CONTROLLING FIVE INVASIVE WOODY WEED SPECIES USING THE DRILL AND FILL STEM INJECTION METHOD

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SUMMARY

A series of field trials were conducted on five invasive woody weeds to determine the efficacy of applying small doses of liquid herbicide directly into the sapwood layer of target plant stems using the application method known as 'drill and fill'. The five target weeds included four trees: leucaena (*Leucaena leucocephala* (Lam.) de Wit), pond apple *(Annona glabra* L.*),* neem *(Azadirachta indica* A. Jus,)*,* and African tulip *(Spathodea campanulata* P.Beauv,), and the vine rubber vine *(Cryptostegia grandiflora* R. Br.)*.* All five weeds can cause detrimental effects in native ecosystems and significant problems for land managers if unmanaged. Drill and fill is a portable, user-friendly application method that can be safely applied anytime of the year on target weeds growing within desirable vegetation and in environmentally sensitive areas. This paper highlights this technique as an effective management option using minimal volumes of herbicides to achieve high mortality rates.

Keywords: Leucaena (*Leucaena leucocephala)*, pond apple *(Annona glabra),* neem *(Azadirachta indica),* African tulip *(Spathodea campanulata)*, rubber vine *(Cryptostegia grandiflora),* stem injection, drill and fill, herbicide control.

INTRODUCTION

A small research team based at the Tropical Weeds Research Centre (TWRC) in Charters Towers investigated the effectiveness of the drill and fill herbicide application technique to control five invasive woody weeds. This is a stem injection method where drilled holes are filled with liquid herbicide. Of the five weeds treated with the drill and fill method, pond apple, African tulip trees and rubber vine are Restricted Matter under the Biosecurity Act (2014), neem and leucaena are not.

Leucaena is a fast-growing shrub or small tree that can reach heights of 10+ m tall. Originally grown for cattle fodder under guided regulations but when left unmanaged leucaena has the capacity to spread rapidly. Dense Infestations of feral leucaena, outcompete native plant species particularly along roadsides and river systems (Campbell *et al.* 2019, DAF 2024a).

Pond apple is a small tree that can grow up to 15 metres tall. It forms dense thickets in wet tropical and sub-tropical habitats. Pond apple has spread across wetlands and river systems in Far North Queensland where infestations disrupt the native vegetation including mangroves and impede water flow (DAF 2024b).

Neem was introduced into Australia for its insecticidal properties and as a shade tree. Neem is a rapid growing tree that can grow 15 - 20 metres tall with frugivore dispersed

seeds. Neem is widespread across North-West Queensland and is rapidly spreading along road and railway corridors, river systems and woodland pastures across northern Australia (DAF 2016).

African tulip is a fast-growing tall tree with bright red flowers that are known to be very toxic to the native stingless bees. African tulips were originally grown as park shade and street trees in many towns and cities throughout Queensland. In tropical areas of Queensland, African tulips are invading forest edges and forest wetlands rapidly out-competing native vegetation (DAF 2024c).

Rubber vine grows as a vigorous climbing vine that smothers other plants or as a free-standing shrub up to 3 metres tall and was introduced into Australia as an ornamental shrub. The woody perennial can be single or multi stemmed with numerous scrambling leaders and infests waterways, woodlands, and pastures throughout northern and eastern Queensland (DAF 2023).

The initial research for each of the target weeds commenced by studying the effectiveness of stem inserted encapsulated herbicides (e.g. Brazier *et al.* 2024). These are dry herbicide formulations enclosed within a 'pill-like' dissolvable capsule (Goulter *et al.* 2018) applied using a stem implant method via an Injecta 400® attached to a battery-operated drill. During the encapsulated studies limitations were noted while using the stem implant equipment including repeatedly manually refilling the capsules into the InJecta magazine while completing treatments.

