Eradication of buffel grass (*Cenchrus ciliaris*) on Airlie Island, Pilbara Coast, Western Australia

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Abstract The aims of this project, now into the second year of the implementation phase, are to eradicate buffel grass (*Cenchrus ciliaris*) from the 25 ha Airlie Island off the Pilbara Coast, to develop and implement methods to restore the indigenous vegetation, and to collect and store seed for future restoration works. The most effective herbicides trialed under these conditions were Roundup Biactive 8 *l*/ha and Verdict 6 *l*/ha. Extensive field trials indicated the main perennial shrubby species on the island (*Acacia bivenosa*, *A. coriacea* and *Rhagodia preissii*) are resistant to Roundup Biactive and Verdict. With the exception of native grasses, these herbicides had no adverse effect on other indigenous plant species. Initial blanket and spot spraying with Roundup to kill the parent plants followed by blanket spraying, avoiding native grasses, with Verdict, is the most cost-effective regimen for control. A temporary (three years) water pipe for filling battery operated 250 *l* spraying units was installed across the centre of the buffel populations. Hoses 60 m long with hand held lances were used to apply herbicide. Four operators with two units can spray about two hectares each day. The best time for spraying is six weeks after heavy rain when the parent plants are actively growing and the new seedlings have grown sufficiently to spray. Spraying too early misses most of the seedlings; too late and the seedlings as well as the parent plants are seeding or too senesced to respond to the herbicide. The window of opportunity for spraying under these conditions is therefore only two weeks. Results of the spraying on Airlie Island indicate that 98% of the original stands of buffel grass has been controlled. Replanting with greenstock is preferable after heavy rainfall, the main shrubby species planted after spraying with Roundup can then be oversprayed, when required, with Verdict. Greenstock survival rates vary considerably between 5% and 90%, and are entirely dependent on follow-up rainfall. Two to four sprays a year, depending on rainfall events, are required for a period of at least three years (estimated age of soil seed bank) to control this weed with follow up monitoring and backpack spot spraying or hand removal. *Eulalia aurea*, a perennial dominant native grass, is best planted at the conclusion of the three year spraying programme to avoid spray damage and for ease of operations to control buffel grass.

Keywords buffel grass control; herbicide; restoration; marine.

INTRODUCTION

Buffel grass in Australia

Buffel grass (*Cenchrus ciliaris*) is a perennial grass native to Africa, the Middle East and southern Asia. It was first introduced to Australia in the packsaddles of Afghan camel drivers (Bryant 1962) and was later used by the pastoral industry for erosion control and as a pasture supplement throughout the Pilbara and Kimberley regions of Western Australia. This grass has also established on a number of islands off the Pilbara coast, including Airlie Island.

Introductions of buffel grass were primarily aimed at improving stockfeed, stabilising soil and revegetating bare and eroded areas (Bryant 1962; Humphrys 1974). The effectiveness of buffel grass at stabilising soils is due to the ready germination, rapid propagation and easy establishment, even on bare or infertile soils (Bryant 1962). Buffel grass is resistant to drought, fire and heavy grazing, so it is dominant and very persistent at a site once established making it useful as an arid zone pasture grass (Bryant 1962; Hodgkinson *et al.* 1989). These characteristics are attributed to the robust root system and swollen stem bases, which accumulate carbohydrate reserves, so that loss of leaf lamina during drought or after fire is not fatal to the plant. Regrowth may then be rapid in favourable conditions (Humphrys 1974).

Buffel grass favours alkaline soils (Christy and Moorby 1975; Griffin 1993). Within the arid zone it establishes best on areas of higher nutrients and moisture, especially creeklines and floodways.

There are several buffel grass varieties in Australia, each with different growth habits and requirements. Seed dormancy and germination characteristics may also be variable between or even within varieties. The varieties biloela, gayndah and others are African in origin and are widely favoured as pasture feed in Queensland. The Western Australian (WA) variety is shorter, reaching a maximum of 75 cm and not as vigorous (Humphrys 1974). Curiously, seedlings of the WA variety have lower drought tolerance, but flowers much more quickly following rains, and is hence able to survive and spread after rare rainfall events. The WA variety was originally introduced from the Middle East, and has possibly since become further adapted to arid Australian conditions.

In higher rainfall areas of Queensland, buffel grass does not spread rapidly, if at all, and usually requires cultivation to establish a population (Hacker and Ratcliff 1989). In the more arid conditions in central and western Australia, however, buffel grass (WA variety) is much more invasive. Its resistance to fire, drought and grazing make it extremely persistent, and its rapid growth and flowering allow it to dominate over native vegetation in some areas

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(Humphries *et al*. 1991). The major mechanisms of dispersal are wind, flood, fire (Griffin 1993) and possibly domestic stock. Seed is also easily spread by humans as they readily adhere to trousers and socks, thus it is very important to make sure seeds are removed from clothing after visiting a buffel grass area. The spiked seed-bearing involucre also increases spread by attaching to animals. Vehicle wind-assisted spread along roads is also evident in Uluru National Park (Griffin 1993). Buffel grass was not reported as spreading until the 1970s, when high rainfall and floods lead to rapid colonisation along creeklines and alluvial flats (Griffin 1993).

