

A review of the Australian Pastures Genebank



**For South Australian Research and Development Institute
& APG Steering Committee**

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Final Report
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Executive Summary

The review consulted widely with RDC investors, APG partners and steering committee members, pasture breeders and end user stakeholder groups. The review has detailed twenty draft recommendations against the five terms of reference.

Delivery of APG KPI targets are in most cases well on track and all KPI targets likely to be met by June 2018. There is transparent *internal* reporting on the APG operation with efficient management of operations, internal communications, meetings and detail in program reports.

There was very positive feedback from interviews on the effective establishment of the APG in a relatively short timeframe and the positive culture in its operations and ease of access by breeders and other users to accessions held.

A delay of another 5 years in the establishment of the APG may have resulted in an inability to access accessions and data for a number of the external interstate collections with risks of further degradation of seed quality. The commitment of SARDI to the investment in the safe storage of the APG collection with continued investment in maintaining storage with multiple fail-safes is commended.

The review indicates that the APG and all partners are currently operating under the International Treaty on Plant Genetic Resources for Food and Agriculture. The APG appears compliant in its obligations under this treaty, however there are specific concerns in regards to the DAFWA Base collection. It should be noted that the International Treaty on Plant Genetic Resources for Food and Agriculture is directly linked and builds on the Convention on Biological Diversity. The review unpacked that compliance obligation risks arising could include impact on the goodwill of other parties contributing to the APG and that the Convention on Biological Diversity creates uncertainty of DAFWA rights to ownership of accessions collected internationally in the core collection.

The internal intent and commitment from the APG delivery team is clear. APG operations have been assembled well in the initial operations however there is room for some operational improvement. While pasture breeders see value in the APG, producers have limited understanding of the existence and role of the APG and are yet to be convinced of its value and an improved strategic approach to communications is required.

The APG must develop and implement a targeted communication strategy to its local and international stakeholders, but in particular end user producers detailing the value, impact and risk management benefits of the APG program. This communication strategy should provide the rationale and benefits for any change to the future APG business model.

There are a number of pathways available to improve the sustainability of the APG. Any changes the APG steering committee ultimately recommend to implementing change to the business model must be first clearly communicated with the rationale and transparent detail of operational costs and tabled for discussion with key national, international and partner stakeholders to address political risks. There is also a need for increased Australian government participation on behalf of the APG in the international Global Crop Diversity Trust and plant treaty meetings to ensure effective carriage and support for any changes. Any changes to APG business and cost recovery models should be fully implemented within the first 3 years of a phase II investment.

The estimated impact of the APG on pasture productivity improvement through genetic gain ranges from 0.5-1% pa to 1-2% pa, based on review interviews. Based on these values, the potential loss of value to pasture improvement and resulting production from no future APG would be between \$62.5 to \$250 million pa.

The return on investment derived from APG accession access is likely to deliver a benefit/cost well in excess of at least 20:1, and likely up to 38:1. A detailed study of industry delivery costs, including commercial breeding is however required to provide a net present value of benefit. A benefit cost return of 20:1 or more is an exceptional return for industry and RDC investment, indicating that industry should have a high level of confidence that the APG program will return significant value to pasture based industries.

The review recommends that RDC investors should consider continued investment in APG Phase II based on the indicated ROI benefits of at least the current APG commitment plus CPI and consider matching of any in-kind commitment when fully detailed through an APG audit. Importantly, it needs to be recognised that public and commercial investment in pasture breeding and production system improvement is required for any benefit of the APG to be realised. The elements of a combined value proposition for return on investment detailed in the review should form the basis of key messages for an APG communications strategy.

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1. APG review terms of reference

Crop Protection Australia has been contracted by the Australian Pastures Genebank (APG) to undertake a review, beginning in November 2016 against the following terms of reference:

- Review the operations of the Australian Pastures Genebank against the objectives and deliverables set in the funding agreement.
- Assess the extent to which the Australian Pastures Genebank aligns with and operates within the International Treaty for Plant Genetic Resources for Food and Agriculture.
- Assess the value of the Australian Pastures Genebank to Australian industries and global food security.
- Identify future opportunities including goals and ways to ensure sustainability for the longer term.
- Assess potential risks to operations and consider mitigation measures.

