Alinytjara Wilurara

BUFFEL GRASS
BEST PRACTICE MANAGEMENT GUIDE
2018
Information current as of 30 June 2018.

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This guide should be cited as follows: Department for Environment and Water. (2018). Alinytjara Wilurara Buffel Grass Operational Strategy, Natural Resources Alinytjara Wilurara.

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Cover image: Natural Resources Alinytjara Wilurara and Ceduna Aboriginal Corporation staff preparing to undertake buffel grass control in the Maralinga Tjarutja Lands by Codee Spitzkowsky
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Introduction

Buffel grass (*Cenchrus ciliaris, C. pennisetiformis*) is a perennial tussock grass native to Africa, India and Asia. Since its introduction into central and northern Australia for pasture improvement and for dust control, buffel grass has become invasive and spread well beyond plantings. Buffel grass is now widely distributed across northern arid South Australia as scattered infestations varying in size and density. Most known infestations occur in South Australia’s arid rangelands. However, spread and establishment of new infestations continue to take place and the actual distribution of buffel grass is likely to be greater than is currently known.

Buffel grass is recognised as one of the worst weeds to invade Australia’s arid rangelands. It impacts include its ability to outcompete native plants, degrade or replace habitats for native animals, and increase fire intensity and frequency. These can lead to alteration of entire ecosystems. It also poses significant risk to human health through the increased risk of fire to remote and outback communities. Impacts in Aboriginal communities include a loss of bush foods and bush medicines, reduced availability of hunting opportunities through species decline, reduced ability to track prey and infestation of rock holes and sites of cultural significance.

Buffel grass is tolerant of drought, fire and grazing. Many of the characteristics that make it a favoured pasture species are also those that make it such a problematic environmental weed, such as its ease of establishment, rapid growth rate, fast maturation, persistence as a perennial, prolonged flowering periods, prolific seed production, ease of seed dispersal and relatively long seed dormancy (Franks, 2002).

A key focus of the Alinytjara Wiluŋara (AW) NRM Board is to build the capacity and ownership of indigenous communities to undertake buffel grass control and management. This best practice guide is for AW staff and other land managers in the AW region who need to know the best management methods to use in managing buffel grass. High-level strategic actions for buffel grass management in the AW region are outlined in the AW Buffel Grass Strategy (2018-2023).

The decision support tool on page 12 is a useful reference to guide staff in the best options available for buffel grass control.
Figure 1: Distribution of buffel grass in the Alinytjara Wilurara Natural Resources Management Region.
**Biology/Ecology**

Buffel grass is a tussock forming, deep-rooted, summer-growing grass that can live for up to 20 years. Seed heads are dense, white to purple in colour, growing in a spike-like flower head up to 15 cm long and are covered in clusters of bristles giving them a fluffy appearance. The flowering heads appear from November to May following rain (Smith 2002) and bristly burrs appear on a zig-zag stem. Buffel grass has several qualities that enables it to survive and persist in harsh arid conditions. In addition to producing lots of seed and germinating easily, buffel grass stores energy at the base of its stems for slow release when needed, and has a deep root system that enables it to access water supplies faster and for longer than most native herbs and forbs. Individual tussocks have a long lifespan and can rapidly re-shoot following fire.

![Figure 2 and 3: Actively growing (left) and dormant (right) buffel grass tussocks.](image1)

![Figure 4 and 5: Ripening and mature seed heads (left) and mature burr and seed (right).](image2)

![Figure 6 and 7: Ring of hairs where the leaf joins the stem (left) and fibrous root system (right).](image3)

For more information see the buffel grass identification fact sheet available on the Biosecurity SA website:

Reproduction

Buffel grass plants are bisexual and commonly reproduce by seed (produced with or without fertilisation) or vegetatively through rhizome or stolon production (Franks 2002). After ripening and shedding from the plant, seeds remain viable for 12 months or longer. Field experiments conducted near Alice Springs (Winkworth 1971) found that a small portion of the seeds can remain viable for up to four years in the soil, however only 10% were viable after two years. Generally, at least 20 mm of rainfall is required for seed germination (Cavaye 1988), although new germinants can grow and set seed in as little as three to six weeks with sufficient moisture (T. Gurney pers. comm.) and re-shooting mature plants can flower within 10 days after a rainfall event (Puckey and Albrecht 2004; Barrett and Dixon undated).

Wildfires may encourage germination as the ashes are reported to make good seedbeds (Paull and Lee 1978). Franks (2002) suggests that buffel grass seeds are triggered to germinate by even minor forms of soil disturbance, including breaking of the soil surface by stock movement.

Preferred habitat

Buffel grass is predominant in areas where summer rainfall varies from 150-550 mm, winter rainfall is less than 400 mm, mean minimum winter temperatures rarely fall below 5°C, and soil texture is loamy (Cox et al. 1988). It favours creeks, alluvial plains, calcareous areas and rocky ranges (Albrecht and Pitts 1997), however, it has been successful in a broad range of soil types and landscapes.