The biology of buffel grass allows populations to be self-maintaining, and encourages rapid spread in favourable conditions. As a result, buffel grass (WA variety) is an aggressive coloniser of native habitats, especially moist environments, where it forms dense monocultures, excluding other species (Humphries *et al*. 1991). Buffel grass also alters fire regimes by increasing fire frequency and intensity, and while buffel survives, native species are suppressed or replaced (Griffin 1993; Humphries *et al*. 1991).

The success of buffel grass raises serious concerns for the welfare of plant and animal species that are restricted to moist sites throughout the arid zone (Humphries *et al*. 1991). These habitats are critical refugia for survival of numerous plants and animals (Griffin 1993; Humphries *et al*. 1991; ANCA 1996). Urgent control methods are required in central Australia (Humphries *et al*. 1991), especially in national parks and nature reserves.

Buffel grass has been reported as a weed or a serious invader in Western Australia in the following reserves and biologically significant areas: Cape Range National Park, western coastal plain of the Carnarvon-Exmouth area and Doole and Roberts Islands where it is potentially a threat. Numerous other islands in the Shark Bay - Exmouth area are exposed to invasion by buffel grass (Department of Environment, Sport and Territories 1996).

Buffel grass in Western Australia

In 1910 the first deliberate introduction of buffel grass in Western Australia was carried out on Wallal Station, Western Australia. Since then numerous introductions have been made, for example aerial sown seed on Mundabullangana Station between 1926-1928 (Bryant 1962).

Buffel grass seed was most likely brought to Airlie Island in soil used in the construction of the lighthouse in 1913 (WMC 1993). By 1987, buffel grass roughly occupied a 2.5 ha kidney-shaped area around the lighthouse (Astron 1988). Later that year Western Mining Corporation constructed an oil installation on the island, removing approximately 1.5 ha of buffel grass in the process (Astron 1988).

Following construction of the oil installation, buffel grass was estimated to be spreading at a rate of 0.2 ha per year and by 1993 had spread over 2.2 ha (WMC 1993). By the year 2000 it covered an estimated area of 8 ha.

The initial spread of buffel was relatively slow, however disturbance events appear to have enhanced its invasive capacity. The proposed decommissioning of the Airlie Island installation presents another disturbance event which could allow buffel infestation to further increase.

On Airlie Island the presence of buffel grass threatens the natural plant communities by replacing, almost entirely, the understorey cover of indigenous grasses and herbs. Buffel grass has already become a dominant plant species on the island and other islands along the Pilbara coast. This environmental weed substantially increases the fire risk which may impact upon the habitat of local fauna and may cause significant and permanent changes in vegetation structure and diversity.

At the start of spraying in 1999, buffel grass formed a near monospecific stand over eight hectares (33%) of the island. This weed may release allelopathic chemicals (Choo 1984) into the soil that inhibit growth of other species, potentially acting as a key displacement agent for most of the native vegetation. Buffel grass may also be detrimental to the island's fauna, especially the breeding cycle of shearwaters and the survival of herpetofauna.

Options for controlling buffel grass

A number of options were canvassed at the outset of the study including biological control which was deemed inappropriate because of potential adverse impact on the pastoral industry throughout northern Australia. Fire was ruled out as a control measure as buffel survives fire (Griffin 1993; Humphries 1991) and there is a complete fire ban on the island due to the risk associated with the oil storage facilities as well as impacts on the indigenous flora and fauna. Although isolated plants on the island are pulled up, physical removal is not usually appropriate due to the large number of plants and the difficulty of removal because of their strong root system. Other problems are the cost, soil disturbance and possible wind erosion (blow out from cyclonic wind). Mowing is ineffective, as well as costly, impractical (petrol mowers cannot be used due to fire risk) and possibly damaging to native fauna. The key option for research into the control of buffel grass focussed on herbicide control.

Key aims of the project

Phase one of this project was to investigate and research the biology of buffel grass and to develop a control programme which will integrate eradication or sustainable control of buffel grass with the reinstatement of indigenous species.

Phase two of the project is the control of buffel grass over the whole island based on the results of Phase 1, restoration of indigenous communities, and initiation of a seed

collection and storage programme for future revegetation works. This phase has been underway for two years, and is the emphasis of this paper.

Outcomes of this study will be directly relevant to the decommissioning of the Airlie Island oil installation while providing benchmark data on the control of buffel grass. The study will therefore be of regional, national and international significance to land managers and conservation agencies where buffel grass is an environmental weed. Information on buffel grass control generated from this programme is already being utilised by local land managers on adjacent islands and adjacent mainland as well as other areas in Australia such as Queensland and central Australia.

Data was generated in Phase one of the project including buffel grass seed production/viability; longevity of the soil seed bank (at least three years); buffel spread; densification and percentage groundcover; seedling recruitment; soil nutrient profiles; indigenous plant resistance to herbicides (8 *l*/ha Roundup no effect on *Acacia bivenosa, A coriacea* or *Rhagodia*); life cycle of buffel (seed can germinate and flower in six weeks, plants can grow, germinate, flower or seed any time of the year as long as conditions are favourable, a minimum of 10mm rainfall) and comparison with *Eulalia aurea* the dominant indigenous grass species. Phase one also found that repeated spray trials (Roundup then Verdict) after regrowth gave excellent kill rates as did seedling spray trials. Detailed summaries of the results of research undertaken in Phase one are being prepared for publication.

