The tolerance of *Acacia* species to herbicides

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Summary Herbicides are often required to reduce weed competition when establishing *Acacias* or are needed to kill them when they become environmental weeds. The work presented provides the dose response curves for herbicides on various species of *Acacia* seedlings. Flumetsulam, glufosinate, iodosulfuron, imazamox and metosulam were tolerated 160, 600, 32, 60 and 35.7 g a.i. ha^{-1} respectively or 3-10 times their normal use rates. Clopyralid and glyphosate were tolerated at the lower end of their normal use rates around 60 and 600 g a.i ha^{-1} respectively. .Clopyralid provided good control of *Acacia* seedlings at rates above 500 g a.i. ha^{-1} and control with glyphosate was variable with rates of 1300-5000 g a.i. ha^{-1} required for greater than 90% kill.

Keywords *Acacia*, clopyralid, dose response curve, herbicide tolerance, imazamox, iodosulfuron, flumetsulam, glufosinate, glyphosate, metosulam, wattle.

INTRODUCTION

Acacia species can be weeds, crops, hosts for sandalwood (*Santalum spicatum*) and endemic native plants. Over 13,000 ha of *Acacia acuminata*, has been established in southern Western Australia since 1990 as hosts for sandalwood production (Anon. 2008). Weeds occurring during the establishment phase can seriously reduce *Acacia* survival. Selective herbicides that control various weeds without affecting *Acacia* species are often required. Alternatively, the long-lived seed bank of weedy *Acacia* species can re-establish an infestation that has been cleared of mature plants and herbicides are required to control the annual crop of seedlings. Land managers need to know the rate of herbicide that will control them, or how much herbicide they will tolerate compared to other weeds they are trying to control.

No herbicides are specifically registered in Australia for selective broadcast spraying of *Acacia* seedlings and only four active ingredients or mixtures for controlling *Acacia* seedlings (Moore and Moore 2009). This paper reports the tolerance of seedling *Acacia* species to various herbicides and presents dose response curves for these herbicides.

MATERIALS AND METHODS

Two trials were conducted at Arthur River, WA (Lat. 33.06S, Long. 117.36E) in a Mediterranean environment with an annual rainfall of 450 mm. A ute-mounted logarithmic sprayer with flat fan, 11002 nozzles that delivers a constantly decreasing dose was used to apply the herbicides. The logarithmic sprayer was calibrated by measuring the change in common salt concentration over time. The volume of mix used for each treatment was measured as a check on calibration.

Tree height was determined by measuring the distance from ground level to the terminal point of the longest stem. Visual assessments were made by measuring the distance along the plot where there was a visually estimated 0, 10, 50, 90 and 100% reduction in green foliage compared to adjacent unsprayed seedlings. This distance was then converted to the rate of herbicide.

Trial 1 Herbicides were applied in 182 L ha^{-1} water at the rates shown in Table 1 over the top of the seedlings. The rates were chosen to approximate one half to ten times the normal use rates. There were four replicate applications per herbicide and each plot was at least 25 m long with one seedling planted at 0.5 m intervals. The centre 20 m of the plot was sprayed leaving controls at each end. The soil at this site was a sandy gravel.

Nursery raised Jam (*Acacia acuminata*) seedlings were planted on 27 August 2008 and herbicides were applied on 7 October 2008. Tycol™ spray oil was applied with the flumetsulam and metosulam treatments at a rate of 1 L per 100 L spray mix. Visual assessments and tree heights were recorded 70 days after treatment and again on 21 October 2009, 379 days after treatment.

Table 1. Herbicides and range of rates applied in Trial 1.

Active ingredient	**Product**	**Rate g a.i. ha^{-1}**
Clopyralid 300 g/L	Lontrel™	60-1200
Flumetsulam 800 g/kg	Broadstrike™	8-160
Glyphosate 540 g/L	Roundup PowerMAX™	135-2700
Metosulam 714 g/kg	Eclipse™	1.785-35.7

Trial 2 A mixture of *Acacia* seeds including the species in Table 5 and some *Hakea* and *Allocasuarina* species were sown at 400 g ha^{-1} on 10 July 2008 to produce a mixed species hedgerow with over 3000 stems ha^{-1}. *Acacia acuminata* seedlings were also transplanted into the lines at 5 m spacings on 1 August 2008 along with two pre-germinated sandalwood seeds (as per Woodall and Robinson 2002). The soil at this site was a sandy loam over clay at 0.5 m.