Buffel grass readily establishes in road and track verges, parking bays, towns and other disturbed areas. The introduction and spread of new cultivars, in conjunction with hybridisation and evolution of the buffel grass complex, are thought to be increasing the range of climates and landforms that are at threat from invasive buffel grass. Climatic suitability for the establishment of buffel grass in the AW region shows 51% is very highly suitable and a further 38% is highly suitable (South Australian Buffel Grass Strategic Plan 2012).

Dispersal and persistence

Buffel grass spreads through dispersal of its fluffy burrs by water, wind, accidental transportation (e.g. in or on vehicles, animals, soils, etc.), inadvertent transport (e.g. in hay), or intentionally introduced by landholders seeking to establish an ‘improved’ pasture (Puckey and Albrecht 2004). Seeds rarely survive ingestion and it is unlikely that herbivores are responsible for significant spread of buffel grass in this manner (Gardner et al. as cited in Griffin 1993).

Seeds are commonly introduced into new areas along roads and tracks. Spread along roads and railways is assisted by vehicle draughts and movement of soil by graders and other machinery. From the road or track verge buffel grass then spreads into the surrounding vegetation by wind or water, with drainage lines acting as conduits for more distant dispersal (Puckey and Albrecht 2004).

Buffel grass may be slow to establish initially, but under favourable seasonal conditions it may spread readily and aggressively into undisturbed areas. Established buffel grass tussocks can remain dormant for long periods and plants can live for at least 20 years (Latz 1997). Leaves die off during dry or cold periods and new growth quickly emerges from the tussock with warm, moist conditions.
Hygiene

Buffel grass is a prolific seeder. Due to the small seed size and fine hairs it has the ability to spread long distances into remote areas via vehicles, earth moving and other machinery, stock, wind, water and other human activities.

It is important to keep cars, clothing and equipment clean to ensure that no buffel grass seed is spread into un-infested areas when working on country. Hygiene of equipment and machinery is important to protect priority assets such as the Great Victoria Desert and other sites of cultural and/or environmental significance.

Key considerations for hygiene to prevent buffel grass spread are:

- Stay on designated tracks when driving and walking.
- Avoid driving and walking through buffel grass. If unavoidable, plan a route from areas of low infestation to areas of high infestation.
- Visually inspect vehicles and equipment when leaving an area containing buffel grass.
- Clean footwear and remove weed seeds from socks and clothing.
- Before exiting an infested area, clean the vehicle from the top down. Clean the foot well and floor mats, and the undercarriage, springs and axles of vehicles.
- Use the same location for cleaning vehicles and monitor the site regularly for germinations following summer rains.

For further information on hygiene see the PIRSA Fact Sheet available online at: http://www.pir.sa.gov.au/biosecurity/weeds_and_pest_animals/weeds_in_sa/weed_id/plant_id_notes/buffel_grass
Surveillance and Control

Regular targeted surveillance and control efforts are integral to successful management of buffel grass infestations. Both surveillance and control should be prioritised based on the density and distribution, accessibility, risk of spread and resources available. Table 1 provides priorities for surveillance and control based on these factors. Rainfall monitoring is critical in providing as much notice as possible to better organise work crews and ensure timely control of buffel grass to prevent seed production and set.

Control of buffel grass at the early stage of invasion (as is the case in the Maralinga Tjarutja Lands) provides the greatest chance of eradication in the most cost-effective manner.

Given the ability of buffel grass to be transported long distances by wind, water and vehicles, it is important that both surveillance and control are undertaken regularly and records kept of all work to assist with future planning. Figure 8 illustrates the flow of information that is used to ensure that reports are followed-up, infestations are mapped and surveillance and control takes place in a timely manner.

Figure 9 (page 12) shows options for control depending on the location and situation of infestations. This diagram is an important place to start when planning control works.

![Figure 8: Flow-Chart illustrating buffel grass Cenchrus ciliaris surveillance and control regime.](image-url)
Table 1: Prioritisation of localised situations for buffel grass *Cenchrus ciliaris* surveillance, control and monitoring in the Alinytjara Wiluṟara region.

