Encapsulated dry herbicides: A novel approach for control of trees

Ken C. Goulter[1], Victor J. Galea[2] and Peter Riikonen[1]
[1] Bioherbicides Australia Pty Ltd, The University of Queensland, Gatton Campus, Gatton, Queensland 4343, Australia
[2] School of Agriculture and Food Sciences, The University of Queensland, Gatton Campus, Gatton, Queensland 4343, Australia
(p.riikonen@bioherbicides.com.au)

Summary Bioherbicides Australia (BHA) is researching innovative and environmentally safe means of controlling tree weeds. Apart from our biocontrol product for parkinsonia (Di-Bak Parkinsonia™), the recent availability of dry formulations of several herbicides has provided an opportunity to apply them by insertion of a soluble capsule directly into tree stems. To facilitate delivery an easy-to-use applicator has been developed. The applicator is designed to drill a hole into the trunk, insert the herbicide capsule followed by a sealing plug. The sealing of the capsule ensures that moisture does not escape preventing oxidation of the immediate wound area and facilitating the dissolution of the capsule and herbicide allowing rapid distribution into the vascular stream.

Trials with a number of chemical formulations encapsulated in Size 0 hypromellose capsules have been conducted against WoNS such as prickly acacia and parkinsonia; other weed trees such as leucaena, calotrope, camphor laurel and privet, and plantation eucalypts such as *Eucalyptus saligna* Sm. and *E. dunnii* Maiden. Di-Bak G (glyphosate) capsules with ~350 mg (700 g kg^{-1} ai) have been shown to be highly efficacious against all species tested except for parkinsonia. Sampling of the point of insertion demonstrates that the capsule and chemical are quickly dissolved.

This application method will significantly reduce environmental and operator exposure to herbicides. It reduces waste as unused capsules can be stored for long periods and eliminates off-target placement. It is not subject to external environmental conditions and provides a targeted, readily calibrated herbicide application to the weed of interest.

Keywords Capsules, glyphosate, tree weeds, safety.

INTRODUCTION

Various strategies for herbicide-based control of undesirable trees exist. Foliar sprays where the herbicide is often dissolved in a water miscible solvent and then diluted into a water solution with the possible addition of adjuvants to aid solubility and adherence to and penetration of plant surfaces. The efficiency of spraying is affected by environmental factors such as wind, temperature and humidity. Basal bark application is performed at the base of target trees typically with a mixture of herbicide and diesel distillate to assist penetration through the bark. It is only recommended for plants less than 5 cm in diameter. For larger woody weeds, the cut stump method (Little and van der Berg 2006) is performed by felling the tree and painting or spraying the cut surface of the stump with a herbicide. Application of insufficient herbicide can allow reshooting or coppicing. Application of excess herbicide can lead to non-target damage or 'flashback' where neighbouring trees are also killed. It is thought that the herbicide travels between anastomosed roots of neighbouring trees (Ashton and Kelty 2017). This phenomenon is also seen with conventional stem injection methods where the herbicide is typically applied in either of two ways, 'frill and fill' (DiTomaso *et al*. 2013) or 'drill and fill' (McKenzie *et al*. 2010). With the former, an axe is used to cut into the stem to form a frill before the herbicide is applied to the cut. In drill and fill a hole is drilled that is then filled with herbicide. Other herbicides such as tebuthiuron can be applied as granules to the soil surface around target trees. This application requires sufficient rainfall to allow solubilisation and movement of the herbicide to tree roots, but excess rain can cause movement of the chemical away from the root zone.

Although suitable for weed control in many circumstances, the above described application methods are associated with various disadvantages. For example, the methods: may involve the handling of herbicides in toxic forms; maybe of limited effectiveness for certain weed types; maybe sensitive to environmental parameters; may involve imprecise or excessive herbicide application; once applied, may result in no control of subsequent distribution of the chemical in the environment; and/or may involve the use of relatively dangerous equipment.

Herbicides undergo constant reappraisal as to their safety to the human population and environment. Tebuthiuron which is currently applied on a broadacre basis in Australia has been banned in Europe due to

concerns that this stable molecule will contaminate ground water. The widely used glyphosate was controversially relicensed in Europe late last year over concerns that is a group 1B carcinogen (presumed to have carcinogenic potential in humans based on animal studies).

With all chemicals there are issues in the use in agriculture and the subsequent residues in food and their safety to the environment and to humans. The goal therefore should be to minimise exposure to alleviate those concerns. This can be achieved by reducing dosage or improving application methods. We will present one approach to achieving these goals using encapsulated glyphosate (Di-Bak G). Other formulations under evaluation include Di-Bak H (hexazinone), Di-Bak M (metsulfuron methyl), Di-Bak I (imazapyr), Di-Bak Teb (tebuthiuron) and Di-Bak TyP (triclopyr and picloram).

