Stopping the invasion of *Persicaria chinensis* (Chinese knotweed) – a herbicide solution

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Summary Invasive weeds impact the economy and society globally and contribute significantly to the ecological degradation to the environment both terrestrially and aquatically. Weed incursions have continually established themselves in Australia since European settlement and will continue to invade into the future. One new weed incursion which has been recently discovered invading two localised areas within NSW is *Persicaria chinensis* (L.) H.Gross, commonly known as Chinese knotweed. This weed has been assessed as a highly invasive species. With limited literature and research available on the control of this species, a field trial using registered herbicides was established to find effective herbicide options to control these incursions. The application of a metsulfuron-methyl was the most effective with 100% control at 47 days after treatment (DAT), followed by a mixture of metsulfuron-methyl and glyphosate with 100% control at 111 DAT. Repeated treatments of a foliar spray are required for two other herbicides used in the trial. Current research for an effective herbicide has been very limited, with this study identifying effective herbicide options for controlling Chinese knotweed in Australia.

Keywords Invasive weed, new incursion, herbicides, metsulfuron-methyl.

INTRODUCTION

This paper has two aims: to review what is known about the biology of Chinese knotweed; and, subsequently, to identify the most effective herbicide to treat and eradicate Chinese knotweed within riparian corridors of New South Wales.

CHINESE KNOTWEED (*Persicaria chinensis*)

Description *Persicaria chinensis* (L.) H.Gross, (syn. *Polygonum chinense*) known as Chinese knotweed, is a scandent, divaricately branched perennial plant with stems and branches that are reddish purple in colour, glabrous and spineless with prominent nodes, and have a zigzag appearance. The stipules form a sheath on the stem, are membranaceous and glabrous with no hairs at the margin (Stuart 2015, Sasidharan n.d). The leaves are simple, alternate, ovate- to oblong-shaped entire with an acuminate apex, truncate base, 50–100 mm long and 30–70 mm wide. The leaf margins are minutely crenulated; the midrib violet-red, the upper surface of leaf with a central darker green inverted 'V' shaped spot (eFloras 2011a and b, Sasidharan n.d.) The inflorescence is a compound corymb, arranged terminally or in terminal and auxiliary positions while the peduncles are glandular and hairy (eFloras 2011a and b). The flowers are campanulate, small, white or pinkish in colour, 2.0 to 3.5 mm bearing 5 tepals, and 8 stamens with purple tips (eFloras 2011a and b, EoL 2014). The fruits are globose in shape turning dark purple when ripe. The seeds are trigonous (triangular in cross-section), small 3 to 4 mm round and black (Stuart 2015, Sasidharan n.d) (Figure 1).

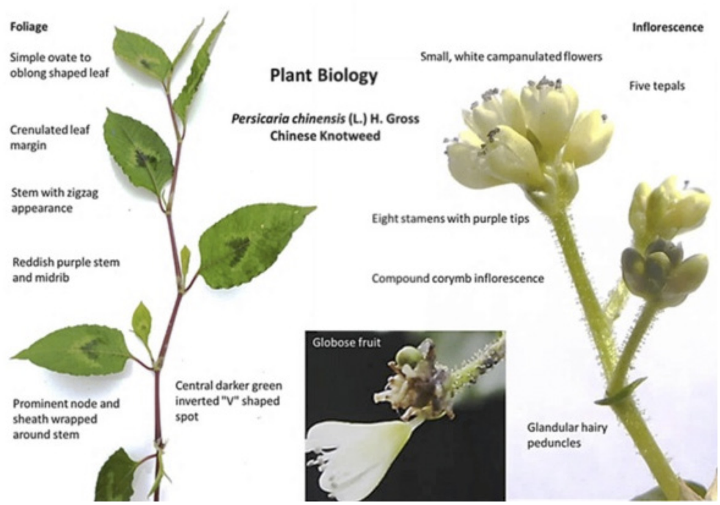

Figure 1. Plant biology close up of Chinese knotweed looking at the foliage, inflorescence and fruit. (Images K. Hignell).

Habit Chinese knotweed is a rhizomatous herbaceous perennial from the Polygonaceae family from South-east Asia (IPNI 2012) and is known as a high-risk invasive species (Wong *et al.* 2015). Chinese knotweed has been described as an upright, shrub-like perennial (Galloway and Lepper 2010), a twining perennial herb (Stuart 2015), a scrambling herb (Turner 1995) and a rhizomatous perennial that sometimes climbs (Wilson 2010). Chinese knotweed can reach a height of 1 to 1.5 m (Turner 1995, Wilson 2010, EoL 2014, Stuart 2015). It is closely related to other invasive *Persicaria* species such as princes feathers (*P. orientalis* (L.) Spach), Japanese knotweed (*P. capitate* (Buch.-Ham. ex D.Don) H.Gross), and mile-a-minute weed (*P. perfoliata* (L.) H. Gross) (Randall 2012).

