Stevia ovata – not so sweet

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Summary Native to elevated areas of the tropical Americas, *Stevia ovata* Willd (candyleaf) does not have a record of weediness overseas. Closely related to *Stevia rebaudiana* Bertoni (a commercially grown sweetening agent), *S. ovata*, with its pretty white flowers and soft sweet-scented leaves, may not seem like much of a threat. However, affected land managers in north Queensland's Atherton Tablelands know better. The woody multi-stemmed perennial shrub has infiltrated open habitats, including cattle grazing lands, and road and power line corridors. Its rate of spread and formation of virtual monocultures is a growing cause for concern. *S. ovata*'s observed weedy behaviour in these situations, coupled with the fact that this region has the only known infestations in Australia, has led to its local declaration by the Tablelands Regional Council, and the formation of the *S. ovata* Working Group.

Keen to quash further *S. ovata* infestation, this group of concerned stakeholders initially requested research into the ecology and control of the plant, and were a driving force behind a successful multi-agency delimitation exercise which took place in June 2015. Biosecurity Queensland took up the research challenge and investigated several aspects, including seed longevity, seed dispersal, growth rates, reproductive age and size, lifecycle trends and control options.

This paper presents an overview of *S. ovata* and its history of in Australia, and describes our research into its ecology and control.

Keywords Candyleaf, ecology, seed, control, herbicides.

INTRODUCTION

Stevia ovata belongs to the tribe Eupatorieae of the family Asteraceae. Also in this tribe are the genera *Mikania* Willd. and *Chromolaena* D.C which contain species that are also priority weeds in Queensland (DAF 2016). A native to the southern United States and tropical Central America, plants of the genus *Stevia* are often found at elevations of 1000–3000 m (Grashoff 1972).

Stevia ovata was first reported in Australia in 2007 near Ravenshoe on the Atherton Tablelands inland from Cairns at an altitude of around 900 m. Despite the plant's limited known distribution in Australia, analysis of the climate in this species native range suggests it has the potential to infest far larger and cooler areas of eastern and southern Australia (Murphy *et al*. 2009). When it first came to the attention of Local Government weed managers, surveys found plants to be within a relatively restricted area. This situation gave rise to the possibility of containing the weed's spread and realistically reducing the population with our research findings providing the tools.

Research into the following aspects have been either completed or initiated:

- Germination requirements,
- Age to reproductive maturity,
- Seed longevity in soil (in Wet and Dry Tropics of north Queensland),
- Seed longevity in water (fresh/salt), and
- Herbicide screening and rate refinement.

A summary of general observations observed during the research along with the key findings are presented in the following sections.

GENERAL OBSERVATIONS

These observations were made in the field and in shade house experiments with both showing very similar results.

The plant itself originates as a single-stemmed herb which is easily identifiable by its distinctive white flower clusters. Flowering occurs around May (late autumn), and seed maturation commences around June (early winter) As the flowers are relatively easily seen in the open dry sclerophyll setting, surveying is best achieved during this period, though treatment is most effective before flowers are fully formed.

Seedlings can flower as early as three months after germination and at heights as small as 8 cm. Plants can exceed 3 m in height reaching densities of up to 30 plants m^{-2} to the exclusion of most other understory species.

Stevia ovata stems die back to ground level around September with re-shooting and seedling emergence occurring after the first substantial summer rain. This aspect of the species biology means that there are periods of each year when control operations are not possible and detection is extremely difficult. After its annual dieback, the following year's growth often

emerges with multiple stems, increasing in number until it obtains a dense, shrubby appearance. Some have over 30 stems, with a large, strong root mass. Reproduction is not limited to seeds with vegetative reproduction occurring from stem sections placed on soil.

RESEARCH OVERVIEW

Germination requirements Freshly collected achenes (hereafter seeds) were placed in temperature/light controlled incubators to determine suitable conditions for germination. Conditions implemented included set temperature (25°C, 24 h), cycling temperatures (30°C, 12 h/20°C, 12 h) and set light (24 h), cycling light (12 h/12 h). Results indicate fresh seed is readily germinable and highly viable at approximately 75%. Varying temperature and light regimes had little to no effect.