MATERIALS AND METHODS

General Glyphosate (~330 mg 700 g kg^{-1} ai, Glymac Dri 700, Macspred Pty Ltd) was prepared in pharmaceutical grade capsules (HPMC Size 0 Natural TR.V700 colour cap and body Vcaps, Suzhou Capsugel®Ltd, China). Capsules were hand packed using a Capsugel Profiller apparatus. The BHA MkIII applicator was used to drill a hole into the stem, insert the herbicide capsule and seal with a polypropylene plug. Generally, one capsule was inserted per 10 cm stem circumference. Tree health was assessed on a 0–4 scale, 0 being dead and 4 being healthy. Observations were made for evidence of 'flashback' in nearby untreated trees. At later assessment times, a small sample of trees were cut down and cross sections of stems containing the sites of insertion were removed. These stem pieces were returned to the laboratory and split open longitudinally through the insertion point.

Case 1. Control of prickly acacia (*Vachellia nilotica* (L.) P.J.H. Hurter & Mabb) with capsules of dry glyphosate (Di-Bak G) The trial was established at Bilaban Station, St Lawrence, Queensland (GPS 22°20.913′S, 149°30.203′E) on 5 December 2016. At application (T0) trees were assessed as being healthy with no dead branches and significant foliage. The trees were mature and flowered regularly. Stem diameters at 30 cm above ground level varied from 4–20 cm and trees were up to four metres tall. Application treatments consisted of applying 1, 2, 3 or 4 glyphosate capsules equidistant around the tree trunks at ~30 cm above ground level of around 10 trees each. The first thorough assessment was done 9 MAT (months after treatment) on 15 September 2017. Stem circumferences at 30 cm above ground level, number of applications per tree, and foliage cover and percentage branch death were recorded. Assessment of foliage cover was confounded by an earlier natural infestation of the introduced biological control agent, the leaf-feeding geometrid looper caterpillar, *Chiasmia assimilis* (Warren) that led to significant defoliation from which the trees were recovering. Weather data was collected at the nearby (<5 km) St Lawrence Post Office.

Case 2. Use of Di-Bak G in the thinning of plantation grown *Eucalyptus saligna* Sm. (Sydney blue gum) The trial was established on Brooklyn Station, Upper Tooloom, near Urbenville on 25 May 2017. GPS co-ordinates of the first treated plot were 28°32.486′S, 152°24.782′E. The trees were about 15 years old and are planted in rows 4 m apart at 1.5 m spacing. Trees were 6–10 m tall. Desirable trees were marked and the other trees were treated. The trial consisted of four replicates with 15 trees per replicate. The number of capsules applied to each tree was dependent on tree circumference which was measured at chest height. The tree circumferences range was from 18–57 cm. Tree health was assessed at four months (25 August 2017) and seven months (20 December 2017). Samples were collected for observation of dissolution of capsule and herbicide. Rainfall data for the closest recording station (Urbenville) was taken from the Bureau of Meteorology (BOM) internet site. No recent temperature data records were available for this site.

Case 3. Dose rate effect of Di-Bak G on *Eucalyptus dunnii* Maiden (Dunn's white gum) In this experiment one, two or three capsules of glyphosate were inserted into *Eucalyptus dunnii* trees irrespective of their circumference. This trial did not include replications. The trial was established in a block adjacent to the trees of Case 2 on 26 May 2017. GPS co-ordinates were 28°32.488′S, 152°24.778′E. The trees were arranged and similar in age and size to the *E. saligna* trees described in Case 2. Desirable trees were marked and the other trees were treated.

The trial consisted of one replicate of 15 trees for each treatment. The number of capsules applied to each tree was independent of tree circumference which was measured at chest height. Tree health was assessed at four months (25 August 2017) and seven months (20 December 2017). Untreated trees were observed for signs of flashback. At the four month assessment, samples were collected for observation of dissolution of capsule and herbicide.

RESULTS

Case 1. The plant health rating scale was formulated as a linear model based on foliage cover and percentage of living branches. Given the defoliation caused by *C. assimilis* confounded the analysis it was decided to compare all treated trees to the mean health rating of the control untreated trees giving a proportional result between 0 (dead) to 1 (as healthy as control trees).

A relationship exists between stem circumference, number of capsules applied, and tree mortality, that is, application of 1 capsule seems sufficient to kill trees with stems up to 30 cm in circumference (n = 5) (Table 1). The same is true for 2 capsules (n = 3) whereas for trees 40–60 cm circumference at least 3 capsules should be applied (n = 5). It is also evident that treating prickly acacia trees with Di-Bak G capsules at any dose caused some deterioration in plant health.

