Minimising the environmental impact of weed management in New Zealand's planted forests

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Summary

Weed control in planted forests underpins highly productive, uniform forests and is one of the most important silvicultural tools when establishing trees in New Zealand. Weed control is normally provided by herbicides.

Environmental certification schemes place an onus on the planted forest industry to reduce or stop using some pesticides in plantation forests. Between 2007 and 2015, the herbicides terbuthylazine and hexazinone were classified as highly hazardous for use in plantation forests certified by the Forest Stewardship Council (FSC).

The New Zealand planted forest industry can minimise effects on the environment and meet environmental certification criteria by optimising herbicide application methods and using alternative, more benign, herbicides.

Weed management research at Scion over the last six years has largely focussed on finding alternative, less hazardous herbicides, as well as also investigating any negative environmental impacts associate with herbicide use. Methods to reduce the impacts of forest management on natural resources have been investigated, including targeted application of herbicides, dose optimisation and non-chemical weed control methods.

The research has shown that the most effective herbicide treatment to manage weeds in planted forests is the current industry standard that uses a combination of terbuthylazine and hexazinone. Both of these were recently re-assessed by FSC and removed from the highly hazardous list. The work has also shown that risks to the soil and water receiving environments from these two herbicides are low. Terbuthylazine mixed with mesotrione was the most promising alternative tested for first year weed control. Using the active ingredient aminopyralid as a replacement for picloram during the second year of weed control also shows potential.

Controlling weeds in planted forests

New Zealand has some highly competitive introduced weeds, including broom, gorse, buddleia, blackberry, and many others. Managing these weeds during the establishment of plantation forests improves tree survival, growth, crop uniformity and productivity. Weed control in radiata pine forests generally involves applying herbicides twice or three times in the first three to five years of a rotation of 28 years.

Environmental certification

National and international demand for environmental certification and reducing the footprint of intensive land-use is putting pressure on planted forest management to reduce the overall dependence on pesticides.

Between 2007 and 2015, terbuthylazine and hexazinone were on the Forest Stewardship Council or FSC "highly hazardous" list and could only be used by certified forests subject to a derogation. The 2014 review of the FSC indicators and thresholds for placement of pesticides on the "highly hazardous" list saw both herbicides removed from the list.

Research

Scion, with forest growers and funding from MBIE and the Sustainable Farming Fund (12/038), has focussed on minimising the environmental impact of weed management in New Zealand's planted forests through research that:

- Investigated the potential of new herbicides;
- Evaluated the risk terbuthylazine and hexazinone pose to soil and water resources;
- Evaluated the potential of biocontrol, spot weed control and oversowing to reduce the input of herbicides into the environment.

Herbicide use in New Zealand planted forests. A survey of weed management practices in New Zealand planted forests[1] found that glyphosate, terbuthylazine and hexazinone are the most widely used active ingredients (Table 1). Together, these three herbicides comprise 90% of the estimated 447 tonnes of active ingredient used annually by the planted forest industry.

Active ingredient	Total annual input (kg)	Annual input (kg ha^{-1})	Application rate (kg ha^{-1})
Glyphosate	175.0 x 10^3	0.0972	3.5
Metsulfuron	5.8 x 10^3	0.0032	0.115
Terbuthylazine	179.3 x 10^3	0.0996	7.0
Hexazinone	44.8 x 10^3	0.0249	1.75
Clopyralid	37.5 x 10^3	0.0208	1.5
Triclopyr	3.8 x 10^3	0.0021	0.15
Picloram	1.3 x 10^3	0.0007	0.05
Total	447.4 x 10^3	0.2485	

Table 1. *Estimated annual input of herbicides for New Zealand's planted forest area (1.8 million ha)*[1].

A typical weed management program includes a pre-planting aerial application of glyphosate and metsulfuron. After planting, a treatment with the principal active ingredients of terbuthylazine and hexazinone is applied. A further treatment is sometimes applied two or three years after planting, depending on the level of weed completion.

Terbuthylazine and hexazinone are not phytotoxic to radiata pine, which makes them effective herbicides for weed control in New Zealand planted forests. These herbicides also persist for a period in the soil. This is especially useful for controlling scrub weeds and grasses.

