Evaluation of restoration of vegetation infested with cat's claw creeper vine (*Dolichandra unguis-cati*): soil seed bank response to herbicide and physical removal

Olusegun O. Osunkoya and Christine Perrett
Invasive Plant Science Group, Biosecurity Queensland, Department of Agriculture, Fisheries and Forestry, Ecosciences Precinct, GPO Box 267, Brisbane, Qld 4001, Australia
(Olusegun.Osunkoya@daff.qld.gov.au)

Summary Cat's claw creeper vine, *Dolichandra unguis-cati* (L.) L.G.Lohmann (formerly known as *Macfadyena unguis-cati* (L.) A.H.Gentry), a Weed of National Significance (WoNS), is a structural woody parasite that is highly invasive along sensitive riparian corridors and native forests of coastal and inland eastern Australia. As part of evaluation of the impact of herbicide and mechanical/physical control techniques on the long-term reduction of biomass of the weed and expected return of native flora, we have set-up permanent vegetation plots in: (a) infested and now chemically/physically treated, (b) infested but untreated and (c) un-infested patches. The treatments were set up in both riparian and non-riparian habitats to document changes that occur in seed bank flora over a two-year post-treatment period. Response to treatment varied spatially and temporally. However, following chemical and physical removal treatments, treated patches exhibited lower seed bank abundance and diversity than infested and patches lacking the weed, but differences were not statistically significant. Thus it will be safe to say that spraying herbicides using the recommended rate does not undermine restoration efforts.

Keywords Biological invasion, habitat restoration, herbicides, seed bank, weeds.

INTRODUCTION

Land managers involve in protection of environmental assets often use herbicides and/or mechanical control to combat exotic-invasive species. In particular, herbicide application is considered more economical and effective than mechanical or biological control. The effects of such a treatment on the above ground species composition, including cover have been studied in details (see Cornish and Burgin 2005, Marushia and Allen 2009), but until recently little is known of herbicide and/or mechanical control impact on short- and long-term composition of the soil biota, including seed bank (but see Rokich *et al*. 2009, Wagner and Elson 2014). Yet such knowledge is crucial where residual seed bank has the potential for restocking and hence valuable for restoration of invaded landscape.

Cat's claw creeper vine, *Dolichandra* (syn. *Macfadyena*) *unguis-cati* (hereafter referred to as CCC), a recently declared WoNS in Australia, is a structural parasite with conspicuous environmental damage (Osunkoya *et al*. 2011, Perrett *et al*. 2012). It is common along riparian corridors and inland conserved and managed vegetation, e.g. Eucalyptus forests of Eastern Australia. Currently there are no proven methods for its long-term control as regeneration is both from its massive underground tubers and sexually via numerous seeds produced from its long pods (Osunkoya *et al*. 2009, Buru *et al*. 2014). In March 2012, South East Queensland Water Corporation initiated series of efforts (via Landcare groups and contractors) to combat the invasive woody creeper along many creek inlets to its North Pine and Wivenhoe Dams – cutting down the climbing stems of the vine and then applying herbicide to both ends of the cut portions (swabbing) and spraying of the thick mats of the weed on the forest floor with approved herbicide/s (mainly glyphosate: 360 g L^{-1}, consisting of 1 L per 2 L water). Around the same time, the landcare group in Oxley, a suburb in western Brisbane embarked on physical removal (using secateurs and hand pulling of CCC in infested open forest (dominated by Eucalyptus species) in its inland catchment (Fort Bushland Reserve, approximately 10.5 ha in size). Thus the aim of this paper is to document likely impact, if any, of the two CCC control measures, on native flora especially the seed bank composition.

MATERIALS AND METHODS

The study sites were around the greater Brisbane region. Permanent plots in four vegetation sites (two in riparian corridors – Dayboro and Lake Manchester areas) and two in non-riparian open forests (conserved) land in the Oxley and Mt Glorious areas). The vegetations at these sites are heavily infested with the weed. Some patches of the infestations are undergoing herbicide (riparian sites) or mechanical/physical (non-riparian sites) control measures, and are consequently being monitored to document changes that are likely to occur through time in the above (standing vegetation) and below ground flora (seed bank) of these patches.

