Investing in weed research in northern Australia: a livestock industry perspective

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Summary Weeds cause major economic losses to the beef industry in northern Australia. Challenging economic conditions increase the demand for cheaper and more cost-efficient weed prevention and control solutions that are not dependent on universal uptake by industry. Therefore a substantial proportion of MLA investment in weed R&D is deliberately focused on the identification of biological control agents. While potential benefits are high, research is often expensive, protracted, carries risks of intermediate failures and relies on a small pool of specialised researchers. Therefore biological control strategies are supplemented with integrated weed management strategies and more novel weed identification and control solutions. Improving awareness and adoption of weed prevention strategies for existing and potential weed species is also important.

Keywords Biological control, prevention strategies, integrated weed management, research investment.

INTRODUCTION

The loss in foregone revenue to the Australian grazing industry from weeds is estimated at $1.9 billion per annum (adapted from Sinden *et al.* 2004). Therefore a substantial reduction in the economic impact of weeds has potential to deliver major improvements in farm profitability. Northern beef producers also regard weeds to be an important issue and, during consultation for research planning, ranked weeds as one of the top 10 issues for research, development and extension (RD&E) investment.

In the years leading up to 2008 the beef industry has been experiencing increasing production costs, rural labour shortages, rapidly rising land values and generally low rates of return on investment. While weed management is regarded as an important issue, there are numerous other factors requiring a pastoral manager's attention. Investment in weed prevention and control can be costly and may not provide obvious net-economic benefits in the short or medium-term. Therefore there is strong demand for cheaper and more cost-efficient weed prevention and control solutions that are not dependent on universal uptake by industry.

INDUSTRY INVESTMENT IN WEEDS RESEARCH

Meat and Livestock Australia (MLA) is in relative terms a modest investor in on-farm RD&E. For 2007–08 the MLA budget for on-farm RD&E in northern Australia (Queensland, Northern Territory, Kimberley and Pilbara) was $5.5m – of this 7% or $450,000 per year is allocated to weed research. There is increasing competition for these limited research funds. It is important, therefore, that funds are invested in activities with potential to deliver the greatest benefits. Increasingly, MLA is seeking solutions and improvements in production as well as in environmental and social areas, the so called Triple Bottom Line.

In 2006, priority weeds for RD&E were identified on the basis of their current or potential industry impact, gap analysis and the likelihood of achieving a successful research outcome. From this process, parkinsonia (*Parkinsonia aculeata* L.), bellyache bush (*Jatropha gossypifolia* L.), lantana (*Lantana camara* L.), sida (*Sida acutifolia* Steud.), hyptis (*Hyptis suaveolens* (L.) Poit.), tobacco weed (*Elephantopus mollis* Kunth) and sicklepod (*Senna obtusifolia* (L.) H.S.Irwin & Barneby) made the short-list.

In northern Australia a large proportion of MLA investment in weed R&D is deliberately focused on the identification of biological control agents to reduce the impact of high priority weeds. However, biological control strategies must also be supplemented with integrated weed management strategies. Therefore demonstration sites and/or extension materials and activities are still required to provide information and encourage the adoption of weed management practices for species such as weedy *Sporobolus* grasses, rubbervine (*Cryptostegia grandifolia* R.Br.) and mesquite (*Prosopis* spp.).

THE SEARCH FOR BIOLOGICAL CONTROL AGENTS

The potential benefits from identifying effective biological control agents are high, but research is often expensive, protracted, carries risks of intermediate failures and relies on a small pool of specialised researchers. Recent advances in molecular biology and simulation modelling techniques promise to increase the efficiency and cost-effectiveness of identifying effective control agents (e.g. Goolsby *et al.* 2005).

Current biological control research for MLA in northern Australia is focused on weedy *Sporobolus* grasses, bellyache bush, parkinsonia and prickly acacia. In most cases MLA is co-investing with other research providers. This small portfolio of MLA biological control research does serve to demonstrate some of the opportunities and challenges of investments in this area.

Weedy *Sporobolus* grasses Weedy *Sporobolus* grasses (*S. pyramidalis* P.Beauv., *S. africanus* (Poir.) Robyns & Tournay and *S. natalensis* (Steud.) T.Durand & Schinz) were introduced to Australia from Africa and have the potential to invade 223 million ha. The leaf smut, *Ustilago sporoboli-indici* L.Ling. and stem wasp, *Tetramesa* sp. were identified from field surveys in South Africa as two promising biological control agents in 2001/02.

