Use of herbicidal gels on woody weeds

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ABSTRACT

This report covers the final group of a series of trials investigating the use of herbicidal gels to selectively control a range of environmental weeds growing in Department of Conservation (DOC) reserves in the North and South Islands of New Zealand and Stewart Island. These trials were set up in early 2000 and assessed at one and two years after treatment. We have investigated a range of application systems to control juvenile and mature trees of (1) Darwin's barberry (*Berberis darwinii*) in Stewart Island, (2) cotoneaster (*Cotoneaster simonsii*) in Southland, and (3) grey willow (*Salix cinerea)* in wetlands near Lake Taupo. Control methods included: (1) applying gel from a bottle on to cut stems; (2) cutting wedges in tree trunks with a pruning saw or axe and applying gel to the wedge; and (3) drilling holes at intervals around the trunk into which herbicide is injected. In a pilot-scale residue study, involving cut-stem and whole-tree treatments of glyphosate or picloram gel to grey willow growing in static water at the Whangamarino wetlands, traces of residues were detected around treated trees and saplings at two to nine weeks after treatment, but levels of residues decreased to nil by 24 weeks after treatment, except in one instance.

This information has been used to develop guidelines for DOC staff on how to use herbicidal gel technologies effectively in the field; these are given inthe appendix.

Keywords: woody weeds, herbicidal gels, selective control, Darwin's barberry, cotoneaster, grey willow

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1. Introduction

HortResearch was contracted by the Science and Research Division, Department of Conservation to continue to investigate the efficacy of herbicidal gels on environmental weeds in DOC reserves, using different methodologies at different growth stages of various plant species. The purpose of this contract was to provide guidelines to DOC on how to use herbicidal gel technologies effectively in the field on a range of environmental weeds.

In an earlier four-year contract, a range of herbicidal gel formulations was developed and applied to the cut stems of woody vines and shrubs. These trials demonstrated that gel techniques were effective for selectively killing old man's beard (*Clematis vitalba*), climbing spindleberry (*Celastrus orbiculatus*), Japanese honeysuckle (*Lonicera japonica*), heather (*Calluna vulgaris*), and grey willow saplings (*Salix cinerea)* (Ward & Henzell, unpubl. reports 1998, 1999).

As a result of these and associated trials, a picloram-based herbicidal gel (trade name Vigilant®) was registered with the New Zealand Pesticide Board in 2000 and is now commercially available for controlling environmental weeds. The use of Vigilant® on environmental weeds is still a novel concept and current knowledge on the best practices or limitations of this product is limited.

The trials summarised here were on Darwin's barberry (*Berberis darwinii*) shrubs and trees on Stewart Island and in Wellington, cotoneaster (*Cotoneaster simonsii*) saplings in Southland, and grey willow at Lake Taupo (Ward & Henzell, unpubl. reports 2000, 2001). From these trials and experience from the earlier trials on old man's beard, climbing spindleberry and Japanese honeysuckle, some provisional guidelines on the effective use of herbicidal gels on woody weeds are proposed (see Appendix 1).

Throughout this project our aim was to develop targeted methods that gave very effective weed control with a single treatment, avoided collateral effects on neighbouring plants, and reduced the risk of herbicide residues entering soil or leaching into waterways. In general we assessed treatment effects at one and two years after treatment application. During these post-treatment visits, observations were made on any collateral damage on plants growing close to treated weeds.

2. Methods

2.1 CUT-STEM TREATMENTS ON SAPLINGS

2.1.1 Darwin's barberry

This trial was set up in late February 2000 on Stewart Island and involved shrubs with single and multiple stems up to 2 m tall. A randomised block design was

used involving single plant plots. At least ten plants were treated with each herbicide formulation. On average there were 5 stems per plant that varied between 15 and 80 mm basal diameter with a 27.7 mm mean diameter. All stems on each shrub were cut and treated at 100–300 mm above ground level with a pair of loppers or a hand saw. Prunings were left on the ground.

A range of herbicidal gel formulations was tested along with an untreated cut-stem treatment as a control. The gels contained 0.25% metsulfuron, 1% metsulfuron (active ingredient in Escort), 5% picloram potassium salt (Vigilant®) or a mixture of 2.5% picloram potassium salt and 0.05% metsulfuron. The gels were applied liberally over the cut stems. On average 3 g of gel per stem or 15 g gel per sapling was applied within five minutes of making the cut. At the time of application the weather was fine but cool (about 14°C) with relatively high humidity. No rain fell for at least four days after application.