Two replicate applications were made of the herbicides in Table 2 using the logarithmic sprayer over the plot length of 40 m. They were applied over the top of the seedlings in 141 L ha^{-1} water on 7 October 2008.

Table 2. Herbicides and range of rates applied in Trial 2.

Active ingredient	**Product**	**Rates g a.i. ha^{-1}**
Glufosinate 200 g L^{-1}	Basta™	50-1000
Glyphosate 540 g L^{-1}	Roundup PowerMAX™	135-2700
Imazamox 700 g kg^{-1}	Raptor™	7-140
Iodosulfuron 50 g kg^{-1}	Hussar™	2.5-50

The mixed species lines were visually assessed on 18 December 2008 (72 days after treatment) and 10 February 2010 (491 days after treatment).

The results of both trials were analysed using the DRC (Dose Response Curve) package in the R statistical program (Ritz and Streibig 2005) using a 4 or 5 parameter logistical model.

RESULTS

Trial 1 Rates greater than 270 g a.i. ha^{-1} glyphosate or the lowest rate of clopyralid reduced growth 70 days after planting (Figure 1) and was reflected in the tree heights (Figure 2). Seventy days after application the height of control trees was 26.8 ± 0.54 cm, which was twice the height of trees treated with the lowest rate of clopyralid. On the clopyralid treatments there were no other symptoms at low rates, but stem and leaf distortions and deaths occurred at higher rates.

One year after treatment, trees were 83.4 ± 1.4 cm tall and considerable recovery and compensatory growth had been made by trees receiving glyphosate or the lower rates of clopyralid. Trees that received rates of glyphosate up to 810 g a.i. ha^{-1} or 60 g a.i. ha^{-1} clopyralid were a similar size to controls (Figure 3). Trees that had survived more than 540 g a.i. ha^{-1} clopyralid, 70 days after treatment, had usually died by 379 days after treatment.

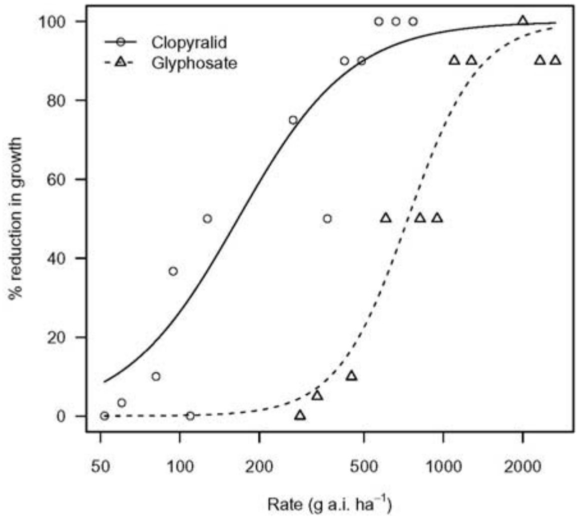

Figure 1. Visual rating of damage to *A. acuminata* caused by clopyralid or glyphosate 70 days after treatment.

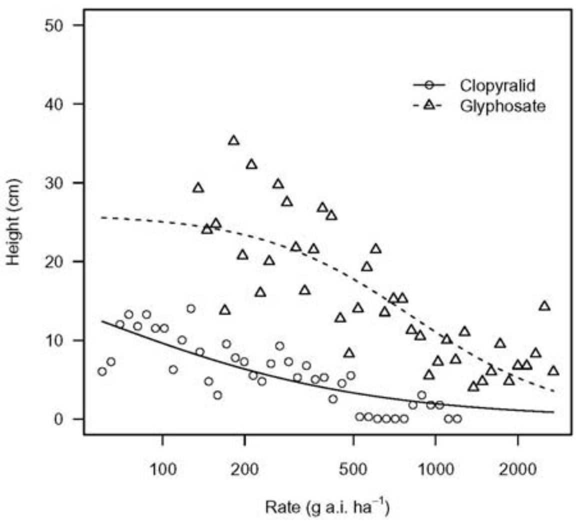

Figure 2. Heights of *A. acuminata* 70 days after application of clopyralid or glyphosate.