<table>
<thead>
<tr>
<th>Location</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watercourses</td>
<td>Extreme</td>
</tr>
<tr>
<td>Mid-track infestations (i.e. between wheel tracks)</td>
<td>Extreme</td>
</tr>
<tr>
<td>Significant cultural sites threatened by fire</td>
<td>Extreme</td>
</tr>
<tr>
<td>Works yards (particularly where machinery, vehicles or road fill are stored)</td>
<td>Extreme</td>
</tr>
<tr>
<td>Railway ballast</td>
<td>Extreme</td>
</tr>
<tr>
<td>Egress points on tracks from infested roadsides</td>
<td>Extreme</td>
</tr>
<tr>
<td>Threatened plant or animal sites</td>
<td>Very high</td>
</tr>
<tr>
<td>Roadside parking bays</td>
<td>Very high</td>
</tr>
<tr>
<td>Roadhouse car parks</td>
<td>Very high</td>
</tr>
<tr>
<td>Nature reserves</td>
<td>Very high</td>
</tr>
<tr>
<td>Camping areas, racecourses</td>
<td>Very high</td>
</tr>
<tr>
<td>Sand dunes</td>
<td>Very high</td>
</tr>
<tr>
<td>Important hunting/foraging areas</td>
<td>Very high</td>
</tr>
<tr>
<td>Roadsides</td>
<td>High</td>
</tr>
<tr>
<td>High traffic tourism areas</td>
<td>High</td>
</tr>
<tr>
<td>Waterpoints where stock or wildlife congregate</td>
<td>High</td>
</tr>
<tr>
<td>Pastoral remote from waterpoints</td>
<td>High</td>
</tr>
<tr>
<td>Sand plains</td>
<td>High</td>
</tr>
<tr>
<td>Rocky hills</td>
<td>High</td>
</tr>
<tr>
<td>Adjacent to houses or fire-sensitive infrastructure</td>
<td>High</td>
</tr>
<tr>
<td>Triodia plains</td>
<td>Medium</td>
</tr>
<tr>
<td>Pastoral adjacent to waterpoints</td>
<td>Low</td>
</tr>
<tr>
<td>Clay plains, gibber, limestone</td>
<td>Low</td>
</tr>
</tbody>
</table>
Figure 9: Decision Support Tool for Buffel Grass Control

[Diagram showing decision criteria and actions for managing Buffel Grass infestations, including considerations such as proximity to watercourses, presence of native plants, and availability of water and spray equipment.]
Herbicide trials

Throughout the state-wide Native Vegetation Council funded Buffel Grass Control in Arid Rangelands project (2013-2016), extensive herbicide trials were undertaken in an effort to identify the best practice control options for buffel grass. A range of selective and non-selective herbicides were trialled in both liquid and granular forms in addition to the use of burning and physical removal.

Trial sites were established in Port Augusta, on Bon Bon Station and in Umuwa in the APY Lands in an effort to account for spatial variations in rainfall, soil and temperature. Results from the herbicide trials were used to inform the best practice management recommendations contained within this report and are summarised in a fact sheet and report available at:


Additional trials were undertaken through a PHD undertaken by Andrea Tschirner from the SA Buffel Grass Taskforce on “The effects of temperature extremes and two herbicides on the germination of buffel grass (Cenchrus ciliaris L.) and implications for its management”. Results from these trials also informed best practice buffel grass management.

The two chemicals (Glyphosate and Flupropanate) recommended for buffel grass control are currently registered under the minor use APVMA permit PER9792 (EXP 2022).

Recent aerial trials with granular flupropanate have shown variable results with effective control in the vicinity of 70-80% at 25kg/ha. The product does negate the need for water and reduces the risk of exposure of the user to herbicide contact and therefore PPE required, however re-application will be required to achieve the desired level of control. Granular herbicides can be spread via a small hand-held 700g shaker pack, use of a handheld fertiliser/grass seed spreader, by a broad-acre fertiliser spreader mounted to a vehicle or aerially.

Ad-hock out of season trials have been undertaken using flupropanate alone (at a rate of 3L/ha applied in 1000L of water per ha) when buffel grass is dormant (i.e. in winter) with successful results, however these trials were not replicated or monitored to a suitable standard to enable confidence in the results. It is suggested that further out of season controls be implemented to confirm this technique is effective.

Caution must be applied when treating buffel grass out of season due to an increased likelihood of significant rainfall (i.e. 100ml in 2-3 days) washing the flupropanate out of the root zone.
Application

Spot spray is the most common method of buffel grass control given the availability of spray equipment and the linear, often patchy occurrence of infestations. Buffel grass is often found amongst native vegetation and on rough terrain that doesn’t suit boom-spray application. A challenge in treating buffel grass in Natural Resources Alinytjara Wilurara is the remote nature of infestations and difficulty accessing and carting the significant quantities of water required to treat infestations.

Buffel grass must be actively growing for effective uptake of herbicides. In arid or semi-arid regions of South Australia the period of active growth is unpredictable and may be short-lived, so timing is very important for control (generally between September and June). Foliar application of select herbicides to young plants or regrowth following rain provides the best opportunity for success.

Operators need to be mindful of water quality when mixing herbicides, especially glyphosate. The active ingredient can be diminished by suspended particles (silt/clay), inappropriate pH level and hardness (percentage of mineral salts content). Ideally, clean soft water with a pH of 3.5-4.0 should be used, however there are products commercially designed to alter pH and mineral levels so that mixing water of marginal quality may still be effective. Try lathering soap with the water as a rough rule of thumb test. If a 20c coin can be seen in the bottom of a nine-litre bucket after lathering, then the hardness of the water should be satisfactory.

