Metsulfuron-methyl impact on native vegetation in the Daintree lowlands, far-north Queensland, Australia

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Summary As part of a continuing control program for Singapore daisy, *Sphagneticola trilobata*, using metsulfuron-methyl herbicide, in the lowland tropical environments of the Daintree, we needed to assess the impact of the herbicide on native vegetation, as the extensive nature of this weed invasion prevents selective application. We assessed the impact on 78 native species exposed to the herbicide and found 63 were resistant, and 17 were killed after a spray application that would reliably kill the Singapore daisy. The native sensitive species by and large were soft leaved pioneer species that could readily re-colonise the area once the Singapore daisy had been removed. This resistance permits a far easier approach to weed control, as the extreme care that is required to avoid spraying native seedlings, can be greatly relaxed. Additionally metsulfuron-methyl is proving to be a highly effective herbicide for controlling an unusually wide variety of other serious environmental weeds, including lantana and syngonium.

Keywords Metsulfuron-methyl, weeds, herbicide resistance, tropical ecosystems.

INTRODUCTION

We (CTTRS) have been carrying out a program of management of Singapore daisy, *Sphagneticola trilobata* (Asteraceae) a fast growing, semi-prostrate creeper, initially introduced from S. America for gardeners as a soil stabiliser and ground cover. In far-north Queensland, it has become a major environmental weed, greatly exceeding lantana in extent and impact in the coastal lowlands, especially along waterways. Herbicides such as glyphosate are not effective in controlling it. Metsulfuron-methyl (Brushoff®, Brushkiller®, Associate®) is proving to be exceedingly effective against Singapore daisy. Given the high densities of the weed and the high probability that there are 'volunteer' seedlings of native species present under the weed cover, we initially set up field trials in representative rainforest environments to determine the spectrum of sensitivity of native species seedlings to metsulfuron-methyl, and this was followed through field observations carried out during later spraying operations.

Sphagneticola trilobata is a prostrate scrambler which produces adventitious roots at each node. Small nodal fragments can re-shoot rapidly. It is able to rapidly colonise disturbed or cleared areas (for example along roads, along the coastline or after cyclone damage) and forms dense mats that inhibit the growth of native plant species. It appears to be allelopathic. While seeding does occur, it is considered relatively uncommon, but in our experience it is definitely not insignificant. Most of the propagules (stem fragments and seeds) are carried by machinery (particularly roadside mowers) or by water, especially during floods. Serious riparian infestations can often be traced to infested garden plots high in the watershed of river and creek systems. These riparian infestations frequently give rise to severe and extensive littoral infestations, the propagules being washed up on shore during periods of heavy rain. Werren (2003) lists *S. trilobata*, as the forb with the highest invasive potential in Queensland.

Sphagneticola trilobata has a reputation as a 'difficult to manage' weed (Biosecurity Qld Fact Sheet). Non-chemical means of combating Singapore daisy (hand pulling) are restricted to 'mopping up' operations in relatively clear areas, especially in sandy littoral zones, where it is easy to dig the intact plants out of the sand by hand. The extent and density of current infestations make manual removal totally impractical. Conventional wide spectrum herbicides such as glyphosate are ineffective as they cause die-off of the exposed plant which is followed by re-sprouting and, more importantly, also results in severe collateral destruction of native vegetation.

MATERIALS AND METHODS

To determine the impact of the herbicide on juveniles of native plant species, we initially observed approximately 350 native plants (79 species), in 3 different ecosystems in the Cape Tribulation area (rainforest, littoral and disturbed forest) to generate a response spectrum of common native species. This was augmented by further observations during control spraying. We also examined its effect on a range of exotic invasive weed species common in the area.

The herbicide Metsulfuron-methyl (Brush-Off®, Brushkiller 600®, Associate®) is a Group B member of the sulfonylurea group of herbicides. The dry concentrate contains 60% active material. It is a translocated herbicide that acts as an inhibitor of the enzyme aceto-lactate synthase, which inhibits cell division in the shoots and roots of the plant. It is biologically active at low application rates and is commercially used in the crops of wheat, barley and pasture and also for the control of certain broadleaf species in native pastures. We apply it as a solution of 0.1 g concentrate per litre water, together with a non-ionic, non-foaming detergent surfactant at 1 mL L^{-1}. Metsulfuron-methyl is rapidly taken up by plants through the roots and foliage. The chemical is translocated throughout the plant, but is not persistent. It is broken down to non-herbicidal products in tolerant plants, avoiding contamination of the soil. The actual speed of break-down in these tropical soils has not been determined. Metsulfuron-methyl is being used in rehabilitation work on bitou bush (on sand) and, in association with 2,4-D-amine, on gloriosa lily (Giles and Milner 2010).