Seed longevity in soil Fresh seed enclosed within mesh packets were buried at the Centre for Wet Tropics Agriculture (South Johnstone near 17° 36'S, 145° 59'E, altitude 15 m) and the Tropical Weeds Research Centre (Charters Towers near 20° 05'S, 146° 16'E, altitude 310 m). The seeds were placed on the soil surface and at depths of 2.5–3, 10 and 20 (Charters Towers only) cm below the surface, a common method for assessing soil seed bank persistence (Brooks and Setter 2012). Packets were retrieved at set intervals for viability testing. Most viable seed buried at 0, 2.5–3 or 10 cm in soil was exhausted within one year. No viable seed was found after three years buried in soil in either trial site.

This indicates that *S. ovata* has a relatively short-term persistent seed bank, according to the classification system developed by Thompson *et al.* (1997). However, seed could be retained on the stems even after the plant had died back. Some of this 'standing seed' was viable after one year.

Seed viability after immersion Longevity was determined by placing fresh seed within porous mesh packets and immersing them in fresh, brackish or salt water in fish tanks in the laboratory at the Centre for Wet Tropics Agriculture. Replicate seed packets were retrieved from the tanks at set intervals between 1 and 128 days for viability testing. Seed placed in fresh water continued to germinate in the water for the first four weeks before being depleted. Seed in brackish and saltwater did not germinate while immersed but were found to be viable after 14 weeks. Whilst immersion in fresh, brackish and saline water is no barrier to dispersal, germination and establishment is ultimately dependent on viable seed landing in a suitable niche.

Seed buoyancy In laboratory trials of seed buoyancy, lots of 50 *S. ovata* seeds placed in beakers of fresh water were observed regularly until all the seed sank. Some beakers were also constantly agitated using a laboratory sample rocker. In all beakers, less than 50% of the seed was floating after 10 hours, less than 10% of seed was floating after 48 hours and nearly all seeds had sunk after 126 hours.

These findings suggest that *S. ovata* has the potential to spread considerable distances down fast flowing tropical creek and river systems. Immersion in different water types is no barrier to viable seed dispersal and the seed can remain buoyant in moving water. Downstream spread is more likely to be limited by the seed reaching a site to establish and the speed of the water, rather than distance or salinity levels.

Seed size and dispersal Although *S. ovata* is in the Eupatorieae tribe, where many species are described as primarily wind dispersed, Cortes-Flores *et al*. (2013) list this species, and several other *Stevia* spp. as having an epizoochorous dispersal syndrome. While the length of the seed is 2.44 mm (n = 100), *S. ovata* has an extremely short pappus. Based on the weights of four lots of 50 seeds the seed is also light with an average weight of 0.086 mg. Due to the form of the seed and shrubby stature of plants, most wind dispersal is likely to be in the vicinity (metres to tens of metres) of the parent plants. Water dispersal and adhesion of the light seed are seen as more likely to lead to long distance dispersal. In Mexico, 92.4% of the 79 native *S. ovata* populations reported by Soejima *et al.* (2001) contained agamospermous polyploid plants; the remaining 7.6% were diploid populations. If plants in the local incursion are apomictic like most of those in Mexico, then a single *S. ovata* could produce viable seed without pollination and start a new infestation.

Age to reproduction Under controlled conditions within shade houses at both the Centre for Wet Tropics Agriculture (South Johnstone) and the Tropical Weeds Research Centre (Charters Towers), newly germinated seedlings were observed for growth rates and reproductive capacity. Cohorts were planted monthly to examine variations due to seasonality. Minimum age to reproductive maturity was recorded at three months with flowering and seeding were found to be synchronised irrespective of planting month, and season-driven. The older cohorts obtained heights of up to three metres with multiple stems.

Herbicide screening A comprehensive herbicide screening trial has been completed in a dense infestation (near 17° 44'S, 145° 25'E, altitude 690 m) south of

the town of Ravenshoe. We applied 12 foliar herbicides as listed in Table 1 at two rates, to 1800 plants, using high-volume, low-pressure application methods. Pulse wetter at 200 mL 100 L^{-1} and Spraymarker dye at 200 mL 100 L^{-1} were used with each treatment (excluding control). Treatments were applied using Croplands Swissmex 20-litre backpack sprayers with hand-wands to deliver an overall foliar spray to the point of run-off.