Aerial application is suitable for large swathes of buffel grass and is particularly cost effective in remote, difficult to access terrain. When coupled with the use of granular flupropanate, the area treated can be as high as 80-100ha per hour although further trials are required to refine the effective application rate of granular flupropanate.

Spot spray of flupropanate should be undertaken at a rate of 300ml/100L of water applied at a rate of 1000L of water/ha, ensuring that a “halo” of up to a foot is treated around tussocks to suppress new germinations from seed that may have fallen in the immediate vicinity (Figure 4). In medium to high density infestations where there is only approximately 1m or less between tussocks, be sure to treat the inter-tussock space to prevent new germinations from occurring within this area.

Boom spraying and aerial application of flupropanate should be applied at 3L/ha and can be undertaken at water rates as low as 300L/ha (ground) and 80L/ha (air). Even coverage is integral to achieve effective control.

Treatment with glyphosate should be applied at a rate of 4L/ha and a water rate of 300L/ha when boom spraying. When spot spraying, a rate of 700ml/100L of water should be used, ensuring that full leaf coverage is achieved for best results.

To destroy aerial and surface seed, Bioweed should be incorporated into a spray mix at a rate of 2% and applied at a rate of 1000L/ha. Spray equipment with sufficient pressure should be used to ensure penetration of the tussock to enable contact with surface seed at the base of the tussock. *Note Bioweed is not buffel grass selective and is likely to destroy native seed of similar structure to buffel grass seed.

All application equipment should be calibrated to ensure that the correct amount of herbicide is applied.
Figure 10: “Halo” around tussocks to limit new germination

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Form</th>
<th>Active Constituent</th>
<th>Rate of Chemical</th>
<th>Water Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundup powerMAX</td>
<td>Liquid</td>
<td>Glyphosate 540g/L</td>
<td>4L/ha or 700ml/100L</td>
<td>300L/ha</td>
</tr>
<tr>
<td>Roundup Biactive</td>
<td>Liquid</td>
<td>Glyphosate 360g/L</td>
<td>5L/ha or 800ml/100L</td>
<td>300L/ha</td>
</tr>
<tr>
<td>Taskforce</td>
<td>Liquid</td>
<td>Flupropanate 745 g/L</td>
<td>3L/ha or 300ml/100L</td>
<td>1000L/ha</td>
</tr>
<tr>
<td>GP Flupropanate</td>
<td>Granular</td>
<td>Flupropanate 86.9g/kg</td>
<td>25kg/ha or 2.5g/m²</td>
<td>N/A</td>
</tr>
<tr>
<td>Bioweed</td>
<td>Liquid</td>
<td>Pine Oil 600g/L</td>
<td>2% of mix</td>
<td>1000L/ha</td>
</tr>
</tbody>
</table>

Table 2: Herbicide Application Rates for Buffel Grass Control
Using Herbicides Safely

Many herbicides are hazardous chemicals toxic to humans and other living things and their inappropriate use can cause harm. Where possible choose herbicides with a low toxicity to humans and animals. The degree of toxicity of a herbicide is outlined on the label as a poison schedule. Poison scheduling is the national system used to classify substances based on their potential health risks.

When using herbicides personal protection equipment (PPE) must always be worn to avoid contact with and absorption of the herbicide into the body. The degree of PPE required may depend on the application method and the herbicide’s toxicity; however, users should always wear:

- Chemical impervious, PVC or nitrile gloves
- eye protection
- a respirator (with a filter appropriate to the level of toxicity) and
- clothes, a hat and boots that cover the whole body.

For higher risk herbicides, more PPE and additional precautions may apply, including wearing a full face respirator and chemical resistant overalls.

Herbicide Selection

Selection of herbicides is a key component of buffel grass management and is influenced by a range of factors such as the situation in which the buffel grass is present (i.e. watercourse, isolation etc.). Availability of application equipment, financial constraints and the availability of labour can also influence herbicide choice.

Consideration needs to be given to resistance build-up to certain Group herbicides, e.g. Roundup (Group A), with different Group herbicides used to minimise the risk. The Group category relates to how the chemical works, including their different chemical make-up and mode of action. Herbicides registered and permitted for use on buffel grass include the Groups A, L, M and J. It is recommended that a mixture of Roundup and flupropanate is used initially for buffel grass control with monitoring and the adaptive management framework used to maintain awareness of potential resistance build-up. Switching between herbicide groups should be undertaken periodically to provide a seamless control effort whilst minimising the risk of herbicide resistance. New chemical products are being continually developed and these should be assessed for suitability on an ongoing basis. The main risk factors leading to glyphosate resistance have stemmed from:

- intensive use of glyphosate, e.g. every year or multiple times per year for 15 years or more
- heavy reliance on glyphosate
- no other weed control options used.

To reduce the risk of herbicide resistance it is vitally important that herbicide control is conducted in a professional manner, following best practice to ensure complete coverage.

