Controlling *Leucaena leucocephala* with encapsulated herbicides

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Summary Unmanaged Leucaena (*Leucaena leucocephala*) can form dense woody thickets which excludes other vegetation causing environmental damage. This trial investigated eight herbicide treatments, including six encapsulated herbicides in comparison with a basal bark treatment and a drill and fill liquid herbicide solution. The field trial was established and assessed prior to treatment and at 2, 6, 12, 18 and 24 months after treatment. Five herbicide treatments resulted in high mortality of leucaena after 24 months. This trial increases the options for effectively managing larger stemmed leucaena growing amongst other desirable vegetation including within riparian and road corridors. These options also offer some environmental and worker safety benefits.

Keywords Leucaena, encapsulated herbicides, stem implant, drill and fill.

INTRODUCTION

Leucaena leucocephala (Lam.) de Wit (leucaena) is a perennial multi-stemmed shrub or tree. It has been widely introduced for land rehabilitation and as fodder in the cattle industry, intended to be grown and managed in rows (Campbell *et al.* 2019). When not heavily grazed or managed, it can rapidly spread and dominate the ecosystem. Unfortunately, feral infestations of leucaena occur throughout eastern Queensland particularly along road and riparian corridors. The negative environmental impacts of unmanaged leucaena have also been recognised internationally (Sharma *et al.* 2022).

Control options for leucaena were summarised by Campbell *et al.* (2019). Triclopyr (240 g L^{-1}) + picloram (120 g L^{-1}) (e.g. Access®) mixed with diesel distillate applied by basal bark or thin line application is registered for the control of leucaena. These methods require the herbicide solution to be liberally applied to the outside of the trunks. Various foliar and cut stump treatments are effective (Campbell *et al*. 2019) but also have challenges with equipment, access to plants and high-volumes of herbicide required for the foliar treatments.

Application techniques that directly apply a small amount of herbicide into a drilled hole within the stem of the plant, may offer an alternative for controlling leucaena trees amongst desirable vegetation or where equipment access is limited (Campbell *et al.* 2019, McKenzie *et al.* 2010). Encapsulated herbicides are dry herbicide formulations placed in a 'pill-like' dissolvable capsule (Goulter *et al.* 2018). Recent studies have assessed the efficacy of 'encapsulated herbicides' (Goulter *et al.* 2018) as an effective option for controlling leucaena (Bradburn 2019, Johnstone and Galea 2023).

Six different actives of encapsulated herbicides (Di-Bak®) were purchased for the trial from BioHerbicides Australia Pty Ltd. The effectiveness of these six encapsulated herbicides (stem-implant method) in comparison to a benchmark liquid herbicide solution (drill and fill method) (Tordon® Regrowth Master), and a registered basal bark method (Access® and diesel) were investigated in this trial.

MATERIALS AND METHODS

The trial was located on a cattle property near Calcium approximately 45 km south of Townsville, Queensland (S19°40.33', 146°48.39'). The property has large areas of leucaena monoculture throughout.

The trial was a complete randomised block design containing four replicate blocks of eight herbicide treatments and one untreated control (Table 1) with plots of 15 plants. The blocks were in either road or riparian corridors throughout the property. Very limited grass cover was present within the trial plots, with the ground layer consisting of leaf litter, bare ground and leucaena seedlings. Plots were with and without an overstory of native trees.

Figure 1. Aerial view of the dense Leucaena growing either side of a property road.

Five hundred and forty leucaena plants with 1 to 3 stems were selected, marked with paint and tagged with an individual number. The stem circumference for each stem (ranged from 8 cm to 46 cm) was measured approximately 20 cm above the ground level, but below any major lateral branches.

The eight herbicide treatments were applied in late November and early December 2021. Six encapsulated herbicide treatments were applied using a stem implant method via an Injecta 400®. The InJecta is fitted with a magazine that holds 30 capsules with wooden plugs (dowels) (manually filled) and attaches to a battery-operated drill. The InJecta mechanism is designed to drill a guided hole into the stem, and then by pulling the drill back and pushing forward a dissolvable capsule containing a granular herbicide is implanted into the hole. The hole is simultaneously sealed with a dowel from the magazine. The InJecta magazines were repeatedly refilled with capsules and dowels throughout each application of different encapsulated herbicide treatment. Depending on plant circumferences, 137 to 143 capsules were used per treatment over 4 replicate blocks.

The drill and fill with liquid herbicide treatment was applied using a battery-operated drill (8 mm drill bit), to drill a downward-angled (8 mm x 40 mm) hole into the stem. The hole was immediately filled with 1 ml of Tordon® Regrowth Master at a rate of 1:4-part water dilution, via a N.J Phillips® metal tree injector fitted to a 5 L backpack. 141 ml of this solution was applied to 60 plants over 4 blocks.