2.1.2 Cotoneaster

The trial was set up on an exposed rolling hill country farm near Mossburn in Southland. A randomised block design was used involving three blocks (under pine trees, along a roadside and in a gully), nine treatments and single plant plots. In general, small and medium multi-stemmed saplings were under the pines, small single stem plants were on the exposed roadside block, and medium and large trees were in the gully block. Ten separate plants were treated with each herbicide formulation within each block. All main stems were treated and within each treatment the plants varied in height between 0.5 and 2 m with main stems between 5 and 40 mm diameter. Treated plants under the pine trees and in the gully blocks had between 2 and 16, and 2 and 24 main stems respectively. Herbicidal gels were applied with a brush bottle and contained either 2.5% picloram salt, 5% picloram salt (Vigilant®), 0.25% metsulfuron, 1.0% metsulfuron, 10% glyphosate or a mixture of 0.05% metsulfuron and 2.5% picloram salt. An untreated cut stem control treatment was also included in the trial.

As DOC staff at the time was using aqueous solutions containing 0.18% metsulfuron (0.3% Escort) or 24% triclopyr (ex Grazon EC) to control cotoneaster, both these treatments were also included in the trial. The herbicidal solutions were applied with a small paintbrush. On average 4.8 g gel or 2.4 g solution was applied per plant. All of the prunings were allowed to remain on the ground where they fell.

2.1.3 Grey willow

This trial was set up along the southern shore of Lake Taupo near Turangi. The site was open wetland that is dry underfoot in summer but prone to flooding in winter. A randomised block design was used involving six groups of eight clumps. The clumps consisted of young saplings up to one metre high or mature multi-stemmed trees between two and six metres high. For each group, two clumps were treated with each herbicide formulation at either 0.3 or about 1.0 metre above ground. The four treatments consisted of 1% metsulfuron gel, Vigilant®, 10% glyphosate gel and an untreated cut-stem treatment as a control. The stems were cut and treated in mid May 2000 on a fine day with a cool breeze. No rain fell for at least two days after the treatments were applied. The

clumps contained between 5 and 100 stems and on average there were 26.7 stems per clump. The gels were applied at an average rate of 2.4 g/stem or 64.1 g/clump and were fully absorbed within about 24 hours of application.

Half the prunings were allowed to remain where they fell and some of this pruned wood was embedded in the ground. The other half of the pruned wood was jammed into the cut stumps above the water line and below the cut surface treated with herbicidal gel. In total there were 1275 pruned stems either lying on or embedded in the ground or held off the ground above the water line.

2.2 WHOLE-TREE TREATMENTS

2.2.1 Wedges on mature Darwin's barberry

The trial commenced on 23 February 2000 at Stewart Island on the same day as the cut-stem trial. A randomised block design was used involving plots of single trees. Five trees were treated with one of five herbicide formulations. A range of medium and large trees were used within each treatment. The trees each contained between 1 and 6 limbs (mean of 3 limbs per tree) and the limbs varied in size between 30 and 250 mm diameter at the base (mean treated limb size was 91.2 mm diameter).

Gel treatments were applied with a brush bottle into 50 mm wide by 20 mm deep blazes or wedges (Fig. 1). These were cut every 100 mm around the limb using a mallet and chisel, axe or pruning saw. In some cases the wedges were overlapping but in all cases the gap between wedges was no more than 50 mm. Once the wedges were cut, gel was applied at a rate of 10 to 15 g per wedge. On average there were 3 wedges per limb.

The five treatments consisted of gel alone, Vigilant®, 1 and 4% metsulfuron gels, and a 10% glyphosate gel. On average 32.1 g gel was applied per tree.

Figure 1. Vigilant® gel applied into a wedge cut into the trunk of a tree.

2.2.2 Trunk injection of Darwin's barberry trees

Trunk injection trials were carried out during early December 1999 on Darwin's barberry trees located at Wright's Hill, Karori, Wellington on mature trees which could be readily accessed from under the canopy.

Three blocks each containing 40 mature trees (3–4 m high) were selected for the trial and each treatment was applied to 10 replicates per block. These were randomly allocated within each block for each of the following four treatments: gel alone, a freshly prepared gel containing 1.67% Escort, a 33% Roundup gel and Vigilant®. The limbs were treated around the base and the size of these limbs varied between 30 and 180 mm diameter (average treated limb size was 85.3 mm diameter).

