 000 seeds per year (Kushwaha *et al.* 1981). Each seed has a pappus of fine white hairs to aid dispersal by wind (Ismail *et al.* 1996). However, wind does not appear to be a major factor in dispersal, with many seedlings emerging in close proximity to mature plants (A. Lindsay, personal communication, July 1998).

In its native habitat, Siam weed is seldom a problem. It is a successional plant that rapidly establishes and thrives in tropical rainforest clearings and river flats, before gradually disappearing as the rainforest canopy closes (McFadyen 1991). Consequently, this opportunistic species is generally confined to forest edges and clearings.

In its non-native habitat, Siam weed is primarily a weed of disturbed areas such as agricultural land, road sides and wastelands (Ambika and Jayachandra 1989). Once it has formed dense thickets, recruitment of native species is suppressed, thereby delaying successional processes. Dense infestations of Siam weed can also increase the intensity and frequency of fire, leading to further changes in the structure and composition of native plant communities (Csurhes and Edwards 1998).

In Australia, Siam weed is believed to be restricted to a small area near Tully in north Queensland, where it is the target of an eradication program (Csurhes and Edwards 1998).

The primary method of control being implemented is the foliar application of the herbicide triclopyr/picloram (Grazon DS®). However, in some cases, foliar application is not appropriate, due to the growth habit of Siam weed and the situations it grows in. Plants that are not suited to foliar herbicide application are basal-bark treated using triclopyr (Garlon 600®) mixed in diesel.

Plants are often treated when mature and flowering, as at this stage they are most visible amongst the diverse flora of the Wet Tropics (O. Zeimer, personal communication, August 1998).

For some weeds, foliar herbicides are known to have adverse effects on the viability of seeds located on the plant at the time of application (Fawcett and Slife 1978, Bebawi *et al.* 1999). This is desirable, particularly if it is the first time plants have produced seed, as it will reduce the amount of viable seeds contributing to the soil seedbank.

This paper reports a field study initiated to quantify the impact of foliar herbicide application on the germination and viability of Siam weed seeds located on the plant at the time of herbicide application.

Materials and methods
A 2 × 3 × 2 factorial experiment replicated three times in a split-split-plot design was established in September 1998 at Tully River Station (17°56'37"S, 145°43'48"E) approximately 20 km west of Tully in north Queensland. Foliar herbicide treatment was allocated to main plots (herbicide and control (no herbicide)), seed maturity stage (Stage 1, 2 or 3) allocated to sub plots and timing of measurements (before and after spraying) allocated to sub-sub plots.

A total of six free-standing mature Siam weed plants spaced at least 3 m apart were selected. Three plants were randomly allocated as controls and the other three allocated to be sprayed. On each of these plants, inflorescences were split into one of three categories based on their apparent stage of maturity (similar to what was done by Mogali *et al.* 1989 for Siam weed in India). Stage 1 seed heads appeared immature – with the flower buds mostly closed, sepals were green, the visible outer part of the petals white, and the achenes were very light coloured. Stage 2 seed heads were of apparent intermediate maturity – the flower buds were mostly open, sepals were green, the petals were lilac, and achenes were light-mid brown. Stage 3 seeds were classified as mature – the petals and sepals were light to mid brown in colour, with most petals having fallen off, and the achenes were very dark brown or black.

For each maturity stage, sufficient inflorescences were tagged to enable at least 1000 seeds to be removed both immediately before treatment application and again three weeks after. From these seed lots, three sub-samples of 100 seeds were randomly selected and placed on moist Whatman™ No. 4 filter papers in 90 mm petri dishes. The petri dishes were placed in growth cabinets under alternating lighting (12 h dark/12 light) and alternating temperature (day and night temperatures of 35 and 23°C, respectively) regimes and moistened daily with distilled water.