At each site, soils (following clearing of the litter layers) were collected from three vegetation patches broadly under three invasion-stage categories (treatments), each replicated five times: (a) CCC infestation patch that was recently controlled with either herbicide or mechanical (hand-pulled), (b) CCC infested patch but untreated, and (c) never infested patches. Within each site, matched-patches were close to each other, usually ≤30 m.

Using 10 cm diameter cores, soils to a depth of 7 cm were collected from these patches (five randomly-selected soil cores per replicated patch and bulked thereafter) in July – October of 2012 and again in the same time period in 2013. Soils were exposed in germination trays to adequate moisture and temperature (17°C to 32°C) for six months at the Eco-sciences Precinct glasshouse in Brisbane. Emergent seedlings were counted every two weeks, taxonomically identified and also classify into functional group of origin (native vs introduced) and life form group (grass, herb/shrub and tree). Data did not meet the assumptions of ANOVA and hence were subjected to non-parametric test. Species diversity per sample was estimated using the Shannon-Weiner index. Non-metric multidimensional scaling ordination (NMDS) using the Bray-Curtis dissimilarity coefficient and analysis of similarity (ANOSIM) on log(x + 1) transformed data (Primer vs 6) was also used to search for overall trends across invasion-stage categories and sites.

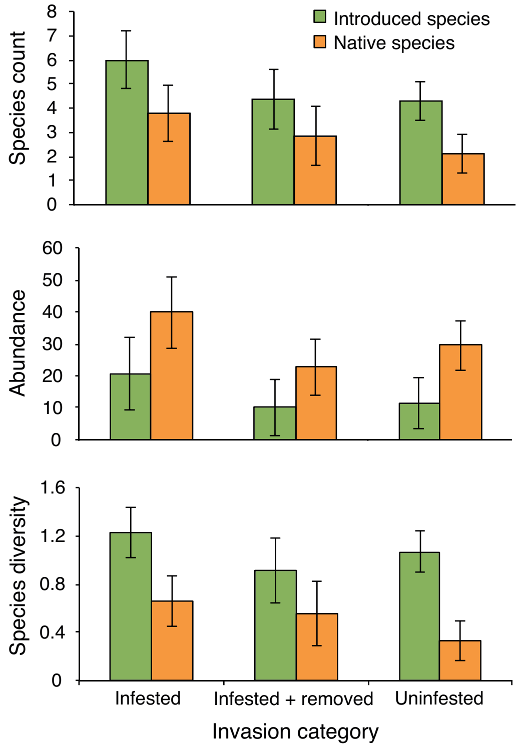

Figure 1. Mean (± SE) values of seed bank data in relation to plant origin. Data have been pooled across habitats and sampling years. Values are per sample.

RESULTS

We recorded 68 plant species from 31 families in the seed bank of the sites surveyed. 32 of the 68 species were of introduced species. Seed bank response, both in terms of abundance and diversity varied significantly between the four sites (ANOSIM, Global R = 0.417, P <0.001) and between the two years of survey (ANOSIM, Global R = 0.781, P <0.001).

Native vs non-native species In the herbicide/mechanical treated CCC plots, the abundance, species number and diversity of introduced species emerging from the soil seed bank did not differ significantly from that of native species (Figure 1). In contrast, for un-infested patches, differences in seed bank based on species origin were significant, with native species having lower species count and diversity, but higher abundance than that of introduced species.

Seed bank assemblage values were always higher in riparian habitat than in the non-riparian open forest vegetation habitat (Table 1). We found no significant difference in seed bank species count amongst the three invasion-stage categories (treatments) (Table 1). The invasion category had marginal effects on abundance and/or species diversity of seed bank, depending on habitat type. For the riparian sites, significantly higher (P = 0.06) seed abundance exists under CCC infestation compared to chemically control (treated) and patches which have never had the weed. In non-riparian sites, seed bank abundance was higher in vegetation patches with and without the weed compared to chemically treated patches (control); seed bank diversity also appeared marginally highest in the infested patches of non-riparian sites (Table 1). Nonetheless it is worth mentioning that in all indices calculated, the tendency was for much reduced values in treated patches, especially where herbicide was used as a control measure.