Near enough is definitely not good enough. Whichever method or technique is chosen for a particular site, the sole aim is to ensure 100% kill and no seed production.
**Flupropanate**

Flupropanate is a slow acting grass selective herbicide predominantly absorbed through the roots. It can take 3 – 6 months or longer to kill the plant, particularly if affected by drought. It is residual in the soil and significantly reduces the quantity of new germinations for a period of approximately 18 months to 2 years (depending on soil type and rainfall).

Significant quantities of rainfall (i.e. 100mm of leaching rain) can impact on the effectiveness of control and suppression of germinations, therefore timing of application should be undertaken to avoid such heavy rainfall where possible. Flupropanate can be applied all year round at a rate of 3L/ha to effectively control mature tussocks and supress new germinations however ideal timing would be in spring to avoid heavy rainfalls. Flupropanate is also available in a granular form which reduces the PPE required for users and negates the need for water (a limiting factor in much of the AW region).

Trials undertaken in SA have shown good results with Glyphosate and liquid flupropanate although variable results have been seen with the granular form of flupropanate. Further trials are recommended for granular flupropanate to perfect the correct application rate required for effective control.

![Figure 11: Buffel grass control at Port Augusta (2014, 2015, 2016) using flupropanate 745g/L @ 3L/ha](image)

**Glyphosate**

Glyphosate is a non-selective foliar herbicide that kills green, actively growing plants. Care should be taken when applying glyphosate to minimise off-target damage. Glyphosate is absorbed through the leaves and green stems, it is fast acting and kills treated plants approximately 4-6 weeks after treatment. Glyphosate is non-residual and stops working once in contact with the soil, therefore follow-up control must be undertaken following subsequent rains.

Treatment of buffel grass in drainage lines should only be undertaken with Roundup Biactive. It is a product that is registered for use in and directly adjacent to drainage lines and doesn’t contain some of the surfactants and adjuvants that are known to adversely impact on the health of frogs and other aquatic organisms. Use of glyphosate in a mix should only be undertaken for spot spray or when there is little native cover within an area to be boom sprayed. If there is an outlier population in close proximity to a dispersal vector or priority asset, irrespective of the native component, glyphosate should be included in the mix to prevent seed production in the short term.
Bioweed

Bioweed is an organically certified product that comes from pine trees. The active constituent, pine oil, when applied at a rate of 2%, has been proven to effectively control aerial and surface seed that it comes into contact with, dramatically reducing the amount of follow-up control required in subsequent years. Its mode of action causes a split in the seed coat which results in the seed dehydrating itself and becoming non-viable (Figure 5). It is recommended that trials be undertaken to assess the effectiveness of Bioweed in controlling mature tussocks at rates starting at 25%.

Alternative residual herbicides

Although Flupropanate is the residual herbicide of choice due to its selectivity and proven effectiveness through formal herbicide trials in South Australia, other forms of residual herbicides should be considered.

There is an urgent need to trial residual herbicides for use on buffel grass in South Australia. Graslan is permitted for off label use on grazing and grasslands although careful consideration must be given to off target impacts due to its non-selectivity. Other residuals may be more appropriate and these should be investigated. Velmac is a granular residual that is rainfall activated. Velpar (Hexazinone) is in liquid form which can start working soon after application if there is sufficient soil moisture. Other more ‘forgiving’ products to be considered are Oust (Sulfometuron Methyl), Trimac (Terbacil) and Arsenal Xpress.

Arsenal Xpress contains glyphosate for initial knockdown and imazapyr as the residual. It is the most expensive of the three but also the kindest to off-target vegetation. Oust and Trimac provide some knockdown action with all three providing pre and post emergence control. Oust and Trimac will last longer and provide a greater degree of control in alkaline soils with low organic matter. All three herbicides require mixing with water for application and require soil moisture activation (rainfall) for best results. If these products are trialled, concentrations should start out low (less than the manufacturers recommended rate, e.g. 50% for Oust) and then build up to the desired level of effect.
Treatment intensity of any herbicide must ensure the death of buffel grass. Although control techniques will be tailored to minimise off- target risks, those undertaking buffel grass control should be aware that off-target impacts to some native vegetation is likely. Bare ground, even if it remains un-colonised for several years until the effects of residual herbicide diminish, is far less ecologically damaging than persistent buffel grass that will likely spread and eventually replace native vegetation on a far larger scale.

The use of residual herbicides can be an important tool in ongoing buffel grass control, especially for small but high-risk infestations where the opportunity to revisit infestations at the optimal time for control is unlikely. Off-target risks are minimised with appropriate training and site selection. Degree of control and duration will depend on soil texture, organic matter content, soil pH and rainfall. With granular herbicides, the equipment is very portable and can be carried in vehicles by land managers, environmental contractors and DEW staff while driving through the region on other business. This can allow an immediate control response to new sightings and not be necessarily dependent on a second trip to apply a foliar herbicide at the appropriate growth stage.

Most soil active residual compounds are designed for use on bare ground so the presence of higher amounts of ground cover will reduce their effectiveness. Hence consideration should be given to reducing plant biomass by burning, cutting, pulling or grazing before application of residual herbicides.