In 2004 MLA funded a team led by Dr Bill Palmer of the Queensland Department of Natural Resources, Mines and Water (QDNRW) to complete the studies required to release these two potential biological control agents for weedy *Sporobolus* grasses into Australia. Researchers at the University of KwaZulu-Natal were contracted to undertake studies of the leaf smut, *U. sporoboli-indici* to understand its biology, host specificity and virulence to Australian weedy populations. Methods to isolate, germinate and store the organism were determined. The smut was successfully inoculated onto Australian populations of four weedy *Sporobolus* species but not the neotropical *Sporobolus jacquemontii* Kunth.

Seeds of 11 Australian native *Sporobolus* species were sent to South Africa for critical host testing to determine the suitability of the agent for release. Unfortunately the smut infected two native Australian species, *Sporobolus creber* De Nardi and *S. elongatus* R.Br. as severely as the weeds and very mild infections were also found on two other natives, *S. scabridus* S.T.Blake and *S. sessilis* B.K.Simon. Therefore it was recommended that work on this agent be discontinued as it was unlikely to be approved for release in Australia.

Problems were also experienced rearing the eurytomid wasp, *Tetramesa* sp., which attacks the flower heads of giant rat's tail grass (*S. pyramidalis* and *S. natalensis*) and Parramatta grass (*S. africanus*) in South Africa. Contracted researchers at the Plant Protection Research Institute in South Africa were unable to rear the wasp in the laboratory. As laboratory culture is an essential prerequisite for quarantine study in Australia, it was also recommended that further work on this insect be discontinued.

Despite the set-back in biological control research, good progress has been made by MLA-funded researchers in Queensland and NSW on improving integrated management of weedy *Sporobolus* grasses. The latest strategies for strategic implementation of property hygiene, herbicide use, fire and/or rotational grazing have been published and made available to producer in a 'Weedy Sporobolus Grasses Best Practice Manual' (Bray and Officer 2007).

Biological control opportunities for prickly acacia Prickly acacia (*Acacia nilotica* subsp. *indica* (Benth.) Brenan) is a weed of national significance in Australia. In 2007 over 6 million ha of arid and semi-arid Queensland were estimated to be infested with prickly acacia (Dhileepan unpublished). However, it has potential to infest 50 million ha of grasslands in Queensland, Northern Territory and Western Australia. Infestations cost cattle and sheep producers over $5 million per annum by decreasing pasture production and hindering mustering (Dhileepan unpublished). Mechanical and herbicide treatments are available, but they are relatively expensive. Biocontrol is considered by many to be the only hope for long term sustainable control.

Previous efforts initiated in the early 1980s to exploit biocontrol agents from Pakistan, Kenya and South Africa did not achieve effective control, although one agent is starting to have an impact on coastal infestations. However, recent studies suggest that the Australian populations of *A. nilotica* subsp *indica* are possibly of Indian origin, and that insects and pathogens from this region could help manage this weed, particularly in the drier Mitchell Grasslands where most infestations are found.

A systematic approach was adopted to native-range survey and agent prioritisation in India that incorporates knowledge from both plant population ecology and plant-herbivore interactions, and makes agent selection decisions explicit. This allows more rigorous evaluations of agent performance and better understanding of success and failure of agents in weed biological control. MLA has funded this approach in its search for Indian biocontrol agents for prickly acacia, by Dr Kunjithapatham Dhileepan from Biosecurity Queensland.

Bellyache bush and parkinsonia Current MLA investment into biological control research for bellyache bush and parkinsonia is part of a package of work led by Dr Tim Heard from CSIRO. Also involved are QNRMW (now Queensland Department of Primary Industries and Fisheries – QDPIF), (bellyache bush) and the Australian Government 'Defeating the Weeds Menace' (DWM) program, (parkinsonia). This new phase of collaborative research is drawing on a range of modern molecular and modelling techniques that will help identify the most efficacious agents, and assist in fast-tracking both the native-range survey work and the processing of potential agents through quarantine.

