

Research reports

Management of the South African grass *Tribolium uniolae* (L.f.) Renvoize invading threatened plant communities in the Brixton Street Wetlands

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Summary

The South African grass *Tribolium uniolae* (L.f.) Renvoize is invading bushland around Perth and has the potential to become a serious environmental weed in southwest Western Australia. Trials were set up to test the effectiveness of herbicides Roundup[®], Fusilade[®] and Sertin Plus[®] on different growth stages of *T. uniolae* at different times of the year. The trials were established in the Brixton Street Wetlands south east of Perth where *T. uniolae* is serious threat to native plant communities. A mean of 26.1% (se ± 8.0) of plants in trial plots resprouted following an unplanned wild fire in January 2000. Fusilade at 10 mL L⁻¹ + Pulse[®] and Roundup at 10 mL L⁻¹ were applied to resprouting plants resulting in 5.4% (se ± 2.9) and 2.2% (se ± 5.1) survivorship respectively. Fusilade at 15 mL L⁻¹ + Pulse was 100% effective on mature plants when applied at flowering time however these results were compounded by one of the driest seasons on record. Younger plants were not effectively controlled at flowering time. When applied before they flowered, Fusilade at 10 mL L⁻¹ + Pulse resulted in only 3.9% (se ± 0.9) survivorship of younger plants. Observations suggest that *T. uniolae* is spreading mainly by seed. Water movement, fire and possibly ants are facilitating invasion of this weed into relatively undisturbed bushland.

Introduction

The genus *Tribolium* is a native of South Africa confined to the winter rainfall areas of the Cape Province. Three species have been recorded as naturalized in Western Australia; *T. echinatum*, *T. oblitterum* and *T. uniolae* (Paczkowska and Chapman 2000). Of these only *T. uniolae* (previously known as *Plagiachloa uniolae*) has been recorded invading bushland (Hussey *et al.* 1997). The species has probably spread from a

number of Department of Agriculture research stations near Perth where it was trailed as a suitable pasture grass in the early 1950s (Rogers *et al.* 1979). *Tribolium uniolae* can now be found invading plant communities on the heavier soils of the eastern side of the Swan Coastal Plain, wandoo and jarrah forest along the Darling Scarp and was recently discovered growing in jarrah woodland 200 km south of Perth (G. Keighery personal communication). Although current distribution is relatively restricted, *T. uniolae* appears to have the potential to become wide spread in southwest Western Australia.

A shortly rhizomatous, tufted, upright perennial C3 grass, *T. uniolae* grows to around 60 cm. In South Africa it is very common in the Cape Floristic Region where it prefers richer well-drained soils derived from granite, sandstone, shales or limestone. Occurring at altitudes from 1 m to 1000 m it is found in all major vegetation types, especially fynbos and renosterveld. It is a highly variable species and appears able to exploit new habitats as they arise. Common as a 'roadside weed' in the region, it successfully invades disturbed ground and appears to be prolific after scrub fires (Linder and Davidse 1997).

Tribolium uniolae was first collected from the Brixton Street Wetlands in 1983, and regular visitors to the wetlands have reported a noticeable increase in its occurrence over the last ten years. Its current distribution suggests initial movement was along tracks and then, over time, into susceptible areas of undisturbed bushland. In particular, large clumps of *T. uniolae* are now invading the drier clay flats and appear to be displacing the very rich annual and perennial herbaceous flora that grow and flower as the flats dry out over the spring. Protection of these plant communities and the native species being displaced is a particularly important focus of restoration work at the wetlands.

In recent times members of the Friends of Brixton Street Wetlands have spot sprayed *T. uniolae* growing along paths with the non selective herbicide Roundup[®] at 10 mL L⁻¹. This treatment has been carried out at various times of the year and has met with apparent success. However, with the weed noticeably spreading away from the path edges and into undisturbed bushland more selective control methods are required. Physical removal of the grass by cutting below the base with a sharp knife is one option. This can be appropriate in small isolated populations when the soil is moist but is labour intensive and impractical on a larger scale. Also, the grass grows very closely among native plants and is difficult to remove without damaging native vegetation. In addition, observations suggest that small ramets left behind quickly produce new plants.