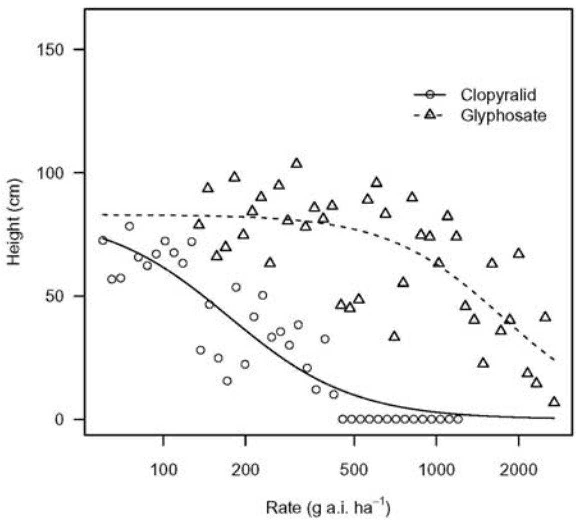

Figure 3. Heights of *A. acuminata* 379 days after application of clopyralid or glyphosate.

There was a logarithmic decrease (straight line on Figure 4) in tree height as the rate of flumetsulam or metosulam increased (P<0.05). The trend 70 days after treatment was similar to that 1 year later. Growth reductions of about 6% were predicted for flumetsulam and 3% for metosulam at label rates of 25 and 5 g ha^{-1} respectively. These responses were too low to be detected by visual inspection.

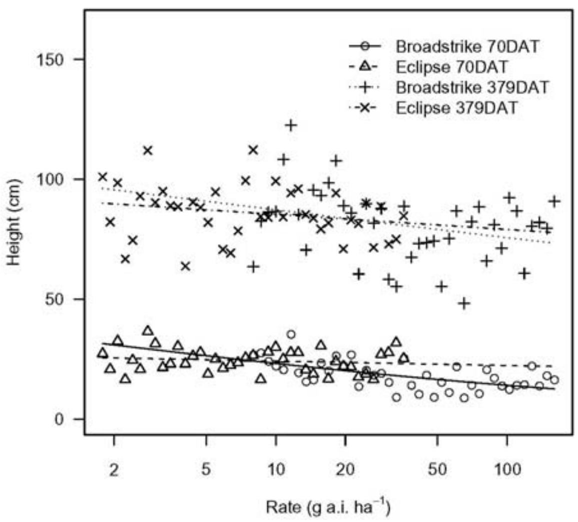

Figure 4. Heights of *A. acuminata* 70 days after treatment (DAT) and 379 DAT after application of flumetsulam or metosulam.

From the dose response curves the ED_{10} and ED_{90} (Effective Dose for 90% and 10% response) were calculated and are shown in Tables 3 and 4 for the various assessments.

Table 3. Calculated rates of herbicide giving 10% growth reduction, based on visual assessment or seedling heights at 70 and 379 days after treatment (DAT). (s.e. in brackets).

Herbicide g ai ha^{-1}	Visual rating 70 DAT	Tree height 70 DAT	Tree height 379 DAT
Flumetsulam	>160	38.4[1](1.8)	>160
Metosulam	>35.7	>35.7	>35.7
Clopyralid	55.8 (12.5)	4.2(3.1)	54.9 (12)
Glyphosate	371 (65.9)	198 (37)	597 (150)

[1] Estimated from linear regression.

Table 4. Calculated rates of herbicide giving 90% growth reduction based on visual assessment or seedling heights at 70 or 379 days after treatment (DAT). (s.e. in brackets).

Herbicide g a.i. ha^{-1}	Visual rating 70 DAT	Tree height 70 DAT	Tree height 379 DAT
Clopyralid	494 (144)	686 (235)	552 (108)
Glyphosate	1447 (312)	3399 (758)	5093 (1635)

Trial 2. The rates of herbicide tolerated by other species is listed in Table 5. *A. redolens* tolerated high rates of glyphosate and was almost the only species left surviving at the highest rates. The data in Table 5 cannot be used to estimate differences in species tolerances directly because a low rate score may simply be due to the absence of the species at the higher rates, rather than it being killed by the herbicide.