Ordination of the vegetation patches based on NMDS also indicated that overall differences between the three treatments were more apparent in non-riparian habitat (ANOSIM: R = 0.237; P = 0.026) than in the riparian habitat (ANOSIM: R = 0.055; P = 0.26) (Figure 2). In both riparian and non-riparian habitats,

Table 1. Mean (± SE) values of seed bank data from soils of three invasion categories of cats claw creeper vine in south-east Queensland, Australia. Significance of differences across invasion categories were tested with Kruskal-Wallis non-parametric procedure. Index values are per soil sample.

Index	Infested	Infested + removed	Uninfested (control)	X^2 test	Prob.
			Riparian habitat		
Species count	15.7 (1.56)	12.14 (1.91)	12.81 (1.56)	1.85	0.40
Abundance	102.3 (17.61)	53.4 (21.04)	64.12 (17.61)	5.46	0.06
Species diversity	1.83 (0.13)	1.74 (0.16)	1.83 (0.13)	0.06	0.97
			Non-riparian habitat		
Species count	4.79 (0.89)	3.56 (0.89)	4.3 (0.84)	0.67	0.72
Abundance	14.44 (3.71)	5.33 (0.37)	14.5 (3.52)	4.62	0.09
Species diversity	1.56 (0.17)	1.17 (0.15)	1.02 (0.14)	5.01	0.08

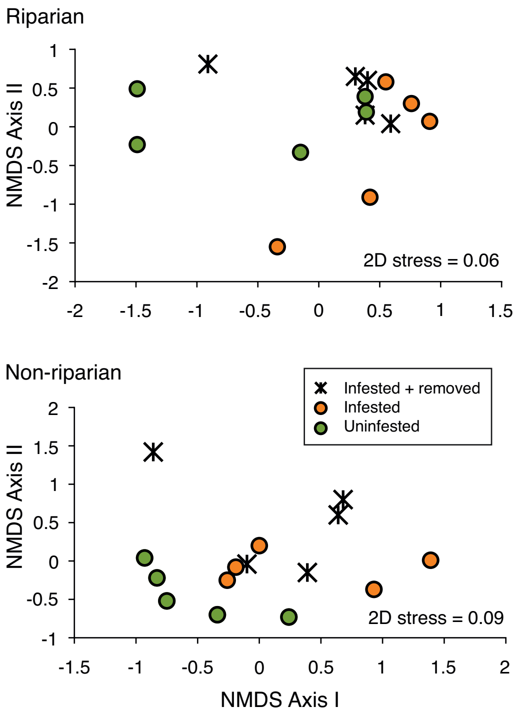

Figure 2. Typical NMDS ordination of patches of CCC invasion-stage category based on soil seed bank plant species composition (in this case that of Dayboro [riparian] and Oxley [non-riparian] sites).

patches where CCC is lacking (i.e. uninfested) pulled slightly away from the CCC treated and untreated patches (Figure 2).

DISCUSSION

A higher diversity of introduced species compared to natives across study sites will suggest that these sites are highly disturbed. Hence any restoration effort towards native biodiversity will have to rely more on assisted regeneration rather than on the soil seed bank. The higher seed bank assemblage value and lack of a major difference amongst the three invasion-stage categories for soils of riparian sites relative to that obtained for inland vegetation reflect the greater exposure and ephemeral nature of the riparian corridors as edges between terrestrial and aquatic ecosystems which tend to enhance fluxes of energy and high species turnover (Goodson *et al.* 2001, Perrett and Osunkoya 2011).