Study site

Airlie Island (Fig. 1) is a 25 ha nature reserve and lies 35 km north-east of Onslow.

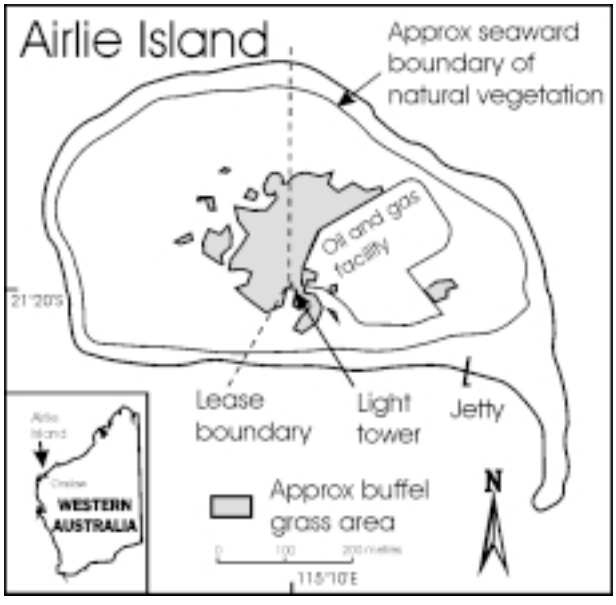

Fig. 1 Airlie Island with infrastructure, lease boundary and approximate buffel grass area when eradication work began.

The island has been used in the last decade as a fuel storage depot for Western Mining Corporation Petroleum Division (WMC), Novus Petroleum's offshore oilfield projects and by the present lease holder Apache Energy. Imminent decommissioning of the petroleum activities on the island require that buffel grass control be undertaken to ensure that the weed is contained, controlled or eradicated. Though the lessee is only required under agreement to control buffel grass and revegetate in the leased area (approximately half of the island), they are undertaking a programme to try to eradicate buffel grass from the entire island and revegetate areas, where necessary.

Airlie Island is on the borders of the Fortescue and Carnarvon Botanical districts (WMC 1988), and receives an annual rainfall of 300 mm from both summer (cyclonic) and winter (cold front) storm systems. Much of this rain falls intensively in irregular intervals, often accompanied by severe winds. The soil on the island is white to pinkish, generally coarse, calcareous sand with poor water holding capacity.

The rainfall pattern, lack of permanent surface water and small size of the island means the vegetation must be drought tolerant and able to cope with salt-laden wind. Most of the island is dominated by two *Acacia* species (*A. bivenosa* and *A. coriacea*), with *Rhagodia preissii*, *Eulalia aurea* and now buffel grass (*Cenchrus ciliaris*) as the major perennials. Shorelines are dominated by *Spinifex longifolius*, *Ipomoea pes-caprae*, *Sporobolus virginicus* and *Eulalia aurea*. During favourable seasons, a large number of annual species can be found in abundance, including *Portulaca intraterranea*, *Euphorbia* spp., *Boerhavia repleta*, *Cleome viscosa*, *Cuscuta australis* and *Threlkeldia diffusa* (WMC 1988).

Only two other weed species are known to exist on Airlie Island. Cotton bush (*Aerva javanica*) plants may be found anywhere on the island. When found during spray operations these are pulled up and any fallen seed is picked off the ground; plants are placed in sealed polythene and taken off the island with all other rubbish for disposal (deep buried). Any plants seen by Apache Energy staff are treated in the same manner. Only a few plants are found each year; locations of these plants are noted and occasionally these sites are visited by Apache staff to check for new plants. The other weed is a native, *Abutilon lepidium*, that occurs naturally on adjacent islands but not on Airlie. To date about 300 seedlings have been removed from one small area (Long pers. comm.).

METHODS

Aerial Photography and Image Enhancement

Aerial photographs of Airlie Island are taken annually. Visual examination of these images from 1993 to 1998 shows only a few small clumps of buffel grass colonising away from the main buffel zone. There are numerous small

plants known to exist that do not show up on the photos. The major feature of the series of images is densification and gap-filling within the existing stand, which is responsible for most of the increase in buffel grass cover on the island.

The set of photographs taken in June 1997 were scanned and colour enhanced for the wavelengths corresponding to buffel grass, beach spinifex and *Eulalia*. These areas were coloured yellow, purple and green respectively to enhance visualisation of the extent of buffel grass spread.

Selection of herbicides

The key aim of the research programme was to identify a safe and effective herbicide to control buffel grass with minimal impact on the indigenous flora and fauna. Buffel grass was known to be very difficult to control due to its ability to survive long periods of drought and resprout from dormant buds. Other species with similar traits (e.g., *Ehrharta calycina*, *Eragrostis curvula* and *Hyparrhenia hirta*) can be successfully controlled using the correct herbicides and spraying at the right stage of growth. For example, spraying *Ehrharta calycina* before flowering results in a high death rate, whereas spraying at flowering time results in dieback of the top part of the plant but resprouting from dormant buds at the base (Dixon 1999). Herbicides known to control other *Cenchrus* species (e.g. *Cenchrus echinatus*), and which would be suitable for Airlie Island conditions, are the grass-selective herbicides Fusilade 212 and Verdict 104 (Parsons 1995).