Spray equipment and herbicide application
On 2 October 1998, a diaphragm pump was used to spray the foliage and stems to the point where the spray mixture dripped from the foliage. The handgun was fitted with a No. 10 cone nozzle and the operating pressure adjusted to 1380 kPa. The herbicide used was triclopyr/picloram applied at a concentration of 1.00/0.33 g a.i. L^{-1}. The herbicide solution contained a 0.02% (v/v) oil-plant extract

surfactant (Spraytech, an 80% canola oil concentrate).

Germination and viability measurements
Germinated seeds were counted and removed from petri dishes daily for 15 days. Seeds were considered germinated if the emergent radicle extended at least 2 mm beyond the seed coat. Cumulative germination percentages were expressed as a percentage of total seed numbers. Seeds that did not germinate within 15 days were checked for viability using a cut test method developed by seed technology staff at the Walkamin Research Station (J. Hopkinson, personal communication, September, 1998). The test involved dissection of the seed and visual inspection of the embryo. Well-developed, turgid embryos with a white sheen were considered viable. Seed viability was expressed as a percentage of total seed numbers, with viable seeds defined as those that germinated within 15 days plus any ungerminated seeds identified as viable following embryo inspection.

Statistical analysis
For both germination and viability, statistical analysis using analysis of variance was performed on arcsine transformed data that was later back-transformed. Fisher's protected LSD test was used to identify differences between treatments.

Table 1. Germination (%) of Siam weed seeds at three stages of maturity collected one week before and three weeks after application of triclopyr/picloram to mature plants. Values followed by the same letter are not significantly different (P<0.05).

Chemical treatment	Timing of measurements	Maturity stage 1	2	3
Control	Before	0d	0d	35b
Sprayed	Before	0d	0d	39b
Control	After	1d	43b	57a
Sprayed	After	0d	12c	53a

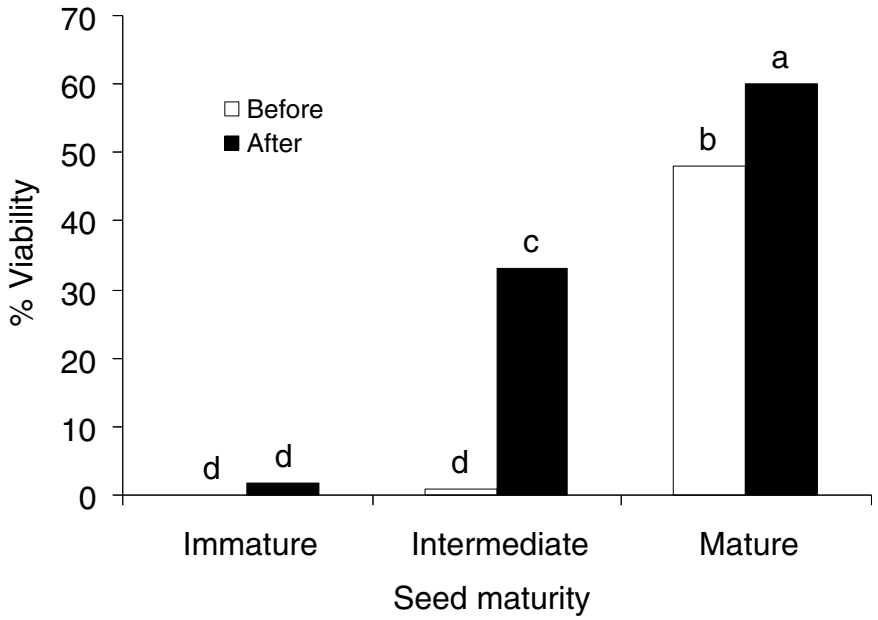

Figure 1. Viability of immature, intermediate and mature Siam weed seeds before and after treatment with triclopyr/picloram.

Results

Seed germination
For seed germination, a significant herbicide × seed maturity stage × time interaction occurred (Table 1). Minimal germination (<1%) of immature Siam weed seeds was recorded, irrespective of treatments applied or the timing of measurements. Germination increased progressively with maturity levels, peaking at an average of 55% for the mature seed stage.