2. Summary of draft recommendations

The review has detailed twenty draft recommendations against the five terms of reference including:

Draft recommendation 1.1

- *That more process and transparency is communicated to external stakeholders on accession regeneration prioritisation in the APG, potentially through delivery of an open prioritisation biennial meeting attached to the TAC*

Draft recommendation 1.2

- *That urgent resolution takes place around deposit of the DAFWA Base collection and is addressed within the agreed APG program timeframe*

Draft recommendation 1.3

- *That the APG load the currently finalised passport and other database data into GRIN Global ASAP and then update the database again when finalised and that consideration is given to how the previous tropical forages database (formerly www.tropicalpastures.org) can be operationalised into the APG GRIN Global ASAP*

Draft Recommendation 2.1

- *That the APG seek to secure the DAFWA Base collection under the existing agreement to ensure its physical preservation*

Draft recommendation 3.1

- *That the APG program reviews its current cost model including all in-kind contributions to fully account for the current and future cost of operations*

Draft recommendation 3.2

- *With difficulty in accessing current detailed pasture investment impact studies, APG partner RDCs should jointly consider commissioning a new impact study including detailed survey of the research/producer community to build confidence and value in not only the APG investment, but associated pre-breeding and production systems investment*

Draft recommendation 3.3

- *All RDCs give consideration to a second phase of investment of at least the current levels plus CPI accounting for matching in-kind investment from partners*

Draft recommendation 4.1

- *The APG SC should oversee an audit of all in-kind research partner contributions to the APG to quantify the actual current and potential future costs of APG operations*

Draft recommendation 4.2

- *The APG should develop a table of revised costs based on seed delivery and regeneration, with revised activity based cost structures*

Draft recommendation 4.3

- *Consideration be given to the development of commercial options for 'trusted' commercial companies or breeding companies to conduct seed regeneration under contract agreement with associated APG protocols and inspection requirements (costs paid by the company), enabling more timely access to accessions and reducing confidentiality conflicts to third parties*

Draft recommendation 4.4

- *The APG increases resources for strategic prioritisation of seed increase in collaboration with other international GRCs (eg CIAT, ILRI and MFGRC) to reduce longer term resource requirements*

Draft recommendation 4.5

- *The APG develop and implement a targeted communication strategy to its stakeholders, local and international, but in particular end user producers detailing the value, impact and risk management of the APG program, incorporating a new impact study detailed in*

recommendation 3.2. This communication strategy should provide the rationale and benefits for any change to the APG business model

Draft recommendation 4.6

- **Any changes the SC recommend to the APG business model and cost recovery model should be first discussed with the Australian Grains Genebank and then formally presented to the Global Crop Diversity Trust members for discussion under the plant treaty. Increased Australian participation in the international GCDT meetings will be required to ensure effective carriage and support for any changes**

Draft recommendation 4.7

- **RDC investors should consider continued investment in APG Phase II based on the indicated ROI and broader industry and public benefits of at least the current APG commitment plus CPI and a consider matching of any in-kind commitment when fully detailed through an APG audit**

Draft recommendation 4.8

- **Changes to APG business and cost recovery models should be fully implemented within the first 3 years of a phase II investment. Following a review which demonstrates a sustainable APG investment model has been achieved, Consideration to a rolling 5 year APG investment cycle should be considered**

Draft recommendation 4.9

- **The APG steering committee consider inviting representative breeders and end user producers onto the steering committee plus consider and conduct a biennial seed regeneration prioritisation meeting open to all interested parties and stakeholders to increase buy-in on APG strategic management and investment**

Draft recommendation 5.1

- **Consideration be given to relocation of the TAS seed regeneration site**

Draft recommendation 5.2

- **Consideration be given to relocation of the WA seed regeneration site and explore long term arrangements for APG service provision**

Draft recommendation 5.3

- **That RDC and partner consideration is given to capital investment particularly focussed on seed cleaning, sorting and processing to offset future labour costs at SARDI; UTAS/TIA; QDAF. Additional infrastructure for land, irrigation and pollen houses should be explored by UTAS/TIA. A business case for future cost savings should be developed for each state program and presented this to the APG investment partners for consideration in offsetting future costs**

Draft recommendation 5.4

- **The APG adopts the implementation of bar coding of accessions through the entire process and resources this for inclusion into the annual operational plan**

3. Methodology

The review methodology is based upon the delivery of expert strategic, technical and commercial business review services delivered jointly by consultants Dr Rohan Rainbow and Mr Cameron Begley. The approach to the APG review is based on established and successful agricultural research review and reporting methodologies previously used in national breeding and pathology programs.

Key review process steps addressing the defined APG review terms of reference include;

1. Desktop review of existing APG program/projects reports
2. Interviews by teleconference and review of submissions from RDC investors in the APG
3. Interviews by up to 8 teleconferences (noting this was significantly exceeded) and review of submissions from relevant industry groups and end user stakeholders (as defined by the APG Steering Committee)
4. Review of research agency partner submissions with compilation of three case studies considering a value proposition to industry from investment in the program
5. APG joint program review 2 day meeting with the technical advisory committee (TAC)
6. Individual research agency site interviews including a review of current and future operational capability to address the following review technical requirements;
 - 1.1 Review of the operations of the Australian Pastures Genebank against the objectives and deliverables set in the funding agreement.
 - 1.5 Potential risks to operations and recommendations of mitigation measures.
7. Review panel consideration of submissions, interviews and review meetings against the defined terms of reference
8. Delivery of a draft review report and recommendations against the defined terms of reference for APG steering committee consideration
9. Delivery and presentation to the APG Steering Committee of a final review report and complementary power-point presentation and recommendations against the defined terms of reference.