Successful trials and large-scale herbicide application on other grasses have been conducted in Kings Park bushland, Perth, Western Australia, indicating several of the grass-selective herbicides are safe to use over most indigenous plants including monocotyledons such as sedges and rushes, kangaroo paws (*Haemoderaceae*) and orchids, and dicotyledons such as the Proteaceae family. As we had extensive experience with the following herbicides, the first trials included the grass selective herbicides Fusilade 212® (212g/*l* fluazifop-p) Fusilade WG® (212 g/kg fluazifop-p) (this formulation of wettable granules is easier and safer to handle and does not smell of hydrocarbons), Targa® (99.5 g/*l* quizalofop-p-ethyl) and the non-selective herbicide Roundup Biactive® (360 g/*l* glyphosate) (the wetting agent in this formulation is claimed to be safer to use over fauna, particularly frogs). It should be noted Roundup® 360 (360 g/*l* glyphosate) and other glyphosate formulations had been tried by several people to control buffel grass in central and eastern Australia, their results were very poor and we were advised not to use it. Verdict® 104 (104 g/*l* haloxyfop) was included in the latter trials. These herbicides were evaluated over a three year period, not all the trials will be included in this paper.

Redeye®, a marker dye incorporated in the spraying tank, was used in the larger trials to make sure there was no area missed and over-spraying was avoided. Though Redeye is a Schedule 6 poison (Australia-wide schedule outlining the toxicity of pesticides) and widely available to the general public, there was no other formulation available, to our knowledge, that would remain evident for several days under the hot spraying conditions experienced on Airlie. We also decided not to use any spraying oils for fear of damaging foliage in the high temperatures and thus inhibiting the translocation of herbicide into the buffel plants.

Spray plots

Spray plot sizes were 1x1 m, each separated by a 0.5 m-wide corridor. Three replicas of each plot were made within each trial site. All plots were sprayed working systematically across the plot and back again in the opposite direction to ensure even coverage. Compressed sheeting was used as a barrier to ensure there was no drift onto other plots.

Trial I

Condition of plants before spraying was scored using Table 5 based on the experience of the authors.

Sprayed in February 1997 when the plants were showing vigorous new growth after the summer wet season, but showed some signs of drying out (spraying condition 4 going on 6).

Treatments used were: Fusilade 212, 2 *l*/ha (plus Agral 60 @ 1 ml/*l*); Fusilade 212, 4 *l*/ha (plus Agral 60 @ 1 ml/*l*); Fusilade WG, 5g/*l* @ 2 *l*/ha (plus Agral 60 @ 1 ml/*l*); Fusilade WG, 10g/*l* @ 4 *l*/ha (plus Agral 60 @ 1 ml/*l*); Roundup Biactive, 3 *l*/ha; Roundup Biactive, 6 *l*/ha; Control.

Trial II

Sprayed in October 1997 when the weather was warm and the buffel grass showing signs of drought stress. The buffel grass was drying out, and had only a few obvious green shoots (Spraying condition 6, Table 5).

Treatments used were: Roundup Biactive 0.6,1.5 and 3 *l*/ha; Targa 6 and 8 *l*/ha + Agral 60 @ 1 ml/*l*; Verdict 6 and 8 *l*/ha + Agral 60 @ 1 ml/*l*; Fusilade 212, 6 and 8 *l*/ha + Agral 60 @ 1 ml/*l*; Control.

Trial III

Sprayed in April 1998 in low to moderate wind conditions. Plants were responding to recent heavy rain with vigorous new growth, in spraying condition 3 (Table 5). This first rain was followed by regular rainfall events for the following 11 weeks.

Treatments used were: Fusilade 212, 6 and 8 *l*/ha + Agral 60 @ 3 ml/*l*; Targa 6 and 8 *l*/ha + Agral 60 @ 3 ml/*l*; Verdict 6 and 8 *l*/ha + Agral 60 @ 3 ml/*l*; Roundup Biactive, 0.6, 1.5 and 3 *l*/ha; Control.
NOTE: The rate of Agral 60 was altered from the previous two trials (3 ml/*l* up from 1 ml/*l*) following the manufacturer's recommendations.

Large-scale spraying trials

A few large-scale (100m^2) trials were attempted with herbicides achieving a high kill-rate in the multi-herbicide trials. These trials using a 15 litre back-pack sprayer were aimed at confirming the effectiveness of herbicides sprayed on a larger scale prior to the implementation phase.

Roundup Trials

Three large areas were sprayed in April 1998 with 6 *l*/ha Roundup Biactive as a broadscale trial. Plants were in spraying condition 3 (Table 5).

Further trials were sprayed at 8 *l*/ha under spraying condition 4 (Table 5).

Verdict Trial

A large area around the buildings was sprayed in July 1998 with Verdict at 8 *l*/ha. Plants were in spraying condition 4 (Table 5).