To our knowledge there is no published information on chemical control methods for *T. uniolae*. However grass selective herbicides may offer some opportunities for control. These herbicides need to be applied in the early post emergence stage in seedling grasses and post emergence but before boot stage (the flower head detectable in the top leaf sheath) on established perennial grasses (Parsons 1995). They are highly selective for susceptible grasses and have little impact on most other monocots or dicots (Preston 2000). In *Banksia* woodland on the Swan Coastal Plain, Fusilade[®] (10 mL L⁻¹ or 4 L ha⁻¹) has been found to have little impact on a wide range of native species (K. Brown unpublished data, B. Dixon unpublished data).

The aim of this study was primarily to determine effective and appropriate control methods for *T. uniolae* in Brixton Street Wetlands. Chemical control needed to be carefully considered as some areas are inundated for part of the year and herbicide application can be inappropriate. Over the course of the study we were also able to gain an understanding of possible dispersal mechanisms and observe patterns of invasion for *T. uniolae*.

Methods and results

Study site

The Brixton Street Wetlands lie on a winter wet clay flat on the eastern side of the Swan Coastal Plain 20 km south east of the centre of Perth. The diversity in the flora (307 native taxa in 19 hectares) reflects, in part, the seasonal nature of the wetlands (Keighery and Keighery 1995). *Eucalyptus calophylla* woodlands cover the deeper well-drained soils on higher ground, herb rich shrublands the drier clay flats and species rich herblands the seasonally inundated claypans. *Tribolium uniolae* can be found invading the *E. calophylla* woodlands, the herb rich shrublands on the drier clay flats and to a lesser degree, the seasonally inundated claypans. All highly

restricted and threatened plant communities (Keighery and Keighery 1991, Gibson *et al.* 1994, Government of Western Australia 2000).

Timing

In the bushland at Brixton Street *T. uniola* is usually dormant from January through to May with active growth starting in June following first rains. After summer fire however, active growth from burnt clumps seems to begin at least a month earlier, before the break of season. Flowering occurs in late October through November as the wetlands dry out

Response to fire

In January 2000 an unplanned fire burnt through the southern section of the wetlands destroying herbicide trials put in the previous November. Counts of *T. uniola* plants in the three control plots from before the fire and a count of individuals resprouting in those plots six months later provided the data on response of *T. uniola* to fire.

Of the plants present in the control plots in November 1999, a mean of 26.1% (se \pm 8.0) resprouted from burnt clumps. By June 2000 many seedlings of *T. uniola* were observed in the plots and surrounding burnt vegetation.

Control of resprouting mature plants following fire

In May 2000 the effectiveness of both Roundup[®] (360 g L⁻¹ glyphosate) at 10 mL L⁻¹ and Fusilade[®] (fluazifop-p as the butyl ester, 685 g L⁻¹ hydrocarbon solvent) at 10 mL L⁻¹ + Pulse[®] (1000 g L⁻¹ polydimethylsiloxane) at 2 mL L⁻¹ on controlling plants resprouting from burnt clumps was tested. The trials consisted of three replicates (2 m \times 2 m plots) of each treatment and three controls. The number of actively growing

plants in plots were counted before and then six weeks after treatment. At the time of these trials in the burnt vegetation, *T. uniola* plants in unburnt vegetation were still in the dry dormant stage with no visible green growth.

Both Roundup and Fusilade were effective at controlling these resprouting plants. A mean of only 2.2% (se \pm 2.2) survived the Roundup treatment and a mean of 5.4% (se \pm 2.9) the Fusilade treatment (Table 1).

Control of mature plants with grass selective herbicides applied at flowering time

In November 2000 Fusilade (15 mL L⁻¹ + Pulse 2 mL L⁻¹) and Sertin Plus[®] (12 mL L⁻¹ + Pulse 2 mL L⁻¹) were tested on large mature clumps of *T. uniola*. These clumps characteristically consist of much dead material surrounding a few actively growing leaves and stems. Given the small number of actively growing leaves, these plants were perceived as difficult to kill and Fusilade was applied at the higher rate. Sertin Plus was trialed as there was some anecdotal evidence that it was more effective than Fusilade on flowering plants. Trials consisted of five replicates of each treatment and five controls. Numbers of plants in the 2 m \times 2 m plots were counted immediately before treatment and then with the emergence of green material the following June. Differences in survival rates between treatments were analysed using Kruskal Wallace ANOVA (Seigel 1956) with *post hoc* Mann-Whitney U-tests used to determine significance between individual treatments.