Glufosinate and iodosulfuron caused significant scorching at rates above 600 g a.i ha^{-1} and 30 g a.i. ha^{-1} respectively when assessed 72 days after treatment but most trees had recovered by 379 days after treatment. The range of rates tolerated by the various species in the replicates at 72, 379 and 491 days after treatment are shown in Table 5. The only *Acacia* death seen in the imazamox plots was *A. neurophylla* at 35 g a.i. ha^{-1}.and may have been due to other causes as other individuals survived higher rates. Some deaths were seen at 72 days after treatment with iodosulfuron, glyphosate and glufosinate at rates greater than 35 g a.i. ha^{-1}, 864 g a.i. ha^{-1} and 700 g a.i. ha^{-1} respectively.

Glyphosate provided greater than 90% control of *Acacia acuminata*, *A. pulchella* and *Santalum spicatum* (sandalwood) at 1728, 1296 and 2484 g a.i. ha^{-1} respectively. Glufosinate, iodosulfuron and imazamox didn't provide reliable control of the *Acacia* species present at five times normal use rates. Iodosulfuron and imazamox appeared to give control of *Acacia neurophylla* at high rates 72 days after treatment but they had recovered by the following season.

Table 5. Rates of herbicide (g a.i. ha^{-1}) tolerated by various species when assessed at 72, 379 and 491 DAT.

Species	Glufosinate	Iodosulfuron	Imazamox	Glyphosate
Acacia acuminata	1000	35-50	140	513-864
Acacia celastrifolia	1000	35-50	77-140	810
Acacia dictyoneura	800	NA	71	1485
Acacia extensa	1000	32	140	1620
Acacia lasiocalyx	860-1000	46-50	140	756-864
Acacia meisneri	600	NA	60	NA
Acacia microbotrya	760	32	112	NA
Acacia neurophylla	1000	40	50	878
Acacia pulchella	680-740	30-35	122-140	648-864
Acacia redolens	740-1000	35	70-133	1998-2268
Acacia saligna	740-800	40-50	130-140	594-1269
Acacia trigonophylla	1000	50	105-150	702-1728
Allocasuarina huegeliana	1000	50	140	864
Hakea corymbosa	NA	NA	NA	1728
Santalum spicatum	1000	50	140	1296

DISCUSSION

Acacia acuminata tolerated metosulam and flumetsulam at five times normal use rates and a range of *Acacia* species tolerated iodosulfuron and imazamox at several times normal use rates. Many broad-leaved weeds and grasses could be controlled by these four group B herbicides by broadcast spraying of young *Acacias.*

Whilst glufosinate caused significant scorching, especially at the higher rates, the recovery of the *Acacias* was very good and it could find application in controlling group B resistant weeds.

The ED_{10} at 379 DAT for clopyralid was around 60 g a.i. ha^{-1} even though these rates halved the height of trees 70 DAT. This rate is adequate for control of some young annual broad-leaved weeds but as the tolerance is marginal some damage could be expected in field operations. It will be useful in amenity or mixed species plantings where a reduction in growth can be tolerated.

Rates of glyphosate around 540 g a.i. ha^{-1} were tolerated by a range of *Acacia* species, but rates down to 200 g a.i ha^{-1} may give a reduction in growth for a few months after spraying, which may be unacceptable in commercial situations. The 540 g a.i. ha^{-1} rate will provide reasonable control of a wide range of annual weeds very economically. Overdosing should be avoided as 3 times these rates could halve tree heights a year after application.

Together with the grass selective herbicides most weeds can now be controlled with broadcast spraying of recently planted or young *Acacia* species, although the tolerance in some cases will be marginal and growers will need to balance the risk of herbicide injury against the potential damage from the weed infestation. The dose response curves presented provide some guidance as to the amount of damage incurred by *A. acuminata* as rates are adjusted to target various weeds.

The design of this trial also allows an assessment of the rates of herbicide required to control these species. Over ninety percent control of was predicted with 550 g a.i. ha^{-1} clopyralid and no seedlings survived on the plots at rates greater than 500 g a.i ha^{-1}. Control of *Acacia* seedlings with glyphosate was variable between sites and between replicates with rates of 1300-5000 g a.i. ha^{-1} required for greater than 90% kill.

Sandalwood and *Allocasuarina huegeliana* had similar tolerance to all the herbicides tested and *Hakea corymbosa* had similar tolerance to glyphosate as the *Acacias.*

These data provide some confidence for roadside spraying and in mixed species vegetation that low doses or drift of these herbicides are not going to cause severe damage to *Acacia* species.

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