This plant grows rapidly, forming thick canopies that have the ability to smother native plants (Galloway and Lepper 2010). Naturally growing from sea level to 3000 m (eFloras 2011b), Chinese knotweed can be found growing in open moist grounds, gardens, riparian zones, roadsides (Galloway and Lepper 2010, US Forest Service 2010, EoL 2014) and swamp margins (Wilson 2010, EoL 2014).

As a new incursion into New South Wales, particularly invading riparian zones (PlantNET 2016), research to identify the most effective control techniques to reduce its impact on the environment is required. There is limited information regarding effective control using herbicides (US Forest Service 2010).

MATERIALS AND METHODS

Trial site The study was conducted within the riparian corridor at Little Flaggy Creek, Kahibah Road, Kahibah, within the Lake Macquarie local government area on the Central Coast of New South Wales (NSW). Little Flaggy Creek flows from Charlestown to the west of the site to the east into Glenrock State Conservation Area then into the Tasman Sea. This site has been infested with Chinese knotweed since the discovery of the incursion in 2012 (PlantNET 2016).

The trial site has creek banks up to 2 m high with full sunlight and a minimal amount of dapple shading early morning on the eastern end of the site. The Chinese knotweed has been growing to 1–1.5 m high, covering the entire northern side of the bank. There were 25 plots established to allow 5 replicates of each treatment at the site. Each plot size was 1.5 m by 3 m with a 100% ground coverage of Chinese knotweed.

Application The applications of herbicides for this trial were performed under the APVMA permit, to allow the conduct of small scale trials with AGVET chemicals – PER 7250. Application of the herbicides was via a 10 L portable knapsack using a variable cone nozzle and a water rate of 3 L 4.5 m^{-2}. Four herbicide applications and one control were randomly selected in each of the 5 replicates. All the herbicide treatments were applied to actively growing Chinese knotweed before flowering stage.

Weather condition At the time of application on the 24 December 2015, starting at 8.00 am, weather conditions were a partly cloudy morning with the dry bulb temperature at 20°C, the humidity was at 87% and a light breeze from the south-east at five km h^{-1}. Light rain had fallen overnight but the moisture on vegetation had evaporated by application time. No rain fell within 24 hours after application.

Herbicides All herbicide applications were applied as a foliage spray and each treatment was applied according to recommended commercial standards as stated on the herbicide labels. Three individual herbicides and a mixture of two herbicides were used for this trial and were applied once only. Each herbicide was selected from a different 'mode of action' group to allow for the management of herbicide resistance.

The first herbicide was a glyphosate product, Eraze 360 Bi-aquatic™ herbicide, with an application rate of 100 mL 10 L^{-1}. Glyphosate is a broad-spectrum herbicide of choice in agriculture, urban parks, gardens, and waterways due to its low toxicity to the environment (Sánchez-Bayo *et. al.* 2010).

The second herbicide was a metsulfuron-methyl product, Metmac 600 WG™, with an application rate of 1 g 10 L^{-1}. Metsulfuron-methyl is a systemic selective herbicide targeting broadleaf and woody weeds and is very effective on weeds that include bulbs or tubers (Spencer 2012). There is an APVMA minor use permit PER14734 to use metsulfuron-methyl on alligator weed in waterways of NSW (APVMA 2015).

The third herbicide was a packaged mixture of amitrole and ammonium thiocyanate, labelled as Amitrole T™, with an application rate of 28 mL 10 L^{-1}. Amitrole and ammonium thiocyanate is another broad-spectrum herbicide routinely used for clearing weeds in irrigation channels (Sánchez-Bayo *et. al*. 2010).

The fourth herbicide treatment was the mix of glyphosate and metsulfuron–methyl. The application rate of the glyphosate was 100 mL 10 L^{-1} and metsulfuron-methyl at 1 g 10 L^{-1}.

Assessment Control assessments were undertaken in the centre 1 metre of area in each plot so that any influences from the adjacent plots were negated. A subjective visual rating of 0 to 10 (Table 1) was used to assess the control efficacy of each treatment. The scoring indicates a commercially accepted rate of

Table 1. The subjective visual rating score used control efficacy assessment.