Implementation phase

This phase involved spraying all of the buffel grass on the island with approved, effective equipment. Some of the key constraints which we had to address are as follows:

- Getting the equipment on the island. This was trucked up to the remote townsite of Onslow then placed on a barge which goes to the island once a week. No large, heavy or dangerous items can be carried on the helicopters which take personnel to the island from Barrow Island, the direct flight destination from Perth.
- Using the best equipment for the job and making sure we had adequate spare parts. No internal combustion engines are allowed on the island (due to possible hydrocarbon contamination/spills), therefore we had to use battery-operated spraying units. Water supply for spraying is from a reverse osmosis supply generated on the island, rainwater also goes into the tanks. This supply is limited; on one occasion the pipe to the tanks burst and we only had just enough water for spraying operations.
- Cyclones during spraying operations. When these develop the island is evacuated and all operations ceased.
- Laying a temporary (three years) water pipe with taps for filling the spray tanks.
- The 250 litre spray tanks have to be carried to each station by hand, no vehicles allowed in the natural vegetation areas. It is therefore necessary to judge very carefully how much material you need in the tank to finish off the area.
- Coping with the extreme weather conditions (e.g. 36°C and 80% humidity during summer spraying operations) and difficult working conditions (e.g. walking backwards when spraying) and abundant dead twigs which fouled boots and clothing.
- Training for the job and safety issues and the need for annual renewal of Helicopter Underwater Escape Training (HUET).

Equipment used

2 x 250 litre sprayers with 12 volt battery operated pump; 2 x 60 metre reel hoses and adjustable spray guns; 1 x 12 volt battery charger; 6 x 12 volt car batteries; 600 metres x 32mm ID pipeline; 10 taps miscellaneous joiners/fittings; 2 Hardie backpack sprayers.

Full-scale spraying operation

Roundup Biactive at 8 *l*/ha and Verdict at 6 *l*/ha were used. The strategy employed Roundup in the first spraying operation as there were few annual indigenous plants emerged that might be affected by the spray. Then Verdict used as a blanket spray as annuals and possibly some native perennial plants are at a susceptible stage.

Each spraying unit requires two operators, one as a sprayer and the other to release and withdraw the hose. Operators needed to change duties on a regular basis to avoid fatigue as a result of the high temperatures. Operators avoid spray drift by spraying upwind which can be difficult as you have to spray around bushes and under them whilst avoiding spray application of the bushes. In dense stands we use a blanket spray and other areas spot spray. Spray is applied in a circular fashion, pulling the hose out and spraying as you go to the extremities of the hose, then working backwards to the spray unit and again pulling the hose out until the entire circle is completed. The unit is then moved onto the next section. Some areas not covered have an extra section of hose added to cover the area; alternatively we use a backpack sprayer for outliers or remove isolated plants by hand. Most of the leased area of the island can be accessed by using a road or around the bund surrounding the oil tanks. In these areas we placed the spraying tank on a tractor for ease of movement.

Round One Spraying - March 1999

The first round used Roundup for ease of operations and because it is more cost effective than using Verdict. Herbicide application was following six weeks of heavy soaking rain. Ideally the spraying programme should have been initiated two weeks earlier as most of the buffel grass had just reached first anthesis and early seeding. The buffel grass was in rapid growth with some plants beginning to dry out by the fourth day of spraying. Most of the application was blanket spraying of heavily-infested buffel areas, avoiding as many indigenous plants as possible with very few annual seedlings present. Previously-sprayed areas were spot sprayed, avoiding contact of Verdict on *Eulalia* to reduce damage to planted greenstock and annual indigenous plants. Though original trials indicated *Eulalia aurea* was resistant to the grass-selective herbicides, probably because they were under stress at the time, subsequent trials showed they were very sensitive and future spraying would need to avoid excessive contact with *Eulalia*.

Round Two Spraying - June 1999

The second round of spraying was mainly blanket spraying resprouts and seedlings with Roundup, as there was such a large amount to spray and low levels of annual indigenous plants in the previously-sprayed area. Some spot

spraying with Roundup in outlier areas and spot spraying Verdict over replanted areas was done.

Round Three Spraying - April 2000

The third round of spraying followed six weeks of substantial rainfall on the island as a result of a cyclone. The buffel was in excellent condition for spraying. About half of the area, low impact areas, were sprayed with Roundup; the remainder, rich herb fields, with Verdict. Backpack sprayers were used on outlier populations. A thorough inspection after the spraying operation detected some other plants which were removed by hand.

Revegetation

Greenstock propagation

All seed was collected from Airlie Island to ensure only local provenances were utilised. Plants of *A. coriacea*, *A. bivenosa*, *Rhagodia preissii* and *Eulalia aurea* were propagated from seed in glasshouses at Kings Park and Botanic Garden and transported to Airlie Island. *Acacia* seed were hot-water treated and left to soak overnight. Seed was sown into punnets and after about six weeks, seedlings were pricked out into tubes. Seed was sown in summer for planting in early winter of the following year. Propagation of larger seedling numbers was in deeper 5cm x 5cm x12cm pots to promote stronger root development and to give a longer holding period in case of dry conditions. In 1999 plants were raised in an 'Accredited' (approved by the Nursery Industry Association of Western Australia) commercial nursery, which was inspected beforehand and during the growing period to ensure adequate hygiene and weed-free propagation. Using an accredited nursery as the source of all plant material reduces the risk of introducing pests, diseases and other environmental weeds.

Transport of the seedlings to the site was by truck to Onslow, then barge to Airlie Island. Plants were watered prior to packing and transport to the trucking company. Polystyrene foam boxes and strong waxed cardboard boxes were used to transport the seedlings.

