Innovative field nurseries to assess weed risk in the rangelands of Western Australia

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Summary There is growing interest in intensifying beef cattle production in the rangelands of northern Western Australia through 'mosaic agriculture' to complement the extensive grazing of native vegetation. Irrigated fodder production and the introduction of improved forage plants (dryland) can broaden the feed base of rangeland grazing systems. With agricultural development there can be unwanted consequences and one of these is that some pasture plants have become agricultural and environmental weeds in certain situations.

Taking an innovative approach a series of four field nurseries have been established in key environments (soil × climate) in the West Kimberley and Pilbara to obtain data on the persistence and/or spread of a wide range of commercial pasture and fodder grasses and legumes. The trials were established under irrigation to simulate a worst case scenario as weed spread in a rangelands context is likely to be episodic, for example, following a cyclone. The results should help to inform debate and provide decision-makers with the information to find the balance between agricultural development and the protection of high value environmental assets. This research is a work in progress and the preliminary results will be presented at the conference.

Keywords Weed risk assessment, irrigated agriculture, assessment of weed potential, pastures, environmental weeds.

INTRODUCTION

There is growing interest in intensifying beef cattle production in the rangelands of northern Western Australia through 'mosaic agriculture' to complement the extensive grazing of native vegetation. Mosaic agriculture refers to, 'irrigation schemes in which small patches of irrigation occur within a region rather than irrigation of one large contiguous area' (Cook *et al*. 2008). Irrigated fodder production and the introduction of improved forage plants (dryland) can broaden the feed base of rangeland grazing systems.

With agricultural development there can be unwanted consequences and one of these is that some pasture plants have become agricultural and environmental weeds in certain situations (Lonsdale 1994, Panneta *et al*. 2001). The challenge is to find the right balance between agricultural development and minimising the risk of weed invasion of high value environmental assets.

Diversification permits are required to grow non-indigenous plants on pastoral leases in WA. In this context, non-indigenous refers to plants which are not native to Western Australia. The current assessment procedure includes a desk-top assessment of weed risk by the state government departments involved. For example, the Department of Agriculture and Food WA (DAFWA) currently uses the environmental weed risk assessment system developed by the Future Farm Industries CRC (Stone *et al*. 2012), with a modified potential distribution system based on climate. However, there is currently a paucity of field data from previous trials or agricultural developments to calibrate the desktop modelling.

This project is collecting data on the persistence and/or spread of a wide range of commercial pasture and fodder grasses and legumes by re-visiting 'old trial sites' and from a series of 'weed risk' field nurseries in key environments (soil × climate) in the West Kimberley and Pilbara. This paper focuses on the series of field nurseries. All of the species being evaluated are commercial pasture and fodder options which are widely used in similar environments in the Northern Territory and Queensland. The only non-commercial species are two native legumes from the Fortescue region in the Pilbara. In addition, as a safeguard, protocols were carefully developed to monitor for and minimise the risk of movement of seed off-site.

MATERIALS AND METHODS

Field nursery trials have been established at four sites which represent key soil-climate environments in the West Kimberley and Pilbara: Birdwood Downs near Derby, Wallal Downs south of Broome, Woodie Woodie in the Pilbara and Gogo Station in the Fitzroy Valley (Table 1). The average annual rainfall at these sites varies from 300 to 600 mm per annum and the soils vary from red-brown sands with 'Pindan' vegetation (*Acacia ancistrocarpa* Maiden & Blakely and

A. eriopoda Maiden & Blakely dominated associations on sandplain) to black cracking clays associated with the floodplains of the Fitzroy River. Two sites had native vegetation; while the other two sites were previously cleared and had been used for dryland agriculture (Table 1). The trials were established over a 13 month period from April 2015 to April 2016.