A battery-operated drill was mostly used to make holes (8 mm diameter × 50 mm deep) at a 45° downward angle at 50 mm intervals around all the main trunks of trees at about 20 cm above ground level (Fig. 2). Each hole was filled from the bottom with about 3 g herbicidal gel using a syringe inserted into the hole. On average there were 1.8 treated limbs per tree. Treatment effects were assessed annually for two seasons after treatment application.

Figure 2. Holes being drilled every 50 mm around the trunk of the tree in preparation for 3 mL of herbicidal gel or solution to be injected into each hole.

2.3 RESIDUES FROM TREATMENTS TO GREY WILLOW IN WETLANDS

2.3.1 Cut-stem treatments on saplings

On 29 November 2002, two large saplings standing in around 200 mm of water were pruned at around 1 m above the water line. Vigilant® (0.65 g a.i.) was then applied liberally over the cut stem (80 mm diameter) of one sapling and 10% glyphosate gel (0.8 g a.i.) over the cut stem (40 mm dia) of the other sapling. The distance between the saplings was about 300 mm. Water samples (200 mL) for analysis were taken in sterile plastic bottles at around 0.5 m from the treated stems prior to treatment and at 12, 24, 41 and 60 days after treatment. At the

same time, control water samples were taken from the same water resource at around 20 m from the treated stems. The water samples were then taken from the trial site to HortResearch's Analytical Chemistry Laboratory at Ruakura and were stored in a freezer at –16ºC or in a refrigerator at 4ºC depending on whether the samples were to be analysed more than a week or a couple of days after sampling. Samples were removed from the freezer or refrigerator, processed and analysed for residues of picloram or glyphosate using a capillary gas chromatography with mass spectrometry detection.

2.3.2 Trunk injection into trees

On 29 November 2002, the trunks (each about 200 mm diameter) of two large grey willow trees approximately 2 m apart and standing in around 300 mm of water were treated. Holes (10 mm dia) were drilled 100 mm deep, angled down at about 45 degrees, every 50 mm around the trunks at 200–300 mm above the water line. One tree was treated with Vigilant® (4.5 g picloram potassium salt in total) and the other with 12 g glyphosate via an aqueous 12% glyphosate solution (ex Growers Herbicide which contained 360g/L glyphosate as the isopropylamine salt in the form of a soluble concentrate). Each hole was filled with about 5 mL of Vigilant® gel or glyphosate solution.

Water samples (200 mL) were taken midway between and about 1 metre from the two trees prior to treatment and at 12, 24, 41 and 60 days after treatment. The samples were stored in sterile plastic bottles. Control water samples were also taken at the same time from the same water resource at about 20 m from the treated trees. The samples were immediately taken from the trial site to HortResearch's Analytical Chemistry Laboratory where they were stored, processed and analysed similarly to the water samples taken for the sapling trial (see 2.3.1).

3. Results

3.1 CUT-STEM TREATMENTS ON SAPLINGS

3.1.1 Darwin's barberry

At two years after treatment in the trial with Darwin's barberry, all but one of the 20 pruned untreated saplings were alive and 15 plants had produced regrowths. Application of either Vigilant® or 0.25% metsulfuron gel to cut stems of saplings had killed all treated plants (Fig. 3), and the stumps and roots had started to rot. This was particularly encouraging as the treatments were applied in cool humid conditions and at least two days were required for the gel to be absorbed into the plant in this locality. None of the lower rates of these herbicides was as effective.

Figure 3. Darwin's barberry saplings two years after the stems were cut and treated with Vigilant®.

3.1.2 Cotoneaster

One year after the treatments were applied to the cotoneaster saplings and trees, all but four of the 30 untreated cut-stem controls produced regrowths, and Vigilant® (Fig. 4), 1% metsulfuron gel or 10% glyphosate gel killed at least 97% of the plants. The solutions of 24% triclopyr or 0.18% metsulfuron were less effective than the gels and led to 83% and 66% kill of treated plants, respectively.

Figure 4. A cotoneaster sapling one year after the plant was cut and treated with Vigilant®.

