**Summary** Woody weeds, particularly bracken fern (*Pteridium esculentum*), are major competitors for light, nutrition and water during the establishment phase of plantation forestry in South Australia. ForestrySA controls bracken with both glyphosate and metsulfuron-methyl, applied either singularly or in combination with the modified polydimethylsiloxane spray adjuvant Pulse Penetrant.

In 2002 ForestrySA established two trials to compare the efficacy and cost of various spray surfactants and adjuvants with Pulse Penetrant, applied in autumn and spring. Pulse Penetrant and its generics performed consistently better than all other spray adjuvants, with a superior level of both initial knockdown and prolonged control, for a range of treatment conditions. The addition of Anti Foam C to spray mixtures containing Pulse Penetrant did not reduce the effectiveness of the spray mixture, but was effective in significantly reducing the amount of re-foaming.

The results from this trial indicate that the most effective adjuvants to use when controlling woody weeds in plantation forestry in South Australia is Pulse Penetrant and its generics.

**Keywords** Spray adjuvants, forestry, woody weeds, bracken, herbicide, application timing.

**INTRODUCTION**

Live bracken (*Pteridium esculentum* (G.Forst.) Cockayne) coverage in excess of 5% will have a significant impact on growth rates and survival of both *Pinus radiata* D.Don (radiata pine) and *Eucalyptus globulus* Labill. (Tasmanian blue gum) seedlings during the first two years of plantation establishment (W Richardson, unpublished data).

While bracken is more receptive to chemical control following new frond emergence in spring and autumn, spring control is generally more successful due to the longer window of receptivity. Autumn control can be very problematic due to the small window of time between end of summer drought conditions when it is too dry, and the onset of winter when it is too cold, for bracken to be receptive to chemical uptake.

Surfactants can be added to herbicide spray mixtures to improve herbicide uptake. Pulse® Penetrant, a non-ionic surfactant, has been used by ForestrySA with herbicides since the 1980s for general weed control and, in particular, woody weed control. Pulse Penetrant is a label requirement when using Trounce®, and a label recommendation when using Brush-Off® and Roundup® 360, and it is often the most expensive component of herbicide spray prescriptions currently used by ForestrySA for plantation establishment.

Since the late 1980s, many new non-ionic surfactants and spray adjuvants for herbicides have been introduced into the Australian market. In 1984 the ForestrySA Research Section compared the surfactant Silwet L-77® and the spray adjuvant Ulvapron® in trials applied with atrazine and hexazinone (Karajalainen, 1984). In 2001 Pulse was trialled against a range of non-ionic surfactants and low foam formulations applied with Roundup 360 at 4 L ha⁻¹ (glyphosate 1444 g a.i. ha⁻¹) over phalaris (*Phalaris aquatica* L.) (Richardson 2003). Results showed very little difference in performance between any of the treatments.

Anti Foam C was also tested in 2001 for its effectivity in reducing excessive foaming during spray tank refilling when using glyphosate in combination with Pulse Penetrant (Richardson 2003). This initial trial proved that adding Anti Foam C to this spray mixture significantly reduced refoaming without causing any loss of herbicide efficacy.

The aims of the trial reported herein were to investigate the efficacy and cost of various spray surfactants and adjuvants with Pulse Penetrant, and to investigate differences in surfactant effectiveness due to timing of application (autumn versus spring).

**MATERIALS AND METHODS**

Two trials were established at Native Wells (37°38'S 140°30'E) on ForestrySA land at the Mt Burr Forest Reserve in the Green Triangle Region of South Australia. Trial A was established in autumn with treatments applied on 14/5/2002. Trial B was established in spring with treatments occurring on 28/10/2002. The adjacent trial sites were located on a wide firebreak that is routinely slashed each spring as a fire prevention measure. This slashing preconditioned the bracken was for chemical control.

Both trials were established as a randomised complete block design consisting of four replicates of each treatment. A total of 12 treatments were applied (Table 1): a nil control, Pulse Penetrant at 0.2%, Pulse...
Penetrant at 0.2% + Anti Foam C spray adjuvant, and nine additional spray adjuvants. Treatments 2–12 were applied with Brush-Off at 60 g ha\(^{-1}\) (metsulfuron-methyl 36 g a.i. ha\(^{-1}\)).

Each plot was 12 m long and 2 m wide. An internal assessment plot of 10 m in length gave a 1 m spray buffer at the start and end of each sprayed strip. There was a minimum 1 m wide buffer between each treatment strip. All treatments were applied using a Solo knapsack with an output rate of 120 L ha\(^{-1}\).

Assessment All plots were visually assessed for the percentage of live bracken ground cover prior to treatment application, and then at 1, 2, 3, 6, 8, 9 and 12 months after treatment. A photographic record of all plots in one replication was collected with each bracken assessment.

RESULTS

Trial A (Autumn 2002 application) The three modified polydimethylsiloxane treatments: Pulse Penetrant, Pulse Penetrant + Anti Foam C, and Spray-sure Penatra, were the outstanding surfactant treatments, performing better than all other spray additives tested in this trial (Figure 1). The level of initial knockdown achieved by the three treatments containing polydimethylsiloxane adjuvants was similar. All of the remaining treatments failed to maintain bracken cover to less than 5% for the first six months after treatment.

Germination of new fronds during the spring following treatment was retarded in all treatments except the control, Hot Up, Adhere, and Hasten plots. This resulted in a significant reduction of live bracken ground cover during the summer drought months, as older fronds naturally died off without being replaced by new growth. The reduction in live bracken ground cover during summer was extended until the onset of autumn rains when new growth emerged in all plots.