Replanting density

Benchmarking (using quadrats and transects) in pristine areas of the island gave a figure of natural plant density and the estimated number of plants required for revegetation of bare areas. This density was doubled to allow for assumed seedling death. The total area requiring revegetation is estimated at one hectare; this excludes the leased area which is to be revegetated after decommissioning the oil facilities.

Planting Times

The lack of summer rain resulted in plantings only being undertaken in winter.

As soon as the plants arrived on the island, they were placed in a shady position and watered. Planting was done with a garden trowel, the root balls of the plants were placed just below the soil surface to avoid drying out. The first planting trial in April 1998 consisted of *A. bivenosa, A. coriacea, Rhagodia preissii* and *Eulalia aurea* which were planted into moist soil. A further trial in June/July used only 200 *A. bivenosa*. A large trial in June 1999 used 1400 plants: *A. bivenosa* and *E. aurea* in high numbers; *A. coriacea* and *R. preissii* in low numbers. These were planted in very dry conditions. Planting was in a number of locations in areas previously heavily-infested with buffel grass. After cleaning with bleach and thoroughly rinsing, the spraying units and long hoses were utilised to water the plants in.

RESULTS

Aerial Photography and Image Enhancement

Aerial photographs taken in June 1997 were scanned and colour enhanced for the wavelengths corresponding to buffel grass, beach spinifex and *Eulalia aurea*. From this it was estimated that 6 ha, or 23% of the island was infested with buffel, and that there was virtually no overlap in the distribution of buffel grass and *Eulalia aurea*. Further data collected in 2000 indicated that buffel grass actually covered almost 8 ha of the island.

Spray Plots

Trial I

The trial was scored 11 weeks after spraying (Table 1) and assessed again after six months. This later assessment, after some resprouting from dormant buds, found no dead

Table 1 Spraying Trial I; applied in February 1997.

Herbicide	Concentration and application rate	Percentage live plants flowering	Percentage death of above ground biomass
Roundup Biactive	7.5ml/*l* @ 3 *l*/ha	<40%	88% ± 7%
	15ml/*l* @ 6 *l*/ha	55%	88%± 7%
Fusilade 212	5ml/*l* @ 2 *l*/ha	65%	4%± 4%
	10ml/*l* @ 4 *l*/ha	68%	22%± 12%
Fusilade (WG)	5g/*l* @ 2 *l*/ha	77%	0 %
	10g/*l* @ 4 *l*/ha	53%	23%± 20%
Control	—	100%	0 %

plants in the control or any Fusilade plots (except one liquid application @ 2 l/ha in one plot, in which 20% of the plants had died). In contrast, most plants were dead in all Roundup trials. Plants that were still alive were flowering. A similar situation was found 18 months after spraying, but numerous germinants had emerged in the Roundup plots.

A comparison of seeds collected 11 weeks after the trial from sprayed and unsprayed buffel showed that all the florets of sprayed plants were empty, compared with the unsprayed plants, which had 80% of florets with seed, with an average of 1.50 ± 0.18 seeds per floret. It appears that although spraying under non-optimal conditions is not very effective at killing plants, it may prevent viable seed-set, and therefore be worthwhile.

Conclusion

Both Fusilade formulations had low kill rates (~20%) at the higher concentration of each. Roundup had a better kill-rate of (~80%), with most plants succumbing the following drought period. The dry weather conditions at the time of spraying limited the effectiveness of the herbicides, although Roundup had achieved complete kill when it was reassessed in August.

Trial II

The trial was scored six months after spraying, when the next rains fell.

The trial was scored again in July 1998, nine months after spraying. All plants were alive, resprouting from dormant buds.

Conclusion

No herbicides caused any buffel plants to die, owing to the unfavourable spraying conditions. These results show the importance of spraying plants at the correct stage of growth, as it appears that stressed plants were drying out and resulting in a lack of translocation of the herbicide from the leaves through to the dormant buds at the base of the plant.

Table 2 Effectiveness of herbicides on kill of buffel grass in trial 2.

Herbicide	Concentration and application rate	Percentage death of above-ground biomass
Roundup	1.5ml/l @ 0.6 l/ha	14% ± 8 %
	3.75ml/l @ 1.5 l/ha	0 %
	7.5ml/l @ 3 l/ha	14% ± 14 %
Fusilade 212	15ml/l @ 6 l/ha	20 %± 20 %
	20ml/l @ 8 l/ha	0 %
Verdict	15ml/l @ 6 l/ha	94% ± 6 %
	20ml/l @ 8 l/ha	0 5%
Targa	15ml/l @ 6 l/ha	12% ± 6 %
	20ml/l @ 8 l/ha	11% ± 11 %
Control	-	0 %

Table 3 Effectiveness of herbicides on kill of buffel grass in trial 3.

Herbicide	Concentration and application rate	Percentage death of above-ground biomass
Roundup	1.5ml/*l* @ 0.6 *l*/ha	57% ± 4%
	3.75ml/*l* @ 1.5 *l*/ha	52% ± 10%
	7.5ml/*l* @ 3 *l*/ha	67% ± 5%
Fusilade 212	15ml/*l* @ 6 *l*/ha	71% ± 18%
	20ml/*l* @ 8 *l*/ha	100% ± 0%
Verdict	15ml/*l* @ 6 *l*/ha	95% ± 5%
	20ml/*l* @ 8 *l*/ha	95% ± 5%
Targa	15ml/*l* @ 6 *l*/ha	44% ± 5%
	20ml/*l* @ 8 *l*/ha	34% ± 23%
Control	-	0%

Trial III

The trial was scored in July 1998, 10 weeks after spraying. During this time rains had been consistent, with several large falls. Conditions for plant regrowth were exceptionally good, so the results in Table 3 are the worst (i.e. maximum regrowth) that could be expected from a spray applied in good conditions.