The large-scale field trial identified several herbicides that caused high mortality of *S. ovata*. For example, fluroxypyr (Starane™ Advanced) and triclopyr/picloram/aminopyralid (Grazon™ Extra) were both very effective. Aminopyralid/fluroxypyr (Hotshot™) also gave high mortality but was not quite as effective as the other two. These chemicals were effective at rates in line with the Queensland Environmental Weeds Permit (APVMA 2016).

Some herbicides were quite ineffective, including glyphosate (Roundup® 360), glyphosate/ metsulfuron-methyl (Roundup® 360/Brushoff® 600) and di-sodium methyl arsonate (DSMA Clear 250). At present, this permit (APVMA 2016) contains only a few recommendations for *S. ovata*, however this research will lead to a specific *Stevia* permit in the future, with more options.

Rate refinement The three effective herbicides listed above were further tested in another field experiment to determine their efficacy at lower rates, bringing some in line with those used for co-occurring weeds such as *Chromolaena* odorata L. King & Robinson (Siam weed) and *Lantana camara* L. The results are currently being analysed but all appear to have been quite successful at the lower rates thus reducing overall costs to management.

Other control options Low-volume, high-concentration application methods for the three herbicides listed previously were also tested in the same infestation as the screening and refining trials, and show very promising results. Further replicated trials have commenced to verify the effectiveness of this method and refine the application rates.

'Splatter' techniques are especially useful for difficult terrain, where access with regular foliar spray equipment may be impossible (Brooks *et al*. 2014). A cut-stump method using 4.47 g a.i. L^{-1} aminopyralid and 44.7 g a.i. L^{-1} picloram (Vigilant II™ gel) has also been trialled which may prove useful in controlling individual plants while surveying in isolated/ rough terrain.

Table 1. Rates of herbicides used in initial herbicide screening.

Product	Active ingredient| (g a.i. L^{-1})	Low rate applied (g a.i. L^{-1})	High rate applied (g a.i. L^{-1})
Roundup® 360	glyphosate 360	4.50	9.00
Grazon Extra™	triclopyr 300	1.50	3.00
	picloram 100	0.50	1.00
	aminopyralid 8	0.04	0.80
Starane Advanced™	fluroxypyr 333	2.00	4.00
Hotshot™	fluroxypyr 140	0.98	1.96
	aminopyralid 10	0.07	0.14
Garlon™ 600	triclopyr 600	1.80	3.60
Tordon™ 75D	2,4-D 625	1.95	3.90
	picloram 75	0.49	0.98
Lontrel™	clopyralid 300	0.38	0.75
2,4-D™ 625	2,4-D 625	2.50	5.00
DSMA™	di-sodium methyl arsonate 250	7.50	14.00
Unimaz™	imazapyr 250	1.25	2.50
Roundup® 360 + Brushoff®	glyphosate 360	4.50	4.50
	metsulfuron-methyl 600	0.03	0.06
MAT™ 28	aminocyclopyrachlor 212	0.10	not applied
	metsulfuron methyl 600	0.76	

Due to an annual capacity to regenerate from ground or below ground level, slashing/cutting without the use of herbicides does not appear to be a useful control measure for *S. ovata*. Field observations of plants after fire have also shown re-shooting from the below ground root mass.

CONCLUSION

The preliminary results of the ecological and herbicide trials provide useful information and a number of tools for land managers to deal with this weed before it becomes a greater problem. They should be confident that they can target a conspicuous plant at a set time of year with effective control measures and a short-lived seed bank. With adequate resourcing, this small incursion can be effectively treated in the short to medium term before this species becomes a more widespread problem that requires control at a much larger cost. However, our studies reinforce the weedy potential of *S. ovata*, as demonstrated by its high fecundity and dominance of pasture situations. The window for detection and control of this species is short and the potential for seed dispersal particularly through vectors such as water, roads and grazing stock is high.

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