3.1.3 Grey willow

At 24 months after the cut-stem treatments were applied to grey willow, Vigilant® applied at either 0.3 m or 1 m above the ground had killed at least 95% of the treated saplings (Fig. 5). A similar result was obtained with the 10%

glyphosate and 1% metsulfuron gels that were applied to cut stems at 0.3 m above the ground but these treatments were less effective (75% kill) when applied at waist height (about 1 m above the water line). Cutting willows high and treating the cut stem with Vigilant® is therefore a potentially useful technique. At the 24-month assessments, none of the pruned wood, either left on the ground or jammed above the water line, was alive.

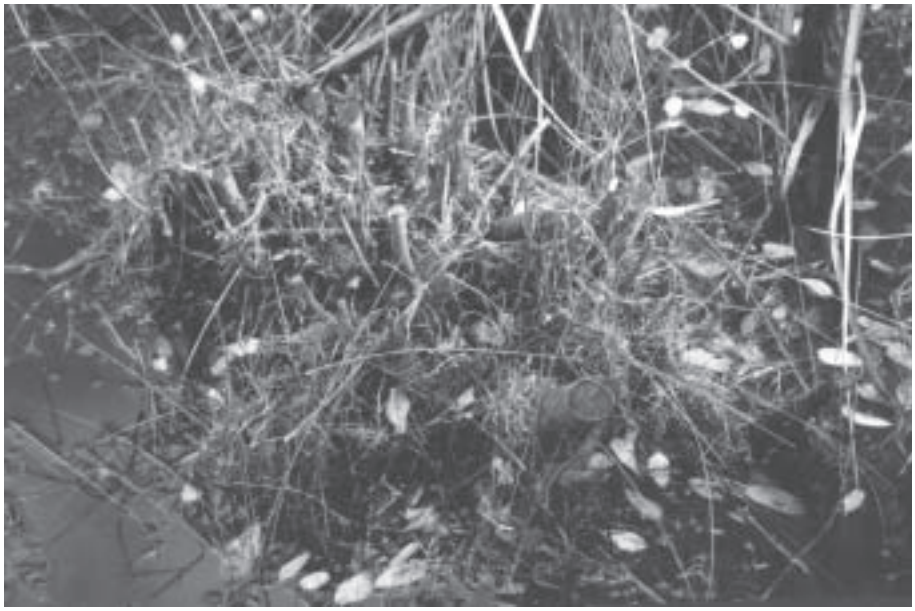

Figure 5. Grey willow saplings in a wetland area on the edge of Lake Taupo two years after being cut and treated with Vigilant®.

3.2 WHOLE-TREE TREATMENTS, DARWIN'S BARBERRY

At two years after application of gels to wedges cut in Darwin's barberry trees at Stewart Island, all of the trees treated with either Vigilant®, 1% metsulfuron or 10% glyphosate were dead. At this time all the untreated trees in the trial were alive. These treatments were slightly less effective in the Wellington trials that involved injection into holes at 50 mm intervals around all the main limbs of mature trees. At 26 months after treatment, 10% glyphosate killed 90% of the treated trees compared with an 80% kill for the other two gel formulations. All of the trees injected with gel alone were alive at this time.

3.3 RESIDUE TRIALS

It appears that, at 40–60 days after treatment, higher traces of residues of both glyphosate and picloram were associated with treated saplings and trees. By 168 days the residue levels were undetectable apart from 0.2 ppb picloram around the base of the cut-stem treatment.

As shown in Tables 1 and 2, trace levels of both glyphosate and picloram were found around both untreated and treated trees. This background residue level may have been due to runoff from nearby farms or application of herbicides in the area prior to our trials. Higher concentrations of both herbicides were detected around the treated saplings or trees up to the 60-day sampling period.

TABLE 1. GLYPHOSATE AND PICLORAM RESIDUES IN STATIC WATER AROUND BASE OF GREY WILLOW SAPLINGS, WHANGAMARINO WETLANDS, AFTER CUT-STEM TREATMENT.

Cut-stem treatment about 1 m above the water line with about 0.8 g glyphosate or 0.65 g picloram potassium salt, late November 2002.

DAYS AFTER TREATMENT	GLYPHOSATE RESIDUES (ppb)		PICLORAM RESIDUES (ppb)	
	UNTREATED TREE	TREATED TREE	UNTREATED TREE	TREATED TREE
7	2.2	9.8	nd*	nd
12	nd	nd	0.16	0.42
24	1.1	8.4	ndl†	0.90
41	1.9	8.0	nd	nd
60	nd	nd	ndl	4.3
168	ndl	ndl	ndl	0.2

* nd not done

† ndl nil detectable levels: level of detection for glyphosate is 1 ppb; level of detection for picloram is 0.02 ppb

TABLE 2. GLYPHOSATE AND PICLORAM RESIDUES IN STATIC WATER AROUND BASE OF GREY WILLOW SAPLINGS, WHANGAMARINO WETLANDS, AFTER TRUNK INJECTION.