The sites were cleared of vegetation, levelled and cultivated to ensure a fine soil seed-bed suitable for sowing and the installation of a trickle irrigation system. Sites were weed-free at sowing following cultivation and spraying with a knockdown herbicide (glyphosate 480 a.i. at 2 L ha^{-1}). The treatments were sown by hand and the seeding depth adjusted from 10 mm to 50 mm to match the seed size. Seeding rates varied depending on species, seed size and were also adjusted for seed-lots with low germination. For the 'plus Rhizobia' treatments the seed was inoculated and lime pelleted the previous day. Where possible the treated seed was kept cool prior to seeding.

Plots were sown as 3 m rows and irrigated with a trickle irrigation system to assist seedling establishment and provide the best possible conditions for growth and seed production. During the seedling stage the trials were irrigated daily to maintain soil moisture near the soil surface. The frequency of irrigation was reduced as the plants grew and developed. The high to extreme temperatures in the late spring and early summer resulted in a high evaporative demand and regular irrigation was required to reduce heat and moisture stress on the plants.

At each site there are two replicated trials. The 'grass' field nursery trials have 23 entries and include a range of warm season (C4) annual and perennial grasses (Table 2). Each entry has plus and minus (+/−) complete fertilizer sub-treatments and each combination is replicated three times. The 'legume' field nursery trials have 23 entries and include a range of tropical legumes, plus the temperate perennial legume – *Medicago sativa* (lucerne) (Table 3). Each entry has +/− fertilizer and +/− rhizobia sub-treatments and each combination is replicated three times (note: Birdwood and Gogo legume trials do not include the 'plus fertiliser and minus Rhizobia' treatment).

The soils are low in many of the essential nutrients for plant growth. All of the sites are low in organic carbon, with a range from 0.32 to 0.6% organic C in the topsoil (0–10 cm). The sites at Birdwood Downs, Wallal Downs and Woodie Woodie are low in the essential nutrients phosphorus, potassium and sulphur, while zinc is also deficient at Wallal Downs. At these sites the Colwell P levels ranged from 2 to 8 mg kg^{-1}. The fine-textured soil at Gogo has an alkaline soil reaction and is sufficient to high in the key nutrients, except for sulphur which is marginal. A complete fertiliser was applied for the plus fertiliser treatments which included nitrogen for the grasses, while nitrogen was not applied to the legume treatments.

A protocol has been developed to minimise the risk of spread from the field nursery sites. The following guidelines are being implemented to minimise the risk of movement of seed off-site:

- Trial area fenced to exclude stock and wildlife
- Regular monitoring (4× times per year) of a 50 m buffer around the trial area to check for and control any plants that have established outside the trial area
- Any plants remaining in the trials after a given period (~two years) will be killed with a knockdown herbicide
- There will be on-going monitoring (2× per year) of the site for a further two years to check for and control any plants within the trial area and surrounding buffer. (This monitoring will be extended for 18 months after the last recorded germination of any species).
- Other factors which reduce weed risk are the low fertility of the soils (without added fertiliser).

At the field nursery at Birdwood Downs the site was fenced with wallaby proof ring-lock fencing, but this proved inadequate to keep out small wallabies, so chicken wire was added which proved effective in keeping the wallabies out.

Table 1. Summary of site details for the established field nurseries.

Pastoral station	Vegetation	Soil type	Annual rainfall (mm)	Date established
Birdwood Downs (Derby)	Cleared pasture	Red-brown sand (Pindan)	600	April 2015
Wallal Downs	Native vegetation (Pindan)	Red-brown sand	350	April 2015
Woodie Woodie (Warrawagine)	Native vegetation (spinifex)	Red-brown loam	300	Sept 2015
Gogo	Cleared – dryland cropping	Black cracking clay (vertisol)	570	April 2016

Table 2. A list of species and cultivars in the grass field nursery trials.