In situations such as railway ballast or other infrastructure where there is a requirement for no vegetation at all, the use of residuals provides ongoing control at little or no risk to other vegetation.

The choice of which residual herbicide to use will come down to weighing up the best application technique. Factors in this assessment should include availability of clean water, soil type, risk to non-target species, intention to reseed or replant, and the risk of spillage during transport of liquid herbicides compared to granular herbicides etc.

Physical removal

Manual removal/chipping is the physical removal of the entire tussock from the ground using a hoe, mattock or shovel. Once removed from the ground, shake soil from the roots or leave in a position with the roots exposed to dry out. Care must be taken with seeding plants to prevent seed dispersal.

If chipped-out when seed heads are present, burn in-situ or carefully bag the whole plant and remove from the site and destroy. Soil disturbance created by chipping is likely to promote new germinations, therefore, follow-up surveillance and control should be undertaken following summer rains. The latter has to be weighed up against the risk of seed escape into un-infested areas and the potential mixing of different hybrids/cultivars. The application of residual chemicals can be a good option to kill any subsequent germination at these sites and is indeed an alternative to mechanical grubbing.
Fire

Fire can be a very useful tool in the management of buffel grass. Buffel grass fires will not kill the mature tussock however they will reduce biomass and therefore the fire risk, destroy surface seed and provide a uniform growth stage that can be sprayed more effectively. Trials have shown that to kill buffel grass seed, it must be exposed to a 400° C fire for 10 seconds or a 250° C fire for 30 seconds (Figure 6).

Fire will stimulate regrowth of the buffel grass tussock and promote new germinations. Be sure to carry out follow up control when there is enough green leaf for uptake of foliar herbicide (approximately 15cm high). Treatment too early following fire will result in ineffective control. Given the survival of both the tussock and soil seed bank following fire, burning must only be used as part of an integrated control plan.

Figure 14: Temperature and duration of fire required to kill buffel grass seed (Tschirner, 2017).

Off-target Impacts

Consideration should be given to the potential for off-target impacts when treating buffel grass infestations. The use of glyphosate should be avoided when boom-spraying to aid re-establishment of native species following buffel grass control.

When treating buffel grass there is a significant likelihood of off-target impacts to some native plants, however in the absence of buffel grass control it is highly likely that the native grasses would be lost from the system either through competition or the impact of fire. In most cases, following the removal of buffel grass, native grass seed will be reintroduced (by wind) from nearby seed sources and is likely to re-establish in the absence of impacts from buffel grass. Re-establishment of grasses such as *Digitaria*, *Enneapogon* and *Astrebla* was noted in plots at all three trial sites treated with flupropanate within 2-3 years of control (Bowman and Prider, 2016).
Timing of Control

Figure 15: Buffel Grass Control Calendar.

Surfactants/Adjuvants

Surfactants and Adjuvants can dramatically increase the effectiveness of herbicides, particularly if climatic conditions and plant growth aren’t ideal for treatment.

An adjuvant is any material that when added to a spray solution enhances or modifies the action of a herbicide. Many adjuvants are included in the formulations of various products to facilitate the stability and functionality of the active ingredient(s) in a spray solution although the addition of products such as Liase (to combat hard water) and LI700 (to act as a penetrant, wetter and increase droplet size to reduce drift) should be considered where appropriate (i.e. when treating with glyphosate alone in less than ideal conditions).
Data Collection, Monitoring and Follow-up Control

Consistent data collection and monitoring is integral in monitoring the success of control programs and enables timely application of herbicides to achieve the best possible control. Consistent data collection is important to enable comparisons between the effectiveness of changing management approaches and for the prioritisation of sites based on known distribution. Detailed information of suitable data collection standards are provided in Appendix 2.

In addition to enabling the monitoring of effectiveness thorough data collection enables the prioritisation of works and forward planning from both an operational and budget perspective.

Rainfall data monitoring is important to inform the appropriate timing of follow-up monitoring and control given the high spatial variability of rainfall throughout the region. Additionally, rainfall monitoring is important to identify rain events that may impact on the residual life of flupropanate by washing the herbicide through the root zone.

Monitoring the effectiveness of control should be undertaken at regular intervals to be sure that the application methods and herbicide rates are suitable in addition to monitoring for the development of herbicide resistance.

Follow-up surveillance and control should always be undertaken following rain events of approximately 10-20mm or more to treat any re-growth or new germinations that occur either within or outside the treated area. Where possible, follow up control should be undertaken prior to seed set which can occur in as little as 3-6 weeks.
Integrated Weed Management

Integrated weed management (IWM) is a term used to describe the long term management of a weed using a combination of different prevention and control techniques. An IWM approach will be tailored for a given weed based on its ecology, density and the land-use in which it occurs. Grubbing, fire and grazing could also be used as additional tools in an integrated weed management program. The example below only used herbicides.