Trunk injection with 12 g glyphosate or 4.5 g picloram potassium salt, late November 2002.

DAYS AFTER TREATMENT	GLYPHOSATE RESIDUES (ppb)		PICLORAM RESIDUES (ppb)	
	UNTREATED TREE	TREATED TREE	UNTREATED TREE	TREATED TREE
7	2.2	18.0	nd*	nd
12	nd	nd	ndl†	ndl
24	1.9	6.4	ndl	ndl
41	1.0	11.0	nd	nd
60	nd	nd	ndl	1.4
168	ndl	ndl	ndl	ndl

* nd not done

† ndl nil detectable levels: level of detection for glyphosate is 1 ppb; level of detection for picloram is 0.02 ppb

In the case of the tree treatments, this was probably due to exudation of low amounts of herbicide moving into and out of the roots. For the doses applied to the cut stems of saplings and whole trees, relatively more of each of these herbicides was present around the cut-stem treatments. This suggested that traces of residues were also being washed off the cut stem.

4. Discussion

4.1 CUT-STEM TREATMENTS

All the cut-stem trials were on woody shrubs and saplings and involved application of gels containing one, or a combination of two of the systemic herbicides: glyphosate, picloram, or metsulfuron. Overall, picloram, as Vigilant® gel, has been consistently more effective than the other two herbicides, producing complete control of Darwin's barberry, cotoneaster, and grey willow. Good control should also be expected with spring or autumn applications of Vigilant® when sap is still actively moving within plants, particularly as this herbicide can remain active in susceptible plant species for two seasons after application.

In the Darwin's barberry trial, untreated cut stems had regrown and produced seeds in the second season after pruning.

In the cotoneaster trial in Southland, the treatments were applied in very strong wind. Even in these conditions the gels remained on the cut stems, and most were absorbed within an hour of application. The activities of the gel formulations selected for this trial were superior to either of the standard herbicidal solutions (0.3% Escort or 24% triclopyr) used by DOC staff in the locality to control *Cotoneaster simonsii* saplings. The gel technology allowed consistent doses of herbicides to be applied to stems cut at a range of angles to the horizontal, whereas it is essential to cut the stem horizontally to minimise runoff when applying herbicidal solutions. This can seldom be achieved consistently in practice. There is also a higher risk of soil contamination with residues when using high concentrations of herbicide (such as 24% triclopyr) in solution compared with gels.

4.2 WHOLE-TREE TREATMENTS

The advantage of killing trees without felling is that it avoids any physical damage to surrounding native vegetation and allows easier access for subsequent follow-up treatments. When applying systemic herbicides into wedges or frills, a gelled formulation is a way to minimise residue runoff. At Stewart Island, all the Darwin's barberry trees were killed with Vigilant® applied into 2–4 wedges around the trunk. For multi-stemmed trees, each stem must be treated, as it has its own separate root system. It is easier to apply gel into wedges cut into vertical trunks than in inclined trunks, for which wedges should be cut around the upper surface so that the gel can be applied to a point where it adheres without dripping off. Spring, summer and autumn applications should be equally effective provided that dry weather prevails for several days after application to allow the gels to be absorbed into the trunk before any wash-off can take place.

In the trials on Darwin's barberry in Wellington in summer, Vigilant® applied into 2–4 wedges around the trunk of mature trees was less effective and more

time-consuming than using diluted Roundup injected into holes spaced at 50 mm intervals around the trunk. For densely packed trunks, where drill access around the entire trunks is limited, the wedge technology could be used in conjunction with drilling.

4.3 RESIDUE TRIALS

Vigilant® is the only commercially available herbicidal gel in New Zealand at present. It is not recommended for use on plants growing near or in waterways. It is effective when applied at 1 m above ground level to grey willow saplings. However, as it is possible for herbicidal residues to enter the water either via wash-off from the surface of treated stems or exudation through the roots, more residue information is vital before the approach could be suggested for widespread willow control. The residue levels detected were extremely low. However, before Vigilant® is used as a high cut-stem treatment, a larger-scale residue trial is recommended in which all the saplings in a dense population are treated and residue concentrations in the surrounding static water are determined.