Botanical species	Common name	Cultivar/variety
C4 annual grasses – fodder		
Cenchrus americanus (L.) Morrone	pearl millet	Pearler Maxa Lawrence
Sorghum bicolor (L.) Moench	sorghum spp. hybrids	Sweet Jumbo LPA Superdan 2 Stargrazer BMR Rocket Sugargraze
Zea mays L.	forage maize	HM 102
C4 perennial grasses		
Chloris gayana Kunth	Rhodes grass	Callide Katambora Finecut Mariner
Megathyrsus maximus (Jacq.) B.K.Simon & S.W.L.Jacobs	panic grass	Gatton G2
Digitaria eriantha Steud.	digit/pangola grass	Premier
Panicum coloratum L.	Bambatsi panic	Bambatsi
Digitaria milanjiana (Rendle) Stapf	Jarra grass	Jarra
Bothriochloa pertusa (L.) A.Camus	bluegrass	Floren
Urochloa mosambicensis (Hack.) Dandy	sabi grass	Sabi grass
Cenchrus ciliaris L.	buffel grass	Gayndah Biloela
Cenchrus setiger Vahl	Birdwood grass	–

Once the plants are well established and have flowered and set-seed the irrigation frequency and duration will gradually be reduced over a period of a few weeks to simulate a naturally drying soil profile at the end of the 'wet' season. The sites will then be monitored for plant persistence and recruitment from seed over the next two years. Large perennial plants were also cut back to reduce the biomass and leaf area and consequently the moisture stress on the plants as the irrigation was reduced. This helps to replicate the rangeland context where there is essentially uncontrolled grazing, whether by stock, wildlife or feral animals. Reducing the biomass also improves the potential for perennial plants to persist over the dry season. The sites were maintained largely free from background weeds while the plants were establishing and the irrigation system was in place. This proved more difficult at Birdwood Downs where there was a large seed-bank of annual and perennial grasses and broadleaf weeds.

RESULTS

In terms of weed risk, the importance of data collection increases once the irrigation has been turned-off. The irrigation was turned-off at Derby (Birdwood Downs) and at Wallal Downs in mid-April 2016 and will be turned-off at Woodie Woodie in late June 2016, while the field nursery trials at Gogo are still establishing.

There was good to excellent establishment of most lines across all four sites, and the few treatments with poor establishment were generally re-sown. Even though it is comparatively early stages of the trials, there have been some interesting observations and results.

Lablab and cowpea were the strongest performing legumes at both Derby and Wallal Downs sites over

Table 3. A list of species and cultivars in the legume field nursery trials.

Botanical species	Common name	Cultivar/variety
Temperate legumes		
Medicago sativa L.	lucerne	SARDI 10
Tropical legumes		
Centrosema pascuorum Mart. ex Benth.	centro	Cavalcade
Lablab purpureus (L.) Sweet	lablab	Highworth Rongai
Vigna unguiculata (L.) Walp.	cowpea	Ebony
Macroptilium bracteatum (Nees & Mart.) Marechal & Baudet	burgundy pea/bean	B1
Chamaecrista rotundifolia (Pers.) Greene	roundleaf cassia	Wynn
Clitoria ternatea L.	butterfly pea	Milgarra
Macroptilium atropurpureum (DC.) Urb.	siratro	Aztec atro
Leucaena leucocephala (Lam.) De Wit.	leucaena	Wondergraze Tarramba
Stylosanthes hamata (L.) Taub.	Caribbean stylo	Amiga Verano
Stylosanthes scabra Vogel	shrubby stylo	Seca Siran
Stylosanthes guianensis (Aubl.) Sw. var. *guianensis*	common stylo	Hughes Beefmaker
Stylosanthes guianensis (Aubl.) Sw. var. *intermedia* (Vogel) Hassl.	fine stem stylo	V8
Stylosanthes seabrana B.L. Maass & 't Mannetje	Caatinga stylo	Caatinga
Desmodium intortum (Mill.) Urb.	greenleaf desmodium	–
Desmanthus virgatus (L.) Willd.	desmanthus	Marc
Cullen graveolens (Domin.) J.W.Grimes	cullen	native
Cullen cinereum (Lindl.) J.W.Grimes	cullen	native

the dry season and grew through to large plants at maturity, produced plentiful seed and by early summer had senesced. However, in spite of seed lying on the soil surface, there were no seedling recruits at either site, but rather the plots were invaded by 'weeds' (i.e. non-sown species). Early growth of the other legumes in the Derby field nursery was slow and compromised by being preferentially grazed by the wallabies until the fence was upgraded. The best performed legumes over the summer 'wet' season at Derby were the two varieties of Caribbean stylo and Wynn cassia.