The stem-implant method of encapsuled herbicide treatments and the drill and fill method of the liquid herbicide treatment were applied at a rate of one dose per 10 cm of stem circumference. This was rounded up so that circumferences under 10 cm received 1 dose and under 20 cm received 2 doses. The maximum circumference was 46 cm receiving 5 doses. All the drilled holes for both these methods were placed as close to ground level as practical. All treatment heights were recorded and the per plant treatment mean height ranged from 3.0 cm to 37.5 cm, with an average of 17.8 cm.

A basal bark treatment of 1-part Access® herbicide and 60-parts diesel was applied with a Swissmix® heavy duty 9 L compression sprayer to the entire circumference of the stem from ground level up to a pre-marked height of 30 cm. Several litres of diesel were used implementing this treatment. One plot per block was left as an untreated control.

Plant health assessments were done at the time of treatment application and at 2, 6, 12, 18 and 24 months after treatment (MAT). The following health scores were used to assess treatment efficacy with the addition of a stem wound for the final three assessments times to determine stem condition.

- (1) Dead, trunk rotting.
- (2) Trunk near dead at base, cut wood darker.
- (3) Main trunk damaged, cut wood lighter colour.
- (4) Base alive green sap, upper branches dead.
- (5) Branch dieback, trunks still alive.
- (6) 100% Leaf drop, and branch tip dieback.
- (7) 75-100% Leaf drop.
- (8) 50-75% Leaf drop.
- (9) Leaf yellowing, up to 50% leaf drop.
- (10) No effect.

Any re-growth present was recorded as abundant, frequent, common, rare or none. Where re-growth was present, damage attributed to herbicides was scored as, no effect, damaged, dying, or dead. The re-growth location was also recorded as above, below, or above and below the treatment height. Plant mortality was determined by a health score = 1. Mean mortality and health scores were analyzed in Genstat® v22 VSN International. Mortality data was arcsine transformed for normality, but untransformed means shown.

Table 1. Herbicides and results 24 MAT (mean n=4). (Numbers followed by same letter are not significantly different at P <0.05).

Herbicide and (treatment type)	Active ingredients and (ai mg per capsule* or product ai in g L^{-1}**)	Mean health score (24 MAT)	Mean % mortality (24 MAT)
Di-Bak AM (drill/capsules)	aminopyralid (37.5) + metsulfuron-methyl (30) *	1.00[d]	100.0[a]
Di-Bak C (drill/capsules)	clopyralid (60) *	1.02[d]	98.3[a]
Di-Bak G (drill/capsules)	glyphosate (261) *	2.53[c]	56.7[b]
Di-Bak I (drill/capsules)	imazapyr (265) *	4.22[b]	8.3[c]
Di-Bak M (drill/capsules)	metsulfuron-methyl (220) *	4.62[b]	1.7[c]
Di-Bak P (drill/capsules)	picloram (70) *	1.00[d]	100.0[a]
Access (basal bark)	triclopyr (240) + picloram (120) **	1.13[d]	96.7[a]
Tordon Regrowth Master (drill/liquid)	triclopyr (200) + picloram (100) + aminopyralid (25) **	1.00[d]	100.0[a]
Control		10.00[a]	0.0[c]
LSD Statistic		0.665	14.25

RESULTS

The final, 24-month assessment is shown in Table 1 and the mortality from 6 to 24 months is shown in Figure 2. After 6 months the highest mortality (92%) was in the basal barked plants rising to 96.7% at 24 months.

Mortality from capsules containing 37.5 mg of aminopyralid and 30 mg of metsulfuron-methyl (Di-Bak AM) was 100% after 12 months. This treatment was effective and the second fastest acting after the basal bark treatment. The results for the liquid drill and fill solution were similar, reaching 100% mortality 18 months after treatment.

The capsules containing 70 mg of picloram (Di-Bak P) also controlled 96.7% and 100% of leucaena trees after 18 and 24 months respectively. Whilst also effective, the picloram capsules were slower acting. Capsules containing 60 mg clopyralid (Di-Bak C) controlled 92% and 98% of trees after 18 and 24 months. Whilst also slow acting, this treatment was similarly effective. At 24 MAT there were no significant differences in the mean health scores and mean mortality between the basal bark, drill and fill, and capsules containing metsulfuron + aminopyralid, picloram and clopyralid (Table 1).

Fifty-seven percent of plants treated with capsules containing 261 mg of glyphosate died, this rate was unchanged between 18 and 24 months (Figure 2). The surviving plants are reflected in the mean health score which was significantly higher than the effective treatments.

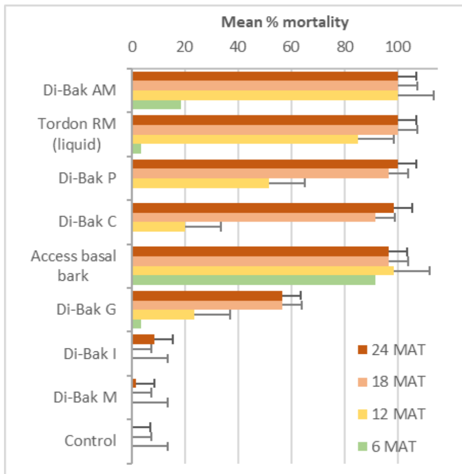

Figure 2. Mean percentage mortality at 6 to 24 months after treatment (MAT). Plot means n=4, pooled SE per assessment time shown.