These results suggest that, under optimal spraying conditions, Targa is of limited use, Roundup provides moderate kill-rates, and Fusilade and Verdict both give excellent results, killing nearly all plants (above-ground biomass) sprayed. Examination of larger Roundup trials showed that plants resprouted from the spray-shadowed portion, killing only leaves that were sprayed directly. Verdict and Fusilade, however, seemed to usually kill the entire clump (above-ground biomass) in a single application. Verdict worked equally well at both concentrations, while Fusilade appeared to work better at the higher concentration, which killed (above-ground biomass) all plants sprayed. Some resprouting of all treatments occurred at a later date but not as much as usual, indicating the plants were sprayed under ideal conditions.

Condition of Plants

The three multi-herbicide trials described previously were applied under different conditions, and showed a marked variation in effectiveness. The major difference between trial conditions was the condition of the plants. The spraying conditions and results are listed in Table 4.

Plants that were vigorously growing were killed more effectively, while senescing plants were not killed, or in the case of Roundup, killed up to the onset of leaf desiccation.

Spraying conditions

Buffel grass must be actively growing (in spraying condition 3 to 5, Table 5). Do not spray senescing plants.

Table 4 Susceptibility of buffel grass to herbicides at different stages of plant condition

Plant Condition*	Herbicides achieving <35% kill	Herbicides achieving 35%-75% kill	Herbicides achieving 80%-100% kill
3. Vigorous new growth	Targa	Roundup, Fusilade at lower concentration	Verdict, Fusilade at higher concentration
4. Vigorous growth and flowering	Targa	Targa, Fusilade at lower concentration, Roundup at all concentrations	Verdict all concentrations, Fusilade at higher concentration
6. Senescing	Targa, Verdict, Fusilade most conditions	Roundup (if plants just starting to senesce)	No herbicides achieved this kill rate

* Full description of plant condition in Table 5

Large scale spraying trials

Roundup

All areas sprayed at 6 *l*/ha had a high rate of kill where Roundup had been directly applied to leaves, but plants and portions of plants within the spray shadow were resprouting. It is therefore necessary to spray a second time when the buffel has had time to resprout.

The results from the 8 *l*/ha trials were outstanding with very few resprouts indicating this is the appropriate rate for use for the implementation programme.

Verdict Trial

Verdict at 8 *l*/ha, sprayed around the buildings in July 1998 gave excellent results, killing all the seedlings sprayed and most of the parent plants.

Conclusion

Roundup has a very high kill-rate where it can be applied directly to the leaves, but for large plants a second spray is needed after the above ground biomass death and subsequent resprouting to destroy plants and culms which were in the spray shadow. Verdict is ideal for spraying seedlings and will also kill previously-sprayed resprouting parent plants as well as some plants not previously sprayed.

Implementation phase – the eradication of buffel grass on Airlie Island

Round One Spraying - March 1999

Most of the buffel could be seen to be yellowing by the fourth day of spraying, indicating a good kill rate. Coverage appeared complete, but occasional unaffected shoots were detected as had been previously observed in herbicide trials.

Cyclonic rain shortly after spraying led to an unexpected rapid regrowth of large plants, however conditions by the end of April were too dry to spray. Desiccation of plants and the combined effect of the spray prevented seed set on the resprouting culms.

Some plants missed spray application, as expected, mainly under acacias as well as occasional plants away from the main populations. One area which was showing signs of drying out towards the end of the spraying period exhibited reduced death rates. However, overall results were better than anticipated with an estimated 80%-90% kill rate of mature plants, though there was resprouting on a number of plants.

Table 5 Buffel grass plant condition and suitability for spraying

Condition Number	Plant Growth Stage	Suitability for spraying
1	Fully dormant (no visible green tissue).	Plants not growing. DO NOT SPRAY.
2	Bud-break (no extended leaf lamina yet visible).	Not enough leaf area for herbicide uptake. DO NOT SPRAY.
3	At least half of shoots with extended leaf lamina. Not yet flowering.	Conditions acceptable for spraying.
4	All shoots with extended lamina. Flowering evident.	Conditions perfect for spraying.
5	Vigorous shoot growth. All mature culms fully extended.	Conditions perfect for spraying.
6	Any evidence of senescence of leaves or culms, i.e. leaf-rolling or desiccation (leaf margins dry).	Plants not growing. DO NOT SPRAY.

The method of spraying, though time consuming, worked well. Spray equipment was adequate and effective with no breakdown, and the batteries lasted longer than predicted (five hours) before recharging was necessary. The correct positioning of the water pipe and taps assisted smooth operation, and judging the appropriate amount of spray to finish spraying an area worked well. On average, four operators with two units can spray two hectares each day, or four days to spray the entire buffel-infested area.