The modified polydimethylsiloxane treated plots had the least new frond development, maintaining bracken levels below 5.25% live ground cover for 12 months. The next best treatment, Kenwet 1000 L.F., had 14.25% live bracken ground cover at 12 months. ARK22004, which was designed for use with Brush-Off, inhibited new frond germination severely during spring and was the best of the oil based adjuvants tested. However, it failed to provide any control past the opening rains in autumn with live bracken ground cover rising from 5.8% in January to 19.5% in May. The addition of Anti Foam C to Pulse Penetrant did not reduce the efficacy of Brush-Off in this trial.

Trial B (Spring 2002 application) Along with the three modified polydimethylsiloxane treatments, BS1000, ARK22004, and Hasten were the best performing treatments providing a good level of bracken knockdown for 12 months (Figure 2). All chemical treatments had a major impact on bracken growth in

Table 1. Spray adjuvant and treatment rates with 36 g a.i. ha\(^{-1}\) metsulfuron-methyl.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Active constituent</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Nil control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Pulse Penetrant</td>
<td>1000 g L(^{-1}) modified polydimethylsiloxane</td>
<td>0.2% spray solution</td>
</tr>
<tr>
<td>3 Pulse Penetrant + Anti Foam C</td>
<td>1000 g L(^{-1}) modified polydimethylsiloxane</td>
<td>0.2% spray solution</td>
</tr>
<tr>
<td>4 Kenwet 1000 L.F</td>
<td>1000 g L(^{-1}) alcohol alkoxylate</td>
<td>0.12% spray solution</td>
</tr>
<tr>
<td>5 Browndown Adjuvant</td>
<td>36 g L(^{-1}) oxyfluorfen</td>
<td>1.0 L ha(^{-1})</td>
</tr>
<tr>
<td>6 Spray-Sure Penatra</td>
<td>1020 g L(^{-1}) polyether modified polysiloxane</td>
<td>0.2% spray solution</td>
</tr>
<tr>
<td>7 BS1000®</td>
<td>1000 g L(^{-1}) alcohol alkoxylate</td>
<td>0.2% spray solution</td>
</tr>
<tr>
<td>8 Swift penetrating adjuvant</td>
<td>700 g L(^{-1}) canola oil ester 200 g L(^{-1}) alcohol ethoxylate</td>
<td>0.2% spray solution</td>
</tr>
<tr>
<td>9 AD-Here™ Spray adjuvant</td>
<td>861 g L(^{-1}) petroleum oil</td>
<td>1.0% spray solution</td>
</tr>
<tr>
<td>10 Hot-Up™ Spray adjuvant</td>
<td>340 g L(^{-1}) non ionic surfactant blend 190 g L(^{-1}) mineral oil 140 g L(^{-1}) ammonium sulphate</td>
<td>0.25% spray solution</td>
</tr>
<tr>
<td>11 Hasten™ Spray adjuvant</td>
<td>704 g L(^{-1}) ethyl and methyl esters of fatty acids (produced from Canola Oil)</td>
<td>0.5% spray solution</td>
</tr>
<tr>
<td>12 ARK22004</td>
<td>Proprietary information</td>
<td>0.25% spray solution</td>
</tr>
</tbody>
</table>
comparison with the control plots, where live bracken ground cover rose to 28.8% after twelve months. The addition of AntiFoam C to Pulse Penetrant did not reduce the efficacy of Brush-Off in this trial.

**DISCUSSION**

Due to seasonal conditions in autumn 2002, Trial A became a test of spray adjuvant efficacy in worst-case conditions. Lack of rainfall delayed new bracken frond development, resulting in uneven emergence and slow frond unfurling. Trial A was scheduled for treatment application when the bracken present was in prime condition for treatment; that is, when new bracken fronds had emerged following the opening rains and were fully unfurled and still soft to touch. Treatment application was delayed (until as late as operationally practical), in the hope of season breaking rainfall and new frond development.

**Figure 1.** Trial A percentage live bracken ground cover over time from 14/05/02.

**Figure 2.** Trial B percentage live bracken ground cover over time from 28/10/02.
When treatments were finally applied in mid May 2002, soil moisture levels were low, negligible new frond development had occurred, and the existing bracken was over mature and woody. Additionally, the onset of winter temperatures and rapidly diminishing hours of daylight combined to make the bracken less receptive to herbicide uptake as it moved into its winter growth dormancy.

The second trial site (Trial B) was established 40 m to the west in spring 2002. Bracken condition was excellent at the time of treatment application, allowing a direct comparison of treatment efficacy under best case conditions. All of the surfactants tested performed better under ideal conditions.

Pulse Penetrant and its generics performed consistently better than all other spray adjuvants, supplying a superior level of herbicide uptake to provide weed knockdown, as well as longer lasting control for a range of treatment conditions. The addition of Anti Foam C to spray mixtures containing Pulse Penetrant and Brush-Off did not reduce the effectiveness of the spray mixture, but reduced the amount of re-foaming dramatically.

Any bracken frond that survives chemical treatment has the potential to re-establish the dominance of this weed over time. In plantation forestry the ultimate aim is to achieve complete control of bracken (i.e. 0% live bracken cover). In practical terms, the reduction of live bracken cover to less than 5% during the first two years following planting will minimise the impact of bracken on initial survival and growth of plantation forests.

The results from this trial indicate that the most effective adjuvants to use when controlling woody weeds in plantation forestry in South Australia is Pulse Penetrant and its generics.

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REFERENCES