Bellyache bush has been the subject of a classical biocontrol project conducted by CSIRO from 1997 to 2003 from its Mexican field station. It was largely funded by the Northern Territory Government, CSIRO and Queensland Department of Natural Resources. Survey work of the natural enemies was conducted in Central America (seven countries) and Venezuela. Approximately 95 species were found, but most remain unidentified. The first potential agents were introduced into Australian quarantine for assessment in 1998 and the first and only agent (*Agonosoma trilineatum* (F.)) was released in 2002. Establishment of *Agonosoma* has not been confirmed despite concerted efforts to mass-rear and release. Approximately eight other insects were imported into Australian quarantine and one fungal pathogen was imported in UK quarantine for assessment. Some of these agents have been rejected while others require further work. South America (besides Venezuela) remains unexplored.

Parkinsonia was also the subject of a biocontrol project, conducted during the 1980s. Extensive native-range surveys were conducted in the USA and Mexico with a short field trip to Costa Rica. As a result of this work two agents were released (*Rhinocloa callicrates* Herring in 1989 and *Mimosestes ulkei* Horn in 1993), but neither became widely established or abundant. Several other potential agents were identified but were either difficult to rear and test, or were rare. A third insect, the seed-feeding bruchid *Penthobruchus germaini* (Pic.) was released in 1995 following limited surveys in South America. This agent has become widespread, although predation rates have been low. CSIRO reactivated the biocontrol program in 2001 (funded by NHT) to survey Central America, the putative native range. This is expected to continue to mid 2009, with quarantine testing scheduled to commence in mid 2008. Many parts of South America remain unexplored, although recent genetic data suggests it to be the source of Australian populations.

The MLA funding will allow results from extensive native range surveying of bellyache bush agents (six years of collections) and parkinsonia agents (five years) in Central America and Venezuela to be synthesised and a list of prioritised agents to be developed. This work will use new molecular techniques to help sort and identify the large suite of unidentified insects already recorded from both target weeds, and to assist the preliminary host specificity testing of potential bellyache agents at the CSIRO Mexican field station.

MLA funds will also be used to survey for potential new agents of bellyache bush in South America (including Peru, Ecuador, Brazil, Argentina, Paraguay), areas not yet covered. Surveys are costly, but will be optimised using data on plant distributions, biogeography, climate and other variables. This survey work will be done in tandem with DWM-funded parkinsonia surveys conducted in the same areas.

PREVENTION STRATEGIES

Preventing the introduction and spread of weeds into and throughout grazing lands is more desirable and cost-effective than attempting control strategies once a weed has been established. MLA has invested, or is currently investing in, three areas related to weed prevention: reducing the availability and spread of nursery plants that pose a weed risk; reducing the threat from rejected forage species; and improving land condition through sustainable grazing management.

Reducing weed threats from nursery plants A MLA supported report by Barker *et al.* (2006) identified over 281 introduced garden plants available in nurseries that present a significant weed risk to Australia's grazing industry should they naturalise. Nearly all these species have been recorded overseas as agricultural or environmental weeds, and over two thirds were still available from Australian nurseries in 2004. This report concluded that preventing the spread of these species requires increasing the awareness of weed risks and costs through the education of graziers and the general public, tighter legislation relating to the importation, sale and movement of weed species and appropriately responding to weed risk assessments of plants already in Australian gardens.

Preventing spread of rejected forage plants During the 1980s and 1990s many exotic legume species were evaluated for their potential as pasture plants within short-term, small-plot plant evaluation programs, conducted mainly in Queensland (Cook and Dias 2006). Of these species four perennial legumes, *Acacia angustissima* (Mill.) Ktze, *Aeschynomene paniculata* Willd. ex Vogel, *Indigofera schimperi* Jaub. & Spach and *Aeschynomene brasiliana* (Poir.) DC. (in decreasing order of weed threat) were identified as posing serious threats to northern Australia and therefore being priority plants for eradication or control (Cox 2006). These target legumes are extremely well geo-climatically adapted to large areas of northern Australia and have the potential to threaten coastal and sub-coastal grasslands of Queensland, the Northern Territory and Western Australia. All have low palatability, can form dense stands and can persist in soil through dormant seed for over 10 years.

In response to this threat it has been necessary to identify, monitor and eradicate these species over a 13 year period at 65 locations and over 100 sites throughout Queensland. Since 1999 over $1.5m has been spent by MLA and QDPIF, in conjunction with QDNRW, Environmental Protection Agency, CSIRO, and James Cook University. This investment will minimise the risk of these four weedy perennial legumes invading and decreasing the production potential and conservation values of northern grazing lands.