Fusilade significantly decreased the number of mature flowering plants with no plants surviving the treatment (P = 0.005). Only 48.3% (se \pm 14.7) of plants in control plots survived the period of the

trial (November 2000–June 2001) (Table 1). Seedling recruitment was observed across all plots in June 2001.

Control of younger plants with grass selective herbicides applied at flowering time

In November 2000 the two grass selective herbicides were also tested on actively growing younger plants. Fusilade at 10 mL L⁻¹ + Pulse at 2 mL L⁻¹ and Sertin Plus (120 g L⁻¹ sethoxydim) at 12 mL L⁻¹ + Pulse at 2 mL L⁻¹. Trials consisted of three replicates of each treatment and three controls. The number of *T. uniola* plants in each 1 m \times 1 m plot were counted before treatment and again following rains in June 2001, corresponding with the emergence of new growth. Observations on the health of plants were made in the intervening times.

Neither Fusilade nor Sertin Plus effectively controlled these younger flowering plants with over 50% surviving both treatments (Table 1). In the control plots 88.8% (se \pm 10.3) of plants survived the period of the trial.

Control of younger plants with grass selective herbicides just before flowering

In August 2001 when plants were actively growing yet not quite flowering (i.e. before the boot stage) Fusilade at 10 mL L⁻¹ + Pulse at 2 mL L⁻¹ and Fusilade at 10 mL L⁻¹ + the adjuvant Ampol D-C-Trate[®] (901 mL L⁻¹ petroleum oil) at 2 mL L⁻¹ were tested on younger plants. Trials consisted of three replicates of each treatment and three controls. The numbers of plants in each 1 m \times 1 m plot were counted immediately before treatment and then six weeks later.

Fusilade + Pulse was the most effective treatment with only 3.9% (se \pm 0.9) of plants surviving. In the Fusilade + D-C-Trate 11.3% (se \pm 4.8) of plants survived. In

Table 1. Mean per cent of *Tribolium uniola* plants surviving in trial plots following herbicide treatments on different growth stages in different seasons. Values greater than 100% indicate recruitment.

Treatment	Growth stage	Date	n	% ^A survival	Standard error
Fusilade [®] 10 mL L ⁻¹ + Pulse [®] 2 mL L ⁻¹	resprout from Jan 2000 fire	May-00	3	5.4	(\pm 2.9)
Roundup [®] 10 mL L ⁻¹ + Pulse [®] 2 mL L ⁻¹			3	2.2	(\pm 5.1)
Control			3	100.8	(\pm 5.1)
Fusilade [®] 15 mL L ⁻¹ + Pulse [®] 2mL L ⁻¹	mature plants, flowering	Nov-00	5	0.0	
Sertin Plus [®] 12 mL L ⁻¹ + Pulse [®] 2 mL L ⁻¹			5	19.5	(\pm 5.7)
Control			5	48.3	(\pm 14.7)
Fusilade [®] 10 mL L ⁻¹ + Pulse [®] 2 mL L ⁻¹	younger plants, flowering	Nov-00	3	54.2	(\pm 11.3)
Sertin Plus [®] 12 mL L ⁻¹ + Pulse [®] 2 mL L ⁻¹			3	56.3	(\pm 5.6)
Control			3	88.8	(\pm 10.3)
Fusilade [®] 10 mL L ⁻¹ + Pulse [®] 2 mL L ⁻¹	younger plants, prior to flowering	Aug-01	3	3.9	(\pm 0.9)
Fusilade [®] 10 mL L ⁻¹ + D-C-Trate [®] 2 mL L ⁻¹			3	11.3	(\pm 4.8)
Control			3	96.4	(\pm 2.5)

^Anumber of younger plants in plots before treatments varied between 17 and 151 and mature plants between 5 and 25.

the control plots 96.4% (se \pm 2.5) of plants survived. (Table 1).

Discussion

Control of T. uniolae in the bushland at Brixton Street

From the results of this study it is clear that *T. uniolae* can be effectively controlled with grass selective herbicides in bushland at Brixton Street. It is possible to control mature flowering plants at the end of spring when the wetlands are dry with Fusilade at 15 mL L⁻¹. However, a high level of natural senescence among mature plants in control plots indicates that extreme seasonal conditions may also have contributed to the high death rate in these trials. The winter/spring of 2000 and the autumn of 2001 were among the driest on record (Bureau of Meteorology 2002) and changes in the abundance of many South African perennial grasses is strongly influenced by year to year changes in rainfall (O'Connor and Everson 1998). The seasonal conditions did not appear to affect the younger plants to anywhere near the same degree.

