Unmanned aerial vehicles used to control giant reed (*Arundo donax* L.)

Philip Milling
6 Rosin Place, Bolwarra Heights, New South Wales 2320, Australia
(phil@skylandmanagement.com.au)

Summary Unmanned Aerial Vehicles (UAVs) continue to grow in popularity to improve efficiency and effectiveness in many industries. Most of the uses to date have involved mapping, land surveying, photography, site monitoring and recording. However, their use for weed control, has been restricted.

Using the UAV as a tool to apply herbicide from above has enabled deep and full application of herbicide. Results to date have shown 80–90% brownout of giant reed after a single treatment using glyphosate. Therefore, understanding this technology and its applications can provide weed managers with efficient and effective options which have not been available in the past. Combining the latest of technologies with tried and true methods can significantly enhance our weed management efforts.

Keywords UAV, glyphosate, spot treatment.

INTRODUCTION

Arundo donax L., commonly known as giant reed (sometimes called elephant grass) is a weed primarily of riparian areas. It is found in every state of Australia and the Northern Territory. In New South Wales (NSW) it is predominantly found along the central and northern coast. In the Hunter valley of NSW, giant reed is prevalent along several major waterways. These include the Pages, Paterson, Allyn, Williams and Hunter Rivers.

Giant reed is a bamboo like plant that can grow up to 10 m tall. It has hollow woody canes that support blue/green leaves that attach to the stem by a sheath wrapping around the stem. It produces a tall plume like flower head, up to 60 cm, which produce seeds. However, in many cases, including in the Hunter Valley, these seeds are unviable. The Hunter population has been studied and found to be sterile clones (Azadeh Haddadchi and Gross, n.d.). Instead, the plant reproduces vegetatively from spreading rhizomes or from fragments of rhizomes that break off and establish at new locations. Fragments of fresh stems can produce roots from the nodes if in contact with soil.

Giant reed forms impenetrable thickets (several hundred stems m^{-2}), creating a monoculture, where no other vegetation can establish or persist. If left unabated, these thickets can spread along entire reaches of a river. Although it is thought that they provide protection for riverbanks, they can also cause large sections to break away because their root systems, although dense, will only grow to a depth of up to one metre. This means the root system can be undercut and easily dislodged. This dislodged giant reed then causes further issues downstream as a flood rack of vegetation, which can cause significant infrastructure and riparian damage. This mobilised giant reed may eventually lodge on a riverbank or bed, where it will set root and establish as a new giant reed colony. Giant reed can block or significantly alter the course of a river.

Giant reed can also establish in areas away from riparian areas and has been seen establishing on soil and gravel stock piles and along areas where roadworks have been undertaken. These most likely have established from plant matter that has been transported in these materials, or possibly on machinery associated with these activities.

Other issues that giant reed presents include its high water use. It can use up to 2000 L m^{-2} (Csurhes 2009), significantly higher than that of native riparian vegetation. Evidence also shows that giant reed has no habitat or feed value to native fauna. In fact, the plant has toxins in it which make it unpalatable to native fauna and is also suspected of releasing toxins into the water, which deters other plants while favouring its own growth (Bell 1997, Dudley 1998, CRC 2005)

The advance of giant reed along our waterways is having a significant detrimental impact on their function. One of the main reasons it has been able to establish so extensively has been due to the time consuming and costly control of traditional methods. Traditional methods of control are varied, with different rates of success. The more proven methods such as cut and paint, although generally effective, are very labour intensive and, hence, costly. Other methods like root removal by mechanical means is costly, and causes a high amount of ground disturbance, which is not desirable, particularly in riparian areas. Foliar spraying is a quicker and more cost-effective method, however the ability to get the coverage required is impeded by the sheer size and density of most thickets.

In all these cases, as with most weed control, follow up is required. This is because giant reed has a high resilience to control due to its extensive root

mass. Therefore, in most cases the use of a variety of control methods is required.