Out of 73 control sites in 2005, 41% were considered clean (no plants found for a number of years), 45% of sites had only small numbers of plants emerging each year only and 12% had larger populations requiring two or more eradication visits per annum. Monitoring and eradication activities are ongoing. This action will minimise future grazier expenditure on weed control and maintain the major beef production resource of north Australia.

Lessons have also been learned. A 'Code of Ethics and Good Practice for the Evaluation and Release of Pasture Plants' has also been developed by QDPIF and QDNRW (Cox and Cook 2003). This Code is currently awaiting adoption as part of the Queensland Government Weed Spread Prevention Strategy.

Property hygiene and sustainable grazing practices The establishment and spread of weeds on pastoral lands can be accelerated by lax property hygiene, poor land condition, and over-grazing (Grice 2004). For example, there has been growing concern about the spread of rubber bush (*Calotropis procera* (Ait.) Ait.f.) in areas of Mitchell grasslands in western Queensland and the Barkley Tableland in the NT. In a recent workshop to scope out possible R&D, researchers suggested the rubberbush problem is closely linked to grazing pressure and is worst in areas affected by overgrazing, such as surrounding water points (Allan 2007).

Therefore managing grazing to promote high levels of ground cover and vigorous healthy 3P (perennial, persistent and palatable) grass pastures is important for minimising opportunities for weeds to establish and spread. In addition, changes to fire regimes (frequency, timing and intensity) can also influence the establishment and spread of both native and exotic weed species. Likewise, strict property hygiene that includes strategies to restrict or control the entry and movement of vehicles, machinery, livestock, hay, livestock and people between infected and weed free properties or areas is also important.

Improving grazing land management practices and land condition are important RD&E investment areas for MLA Northern Beef. This work will also contribute significantly to minimising weed impacts on pastoral land. Producers are encouraged to attend Grazing Land Management (GLM) workshops developed through the MLA EDGE*network* and customised for regions throughout northern Australia to gain information and skills for improving grazing land management as well as learning more about strategic weed management specifically.

CONFLICTS BETWEEN IMPROVED PASTURE SPECIES AND WEED RISKS

Introduced pasture plants are an important part of many northern beef production enterprises, especially in more mesic regions which tend to have the highest densities of cattle and the highest rates of turn-off. However, the weed potential of introduced pasture plants has received increasing attention in northern Australia (Chudleigh and Bramwell 1996, Cook and Dias 2006). In a paper titled 'Inviting Trouble', Lonsdale (1994) reviewed the consequences of past plant introductions. He reported that of the 463 species that had been introduced to Australia between 1947 and 1985 only four species were found to be useful and had not become weeds. Sixty species had become listed as weeds and 17 were listed as weeds despite being identified as being useful. Even useful exotic pasture plants come with an implicit risk in that they are likely to be able to spread and persist.

The grazing industry therefore has a responsibility to be aware of these risks and be able to address potential conflicts. Important lessons have been learned from the cost of eradicating unwanted forage plants (Cox 2006). However, strategies based on objective information may be required to prevent the establishment and spread of pasture species such as gamba grass (*Andropogon gayanus* Kunth), leucaena (*Leucaena leucocephala* (Lam.) de Wit) and even buffel grass (*Cenchrus ciliaris* L.) on non-pastoral lands.

Minimising weed risks from leucaena Leucaena is an example of a highly productive and valuable forage plant that has potential to become a damaging weed. In 2007 over 100,000 cattle were grazed on 120,000 – 150,000 ha of leucaena. This area is predicted to increase to between 130,000 and 150,000 ha over the next 10 years (M. Shelton pers. comm.). However, leucaena also has potential to produce large amounts of hard seed which can stay viable for many years. If leucaena escapes to ungrazed areas it can form dense thickets over time. This presents a significant weed threat. Some creek banks in north-east Queensland already have areas of 'wild' leucaena, which may have established and spread many decades ago from both garden and pastoral plantings.

The Leucaena Network, a group of cattle producers, leucaena growers, extension officers and researchers who 'promote the responsible development of leucaena in sustainable and productive grazing and agroforestry systems' sought to reduce the weed threat directly. As part of their proactive approach the Leucaena Network has introduced a Code of Practice for the sustainable use of leucaena-grass pasture systems in Queensland. The main aims of the Code of Practice are to: 1. restrict leucaena planting near to potential weed risk zones; 2. minimise seed production in grazed stands; 3. diminish the risk of live seed dispersal; and 4. control escaped plants from grazed stands (http://www.leucaena.net/codeofconduct.pdf)

While this direct approach is commendable, the development of sterile hybrids will help reduce the weed risk over the longer term (Shelton 2001).