The herbicide also is reported to have extremely low toxicity to both terrestrial and aquatic vertebrates and invertebrates (EXTOXNET), Gunasekera (2006) which allows its use along stream banks where some of the highest densities of Singapore daisy are found, assuming care is taken not to spray directly in the stream. EXTOXNET reports that the LD_{50} of metsulfuron-methyl for aquatic animals is approximately the same as the applied spray concentration, so with the possible exceptions of small standing bodies of water, the water body dilution should be such as to render it (and the surfactant) effectively harmless (although algae and some water weeds are sensitive). Gunasekera (2006) discusses in great detail the probable fate and impacts of applied metsulfuron-methyl when used in waterways for control of *Alternanthera*, and comes to a similar conclusion.

Field survival assessment We set up the assessment study in conjunction with continuing weed-control spraying for Singapore daisy in the Cape Tribulation to Cow Bay region (Map 1). We tagged each native seedling with numbered survey tape, and attempted to determine their identity as early in the project as we could (which was not always possible). All seedlings in the areas infested with Singapore daisy were sprayed, however spraying larger native plants (larger than 300 mm height) was avoided.

The original field-based study extended from October to December 2006 during a relatively dry period, and the final assessment was carried out mid-February 2007. However, continuing Singapore daisy control work since then has allowed us to add significantly to the list of resistant species, from a wider variety of habitats.

In the initial study, the state of the plants were assessed at 2-week intervals over 6 weeks, and scaled on a 1–5 scale. 1: apparently totally healthy, 2: with some wilting or browning, 3: with substantial wilting or browning, 4: moribund, 5: dead.

All the plants in the initial study marked were distributed in 4 areas (Map 1):

- Dead Cow Creek (seriously degraded, bulldozed land with soil dumping)
- Noah Flat (rainforest regrowth on rocky eroded soil)
- Thornton Beach (littoral and disturbed littoral forest on sand)
- Rainforest Camp (roadside and stream bank).

Map 1. Location of initial study sites (black areas). TTRS is the location of the Cape Tribulation Tropical Research Station. The dark grey areas represent various conservation buy-back blocks (not relevant to this study). Subsequent weed control work has covered much of the cleared areas (the pale areas outside the light grey zone) as well as beach infestations.

Spraying was carried out using a specially designed, battery powered 'Quick-spray' unit, fitted with a 250 litre tank, 250 metre retractable hose and hand-piece ('Turbo spray'), using flows of approximately 2 litres per minute at approximately 8 atm pump pressure. As many of the infested areas were quite extensive, this allowed rapid and controlled spraying of the Singapore daisy, and hand-spray access to areas far removed from tracks. The flow resistance of the length of hose (250 m) produced effective low operating pressures (at the handpiece) which reduced the degree of uncontrolled spray drift and made targeting infestations far easier. Metsulfuron-methyl (600 g kg^{-1}; various brands) had concentrations of 100 mg L^{-1} with 1 mL L^{-1} wetting agent (BS 1000 or Econowet 1000).

RESULTS

Space does not allow for a detailed analysis of the results from the 4 areas. The following set of tables summarises the species tested (both initially and, as a result of continued weed control over the ensuing 6 years), and their responses to spraying with metsulfuron-methyl. From these tables it should be evident that a wide range of native genera are insensitive to metsulfuron-methyl, and a wide range of serious weeds are sensitive to it.

Resistant plants were those which either showed no effects following spraying, or some degree of leaf damage (or leaf drop) then followed by recovery. Sensitive plants either died immediately, or showed increasing damage over time, eventually dying. There was a lot of variation in responses within families of plants. While *Syngonium* (Araceae) was sensitive, *Epiprenum* (native Monstera) (Araceae) was not.