We were not able to demonstrate a clear negative effect of control treatment using herbicide on seed viability of buried seeds. Thus it will be safe to say that spraying herbicides using the recommended rate does not undermine restoration efforts. This is in contrast to the findings of Rokich *et al*. 2009 and Wagner and Nelson 2014. It is possible that a significantly greater effect might still be picked up at a later stage in the growth cycle of plants inhabiting such treated patches (see Rokich *et al*. 2009). Our observed trend could also be due to fast degradation in the soil of the herbicide/s used (Cornish and Burgin 2005, Foo *et al*. 2010). We also observed no difference in seed bank assemblage across invasion-stage categories, which also included uninvaded patches, a result similar to that obtained for soil ant assemblage (Osunkoya *et al*. 2011). Thus despite the structural dominance of the investigated weed in habitats infested, minimal impact on soil biota is evidenced. We have limited data on invasion history of the investigated patches; if time since invasion is relatively short and where soil seed bank are long lived, there may be insufficient time to observe native seed bank depletion (see Warr *et al*. 1994, Mason *et al*. 2007).

ACKNOWLEDGMENTS

We thank Daniel Garcia for showing us the network of riparian corridors under the jurisdiction of SEQ Water that are infested with cats claw creeper vine and undergoing herbicide and/or physical removal control measures.

REFERENCES

Buru, J.C., Dhileepan, K., Osunkoya, O.O. and Scharaschkin, T. (2014). Seed germination may explain differences in invasiveness and prevalence: a case study using cat's claw creeper. Proceedings of the 19th Australasian weeds conference, ed. M. Baker, pp. 223-6. (Tasmanian Weed Society, Hobart).

Cornish, P.S. and Burgin S. (2005). Residual effects of glyphosate herbicide on ecological restoration. *Restoration Ecology* 13, 695-702.

Foo, C.L., Harrington, K.C. and MacKay, M.B. (2010). Herbicide tolerance of three ornamental ground cover species: *Polygonium capitulum*, *Sedium mexicanum* and *Soleirolia soleiroli*. Proceedings of the 17th Australasian weeds conference, ed. Zydenbos, S.M., pp 303-6. (NZ Plant Protection Society, Christchurch, New Zealand).

Goodson, J.M., Gurnell, A.M., Angold, P.G. and Morrissey, I.P. (2001). Riparian seed banks: structure, process and implications for riparian management. *Progress in Physical Geography* 25, 301-25.

Marushia, R.G. and Allen, E.B. (2009). Control of exotic annual grasses to restore native forbs in abandoned agricultural lands. *Restoration Ecology* 19, 45-54.

Mason, T.J, French, K. and Russel, K.G. (2007) Moderate impacts of plant invasion and management regimes in coastal hind dune seeds. *Biological Conservation* 134, 428-39.

Osunkoya, O.O., Pyle, K., Scharaschkin, T. and Dhileepan, K. (2009). What lies beneath? The pattern and abundance of the subterranean tuber bank of the invasive liana cat's claw creeper, *Macfadyena unguis-cati* (Bignoniaceae). *Australian Journal of Botany* 57, 132-8.

Osunkoya, O.O., Polo, C. and Andersen, A.N. (2011). Invasion impacts on biodiversity: responses of ant communities to infestation by cat's claw creeper, *Macfadyena unguis-cati* (Bignoniaceae) in subtropical Australia. *Biological Invasions* 13, 2289-302.

Perrett, C., Osunkoya, O.O. and Clark, C. (2012). Cat's claw creeper vine, *Macfadyena unguis-cati* (Bignoniaceae) invasion impacts: comparative leaf nutrient content and effects on soil physico-chemical properties. *Australian Journal of Botany* 60, 539-48.

Rokich, D.P., Harma, J., Turner, S.D.R, Sadler, R.J., and Tan, B.H. (2009). Fluazifop-p-butyl herbicide: implication for germination and growth of Australian plant species. *Biological Conservation* 142, 850-69.

Wagner, V. and Nelson, C.R. (2014). Herbicides can negatively affect seed performance in native plants. *Restoration Ecology*, 1-4.

Warr, S.J., Kent, M. and Thompson, K. (1994) Seed bank composition and variability in five woodlands in south-west England. *Journal of Biogeography* 21, 151-68.