Round Two Spraying - June 1999

As the parent plants had decreased significantly in number, regrowth was easier to target with spray. There was a significant increase in the number of seedlings, but not as high as anticipated in previous trials; this may be due to the drier conditions experienced in 1999. The extent of the buffel infestation appeared not to have increased or decreased, but the area took less time to cover as most of the main stand of buffel had been decimated. The kill rates were high, eliminating most of the resprouting plants and other parent plants that were missed in the first spray. There was little damage to non target species and certainly no recorded damage to the perennial species, with the exception of some damage to young *Eulalia aurea* plants in revegetation trials where Verdict was sprayed.

Round Three Spraying - April 2000

The third spraying was mainly of seedlings, as few mature live plants remained. At this stage we estimate most of the seedlings and over 98% of mature buffel grass plants on the island were eradicated. Seedlings may germinate from the soil seed bank. However, the viability of the soil seed bank is rapidly declining and sustainable control of buffel grass will depend upon careful monitoring and a judicious 'mop-up' spray programme.

Revegetation

Greenstock propagation

The seedlings produced both in the small trials and by the accredited nursery were healthy and vigorous, and no weeds were present in the pots. The most successful container for transportation was found to be polystyrene foam boxes as strong waxed cardboard boxes became moist and collapsed, causing some damage to seedlings.

Replanting density

The density of planting in our trials proved successful and we recommend a planting rate that would result in *A. bivenosa* and *A. coriacea* at a density of 1250/ha and *Rhagodia preissii* and *Eulalia aurea* at a density of 2500/ha.

We recommend that planting densities be double to allow for a 50% death rate. However, we must be vigilant as *A. coriacea* has declined in some areas and it is much slower growing when compared to *A. bivenosa* which may eventually outcompete it and require thinning.

Planting

The results from the first two planting trials were outstanding with 89% to 97% of all species surviving and growing vigorously 10 weeks after planting.

Further monitoring in April 2000 indicated there was no further death in the April or June/July 1998 trials. This may have been due to substantial rainfall after planting.

The large planting in June 1999 was a failure with no rain for six months after planting. Almost all the plants of all species died. Though no exact count was done, a few plants of *A. bivenosa* are alive in two or three locations, with survival of <1%.

DISCUSSION

The research results from Phase one of the programme underpinned the implementation phase of the programme. A good knowledge of the biology of the buffel plants opened up a narrow window of opportunity for spraying and optimising kill rates, and seed production, soil seed bank and longevity of seed enabled us to plan ahead with a work schedule. This is aimed at eradication of buffel grass from Airlie Island in the near future, as long as the appropriate funding is available.

Spraying needs to occur whenever there is sufficient rainfall to control the few remaining mature plants and the emergent seedlings of buffel grass. As the estimated age of the soil seed bank for buffel grass (Phase 1 unpublished data) is three years, rapidly declining after eighteen months, further large-scale spraying operations will not be necessary. Trials with motorised, battery operated backpack sprayers indicate this is the best option for spraying smaller numbers of plants. Hand-operated units are too debilitating for operators in the hot, humid conditions experienced on the island.

The initial trials provided an appreciation of the problems and how adaptable you have to be with your implementation programme which is entirely dependent on the vagaries of the weather. The spraying results proved to be inconsistent as every trial was different. However, the results from the large-scale spraying programme were used as the basis for the implementation phase. The authors are confident that the herbicides, and their concentrations, used in the implementation phase are ideal for the expected varying conditions of the plants. Future operations, due to the recruitment of herbs in the buffel areas, will be using Verdict to avoid damage to these plants. Planting *Eulalia aurea* should be delayed until the soil seed bank is eliminated, otherwise further spraying could kill or damage *Eulalia.*

The best time for spraying adult plants is within the range of three to five weeks after sufficient rain has fallen. If spray is applied too early the seedlings are too small to target and with extra rainfall there may be delayed germination. Also it is not cost-effective to spray twice when

one operation can achieve good results. Under quick drying conditions some plants are beginning to get stressed, and may occasionally drop some mature seed before they are sprayed.

Logistically there are major problems with a remote insular site such as Airlie Island. For example we have to rearrange our usual work schedules when the spraying is necessary as rainfall in the arid zone is erratic. All the accommodation, flights and so on are arranged by the oil company and, if urgent work is being done on the oil installations, securing necessary flights and accommodation can be problematic.

Though the spraying programme is in hand, the programme has identified an urgent need to revegetate bare areas. The dead below-ground biomass of buffel does provide soil-binding to prevent wind erosion for at least three years, in which time revegetation needs to proceed.

Planting greenstock can give excellent results if the ground is moist and there is follow-up rain. We recommend the best time for planting is in late autumn or early winter, though it can also be dry at this time of the year as experienced in the 1999 trial.

High on the priority list is a comprehensive seed collecting and storage programme of all species native to the island, with key areas being the rich herbfields between the Acacias and other perennial plants when decommissioning takes place. Some stabilisation trials also need to be undertaken as cyclonic winds are a regular occurrence during the summer season. A recent cyclone altered the shape of the island and caused erosion near a flare installation which is being re-stabilised and revegetated by consultants based on the mainland.

The ongoing success of the control of buffel grass and revegetation of Airlie Island with indigenous species depends upon the good aegis of the funding sponsors who manage the island. The programme does show that with careful, focussed research, it is possible to achieve effective and timely weed control in the arid zone.

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