Tables 1–4 (responses of plants to metsulfuron-methyl herbicide) are summary lists, including species from the initial study, as well as species later encountered during the succeeding 6 years. No detailed records were taken of individual species during routine spraying (that was not possible), but each of the species listed in the following tables have been encountered (and sprayed) well over 25 times each.

DISCUSSION

Singapore daisy is fast becoming an environmental weed with major impacts in the Wet Tropics. Very little control has been undertaken, in part it appears, due to concern about the impact of herbicide on native plant seedlings (given that most experience is with glyphosate), and evident apparent lack of awareness of the efficacy of metsulfuron-methyl, which until recently, with the expiration of the patent, was expensive (despite its being listed as a suitable herbicide for Singapore daisy by Biosecurity Qld). Glyphosate causes dieback of Singapore daisy, followed by vigorous regrowth, as well as causing extensive 'collateral damage' to other species.

The results of this study indicate that for WT lowland rainforests, the great majority of the native species encountered are resistant to metsulfuron-methyl (62/78). A study completed in 2010 as part of a project to eliminate glory lily (*Gloriosa superba*) on the Sunshine Coast, indicated that using a mix of metsulfuron-methyl and 2,4-D amine was equally remarkably sparing of native flora, with 44/52 species surviving the treatment (Gilles and Milner 2010).

This study clearly indicates that 'broad area' spraying (that is with minimal effort being taken to avoid spraying native seedlings), can achieve very high rates of success with very limited impact on most native species. The native sensitive species, by and large were soft leaved pioneer species that could readily re-colonise the area once the Singapore daisy had been removed, or after replanting. Metsulfuron-methyl does not appear to impact any grass species that we encountered, and we have not observed any impact on natural regeneration.

It is essential that the areas sprayed be re-visited at least twice (at 3-month intervals) after the initial spray (which should be undertaken, if possible, in summer— at the period of maximum plant metabolic activity), to locate missed areas, and to kill seedlings and re-sprouts. After that, a once-a-year visit should be sufficient. Failure to do this can have the result, in our tropical climate, that the area sprayed will return to its pre-spraying state in about 2–3 years. We have some very salutary examples in the Daintree lowlands of this having happened.

CONCLUSIONS

In the lowlands wet tropics, metsulfuron-methyl is proving to be an effective herbicide for the management of a wide variety of introduced weeds, not only Singapore daisy, as it targets such a wide variety of currently targeted weed species, with relatively little impact on the native flora. Given the increasingly erratic nature of our climate here (it is getting significantly wetter), the dry weather opportunities for careful focussed weed control are diminishing—it becomes essential to 'get in fast, and get everything'. We suggest that it should be used as the first herbicide in regeneration areas— and its impacts on native and introduced species noted. It is primarily a broadleaf herbicide, and should be effective against a wide range of weed species. If it is not effective, then other herbicides such as glyphosate can be used.

Table 1. Summary list of resistant native plant species. (V = vine, G = grass).