Several of the initial encapsulated herbicide trials included a standard liquid herbicide treatment applied via the drill and fill application method. Given the efficacy of these liquid treatments (Brazier *et al.* 2024, O'Brien *et al.* 2022) later trials included an expanded range of liquid drill and fill herbicide treatments. These were mixed at rates from their respective herbicide labels for the control of other woody weed species using a stem injection application method. Some herbicide treatments were also mixed at concentrations similar to active ingredients within an encapsulated herbicide product. Trials also investigated the efficacy of various active herbicide ingredients recommended as control options for the five weeds but applied via a different type of herbicide application technique. This paper summarises only the drill and fill herbicide treatments that resulted in at least 98% plant mortality of the five weed species.

MATERIALS AND METHODS

Design and assessment

All trial sites were in field locations with a high density of one of the five weeds. All trials were a randomised complete block design, with untreated controls, although only a selection of drill and fill treatments are presented. All selected plants were tagged and the plant stem circumference for each were measured below any lateral branches for each single or multi-stemmed plant. Measurements provided the number of stems per plot, the sum of the plot basal areas and approximate number of doses required per drill and fill treatment. Plant health assessments were done prior to treatment application, and at scheduled post treatment intervals. Health and regrowth scores described by Brazier *et al*. (2024) were used to assess treatment efficacy and derive

mortality figures. A stem wound was also used to determine stem condition and plants were considered dead where no live tissue was present.

Treatment Application Equipment

A battery-operated Makita® 18v brushless hammer drill with an 8 mm diameter twist drill bit attached was used to drill all treatment holes. Holes were drilled at a downward angle, approximately 40 mm into the stem creating a small pocket. Drill holes were at 10 cm or 15 cm spacings placed around the stem circumference. Each hole was immediately filled with a liquid herbicide solution via either a Velpar® 4 ml spot gun applicator or a NJ Phillips® 5 ml Metal 'Tree Injector' fitted to a five-litre backpack reservoir. The total number of drill holes, treatment heights per plant, and the volume of solution applied per treatment were recorded. The treatment height from ground level, assessment schedules, application equipment, 1- or 2-ml dose and interval variation were consistent within each trial but differed between the trials and are noted below.

The leucaena trial site was described in Brazier et al. (2024) and was located on a cattle property south of Townsville, Queensland (19°40.33'S, 146°48.39'E). Four replicate blocks with 15 plants per plot included one drill and fill treatment applied to 60 leucaena plants with 1-2 stems. The stem circumference for each plant was measured at approximately 20 cm above the ground level and ranged from 6 cm to 46 cm with an average of 16 cm. Plant health was assessed prior to treatment and at 2, 6, 12, 18 and 24 months after treatment (MAT). In December 2021, a herbicide treatment of Tordon® Regrowth Master (Table 1) was applied into drilled holes at a rate of 1 ml of solution for every 10 cm of stem circumference. Circumferences under 10 cm received 1 dose and under 20 cm received 2 doses, up to a maximum of 5 doses. Treatments were applied at an average height of 26 cm and 137 ml of this solution was applied to 60 plants.

The pond apple trial site was in a swampy paddock out from the banks of the Russell River located near Babinda, Queensland (17°16.30'S, 145°57.20E). Three replicate blocks with 15 plants per plot, included one drill and fill treatment. Due to the spreading buttress type roots, each plant was measured above any major stem bulge (approximately 45 cm) above ground level. Stem circumference sizes ranged from 14 cm to 45 cm with an average of 25 cm. Plant health was assessed prior to treatment 2, 9, 14, 21 and 25 MAT. In August 2022, a 2 ml herbicide treatment of Weedmaster® Duo (Table 1) was applied immediately into each holed drilled every 10cm of stem circumference. Drilled holes were placed above any major stem bulge at an average treatment height of 38 cm. Forty-five single stemmed plants were treated with a total of 260 ml of the herbicide solution.