The survey also found that pressure to reduce inputs of chemicals has resulted in a shift from aerial application of herbicides to wider use of spot weed control in the forest industry. This is possible where terrain and safety considerations make it an appropriate method of control.

Alternative active ingredients. Scion has tested a range of active ingredients to replace terbuthylazine and hexazinone, with particular focus on the first post-planting weed control operation carried out in spring[2,3,4]. The active ingredients tested, excluding terbuthylazine and hexazinone, are listed in Table 2 and recommendations for their use are summarised on pages 6-7.

Active ingredient	Product	Mode of action
Indaziflam*	'437'	Broad spectrum pre-emergent. Can be used in post-emergent applications in a mix.
Mesotrione	Callisto®	Systemic herbicide with foliar and root uptake. Pre- and post-emergent control of weeds.
Clopyralid	Versatill™	Absorbed by leaves and roots. Post emergence control of selected broadleaf weeds (legumes)
Triclopyr	Grazon™	Selective systemic herbicide absorbed by foliage and roots – affects broadleaved weeds only.
Aminopyralid	Tordon Max™	Systemic herbicide absorbed by leaves and roots. Synthetic auxin causing epinasty.
Clethodim	Sequence®	Selective systemic herbicide absorbed by foliage. Post emergence control of grasses.
Nicosulfuran	Guardian®	Selective systemic herbicide absorbed by foliage and roots.
Haloxyfop	Gallant™	Post-emergence control of annual and perennial grasses.

*Not registered for use in New Zealand

Table 2. *Active ingredients tested for first year weed control.*

A quick guide to the performance of alternative herbicide treatments

We recommend you contact Scion before implementing any alternative treatments.

- Recommended
- Alternative (growth loss possible)
- Potential (needs more testing)
- Not recommended

1 Broom and gorse and other perennial woody species.
2 Herbaceous broadleaves (HBL) including a wide spectrum of annual weeds.
3 Average tree size relative to the operational standard (%).
4 Tordon PastureBoss is not registered for aerial application in New Zealand.
5 Indaziflam is not registered for use in New Zealand.
6 Only tested on one site.
7 Picloram is on the FSC Highly Hazardous list.

Treatment group	Products (ha^{-1})
Operational standard	17.5 L Valzine Extra
Treatments that use terbuthylazine	15 L Gardoprim and 0.75 L Callisto
	15 L Gardoprim and 5 L Versatill
	15 L Gardoprim and 0.6 L Tordon PastureBoss[4]
	15 L Gardoprim and 1 L Tordon Max
	15 L Gardoprim and 0.188 L Grazon
Treatments that do not use terbuthylazine or hexazinone	3.8 L Versatill, 0.38 L Tordon and 2.5 L Gallant
	3.8 L Versatill and 1.0 L Callisto
	3.8 L Versatill and 1.0 L Tordon Max
	0.6 L ‘437’ and 1.0 L Callisto
	0.6 L ‘437’ and 0.6 L Tordon PastureBoss[4]
	0.6 L ‘437’ and 5 L Versatill
	0.6 L ‘437’ and 1 L Sequence
	0.6 L Tordon PastureBoss[4] and 1.0 L Callisto
Treatment that does not include picloram[7]	5 L Versatill and 0.75 L Tordon PastureBoss[4]

Active ingredients (ha^{-1})	Recommendations			Relative performance across sites (%)[3]
	Scrub[1]	HBL[2]	Grass	
First year treatments				
7500 g terbuthylazine and 1750 g hexazinone	[Dark green]	[Dark green]	[Dark green]	100
7500 g terbuthylazine and 360 g mesotrione	[Light green]	[Light green]	[Light green]	90
7500 g terbuthylazine and 1500 g clopyralid	[Light green]	[Light green]	[Light green]	80
7500 g terbuthylazine,120 g triclopyr and 18 g aminopyralid	[Blue]	[Orange]	[Orange]	75
7500 g terbuthylazine and 30 g aminopyralid	[Orange]	[Blue]	[Blue]	68
7500 g terbuthylazine and 113 g triclopyr	[Orange]	[Orange]	[Orange]	58
1125 g clopyralid, 113 g triclopyr and 250 g haloxyfop	[Light green]	[Orange]	[Orange]	70
1125 g clopyralid and 480 g mesotrione	[Orange]	[Orange]	[Orange]	69
1125 g clopyralid and 30 g aminopyralid	[Orange]	[Orange]	[Orange]	46
300 g indaziflam[5] and 480 g mesotrione	[Orange]	[Blue]	[Blue]	60
300 g indaziflam[5], 113 g triclopyr and 17 g aminopyralid	[Orange]	[Blue]	[Blue]	51
300 g indaziflam[5] and 1500 g clopyralid	[Orange]	[Orange]	[Orange]	35[6]
300 g indaziflam[5] and 240 g clethodim	[Orange]	[Orange]	[Blue]	84[6]
120 g triclopyr, 18 g aminopyralid and 480 g mesotrione	[Blue]	[Orange]	[Orange]	95[6]
Second year treatment				
1500 g clopyralid, 150 g triclopyr and 22.5 g aminopyralid	[Light green]	[Orange]	[Orange]	Not tested