FAMILY	PLANT	FAMILY	PLANT
Acanthaceae	*Pseudanthemum variable*	Meliaceae	*Dysoxylum* sp.
Annonaceae	*Haplostichanthus johnsonii*	Meliaceae	*Vavae amocorum*
Annonaceae	*Pseudovaria froggatti*	Menispermaceae	*Pachygone longifolia* (V)
Apocynaceae	*Alyxia spicata*	Mimosaceae	*Adenanthera pavonina*
Apocynaceae	*Ichnocarpus frutescens*	Myristicaceae	*Myristica insipida*
Araceae	*Epiprenum pinnatum*	Myrsinaceae	*Rapanea porosa*
Araliaceae	*Polyscias* spp. (variable response)	Myrtaceae	*Lyndsayomyrtus* sp.
Araliaceae	*Scheffera actinophylla*	Myrtaceae	*Syzygium monospermum*
Caesalpiniaceae	*Pongamia pinnata*	Myrtaceae	*Syzygium* sp.
Celastraceae	*Salacia disepala* (V)	Palmae	*Archontophoenix alexandrae*
Combretaceae	*Terminalia arenicola*	Palmae	*Normanbya normanbya*
Combretaceae	*Terminalia catappa*	Pandanaceae	*Freycinettia scandens*
Combretaceae	*Terminalia sericocarpa*	Pandanaceae	*Pandanus* spp.
Convolvulaceae	*Ipomea pes-caprae* (V)	Poaceae	Grasses (in general)
Dilleniaceae	*Tetracera daemeliana* (V)	Poaceae	*Haplosmenius hirsuta* (G)
Euphorbiaceae	*Breynia cernua*	Poaceae	*Icheimum rugosa* (G)
Euphorbiaceae	*Endospermum morocephalotus*	Poaceae	*Oplisemus* spp. (G)
Euphorbiaceae	*Glochidion sumatrum*	Poaceae	*Thuarea involucra* (G)
Euphorbiaceae	*Macaranga involucrata*	Proteaceae	*Darlingia darlingiana*
Euphorbiaceae	*Macaranga polyanum*	Proteaceae	*Helicia montoniana*
Euphorbiaceae	*Macaranga tanarius*	Rhizophoraceae	*Carallia brachiata*
Fabaceae	*Derris trifoliata* (V)	Rubiaceae	*Cyclophyllum multiflorum*
Fabaceae	*Vandesina retusa* (V)	Rubiaceae	*Tarenna dalaychyanum*
Fabaceae	*Vigna mauritiana* (V)	Sapindaceae	*Dodonea viscosa*
Icacinaceae	*Gomphandra australiana*	Supindaceae	*Guioa aculifolia*
Lauraceae	*Cryptocarya* sp.	Supindaceae	*Mischocapus exangulatus*
Lauraceae	*Entiandra glauca*	Supindaceae	*Mischocarpus granissima*
Lauraceae	*Litsea brevumbellifera*	Supindaceae	*Synima cordiorum*
Lauraceae	*Litsea leefeana*	Sapindaceae	*Toecheima* spp.
Meliaceae	*Dysoxylum arborescens*	Smilacaceae	*Smilax* spp. (V)
Meliaceae	*Dysoxylum papuanum*	Verbenaceae	*Clerodendron* sp.
Meliaceae	*Dysoxylum pettigrewanum*		

Table 2. Sensitive native species.

FAMILY	PLANT	FAMILY	PLANT
Asteraceae	*Melanthera biflora*	Melastomaceae	*Melastoma affine*
Bignoniaceae	*Deplanchea tetraphylla*	Mimosaceae	*Acacia* sp.
Casurinaceae	*Casurina equisitifolia*	Moraceae	*Ficus congesta*
Elaeocarpaceae	*Elaeocarpus grandis*	Myrtaceae	*Melaleuca leucodendron*
Goodeniaceae	*Scaevola taccada*	Rhamnaceae	*Alphitonia petriei*
Lamiaceae	*Clerodendrum* spp.	Rosaceae	*Rubus* spp.
Lecythidaceae	*Barringtonia asiatica*	Rutaceae	*Euodia elleryana*
Malvaceae	*Hibiscus tiliaceus*	Sapotaceae	*Pouteria* sp.?

Table 3. Resistant weed species.

FAMILY	PLANT	FAMILY	PLANT
Annonaceae	*Anona glabra* (W)	Heliconiaceae	*Heliconia pittascorum*

Table 4. Sensitive weed species.

FAMILY	PLANT	FAMILY	PLANT
Acanthaceae	*Brilliantasia lamium* (Brilliantasia)	Melastomaceae	*Dissotis rotundifolia*
Acanthaceae	*Odontonema tubiforme*	Melastomaceae	*Tristema mauritianum*
Araceae	*Dieffenbachia maculata*	Mimosaceae	*Mimosa pudica*
Araceae	*Syngonium* spp. (Arrow vine)	Nephrolepidaceae	*Nephrolepsis ?exaltata* (Fishbone fern)
Araceae	*Alocasia* spp.	Verbenaceae	*Lantana camara*
Araceae	*Philodendron* spp.	Verbenaceae	*Stachytarpheta* spp.
Asteraceae	*Elephantopsis mollis* (Tobacco weed)	Fabaceae	*Pueraria phaseoloides*
Asteraceae	*Praxelis* (*Eupatorium*) *clematidea*	Fabaceae	*Centrosema pubsecens*
Asteraceae	*Sphagneticola trilobata* (Singapore daisy)	Lamiaceae	*Hypsis capitata*
Convolvulaceae	*Ipomea indica* (blue morning glory)	Zingerberaceae	*Costus speciosus*

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