At Wallal Downs the early growth of most legumes apart from lablab and cowpea was also slow until late spring even though they were regularly irrigated across the dry season and night temperatures over winter are mild due to the proximity to the coast. This was the only site where leucaena has grown well and after 12 months the largest plants were 180–200 cm in height. However, at this site the leucaena plants were attacked by termites once the stems started to get woody (i.e. about the diameter of a pencil or larger). Large termites (*Mastotermes* spp.) hollowed out the taproot and stem of some leucaena seedlings at Wallal Downs resulting in the death of plants. Conventional mud tunnels and termites are also common on leucaena plants. The continuity of the mud tunnels was deliberately broken on most of the remaining plants so that persistence can be assessed in the medium-term.

Butterfly pea grew well following the out-of-season rainfall at Wallal in early May, but it had grown slowly over summer even with trickle irrigation. Growth of siratro was strong at both the Woodie Woodie and Wallal Downs trials with the trailing stems more than 2–3 m across, but growth was patchy at Derby.

The extreme temperatures at Woodie Woodie in early January, (i.e. six consecutive days with maximum temperatures >44°C) resulted in the death of 96% of the Highworth lablab, 100% of the Rongai lablab and 98.5% of the cowpea plants (20–30 cm in height). All (100%) of the maize plants were also killed (bleached) by the extreme temperatures.

Most of the warm season C4 annual grasses and the C4 perennial grasses had good plant vigour and competed well with any 'weeds', so there have been comparatively few non-sown species in the grass trials across all of the sites. However after the annual grasses had senesced at Derby these rows were invaded by broadleaf weeds.

DISCUSSION

In the WA rangelands the spread of weeds is often episodic so the field nursery trials were established under irrigation to simulate the worst case scenario, i.e. if plants establish and set seed following a tropical cyclone or an extremely high rainfall year. The irrigation was gradually turned off over the 'wet' season once the plants were well established, and most species had flowered and set-seed. Persistence of annual species relies on regeneration from the seed-bank, while with perennial species individual plants can persist for two to many years or regenerate from the seed-bank.

The native vegetation is adapted to the environment and the method of adaptation depends on the plant growth habit. The herbaceous perennial grasses and forbs tend to respond rapidly to rainfall in certain periods (e.g. early wet season) and then persist by going into a semi-dormant to dormant state for an extended period (Petheram and Kok 2003). The woody perennial plants have conservative growth patterns in line with the long-term rainfall. However, the native ephemeral annual herbs and grasses are adapted to the climate by having extremely rapid seedling growth and plant development following good rainfall. For instance, the annual herb *Cleome viscosa* L. (tickweed, mustard bush) a common volunteer plant at both the Wallal Downs and Woodie Woodie trial sites displays rapid growth following good rainfall. Tickweed plants germinated, grew to a height of 60–70 cm, flowered and set-seed in a period of four to six weeks, while the sown legumes alongside which were already established grew slowly and were still comparatively small plants. On the whole, the annual and perennial grasses tend to be more competitive than the legumes, so there is a much lower density of volunteer plants within the grass field nurseries. The warm season annual grasses (hybrid sorghum, pearl millet, maize) had the highest seedling and early vigour of all the sown species, while *Cenchrus ciliaris* recruits from the naturalised populations at Wallal Downs and Woodie Woodie displayed both good vigour and an ability to adapt and set-seed under a range of environmental conditions.

The growing of non-indigenous plants in a rangeland context can be a contentious issue, with many interest groups with a wide range of viewpoints. The results of these studies will help to inform the debate so that a balance can be achieved between agricultural development on one hand and protecting high value environmental assets on the other.

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