The fate of herbicides in a planted forest environment

FSC-certified forest companies need to demonstrate that they are using pesticides in an environmentally acceptable manner. The potential for continued use of herbicides depends, in part, on whether they break down in forest soils or leach into waterways. There is a lack of information about the fate of herbicides used in New Zealand planted forests, which translates to uncertainty about the potential effects on the wider environment[1].

The fate of terbuthylazine and hexazinone in a Pumice soil has been evaluated [5,6,7]. Pumice soil makes up about a quarter of New Zealand's planted forest soils and is considered vulnerable to herbicide movement due to its low carbon content.

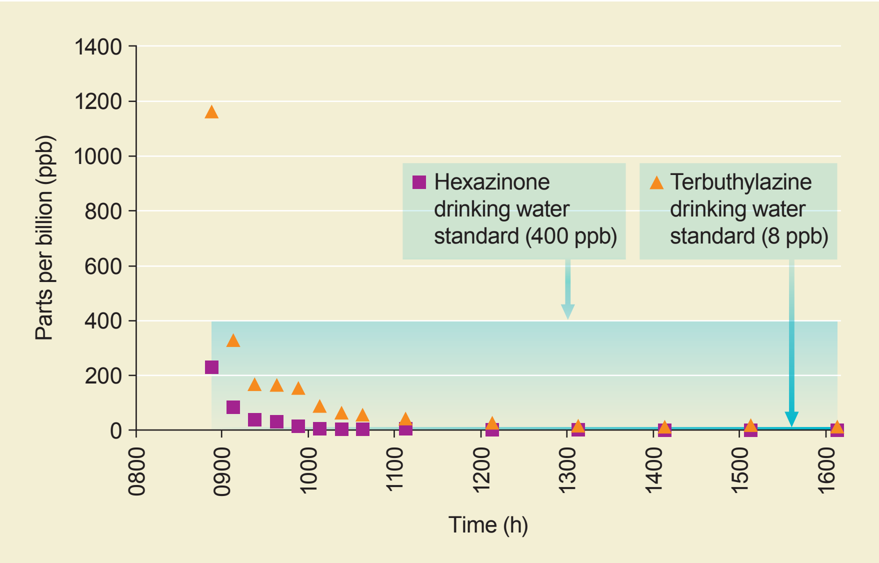

Figure 1. *Concentrations of terbuthylazine and hexazinone measured in a small stream immediately after herbicide application, then at hourly intervals*[6].

The risk of herbicides moving off-site from a Pumice soil to an aquatic environment was found to be highest on the day of aerial application or during rainfall events occurring shortly after application (Figure 1). Thereafter, herbicide concentrations in the stream were below New Zealand and World Health Organisation drinking water standards and rapidly diluted downstream as intersection with other downstream water bodies occurred. The first month after spray application was found to pose the greatest potential risk of movement off-site. Potential risks were low after this period as the amount of the herbicides on-site degraded rapidly (Figure 2).

Forest litter and harvest residues on site were found to be important to retaining terbuthylazine, and hexazinone to some extent, in the upper soil profile.

This work has played a key role in supporting the continued use of terbuthylazine and hexazinone on FSC-certified land under derogation and has possibly supported their removal from the list of prohibited herbicides.

A similar trial is underway on a Recent soil, which is also considered a vulnerable soil, with the aim to extend to other planted forest soils such as Brown soils.