4.4 REGROWTH OF PRUNINGS

One possible disadvantage of treating cut stems of weeds is that the prunings may need to be removed and destroyed if they re-root when in contact with the ground.

We have not observed rooting of grey willow prunings in any trials. In an earlier cut-stem trial in the Whangamarino Wetlands, we allowed all the prunings of grey willow to remain at ground or water level. After two years, none of these had re-rooted or grown. In the trial at Lake Taupo, half the prunings were allowed to remain where they fell (that included being embedded in the ground) and the other half of the pruned wood was jammed into the cut stumps above the water line and below the cut surface treated with herbicidal gel. In total there were 1275 pruned stems either lying on or embedded in the ground or held off the ground above the water line, and none of these prunings was alive at 24 months after pruning. Thus at both the Whangamarino and Lake Taupo sites, there does not appear to be a need to remove or dispose of grey willow prunings. This improves the economics of control methods involving cut-stem treatment of grey willow saplings and trees in these localities. Similar conclusions were drawn from the Darwin's barberry trials.

However, at the exposed Southland site for the cotoneaster trial, where consistent strong winds dislodged soil at ground level, a couple of the prunings became covered with soil and had taken root. It clearly is a time-saver if prunings do not need to be removed and destroyed, but it is essential when using cut-stem methods to revisit treated sites within two seasons of the treatment application to monitor and treat any regrowths from both prunings or treated plants.

4.5 OFF-TARGET EFFECTS OF HERBICIDES IN THE TRIALS

When using herbicidal gels to control weeds in dense native bush, there are a number of possible reasons that off-target effects could occur. These include: (1) accidentally dropping or brushing the gel on surrounding plants; (2) exudation of active ingredient from roots of treated plants; (3) movement of herbicide from the roots of the treated plant that is grafted to the roots of an adjacent plant; (4) dragging the prunings across treated stems and onto non-target plants when removing them to facilitate subsequent access; (5) gel falling off steeply inclined cut stems; and (6) rain or heavy dew diluting or washing the gel from the cut stem soon after application.

In the eight years of trials on the conservation estate in which a range of herbicidal gels and application systems have been evaluated, we have observed only two instances of collateral damage to nearby native vegetation.

At one year after application of the cut-stem treatments to Darwin's barberry saplings at Stewart Island, off-target effects were noted on ferns around a few plants treated with Vigilant® and about half the plants treated with 1% metsulfuron gel. These off-target effects were not obvious two years after treatment as the dead stumps were overgrown with other native plant species. In our earlier cut-stem trials on Darwin's barberry saplings in Wellington, off-target effects were not apparent on the Vigilant® treated plots but were very obvious around stems treated with a gel containing a high rate (4%) of metsulfuron. During this trial, light rain started to fall towards the end of the application period and metsulfuron residues may have been washed from the treated cut stems before the herbicide was fully absorbed. This highlights the need for caution when using herbicides, either as gels or solutions, around desirable plant species.

Off-target effects were not observed around any Darwin's barberry trees given whole-tree treatment.

Killing weed trees within native bush opens up the canopy in many cases and can lead to germination of previously dormant seeds in the litter layer. These seedlings occur in the under-canopy, and even shielded spraying of these seedlings may lead to spray drift damage on nearby native seedlings. A possible alternative method is to wipe a gel over weed seedling mats, but this needs to be investigated further before any recommendation could be made.

4.6 PICLORAM AND THE ENVIRONMENT

Vigilant® is the only gel technology currently available to control environmental weeds. However, as the active ingredient (5% picloram as the potassium salt) can persist in the soil, ways of using this product to control weeds in native bush to minimise environmental contamination need to be considered.

The potassium salt of picloram is water-soluble, does not bind strongly to soil particles, and can be persistent and mobile in the environment (Kidd & James 1991). In plants, it is either metabolised (in non-susceptible species such as

grasses) or can remain intact for some time (in susceptible species) (Weed Science Society of America 1994). Unabsorbed picloram may photo-degrade or be washed-off cut stems by rainfall. Estimates of the persistence of picloram in soil vary from a few months to a year depending on soil type and environmental conditions. The chemical has a high potential to move vertically and horizontally in soil, which can lead to contamination of water sources and non-target (terrestrial and aquatic) sites.