Case 2. The range of stem circumferences of treated trees ranged from a minimum of 12 cm to a maximum of 70 cm. On average, a capsule was inserted every 13–14 cm of stem circumference.

Stem pieces that were cut and split four months after treatment revealed that the capsules had dissolved in all treatments and no traces of glyphosate were observed. At four months there were indications of deterioration in tree health as expressed by leaf drop and bark splitting.

There was over 90% mortality at four months. By the seven month assessment there had been good rainfall but no indication of reshooting or flashback was observed. The failure of full strength glyphosate to kill all treated trees may have been due to loss of the sealing plugs. If the plug, for whatever reason, is displaced soon after application it is likely that moisture loss will prevent solubilisation of the capsule and herbicide. More recent modifications to the applicator in the new design of BHA Applicator MkIV has reduced the probability of sealing plugs being lost.

Case 3. Applying 3 capsules of glyphosate had killed all treated trees by four months. At four months ~90% of trees treated with 2 capsules were dead and by seven months all had been killed. However, on average, the trees treated with 2 capsules had the largest girth of the treatments (Table 2). This might explain the delayed response. Use of a single capsule resulted in ~70% mortality at four months which increased to ~80% by seven months. The observation that a better kill was achieved with *E. dunnii* compared to *E. saligna* might be explained by the former having a thicker bark and softer wood which allowed more complete insertion of the plug. There was no sign of flashback even with the highest dose rate.

Table 2. 'Chest Height' measurements of tree circumferences and mean distance between capsules.

Treatment Di-Bak G	Stem circumference (cm) Min – (Average) – Max	Distance between capsules (cm)
1 Capsule	20 – (38.67) – 58	38.7
2 Capsules	26 – (45.60) – 59	22.8
3 Capsules	16 – (34.80) – 75	11.6

Table 1. Relationship of capsule number applied and tree circumference on prickly acacia tree health at nine months after treatment.

Stem circumference (cm)	# of capsules applied					
	1	2	3	4	5	6
0–20	0.0A (n = 2)B					
21–30	0.0 (n = 3)	0.0 (n = 3)				
31–40	0.1 (n = 2)	0.17 (n = 2)	0.0 (n = 2)			
41–50	0.35 (n = 6)	0.21 (n = 3)	0.01 (n = 2)	0.016 (n = 5)	0.0 (n = 2)	
51–60	0.58 (n = 4)	0.18 (n = 3)	0.01 (n = 1)	0.0 (n = 2)	–	0.01 (n = 3)
>61		0.42 (n = 1)		0.06 (n = 2)	0.18 (n = 1)	

Mean plant health of treated trees as a proportion of healthy untreated trees. 0.0 – plants dead to 1.0 plants as healthy as untreated trees.
Number of plants assessed in each cohort.

DISCUSSION

We have demonstrated that insertion of encapsulated dry glyphosate can be a potent control method for unwanted trees. This method delivers a minimum recommended fatal dose of chemical directly in the trees vascular system thereby utilising 100% of the active agent's potential. In comparison to other commonly used manual methods such as cut stump and basal bark spraying, only 20–30% of the chemical quantity is required with Di-Bak G to achieve the same result. Application of minimal dosages will reduce occurrence of 'flashback'. Also, no axes, hatchets, backpacks and tank mixes of liquid herbicide, chainsaws or diesel distillates were required. There was no waste, no need to dispose of unused chemicals and easy storage of capsules are all additional benefits. Application of a single capsule could kill prickly acacia trees with stem circumference of up to 30 cm. On larger stems insertion of a capsule every 10–15 cm was effective. Care needed to be taken to ensure that insertion was done below major branches. Evaluation of Di-Bak G and other herbicides on prickly acacia is currently underway in western Queensland. Di-Bak G was seen to be highly effective against the eucalypt species tested, and may find application as tool in plantation thinning.

The insertion of encapsulated Di-Bak G is highly targeted and does not expose the operator or the environment to accidental exposure to the herbicide. It should be broadly applicable to all trees sensitive to glyphosate. We are also developing a range of other herbicide capsules that maybe suitable to treat trees which are tolerant to glyphosate.

Although not presented in this paper, preliminary results to date show that Di-Bak G is active against leucaena, calotrope, camphor laurel, privet and ficus. This methodology could be seen as a ready replacement for cut stump application in plantations, weed tree control in sensitive areas such as waterways and National parks and in areas that are inaccessible to other equipment such as hillsides.

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