The neem trial site was established along 500 m of road corridor at Gumlu, Queensland (19°52.42'S, 147°41.13'E). Three herbicide drill and fill treatments were each applied to three replicate blocks with 15 plants per plot. The stem circumference for each stem was measured at approximately 20 cm above the ground level and ranged from 10 cm to 77 cm, with an average of 23 cm. Plant health was assessed prior to treatment and at 3, 6, 10 and 17 MAT. In June 2023 three 2 ml herbicide treatments (Table 1) were applied into holes which were drilled every once 15 cm of stem circumference, at an average treatment height of 3 cm. A total of 532 ml of herbicide solutions was applied

to the 135 drill and fill treated plants. An average of 177 ml of treatment solution was applied per treatment of 45 single stemmed plants.

The African tulip tree trial site was in the Tyto Wetlands, Ingham, Queensland (18°39.49'S, 146°08.17'E). A drill and fill treatment was applied to three replicate plots of 20 single stemmed plants. The stem circumference for each stem was measured at approximately 20 cm above the ground level and ranged from 8 cm to 41 cm with an average of 16 cm. Plant health was assessed prior to treatment and at 2, 6, 12 and 24 MAT. In May 2022, 1 ml of a herbicide solution of Tordon® Regrowth Master, (Table 1) was applied into holes drilled every 10 cm of stem circumference. All drilled holes were placed into the stem at an average treatment height of 16 cm and 175 ml of the herbicide solution was applied to 60 treated plants.

Table 1. Weeds, herbicide mix and application rates and final mortality (%).

Weed Species	Herbicide	Active Ingredient/s	Mix Rate (Chemical to Water)	Application Rate	Mortality %
Leucaena	Tordon® Regrowth Master	200 g/L triclopyr + 100 g/L picloram + 25 g/L aminopyralid	1 to 4	1 ml dose per 10 cm of stem circumference.	100 %
Pond Apple	Weedmaster® Duo	360 g/L glyphosate	1 to 2	2 ml dose per 10 cm of stem circumference.	100 %
Neem	Tordon® Regrowth Master	200 g/L triclopyr + 100 g/L picloram + 25 g/L aminopyralid	1 to 4	2 ml dose per 15 cm of stem circumference.	100 %
	Weedmaster® Duo	360 g/L glyphosate	1 to 1		100 %
	Tordon® 75 - D	75 g/L picloram + 300 g/L 2,4-D	1 to 1.5		99 %
African Tulip	Tordon® Regrowth Master	200 g/L triclopyr + 100 g/L picloram + 25 g/L aminopyralid	1 to 4	1 ml dose per 10 cm of stem circumference.	98 %
Rubber vine	Tordon® Regrowth Master	200 g/L triclopyr + 100 g/L picloram + 25 g/L aminopyralid	1 to 4	2 ml dose per 10 cm of stem circumference.	100 %
	Anon® 600WG	600 g/Kg metsulfuron-methyl	25 g to 1L		100 %
	AC Ray 675 WG	375 g/Kg aminopyralid + 300 g/Kg metsulfuron-methyl	50 g to 1L		100 %
	Komachi Activator®	80 g/L aminopyralid	1 to 3.5		100 %
	Dicamba® 500	500 g/L dicamba	1 to 12.5		100 %
	Tordon® 75 – D	75 g/L picloram + 300 g/L 2,4-D	1 to 1.5		100 %

The rubber vine trial site was located on a creek system within a cattle property near Charters Towers Queensland (19°57.59'S, 146°29.35'E). Six drill and fill treatments were each applied to three replicate blocks of 15 plants per plot in December 2023. The stem circumference for each plant was measured as close to ground level as practical and ranged from 10 cm to 34 cm in circumference, with an average of 17

cm. Plant health was assessed prior to treatment and at 2, 6, 9 MAT. Treatments compromised of six herbicide solutions (Table 1) with 2 ml of each solution applied into holes drilled every 10 cm of stem circumference. All drilled holes were placed as close to ground level into the stem as practical with an average treatment height of 3 cm. A total of 1151 ml of all herbicide solutions was applied to 270 treated plants, with an average of 191 ml of solution treating 45 single stemmed plants per treatment.