Rate of Control	Visual appearance	% Control
0	Nil Control with no wilting or leaf colour change	0%
1	Wilting, Leaf drop, Leaf colour change	10%
2	Wilting, Leaf drop, Leaf colour change, Dieback and/or Regrowth	20%
3	Wilting, Leaf drop, Leaf colour change, Dieback and/or Regrowth	30%
4	Leaf drop, Leaf colour change, Dieback and/or Regrowth	40%
5	Leaf drop, Leaf colour change, Dieback and/or Regrowth	50%
6	Leaf colour change, Dieback and/or Regrowth	60%
7	Leaf colour change, Dieback and/or Regrowth	70%
8	Dieback and/or Regrowth	80%
9	Dieback and/or Regrowth	90%
10	Total Control with no regrowth	100%

control by considering the visual appearance of the plant material and the amount of dieback and/or re-growth each plot had without disturbance (Cook and Shoemark 2015). The site was assessed seven times throughout the trial, occurring at 14, 35, 47, 71, 91 and 125 Days After Treatment (DAT).

RESULTS

The results indicate that there is little difference in the control efficacy of Chinese knotweed between the three herbicide treatments, metsulfuron-methyl, glyphosate and the mix of these two herbicides (Figure 2). All three treatments significantly reduced the health and coverage Chinese knotweed in all plots at 35 DAT and continued to trend through to 125 DAT retaining a percentage control of 90% or above from 47 DAT.

The most effective herbicide of the trial was metsulfuron-methyl, with a control score of 10 from 47–125 DAT without regrowth. Metsulfuron-methyl was the slowest activating herbicide at 14 DAT, with only the visual appearance of leaf colour change observed. The mix treatment was second by achieving a control rate score of 10 at 111 DAT and this continued through to 125 DAT with no regrowth present. Glyphosate was the fastest activating herbicide at 14 DAT with wilting and leaf drop, then matched the rate

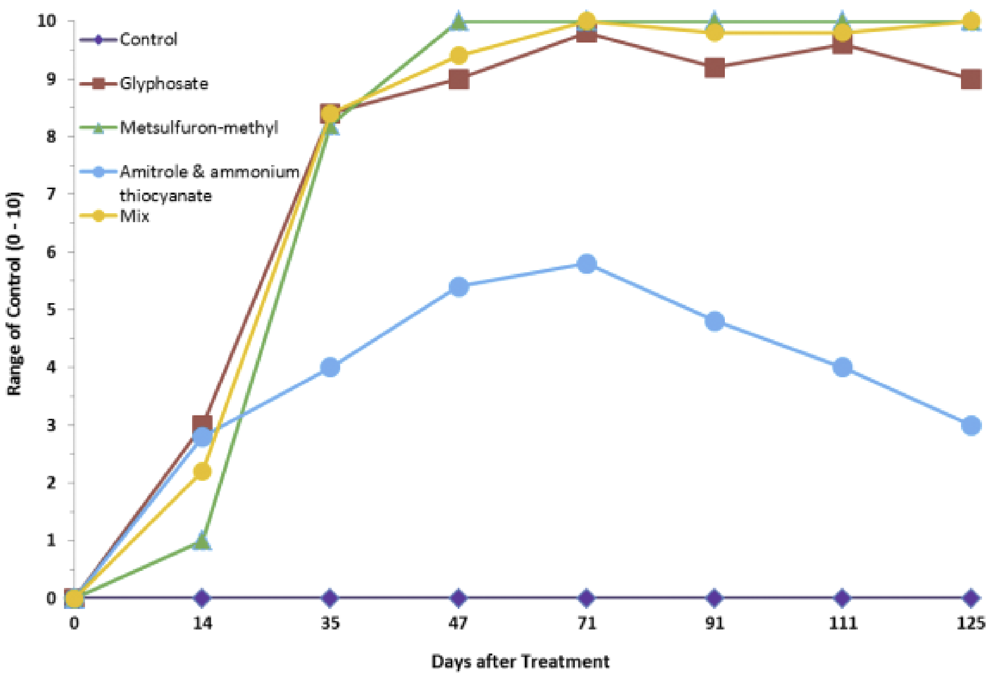

Figure 2. The average control results of each herbicide treatment on Chinese knotweed showing the variance of control from 0 to 125 DAT.

of control at 35 DAT with metsulfuron-methyl and the mix, but evidence of regrowth was present at 91 DAT and again at 125 DAT. The packaged mixture of amitrole and ammonium thiocyanate had poor control on Chinese knotweed. Its control efficacy peaked at 71 DAT with a score of 6, then declined steadily and regrowth became evident after 71 DAT.

At 35 DAT, metsulfuron-methyl, glyphosate and their mix had a control rate of 8, exhibiting a few living stems and green leaves. The packaged mixture of amitrole and ammonium thiocyanate was showing signs of approx. 40% of leaf drop and living stems plus the bleaching of foliage, with a control rate of 4.

At 91 DAT, the metsulfuron-methyl treatment had no living Chinese knotweed plants and had a control rating of 10. Both the mix and glyphosate exhibited a few live stems and a few discoloured leaves, while glyphosate had one branch of regrowth though both have a control rate of 9. The packaged mixture of amitrole and ammonium thiocyanate showed signs of leaf drop, bleaching of the leaves and tip regrowth with a control rate of 5.