At 24 MAT, mortality was concentrated in plants that received one capsule every 5 to 6 cm of circumference, regardless of the diameter. Mortality was much less consistent across plants that received a capsule every 6 to 11 cm of circumference (3 plants received capsules above 1 per 10 cm of circumference).

Whilst the health of plants treated with 220 mg of metsulfuron-methyl and 265 mg of imazapyr capsules was herbicide affected; final mortality was below 10%. After 24 months these were not considered effective treatments. Both treatments were defoliated but commonly had herbicide affected regrowth, so health scores were below the control but significantly above the other herbicide treatments (Table 1). Whilst metsulfuron-methyl and imazapyr capsules may prove fatal over a longer time frame, three other capsule treatments were effective within a shorter time frame.

DISCUSSION

This trial demonstrated the efficacy of herbicides applied using two drill applied herbicide methods (stem-implant and drill and fill) and a basal bark method to control leucaena with stems up to 46 cm circumference. Capsules containing picloram, clopyralid, and metsulfuron + aminopyralid were as effective as the alternative reference treatments.

Between 16 and 32 weeks Bradburn (2019) noted less plant necrosis in leucaena treated with glyphosate capsules (245 mg ai per capsule) and more regrowth than other encapsulated treatments tested. After 57 weeks, Johnstone and Galea (2023) also recorded 86.7% mortality for capsules containing 261 ai mg of glyphosate. Neither of the other studies provided stem size data. From the current study, glyphosate capsules would provide more consistent control at a greater application rate (1 capsule per 5 cm of circumference). This would only be warranted if more effective treatments (at 1 capsule per 10 cm) were unavailable.

The current study found the clopyralid capsules to be effective at controlling leucaena. This was at a lower active rate than Bradburn (2019) who recorded >91% control after 32 weeks from capsules containing 337.5 mg of clopyralid.

Capsules containing 70 mg of picloram were effective in this trial with 96.7% mortality 18 MAT, while Johnstone and Galea (2023) controlled 81.4% of leucaena after 57 weeks (14.8 MAT) with the same concentration of picloram. This indicates the importance of allowing enough time for the full effect of the small amounts of implanted herbicides to be evident when determining efficacy and whilst leaves may drop quickly, the stems may take 1 to 2 years to be controlled.

Similar efficacy of aminopyralid + metsulfuron-methyl capsules on leucaena was recorded by Bradburn (2019) who used 58.1 mg aminopyralid + 37.5 mg metsulfuron-methyl per capsule, and Johnstone and Galea (2023) using the same capsule concentrations as in this trial. Given the low mortality from the capsules treated with of 220 mg of metsulfuron-methyl (Table 1), the aminopyralid within the Di-Bak AM product seems more likely to be responsible for the efficacy across three trials than metsulfuron-methyl.

An aminopyralid based herbicide is recommended for the ‘hack and squirt’ control of leucaena in Hawaii (Leary *et al.* 2012). There may be other drill and fill solutions that warrant additional research. Bradburn (2019) tested capsules containing 120 mg triclopyr + 40 mg picloram on leucaena and noted some re-growth but >91% mortality 32 weeks after treatment. This combination, or capsules with triclopyr were not available in a suitable form for this trial. However, these combinations can be tested as drill and fill solutions and may provide more options for treating individual leucaena plants. Herbicides containing picloram and/or aminopyralid were among the effective treatments discussed by Campbell *et al.* (2019).

There are potential environmental benefits for both drill applied methods trialled (dry capsule herbicides and liquid herbicide) which apply a small amount of herbicide directly into the plant stem, compared to the basal bark treatment that liberally applies diesel and herbicide to the outside of the plants and the adjacent soil. Both drill applied methods are also suited to treating unwanted leucaena amongst desirable plants, as was done in this trial, with no off-target damage noted.

Plants in this trial were treated after rainfall, so plant health and foliage effects could be documented. However, all the treatments tested can be applied at any time of the year. Both drill applied methods also have the benefit of being more portable than the litres of high-volume foliar spray or basal bark solutions required to treat leucaena. Operators spend less time refilling the liquid containers than the capsule magazine, however, there is more human contact with the liquid herbicides than the capsules and a greater potential for spillage. There is no direct contact with the herbicides when handling the capsules.

The drill applied treatments of (both capsules and liquid) were applied to stems from 8 cm circumference. The treatment of dense or extensive infestations with many smaller stems may warrant broader scale treatments including mulching (e.g. Campbell *et al.* (2019). Once larger plants are removed, recruitment from a persistent leucaena seed bank (Campbell *et al*. 2019) will require follow-up control, such as using a high-volume foliar herbicide application.

This trial increases the options for effectively managing woody leucaena trees amongst other desirable vegetation, particularly along river and road corridors.

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