Fusilade at 10 mL L⁻¹ was not effective on younger plants at flowering time but was when applied just before flowering, in August. It seems that for effective control of younger plants at least, Fusilade application needs to take place before flowering, in winter. With standing water in parts of the wetland at this time herbicide application will need to be very carefully considered.

Although oils have been reported to increase uptake of grass selective herbicides by improving penetration through the cuticle (Chambers and Andreini 2000), D-C-Trate did not increase the effectiveness of Fusilade in these trials. This may be because spray oils are generally only useful for increasing uptake of grass selective herbicides at lower rates than those used in the trial (J. Moore personal communication).

The best opportunity to control *T. uniolae* in this habitat seems to occur following fire. As well as killing 74% of plants in the plots, the burn left the remaining 26% vigorously producing lateral tillers before the break of season and winter rainfall. This was also well before the native vegetation has begun to recover from the fire. In the blackened landscape the green *T. uniolae* plants were highly visible and easy targets for spot spraying. From the results of our trials it is clear they were also highly receptive to herbicide application and were effectively controlled by both Fusilade and Roundup.

It is important to note that chemical control of established plants is only going to be one part of any strategy to control *T. uniolae*. High levels of seedling recruitment were observed in the space opened up by the January 2000 fire. Disturbance

including the removal of perennial vegetation through fire tends to promote germination and establishment of seedling grasses (Cheplick 1998) and without follow up control of germinants, fire will almost certainly contribute to the further spread of *T. uniolae* in the bushland. Seedlings appeared in post fire vegetation in June and were effectively controlled with Fusilade at 10 mL L⁻¹ (K. Brown and K. Brooks unpublished data).

Over the winter of 2001 seedling recruitment was also observed in plots where there had been high levels of senescence (both natural and as a result of herbicide treatments) among mature plants. As tufts of perennial grasses die back they can create gaps that are available for colonization by seedlings (O'Connor and Everson 1998). Effective management of *T. uniolae* invading bushland clearly relies not only on control of mature plants, but also, control of subsequent seedling recruitment.

Just how many years soil stored seed will continue to germinate once established plants have been eradicated or killed by fire is unknown. Using baseline distribution maps of the weed, it will be necessary to systematically monitor the bushland for seedling recruitment over a number of years.

Mechanisms of dispersal and patterns of invasion; some observations.

As well as knowing how to control *T. uniolae*, effective management relies on understanding how the weed is dispersing and spreading. Within the Brixton Street Wetlands reproduction is mainly by seed and diaspores have no obvious features for dispersal apart from light weight and small size. Sheet water flow occurring across the wetlands in winter probably carries such seed from the path edges facilitating movement into undisturbed bushland. Fire also appears to facilitate invasion. Seedlings are able to exploit space, light and nutrients made available by fire, establishing early and displacing regenerating native species. Ants may also be moving seed around with seedling recruitment consistently observed around nests.

Clonal fragmentation is a common characteristic of perennial caespitose grasses (Briske and Derner 1998) and *T. uniolae* also reproduces from small perennating buds that break off from the base and go on to produce new plants. Although this does not appear to be a significant method of reproduction or dispersal for *T. uniolae* at the study site it does have implications for any hand removal program.

Management implications

Keeping fire and other disturbance out of the bushland at Brixton Street is essential in stopping the spread of *T. uniolae*. Any unplanned fire however, should be taken

as an opportunity to effectively control mature plants and seedlings using the successful treatments described in this study. Knowing how long seed remains viable in the soil seed bank is important in long term planning of follow-up work and seed biology is an area that requires further research. In addition using lower rates of Fusilade in conjunction with an oil based adjuvant is worth further investigation.

The focus of our work at Brixton Street is protection of the native plant communities rather than simple elimination of *T. uniolae*. Consequently, plant species moving into the gap created as the weed is removed will need to be carefully monitored. As control is taking place in largely intact bushland with high species diversity the current policy is to allow natural recolonization of indigenous species. Importantly though there are other serious perennial weeds invading the Wetland that have the potential to recolonize the control sites including *Sparaxis bulbifera*, *Watsonia* spp. *Gladiolus undulatus* and *Eragrostis curvula*. These are all subject to fairly intensive control programs at present.