The gamba grass debate Since the early 1990s there has been concern and debate about the role of gamba grass (Cook 1991). Gamba is a perennial pasture grass introduced from Africa. It grows up to 4 m in height, and in dense stands can produce standing crops of 4–10 t ha^{-1} in high rainfall areas.

In well managed grazing systems gamba grass significantly increases cattle carrying capacities and liveweight gains. Economic net-benefit between $4–10 ha^{-1} of gamba grass systems over native pasture has been suggested (unpublished data, Gamba Grass Forum October 2007). However, gamba grass is also highly invasive and has potential to change fire regimes, deplete soil nutrients, and disturb the soil water cycle in eucalypt woodlands across large areas of northern Australia (NT NRETA).

One difficulty with grazing systems based on gamba grass is their requirement for high levels of management to control biomass accumulation, seed production and seed spread during the growing season. As a result, seed can easily be dispersed and plants can establish in uncleared native vegetation from pastoral lands and infestations on roadsides and other areas of disturbance.

Since 1931, from deliberate widespread plantings and natural spread, gamba grass is now thought to occupy between 10,000 and 15,000 km^2 in the Northern Territory. Based on the plant's rainfall and soil suitability requirements it has potential to occupy an area covering 380,000 km^2 in the Northern Territory (NT NRETA).

The most worrying threat from gamba grass spread is related to its high fuel loads which are between four and 10 times greater than native grasses. In the Top End of the Northern Territory this altered fuel layer significantly increases the risk, frequency and intensity of destructive late-dry season wildfires which are difficult to control and increase risk of damage to life and property, particularly in peri-urban areas (NT Bushfires Council). There is also evidence from research in the Northern Territory that gamba grass will promote a more frequent and intense fire regime which has potential to causes loss of tree cover and irreparable ecological damage to vast areas of north Australia eucalypt savanna ecosystems (Cook and Mordelet 1997).

Concern about the impact of gamba grass in Queensland has prompted conservation groups, government authorities and concerned researchers to consider action. In Queensland gamba grass is estimated to be scattered across 60,000 ha of Cape York. This is, however, likely to be a small fraction of its potential range (unpublished data, Gamba Grass Forum October 2007). Proposed policy options include limiting further spread, having gamba grass declared as a weed in order to prevent sale of seed and further planting, and requiring land holders to take reasonable action for its control.

The need for objective information While introduced pasture species have an important role to play, the grazing industry will increasingly be held responsible for the economic and environmental costs caused by invasive pasture species originating from pastoral lands. Somehow these conflicting issues need to be addressed.

It is therefore essential that debates and policy decisions are informed by objective information rather then emotion. Evaluations should be based on evidence-based methods for quantifying the economic, environmental and ecological costs and benefits of pasture species that pose a potential weed threat over short- and longer term scenarios. Economic evaluations over extended time periods are complex and often contentious. However, this should not be a barrier to seeking improvement in these decision-making tools.

FUTURE WEED RESEARCH AND CONCLUSIONS

In additional to research into biological control and integrated weed management, future research should explore novel weed identification and control solutions. One example is a new MLA research initiative with the Australian Centre for Field Robotics (AFCR) at the University of Sydney, which will investigate the application of unmanned aerial vehicles (UAVs) for the automated detection, relocation and control of weeds in open Mitchell grasslands. This work will use high dimensional data from multiple sensor sources (for example hyperspectoral and vision) and non-Guassian probability models to undertake autonomous detection and classification of woody weeds, while also being able to distinguished these weeds from surrounding native vegetation and landscape. UAV applications are already being developed for control of aquatic weeds (Salah Sukkarieh pers. comm.).

More than ever, producers need simple tools to identify the most cost-effective weed management solutions for their paddock, property or catchment. There appears to be a need and opportunity to explore the use of mathematical programming models to incorporate information about the distribution, ecology, population dynamics, management and control economics of mixed weed populations, for the purpose of identifying realistic, control options that offer best value for money.

Finally it is essential that the right mix of research skills and collaborative networks is in place to effectively address the current and emerging needs for weed RD&E. The challenge remains to establish a multi-agency research model that can value-add independent research and facilitate the strategic co-investment of limited funds into collaborative weed RD&E activities.

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