RESULTS

Plant mortalities for each species and treatment at the final assessment times for each trial are shown in Table 1. The first recorded leucaena plant mortality was at 6 MAT and reached 100 % mortality at 18 MAT. Pond apple mortality was first recorded 9 MAT, with 84 % at 14 MAT, 98 % at 21 MAT and 100 % mortality 25 MAT at the final assessment. All neem treatments recorded plant mortality by 6 MAT and reached 99 to 100 % mortality at the final assessment 25 MAT. African tulip mortality reached 75 % at 12 MAT and 98 % at 24 MAT at the final assessment. All six rubber vine treatments caused 100 % plant mortality at 6 MAT which was notably quicker compared to other species. No off-target damage was observed during these trials.

DISCUSSION

Drill and fill was found to be an efficient application method to effectively control five weeds species. The equipment used during the drill and fill applications was very user friendly, portable and carried all the required quantities of treatment solution per treatment, which saved valuable time during the herbicide treatments. The battery-operated drill is light to carry, easy to manoeuvre around weeds and has the capability to operate for hours, with the additional spare rechargeable batteries. The liquid herbicide solution is comfortably carried within a five-litre backpack reservoir and efficiently delivered in small, measured doses which optimises treatment times.

A small amount of herbicide solution is needed for drill and fill to achieve effective control of an individual plant. One operator with a 5 L mixture could treat 1,250 20 cm stem circumference plants at an application rate of 2 ml every 10 cm of stem circumference. Depending on the herbicide and packaging, the cost of a 2 ml dose ranged between 0.23 to 3.54 cents. Using the same application rate and plant dimensions as above, for 10 L Tordon® Regrowth Master mix rate 1:4 the 2 ml dose cost 2.44 cents, which equates to $4.88 to treat 100 plants.

The technique is a very economical herbicide application method and a safe option for operators, as there is no direct exposure to the herbicide and a low volume used. Another advantage includes its flexibility around application times. Drill and fill can be applied to actively growing plants within both dry and wet land locations any time of the year.

The application process delivers a small volume of high concentrated herbicide solution directly into a weed’s sapwood and cambial layers where it’s translocated throughout the plant. The active ingredients are inserted and retained inside the plant, minimising herbicide exposure to the surrounding environment. This makes it an

effective option to control weeds where precise application is required to avoid any damage to desirable plants.

There is a demand from land managers for an all-round herbicide treatment option to control infestations of multiple weed species, particularly in sensitive situations such as riparian zones. From the trials, products containing; triclopyr (200 gL^{-1}) + picloram (100 gL^{-1}) + aminopyralid (25 gL^{-1}) such as Tordon® Regrowth Master provided high plant mortality on all weed species it was subjected to via the drill and fill method. This resulted in a product and application method suitable for controlling multiple weed species such as rubber vine, leucaena and neem, which can co-occur and impact native ecosystems. This management option is allowed as stated under the APVMA Minor Use Permit 11463v7 for environmental weeds in Queensland.

The technique has shown to be useful for controlling singular to multi-stemmed medium to large woody weeds and vines that have a stem circumference of 6 cm or larger. However, there is room to further explore treating smaller stemmed plants. Drills have the option to swap out drill bit sizes. Using a smaller diameter bit will enable the herbicide solution to be applied within the sapwood of smaller stems. A smaller drill bit size will lower the dose applied as the hole size reduces.

The TWRC research team are continuing efficacy studies of a variety of herbicides applied via drill and fill to control pond apple, African tulip and rubber vine. This research aims to determine the best rates and most cost-effective treatments. Further research using drill and fill for the control of other woody weeds is being planned.

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