Ongoing research into new and improved methods of buffel grass management should be undertaken to improve both the effectiveness and efficiency of programs. Education is also a key component of integrated weed management. Awareness of hygiene protocols and a need for early intervention to prevent establishment of buffel grass both play a key role in the management of this devastating weed.

Herbicide resistance must be considered when treating a perennial weed, therefore it is recommended to switch between herbicide groups as part of an integrated weed management plan. A typical buffel grass management plan could involve the following series of treatments to achieve the best possible control whilst providing native species an opportunity to re-establish and preventing herbicide resistance.

Please note, this treatment plan is general, and a suitable management plan should be developed on a site-by-site basis depending on the variables at each site. This treatment plan should be altered as new herbicide control options are proven successful with particular attention given to ensure alternate herbicide groups are applied to prevent resistance.

Primary Treatment- Year 1 and 2

The general liquid mix used for spot spraying should be a combination of glyphosate, flupropanate and pine oil at rates of 260ml, 300ml and 2L per 100L of water respectively. This mix will be effective in preventing seed production in the short term, controlling mature tussocks, suppressing new germinations for approximately 18 months in addition to destroying aerial and surface seed. Follow-up control should be undertaken following subsequent rain events of approximately 10-20ml for the remainder of the current and next growing season using the above mix.

Secondary Treatment- Year 3 and 4

Re-treatment of the entire infestation should be undertaken using flupropanate from August to September to allow enough time for the herbicide to enter the root zone before active growth. All surviving buffel grass tussocks and new germinations should be followed up with glyphosate and pine oil for the remainder of the season and in year 4.

Ongoing Treatment and Monitoring

All sites should be monitored and follow-up control undertaken as necessary by alternating between the flupropanate and pine oil mix and glyphosate and pine oil mixes annually.
Appendix 1 – Control Considerations

Cost of Herbicide Control

Friedel et al (2009) provide an example of the very high cost of chemical control of buffel grass in arid regions following a project conducted at Alice Springs Desert Park in the Northern Territory between 1997 and 2007. The cost of labour and materials for herbicide spraying varied from almost $10,000 per hectare in 2000 in the initial stages of the project to $50 per hectare in 2006 for regular follow-up spraying after rain events once the buffel grass was largely under control. Over the 10-year period (1997-2007) the average cost was $5500 per hectare.

The high cost of herbicides and associated labour is a hindrance to control. All control programs require several years of follow-up treatment and monitoring, which further increases the cost. Therefore, flexibility in work plans must be maintained to allow the short notice allocation of staff and other resources to respond to rainfall events. Appropriate work plans must be developed prior to the commencement of works to ensure the required follow-up control is able to take place.

Aerial control can be highly cost effective when dealing with large dense infestations and enable access into terrain that is otherwise inaccessible. Recent trials in South Australia estimate the cost of aerial granular spreading to be $30 per/ha and aerial spraying to be $90 per/ha (+ herbicide and $1050p/hr ferry). Although 100% effectiveness of granular fluopropanate is not yet proven, a cost saving is likely even when factoring in the requirement for secondary treatment.

Biological control

Biological control is the most cost effective management method for dense areas of many weeds. However, as buffel grass is recognised as a valuable forage species in some parts of Australia, the application or even investigation of biological control agents requires careful management, awareness and advocacy. There are currently no accepted or proven biological control agents for buffel grass, nor any attention or resources allocated to pursue such options. As such investigation of bio-control agents is key priority of the research and development section of the Alinytjara Wiluŋara Buffel Grass Strategy (2018-2023).
Appendix 2 – Alinytjara Wiluṟara Data Collection Manual

A field guide for staff and contractors working to control buffel grass incursion in the AW Region.

Why collect weed data?
Consistent and reliable weed data is critical requirement for effective weed management. It helps with prioritising on-ground actions and strategic decision making. It allows evidence to be used for meaningful evaluation, decision making and improved reporting to the funders.

How do I collect useful data?

- Data needs to include the characteristics (attributes) of the weeds and where the weed is.
- A range of digital mapping devices including tablets can be used. Whichever tool is used, the attributes required remains the same.

Buffel grass is the weed of focus for this manual. Buffel grass has been identified as a key threat to rangelands in the AW Buffel Grass Operational Strategy.

Step 1 – Preparations

Before heading to the field
Have a clear operational work plan. The Buffel grass project manager/ coordinator should outline the work areas (sub-regions) that you are required to work, timeframe and when.

Digital GIS Data Entry
If you are contracted to do the work, it is expected that you will collect and return the data in electronic format. Manual data entry are acceptable for small jobs or volunteers.

AW can provide tablet or smartphone with inbuilt GPS. Cybertracker is the software used for data entry and customised sub-regional maps can be loaded into Avanza Maps app to use for on-ground map references. After completion of the job, the device will need to be returned to Ceduna NRC for data processing.