MATERIALS AND METHODS

The trials comprise a combination of control methods, based on the stage in the control timeline as well as the location of the giant reed on the riverbank. The giant reed at the first trial site on Paterson River at Tocal in the lower Hunter valley NSW stretched from the river bank up onto the flood plain, with the thickest vegetation being up to 70–80 m long and up to 30–40 m wide. The second site, on the Pages River in the upper Hunter valley, near the township of Murrurundi, was composed of more isolated clumps on the river banks, ranging in diameter from a few meters up to 15–20 m. To overcome the difficulty in accessing the giant reed an Unmanned Aerial Vehicle (UAV) was used to apply herbicide as the primary treatment. The aircraft used was a Yamaha® Rmax rotary wing UAV. The first trial site along the Paterson River, Tocal was broken into six adjacent sections, each of which received different herbicide treatments.

The treatments used were glyphosate 360 g L^{-1} (Roundup® Biactive) and glyphosate 570 g L^{-1} (Roundup® UltraMax), both with and without an acidifier (LI700®). The initial application was done in autumn 2016 on four of the six plots only, using a low rate, then followed up with treatment of all six sites at a higher rate in spring 2016 (Table1).

The next stage was to burn the plots to remove a significant proportion of the biomass. The burn was initially scheduled for autumn 2017 however circumstances delayed this to late winter. The burn was unfortunately hampered on the day by some light rain and no wind. Despite these conditions, those areas that did burn showed a significant reduction in the amount of biomass.

Following the burn, a follow up herbicide application on the regrowth was done using the UAV, in spring 2017. This application was done when the canes had reach approximately one m in height.

Once the giant reed is mostly under control the site will be revegetated through aerial seeding using the UAV. The seed mix will include a sterile cover crop and suitable native riparian vegetation for the site. Note that a buffer strip along the water edge was not treated, to provide some stability to the river bank. Once vegetation is well established behind this narrow strip of Giant reed, it can be manually removed using cut and paint methods.

The second trial site at Pages River, Murrurundi, was first sprayed using the Yamaha® Rmax UAV in Autumn 2017. The results from the first trial site at Tocal indicated that the higher rate (20%) of glyphosate 360 g L^{-1} without acidifier would most likely achieve the best result, thus it was included.

RESULTS

While the trials are currently in progress, the results to date appear to be quite successful. One of the benefits anticipated from using the UAV was its ability to force the herbicide through the full stratum of the giant reed. Water sensitive paper was placed from ground level up to 2400 mm off the ground to establish if this was achieved. All aerial paper had droplets on them, with decreasing coverage closer to the ground with some ground coverage found. This showed that the herbicide was getting right through the plant canopy.

At Paterson River, the autumn treatment at the lower rate resulted in a biomass brownout rate of 80–90% of the thickets. It resulted in no new shoots in the following spring, as was evident in the non-treated adjacent giant reed. New giant reed shoots off existing canes showed signs of herbicide damage, that is they were stunted and had yellowed margins, (Figure 1). This was generally only found less than half way up the canes, with the top half of the canes having no re-growth.

The benefit of the acidifier was indistinguishable when comparing plots that did not have it added, and hence it was decided that this would not be used in the next herbicide treatment. The lower concentration

Table 1. Herbicide treatments trialled for giant reed.

Plot	Herbicides	Autumn 2016 – rate	Spring 2016 – rate
1b	Glyphosate 360g L^{-1} (Roundup® Biactive)	2%	20%
1ba	Glyphosate 360g L^{-1} (Roundup® Biactive)	2% + acidifier (LI 700®)	20%
2u	Glyphosate 570g L^{-1} (Roundup® UltraMax)	1.4%	13%
2ua	Glyphosate 570g L^{-1} (Roundup® UltraMax)	1.4% + acidifier (LI 700)	13%
3b	Glyphosate 360g L^{-1} (Roundup® Biactive)	**No treatment**	20%
3u	Glyphosate 570g L^{-1} (Roundup® UltraMax)	**No treatment**	13%

of glyphosate 360 g L^{-1} was slower acting than the glyphosate 570 g L^{-1} however the final result was the same. The weaker formulation achieved the 80–90% brownout at 12–14 weeks, whereas the other formulation achieved the same milestone at 8–10 weeks.