DISCUSSION

No single herbicide can kill all weed species (Harrington 2000) but trialling various herbicides in a riparian zone, allows better choices to control Chinese knotweed in Australia. Consideration must be given to the accuracy and efficiency of an application of herbicide to ensure minimal export of the herbicide into the aquatic environment (Kent and Preston 2000). For this study, broad-spectrum herbicide registered for aquatic use or having an APVMA permit for minor use, directs the selection.

This study showed that metsulfuron-methyl delivered the highest rate of control at 47 DAT with 100% kill. That level of control continued over the length of the study to 125 DAT, with no emergence of other weeds within metsulfuron-methyl plots, which was probably due to the persistence of metsulfuron-methyl in the soil (Kent and Preston 2000).

Glyphosate is the most commonly used knockdown herbicide and can be applied over the full growing season and will translocate throughout the plant (Harrington 2000). This study has shown that although glyphosate was the quickest to show signs of control such as wilting and leaf drop at 14 DAT, and continued to increase in control, one application is insufficient to control Chinese knotweed due to the regrowth that occurred from 91 DAT.

Many herbicides have a narrow spectrum of weed control, so to increase control efficacy, a combination of herbicides applied to the target weed can retain longer residual, increase the herbicide effectiveness and delay the development of herbicide resistance (Damalas 2004). The mix, a knockdown herbicide glyphosate mixed with metsulfuron-methyl, a systemic known for its effectiveness on bulbs and tubers (Department of Primary Industries, Parks, Water and Environment, 2002), gave 100% control after 111 DAT. Therefore, the mix appears to be a desirable combination to control Chinese knotweed.

Another broad-spectrum herbicide treatment, amitrole and ammonium thiocyanate, is an efficacious product to control broadleaf weeds and suitable to use as an alternative to glyphosate (Sánchez-Bayo *et al.* 2010). Its systemic action, though slower than glyphosate at 14 DAT, showed what is commonly observed with a Group Q herbicide, such as the bleaching of leaves and cessation of growth at 35 DAT. This stunted growth habit allowed other weeds that germinated at the site to take over each amitrole and ammonium thiocyanate plot after 47 DAT. Amitrole and ammonium thiocyanate was not as effective as the other three herbicide treatments and is not recommended for the control of Chinese knotweed.

For similar plants of the Polygonaceae family, the United States of America (PCD 2016), New Zealand (Galloway and Lepper 2010), Indian subcontinent, Sri Lanka and West Java (Panda 2011), used a glyphosate based product to control *P. perfoliata* and *P. maculosa* Gray (syn. *Polygonum persicaria)*, (redshank) and Chinese knotweed. Research is limited with the use of metsulfuron-methyl on the Polygonaceae family, although in Norway, it has been found that *P. maculosa* first evolved resistance to Group B/2 tribenuron-methyl herbicides in 2009 and they may be cross-resistant to other Group B/2 herbicides (Heap 2018).

The consideration of alternating herbicides rather than using the same mode of action herbicides can reduce the risk of weed resistance (Rattray *et al.* 2006). Rattray *et al.* (2006) states as herbicide resistance develops, there is often a decision to increase herbicide rates for control, but avoiding this situation suggests that herbicides can be used more effectively for longer. Three different 'mode of action' groups (B, M and Q) were used in this study. With the result of effectiveness with both herbicides, metsulfuron-methyl and glyphosate on Chinese knotweed, there is the choice of using either group or the combination of both groups as the mix, to prevent the herbicide resistance especially with Group B.

The use of herbicides as a control is the most efficient way to treat Chinese knotweed due to the morphology, especially its underground rhizomes. This study has shown that the preferred control for Chinese knotweed is a foliar application of metsulfuron-methyl or its mixture with glyphosate. Weed managers may choose to select a broad-spectrum herbicide and use the chemical glyphosate; however, this herbicide will give a lower level of control and will require further treatments. The continual monitoring of sites after herbicide applications will be required to control any further regrowth. If one small plant were left to regrow, it would develop into a significant infestation within a short period.

Herbicides are an integral part of weed management and to maximise their efficacy, weed managers needs to have an understanding of their characteristics so they can minimise adverse impacts to the environment while achieving an effective control of the targeted weed. For Chinese knotweed, current research for effective herbicide options has been very limited. There is a need for continuing research and monitoring of this study, and future studies to gain long-term data on effectiveness of the herbicide application. This research has identified some effective herbicide options for the control of Chinese knotweed in Australia and may help in acquiring a minor use permit from the APVMA to treat Chinese knotweed in riparian corridors.

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