Acknowledgements

Sally Madden and Elizabeth Buters helped set up earlier trials and The Friends of Brixton Street Wetlands (Inc.) assisted with field work. John Moore, John Pierce and Bob Dixon provided valuable technical advice. The work was part of a project managed by the Environmental Weeds Action Network and funded through a Natural Heritage Trust Bushcare Grant.

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Post-dispersal seed predation of three major pasture weeds in southern Australia

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Summary

The weed species, *Echium plantagineum* L. (Boraginaceae), *Carduus nutans* L. (Asteraceae) and *Onopordum illyricum* L. (Asteraceae) are major problems of pastures in southern Australia. This study investigates the importance of post-dispersal seed predators and their contribution to weed control. The results are supported by pitfall trapping of potential arthropod seed predators. The study showed that significant numbers of seeds from these weed species are not being incorporated into the seed bank. Rodents were found to be responsible for the largest seed loss (*Echium* 36%, *Carduus* 22% and *Onopordum* 40%) while arthropods were also found to be responsible for significant seed destruction (*Echium* 13%, *Carduus* 8%). The study of arthropod activity revealed a range of potential seed predators including; carabid beetles, field crickets and ants in the genera *Rhytidoponera* and *Pheidole*. Both *E. plantagineum* (47%) and *C. nutans* (18%) seed were lost in the treatment fully protected from predators, suggesting that rotting and soil micro-organism attack may be responsible, while *Onopordum* (0.1%), did not appear to be susceptible. For all three weed species under study, birds played no role in seed predation.

Introduction

Financial losses from weed incursions in Australian pastures are estimated at \$494 million annually (Centre for International Economics 2001). Three of the most invasive broadleaf weeds in southern Australian pastures are the winter annual Paterson's curse, *Echium plantagineum* L. (Boraginaceae), the facultative perennial Illyrian thistle, *Onopordum illyricum* L., and biennial nodding thistle, *Carduus nutans* L. (Asteraceae) (Parsons and Cuthbertson 1992). *Echium plantagineum* is a major problem throughout southern Australia, while *O. illyricum* is a problem in the central and southern tablelands and *C. nutans* in the tablelands of New South Wales (Briese *et al.* 1990, Woodburn and Sheppard 1996). These weeds compete vigorously with pasture for resources (Parsons and Cuthbertson 1992) and reproduce entirely

by seed. They are prolific seed producers (*C. nutans* up to 7000 seed plant⁻¹, *O. illyricum* up to 20 000 seed plant⁻¹, while up to 30 000 seed m⁻² has been measured in dense patches of *E. plantagineum* (Parsons and Cuthbertson 1992).

Studies of *E. plantagineum* seed banks suggest that in some years, despite high seed production per unit area, the expected seedbank increase did not occur (Smyth *et al.* 1997). Similarly, large quantities of *O. illyricum* seed produced at some sites are subsequently not recorded in the seed bank as expected (Pettit *et al.* 1996). Field estimates of the proportion of the seed production that enters the seed bank are highly variable and this is often one of the hardest population parameters to accurately estimate. Nonetheless, it is critical for understanding the population dynamics of these weeds (Grigulis *et al.* 2001). Losses between seedrain and incorporation into the seedbank are considered to be due to predation (vertebrate or invertebrate) or immediate germination. In New Zealand, a loss of 85% of *C. nutans* seeds, before they reached the ground, was attributed to predation by birds and mice (McCallum and Kelly (1990).

The post dispersal consumption or relocation of seeds can be both common and important in plant communities (Hobbs 1985, Naylor 1984, Thompson 1985). Any changes to seed bank recruitment become more significant for population survival when seed input is driven close to zero by pre-dispersal seed feeders and other mechanisms, which reduce the density or vigour of these plants.

This study aimed firstly to determine how much post-dispersal seed predation of these three weed species was occurring, and secondly, to establish the relative importance of each group of seed predators in reducing seed bank recruitment. Particular focus on the actual seed predator species involved in post dispersal seed predation was restricted to invertebrates. Understanding the influence of seed predators on weed seed densities in pastures is essential for developing effective Integrated Weed Management (IWM) practices to control these weeds.