The timing of measurements had a significant effect for intermediate and mature seed lots, with those collected after treatment always recording the highest germination. The application of herbicide exhibited a significant effect on the intermediate seed only, where it caused a 65% reduction when compared with the unsprayed control.

Seed viability
Unlike seed germination, seed viability was not significantly (P>0.05) affected by herbicide application, irrespective of the stage of seed maturity. There was, however, a significant interaction between maturity stages and measurement times (Figure 1). Less than 1% of the immature seeds were viable at either measurement time. Viability of intermediate seeds was similarly low before treatment, but by the second measurement had increased to 34%. Mature seed exhibited by far the highest viability (>48%), particularly the post-treatment samples.

Discussion

Foliar application of triclopyr/picloram to Siam weed did not directly affect the viability of seeds located on plants at the time of spraying. In fact, both the germination and viability of seed samples collected from inflorescences classified as 'intermediate' and 'mature' increased between the pre- and post- treatment sampling periods. There was, however, some prevention of germination in intermediate seeds following spraying, the reason for which was not determined.

'Immature' seeds exhibited minimal germination and viability at both sampling times, irrespective of whether they were sprayed or untreated. It is suspected that the short duration between sampling times (three weeks) did not allow sufficient time to determine whether the treated seeds had been deleteriously affected by chemicals, or whether they would eventually develop into viable seeds. A further study on immature seeds over a longer timeframe is required to investigate this result.

Applications of foliar herbicides early in the reproductive phase, such as at flower bud formation or full bloom stages, have been shown to reduce seed production and germination of Siam weed. Mummigatti *et al.* (1995) applied several chemicals (2,4-D, paraquat and glyphosaste) to Siam weed plants in India. They found that whilst seed production was only reduced at the flower bud formation stage, all herbicides significantly reduced seed germination at both stages. Flower bud formation was the most susceptible stage and paraquat was the most effective chemical.

The current study suggests that some viable seed will fall from plants and add to the soil seedbank, despite the foliar application of triclopyr/picloram. Therefore, if eradication of Siam weed is to be achieved, follow up treatments will be required to kill subsequent seedlings before they have a chance to become reproductive and replenish the soil seedbank. This will require considerable diligence as Siam weed can reach reproductive maturity within seven

months of seedling emergence (Sajise *et al*. 1974). How long the seedbank will take to be totally depleted in the absence of any further replenishment has not yet been determined. Etejere (1980) reported that some Siam weed seeds remained viable for at least two years under laboratory conditions. Similarly, one of the authors found a considerable percentage of Siam weed seeds to be germinable after 12 months under Queensland field conditions (M.J. Setter, unpublished data).

In the current study, foliar herbicide applications did not directly affect seed viability. However, Etejere (1980) found that the application of herbicides decreased the life of the seedbank. For example, germination of control seeds kept at a temperature of 27.5°C had not reduced significantly after 13 months, averaging 68%. In contrast, only one of the 14 chemical treatments averaged greater than 2% germination after 13 months. Whilst triclopyr/picloram was not one of the products tested, Etejere (1980) concluded that application of herbicides to mature flowering plants in environments that experience high temperatures may help diminish the longevity of the soil seedbank.

Further studies are needed to determine whether application of triclopyr/picloram can produce a similar reduction of seed longevity. Nevertheless, while it is difficult to achieve, chemical control before plants have a chance to flower and set seed appears to be the only way to prevent the need for prolonged follow up control.

Acknowledgments

The authors would like to thank Owen Zeimer for selecting a suitable experimental site and for the implementation of treatments. Thanks also to John Hopkinson for his invaluable assistance and advice in the development of seed-testing techniques. The technical assistance of Stephen Setter, Joanne Collins and Peter Jeffrey is gratefully acknowledged. Thanks also to Joe Vitelli, Peter van Haaren and Dr Joe Scanlan for their constructive comments on the manuscript.

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