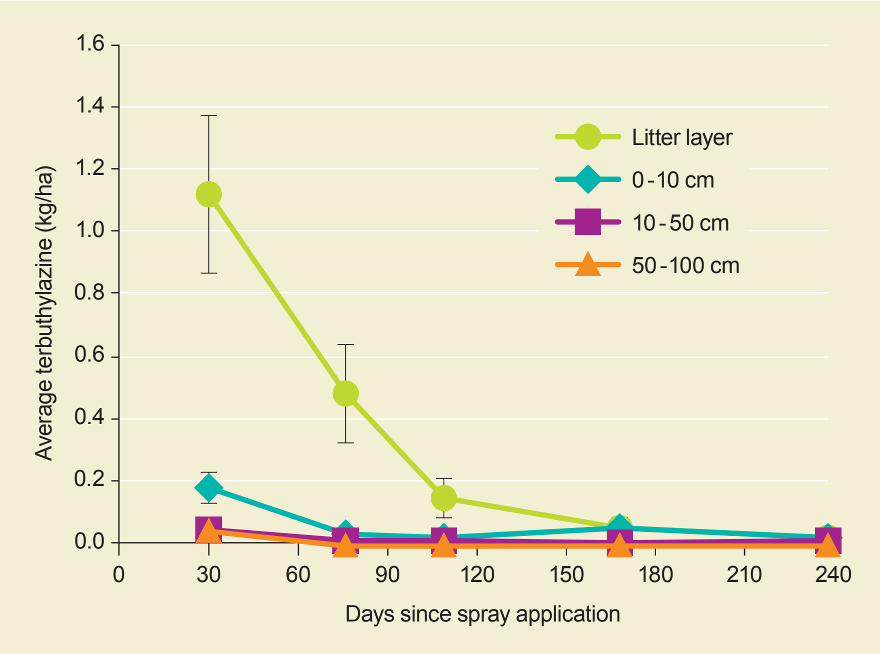

Figure 2. *Amount of terbuthylazine found in the soil profile following operational application in spring*[7].

Non-chemical weed control

Non-chemical weed control methods, such as mechanical and manual control, were widely used in planted forest weed management prior to 1970. Effective, low cost herbicides became available for large scale use during the 1970s and have been used almost exclusively for weed control since.

Other non-chemical weed control methods include the use of grazing, mulches, mycoherbicides and oversowing.

A 2011 review(8) estimated the costs of non-chemical control and the potential impacts on the financial rates of return on capital employed for forest companies (Table 3).

Although all of the non-chemical methods have potential in certain situations, they are expensive and often less effective than chemical control. Consequently, they are not widely used by the planted forest industry.

Method	Total cost to 'free to grow'	IRR*	Economic viability
Chemical	$ 740 ha^{-1}	6.2	0%
Spot control	$ 450 ha^{-1}	5.1	-17%
Manual	$2385 ha^{-1}	4.3	-31%
Mechanical	$3307 ha^{-1}	3.9	-37%
Weed mats	$3473 ha^{-1}	3.6	-42%

*Indicative change in internal rate of return for a medium yielding *P. radiata* site for forest companies using different weed control regimes.

Table 3. *Indicative cost (2011) of weed control regimes and their potential impact on financial rates of return*(8).

Gorse roller

Biological control: The case of *Buddliea davidii*

Biological control can be effective at controlling individual weed species. However, chemical control is also often needed to control other weeds on a site.

The use of biological control in planted forest weed management has not been widely explored in New Zealand forestry[9]. A particularly strong candidate for biological control is *Buddliea davidii*, a key weed species of the central North Island. A biocontrol agent for buddliea, *Cleopus japonicus*, or buddleia leaf weevil, was released in 2006.

The impact of *C. japonicus* on the growth of buddleia during the first three years of *P. radiata* establishment was determined in a pilot trial (unpublished data). While the weevil significantly reduced the growth of buddleia, the rate of the weevil's spread, and population growth, was not sufficient to reduce the requirement for chemical control. The study indicated that, with the wide spectrum of weeds that emerge on site, the removal of just one of the competitive weed species was not sufficient to reduce the requirement for chemicals. Other weeds were found to occupy the "ecological space" vacated by the weakened buddleia.

C. japonicus, *buddleia leaf weevil feeding on buddleia folige.*

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