The active ingredient can move into local waterways through surface and subsurface runoff. The extent to which it enters a waterway depends largely on the type of soil, rates of application, post-application rainfall, and distance from the point of application to the nearest water body or groundwater. In general, the larger the buffer between treated sites and surface waterbodies or groundwater, the smaller the potential for water contamination. Once in a waterway, picloram may be degraded through photosynthesis, especially in clear and moving water. The half-life of picloram in water is 2–3 days (Weed Science Society of America 1994).

When applied to cut stems, the majority of picloram (probably 90%) is absorbed and remains within about 10 mm of the cut stem, and only a small percentage is conducted to stems and roots. The rate of absorption into the cut stem can vary from 0.25 to 2 days, depending on the plant species treated, its location, and the prevalent environmental conditions after application. In the low-light conditions under native bush canopies, unabsorbed picloram remaining on cut surfaces is unlikely to photo-degrade to any extent and is probably more vulnerable to wash-off if rain falls within about half a day of application. Picloram absorbed by plants can also be released into the soil by passive transport through the roots and then possibly be taken up by roots of nearby plants. The active ingredient in Vigilant® has a half-life in soil of 20–300 days with an estimated average of 90 days (Wauchope et al. 1992).

Picloram is 'slightly to practically non-toxic' to birds and mammals. The LD_{50} for rats is > 5000 mg/kg. Picloram is 'slightly to moderately toxic' to aquatic species. The LC_{50} (96 hours) for rainbow trout, bluegill sunfish, and fathead minnow are 19.3 mg/L, 14.5 mg/L, and 55 mg/L, respectively (Extonet 1996). These values are above the peak runoff concentrations reported by researchers under various environmental conditions and are at least 3000 times greater than the highest level found in the residue trial on willow covered in this report. In terms of its effects on soil micro-organisms, picloram had no effect on *Erwinia carotovora* and *Bacillus* sp., but inhibited growth in *Pseudomonas fluorescens* by 28.8%. Picloram does not bio-accumulate in organisms (Breazeale & Camper 1972).

5. Acknowledgements

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Appendix 1

GUIDELINES FOR USING HERBICIDAL GEL

Note any reference to gel in these guidelines refers to Vigilant®, as this is the only herbicidal gel currently commercially available for general use.

General comments

These guidelines encompass observations made during 1999–2003 when a range of herbicidal gels were formulated and evaluated for killing woody shrubs, saplings and trees.

From the outset there should be a control strategy in place that is based on methods that have been proven over at least two seasons following treatment to effectively kill the weed at the targeted stage of growth (e.g. seedling, sapling or adult plant) with known minimal environmental impact. For example, do not apply herbicidal gel to cut stems or stumps within 12 hours prior to rain. Record the weather condition daily for up to five days after treatment at given treatment sites and monitor the effects on the treated plants at both one and two seasons after treatment. Also monitor a random selection of treated sites a few weeks after the team has left the site and assess the number of plants missed at given sites as part of a quality control procedure.

Ideally the herbicidal gel should be applied immediately after the plant stem/trunk has been cut or drilled. In many situations this is not practical, and in these cases the gel should be applied within five minutes to maintain good efficacy of treatment.

When treating weeds in the bush, most time is involved in locating and identifying weed plants. Entry to treat invasive weeds in native bush can also be very time-consuming and is influenced by the terrain, and the height and density of the weeds and native plants at the site. Access is an important consideration, not only for the initial application, but also for subsequent treatment of seedlings and plants that are inadvertently not treated in the first pass. Where the native vegetation is low to the ground, tracks may need to be cut for access to isolated shrubs and trees.

Cost of labour is always likely to outstrip chemical costs. Under-canopy entry is more cost-effective than cutting accessways through bush and is the preferred approach.

It is more cost-effective to identify all the target weeds at a given site and treat them effectively before moving away to another infested area. Even under this strategy the team will miss weeds at a site, so a follow-up treatment the following seasons is essential.

A detailed count of treated and untreated vines in earlier trials on climbing spindleberry suggested that only about 40–50% of vines had been treated on the first pass. Three passes were required to locate and treat about 95% of the vines

within a given area of bush. Thus monitoring is also a key component in effective weed control.

Care should also be taken by staff when removing prunings from a site to avoid dislodging gel that has been applied to cut stems.