Maps
Customised buffel grass site PDF maps of each sub-region are available for printing or for loading into tablet using Avenza map app. See Internal DEW staff for access to a copy.
Step 2 – Data collection

A weed (buffel) infestation site is usually given a single data point and unique record identifier (GPS waypoint Number). Data attributes must be collected and entered for each area of infestation.

The minimum core attributes are:

- **Who collected the data?** Name of recorder(s)
- **Where was the data collected?** GPS coordinates, waypoint or site number or marker on map.
- **When was date recorded?** Dates are recorded via GPS waypoint capture.

**Chemical** – Glyphosate/Flupropionate, Glyphosate, Grazlan, Pine Oil etc. Chemical and volume. (This can be recorded in the Activity report instead of data logger).

**Treatment** – No treatment, sprayed, pulled/dug out, burnt, spread, other.

**No. of plants** – Estimating the number of plants should be sufficient. If no plants are found at location, record it as ‘previously treated’.

**Density** – Sparse, Low, Medium or High

<table>
<thead>
<tr>
<th>Plant Density Guide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sparse</td>
</tr>
<tr>
<td>Distance between single or small clumps of plants is 11 - 100 metres.</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>Average distance between plants is 3-10 metres</td>
</tr>
<tr>
<td>Medium</td>
</tr>
<tr>
<td>Average distance between plants is 0.5 to 2 metres</td>
</tr>
<tr>
<td>High</td>
</tr>
<tr>
<td>Majority of the buffel grass canopies are touching each other or will be when they are fully grown.</td>
</tr>
</tbody>
</table>

**Size** – Size of infestation. Pick from 20, 50 or 100 metres.

**Notes** – Other attributes that could include soil vegetation characteristics, other threats such as water courses or location specific such as south side of road or rail line etc.

**Tools for data collection**

There are numerous data collection tools and phone apps available in the market. The most common tools used in our regions are mobile phones or tablets using software such as:

- Cybertracker
- Fulrcum
- ArcCollector

The attributes you collect should remain the same irrespective of which tool you are using. AW has Cybertracker set up with smart phone/tablet for ease of data entry with the correct prefill attributes. See Appendix 1.
Manual data entry with GPS

If you don’t have access to a data logger, weed data can be recorded manually with hand held GPS using a data collection sheets with corresponding location recorded.

Step 3 – Data Processing

After completion of field work. Data needs to be exported from the GPS devices (data loggers) and AW GIS administrator will load into to centralise ArcGIS Geodatabase. The results from geodatabase processing are:

- Buffel Sites – each site has a unique number and size classification of initial infestations source from no of plants recorded. Each site has a waypoint.
- Buffel Treatment – historic treatment records of each site.
- Analysis of data can then be performed.

New sites are exported into BDBSA via data load template. BDBSA Project number is 1007.

Step 4 – Data Viewing, Analysis

As described in step 1, PDF maps of each sub-region are available for download. They can be printed or loaded into PDF map app.

Use the map to:

- Distinguish between core and isolated infestations. Keep clean areas clean by treating isolated infestations. The graduated symbols and size classifications provides that distinction on the map.
- Identify key management areas and pathway incursions such as road, rail, wind directions and watercourses.
- Determine resource allocation – personal, herbicide, on-ground equipment

What happens to the data?

Public Maps

The buffel site layer gets imported into BDBSA. BDBSA is the data source for public online maps such as Nature Maps and Atlas of Living Australia.

The on-line maps allow for collaboration with the community, cooperative research centres, universities, and government and non-government agencies to help us deliver conservation priorities.

The delivery of buffel grass data in the BDBSA also ensures the presence of buffel grass are included in the risk assessments of on-line mining referrals, development applications and prescribed burn planning.
Analysing progress

Data analysis – Buffel Grass from Ooldea to Malbooma (August 2013 – May 2016)

Buffel Sites

Mean Average size increase: 57 plants
Mean Average size reduction: 270 plants

New Sites recorded in 2016

Classification of Infestation Size

<table>
<thead>
<tr>
<th>Size</th>
<th>No of plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>1 – 10</td>
</tr>
<tr>
<td>Small/Medium</td>
<td>11 – 20</td>
</tr>
<tr>
<td>Medium</td>
<td>21 – 50</td>
</tr>
<tr>
<td>Medium/Large</td>
<td>51 – 100</td>
</tr>
<tr>
<td>Large</td>
<td>101 – 500</td>
</tr>
<tr>
<td>Very Large</td>
<td>501+</td>
</tr>
</tbody>
</table>
Buffel Sites reduced by more than 250 plants from 2013 - 2016. Highlighted in blue.
Using Cybertracker...
for buffel and weed mapping
Further Reading


Bowman, T. and Prider, J. (2016). Buffel Grass Herbicide Trials- South Australia, Department of Primary Industries and Regions, SA.


Tschirner, A. (2017). The effects of temperature extremes and two herbicides on the germination of buffel grass (Cenchrus ciliaris L.) and implications for its management, University of Adelaide, SA.