The single application of the higher dilution rate of glyphosate had a significant result with plot 3u achieving close to 100% mortality within 6 weeks and plot 3b achieving the same result in 8–10 weeks. The four plots previously treated in autumn showed further decline resulting from the secondary application. A further 50% of the live giant reed was killed with this second treatment. This result was not as successful as anticipated. The reason for this may be due to the fact that these plants were still showing signs of the impacts from the previous treatment and may not have had enough foliage on them for the second application.

The burn of the giant reed at Paterson River took place in winter 2017. It was initially planned for autumn 2017, however this was not possible due to several factors outside of the control of the trial. Burning of hayed off giant reed was patchy, with some denser areas burning well. Regrowth in these areas was minimal through the following dry spring and summer. Since significant rainfall fell in early autumn 2018 recovery of the weed has increased, however the density is greatly reduced.

Figure 1. Glyphosate symptoms on new shoots off existing canes of giant reed (Paterson River).

The findings from the Tocal (Paterson) trial influenced the approach to be taken at the Murrurundi site, that is the higher rate of herbicide was required to achieve the desired result. The giant reed treated at this site achieved a greater than 95% brownout rate (Figure 2). This could have been as a result of the seasonal conditions at the time which appeared to be more favourable than those at Tocal.

The giant reed at the Murrurundi site was burned in the winter of 2018, with great success. The burns eliminated the majority of the above ground biomass. This burn was far more successful than that at Tocal. This is because the conditions where right at the time as well as the high percentage of dead canes, which burned more readily. Figure 3 below shows the results of the burn (same clump as in Figure 2).

Figure 2. Higher dilutions of glyphosate worked well on giant reed at Murrurundi, with >95% brownout with near perfect control (6 months after treatment, November 2017).

Figure 3. Burned giant reed clump at Murrurundi, as shown in Figure 2 (August 2018).

DISCUSSION

Based on the results, the recommended application rate of herbicide using this application method is the higher rate (glyphosate 360 g L^{-1} at the dilution rate of 20% (e.g. 200 mL product in 1 L water and glyphosate 570 g L^{-1} at a dilution of 13–14%). These rates achieved the best result with a single treatment and left the giant reed in a suitable state to burn. Giant reed has an extensive root mass and is a large plant. The key is to apply sufficient volume of herbicide onto the plant, which the UAV was able to achieve. Although the glyphosate 570 g L^{-1} (Roundup® UltraMax) worked quicker, the glyphosate 360 gL^{-1} (Roundup® Biactive) provided almost the same result after a longer time.

As giant reed tends to grow adjacent to or in waterways, the only option is to use a herbicide such as (Roundup® Biactive), which is permitted for use in aquatic zones. Despite these interim results, the use of the rotary winged Unmanned Aerial Vehicle (UAV) has proven effective and efficient in the application of herbicide on giant reed. The UAV presents several advantages over traditional methods in the treatment of giant reed. Firstly, the aircraft efficiently accesses the entire thicket and secondly, the rotor wash created by the UAV accurately pushes the herbicide through the entire stratum of the giant reed.

The ability to get over the entire thicket and achieve the necessary herbicide coverage has resulted in a significant time and cost saving as well as having zero impact on the ground. This also applies to other weeds that would otherwise be difficult to access or to gain full coverage using ground-based methods.

The burn is an important step in the control of giant reed as it eliminates the above ground biomass which has the potential in a high river flow event to form flood racks, which pose a significant risk to downstream infrastructure. Burning was the chosen method for biomass reduction in this case, however if this is not possible them mulching may be done to achieve the same outcome.

As with any weed control program follow up treatment will be necessary. It is anticipated that monitoring and required treatment will be necessary for approximately 5 years post primary treatment. This can be achieved by spot spraying small regrow before it reaches more than one m tall.

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