Ease of access both in the season of treatment and subsequent follow-up seasons is essential, as it can have a marked effect on entry to the site. Time should be taken to carefully select where prunings are to be disposed of, so that subsequent entry to the site will not be impeded.

Maintaining staff morale over prolonged periods is a key issue in controlling dense infestations of a weed such as climbing spindleberry and old man's beard in native bush growing in difficult terrain.

Saplings

Saplings can be shrubby plants such as cotoneaster or juvenile Darwin's barberry and grey willow plants less than 2–3 m tall. The most effective technique to kill these was to treat cut stumps. When treating saplings follow these general guidelines:

- Small plants should be hand-pulled if the likelihood of roots breaking and re-shooting is negligible and the plants are not too difficult to pull out. If not, cut and treat at least 80% of all main stems of saplings.
- In general, all main stems should be cut at around 300 mm above the ground and Vigilant® gel applied liberally and uniformly over the cut surface soon afterwards. There are exceptions to this (such as grey willow and privet). Grey willow can be cut and treated up to 1 m above the ground but privet stems should be cut and treated about 50 mm above ground to ensure the active ingredient translocates to the roots.
- Although the gel adheres well to inclined cut surfaces, cuts should be as horizontal as possible to reduce the chance of gel dislodging from the cut stem and contaminating the soil below.
- Work away from treated plants to avoid contact with previously treated surfaces and inadvertently dislodging the gel.
- Ensure the gel does not come into contact with nearby plants. Occasionally in dense canopies the leaves of nearby plants can touch the treated cut surface.

In general, sap ceases to flow once the stems are severed and the cut surface begins to dehydrate. Vigilant® is formulated as an aqueous gel that reduces rapid drying of the cut surface and assists absorption and translocation of the active herbicidal ingredient into the plant. Care should be taken to avoid drippage or direct contact of dispensed gel with soil.

As plants like Darwin's barberry have spines, wear gloves while cutting these plants. Apply the treatment in fine weather and expect the gel to have almost dried on the cut stem within six hours if applied in spring or summer. The gel is absorbed more rapidly from the outer surface of cut stems and under cold, humid conditions may take up to 48 hours to be absorbed completely.

Darwin's barberry prunings do not take root but can take several years to degrade. Ideally they should be lodged where they do not interfere with access

to other plants being treated in the first or subsequent passes. Cotoneaster prunings in some localities may need to be destroyed, as they can take root.

Whole trees

Based on our trials, two control strategies were the preferred options for treating trees. Cut wedges into the trunk using a pruning saw or axe and treat the lower cut surface of the wedge with herbicidal gel. Alternatively drill holes around the trunk and inject herbicidal gel or solution into the holes.

Wedges

- Wedges (50–100 mm wide and 15–30 mm deep) are cut into each trunk about 30 cm above ground using a pruning saw or axe. Cut two wedges per trunk for small trees (up to 150 mm diameter at about 20 cm above ground).
- For larger trees, cut a series of wedges around the trunk with no more than a 20–40 mm gap between them. Soon after cutting the wedge, the lower cut surface of each wedge should be covered liberally with about 5 mm layer of gel.

It is easier to apply gel into wedges cut into vertical trunks than in inclined trunks, for which wedges should be cut around the upper surface of the trunk and gel applied to a point where it adheres without dripping off.

Drilled holes

- Drill 10 mm holes at 50 mm intervals around the trunk of the tree 200–300 mm above the ground. Holes should be drilled at a downward angle of 45° to a depth of 60 mm.
- Immediately after the holes are drilled, fill the holes with herbicidal gel or solution.
- Avoid overfilling holes. Overflow from the holes will lead to herbicide spilling down the trunk and contaminating the soil, potentially leading to off-target effects on adjacent plants.

Other comments

All of our methods have been directed at controlling established plants effectively and ideally in the first pass. More research information is required on methods and optimum application times to control seedlings and the impact of different control practices on subsequent seedling germination. In general, removing or killing the canopy of weed plants growing amongst native bush can lead to light wells that can encourage germination of weed seeds in the open patches. These will need to be controlled in subsequent seasons, ideally with systems that avoid chemical drift on to native plants in the understorey.

If any technique is to be used on weeds that are not listed on label claims for the herbicide, it should be carried out first on a small number of the particular weeds in an area away from any desirable plants. This will establish the effectiveness and suitability of the technique for eradicating that particular weed species.