4. Review consultation

The review consulted with the following APG stakeholder organisations:

- APG investor research and development corporations
 - Meat and Livestock Australia
 - Australian Wool Innovation
 - Grains Research and Development Corporation
 - Dairy Australia
 - Rural Industries Research and Development Corporation
- APG partners & Technical Advisory Committee members
 - South Australian Research and Development Institute (SARDI)
 - Department of Primary Industries New South Wales
 - Department of Agriculture Fisheries and Forestry Queensland
 - Department of Primary Industries, Parks, Water and Environment Tasmania
 - University of Tasmania/Tasmanian Institute of Agriculture
 - Department of Economic Development, Jobs, Transport and Resources
 - Department of Agriculture and Food Western Australia
 - Australian Government Department of Agriculture and Water Resource
- Visits to APG regeneration sites SA, TAS, WA and QLD
- Seed Services Australia
- SARDI APG facilities
- Global Crop Diversity Trust
- Pre breeders/researchers
 - SARDI
 - DAFWA
 - QDAF
 - UTAS/TIA
 - University of Queensland
 - University of Western Australia
- Breeding/distribution companies
 - Heritage Seeds
 - PGG Wrighton Seeds
 - Valley Seeds
 - Ardent Seeds
 - Pasturewise
 - Private Breeders x2
 - Northern Queensland Tropical Seeds - Seed producer
- Industry stakeholders
 - Lucerne Australia
 - Australian Fodder Industry association
 - Grain Producers Australia
 - Sheepmeat Council
 - Cattle Council

5. Current Australian perspective on pasture and livestock production

The review recognised key broad factors impacting on pasture and livestock industry production. These include:

- Northern
 - Significant opportunity for pasture productivity improvement through introduced legumes and reducing buffel grass decline
 - Increased incidence of disease is a future challenge
 - Adoption rates remain low
 - Significant opportunity for a number of new introduced pasture species
- Southern Mediterranean
 - Climate and drought adaptation remains a great challenge
 - A number of disease and invertebrate pest challenges exist
 - Integration with cropping systems remains a key need for business enterprise sustainability
 - Significant opportunity for a number of new introduced pasture species including perennials
- Southern Temperate
 - Many pastures currently at <20% of potential productivity
 - Only 30% of the pasture area are introduced pasture species
 - Commercial breeding focus on major pasture species
 - Significant opportunity for a number of new introduced pasture species

6. TOR 1 - Review the operations of the Australian Pastures Genebank against the objectives and deliverables set in the funding agreement

Delivery of APG KPI targets are in most cases well on track and all KPI targets likely to be met by June 2018. There is transparent *internal* reporting on the APG operation with efficient management of operations, internal communications, meetings and detail in program reports. Positive feedback includes:

- Positive comments from investors and users on the importance and value of the APG, mainly for industry productivity insurance, however quantification of this value has been difficultly to determine. There has been limited recent direct use of the APG by commercial pasture breeders, however there has been significant historical indirect use by commercial breeders through pre-breeding and pasture improvement programs utilising the APG
- There appears to be ongoing commitment from APG delivery partners to continue current technical and infrastructure support for the APG evidenced through in-kind commitment greater than original APG agreement
- Very positive feedback on the leadership in the establishment of the APG and its delivery to users including access to accessions of suitable quality and volume.
- Effective establishment of operational systems across a national framework and a robust culture of collaboration

A delay of another 5 years in the establishment of the APG may have resulted in an inability to access accessions and data for a number of collections with risks of further degradation of seed quality. The commitment of SARDI to the investment in the safe storage of the APG collection with continued investment in maintaining storage with multiple fail-safes is commended.

Importantly, it needs to be recognised that public and commercial Investment in pasture breeding and production system improvement is required for any benefit of the APG to be realised.

The review received one submission from SARDI which suggested the following improvements to the APG including:

- Implementation of A15 Quality Management System including policies and procedures developed for all APG activities (acquisition, biosecurity, conservation, information management, distribution and safety duplication) and are fully integrated into GRIN Global system.
- Add value to the collection with detailed characterisation to maximise utilisation:
 - Completeness of passport data esp. latitude and longitude
 - Capture and incorporate historical characterisation, evaluation and core collection data
 - Require that RDCs who commission pasture and forage pre-breeding projects include a milestone to return data on germplasm characterisation to APG
 - Expand the efficiency and scope of regional regeneration, including incorporation of new technologies for nutritive assessment, ploidy determination, genotyping-by-sequencing and development of core collections
 - Maintain and enhance alignment with Global Information Systems e.g. DivSeek & GeneSys.

The review considered that these were appropriate goals and targets for operational implementation for a Phase II APG program and that these quality control and efficiency standards aligned with those goals of the Global Crop Diversity Trust and the International Treaty for Plant Genetic Resources for Food and Agriculture. These should be factored into operational planning for APG Phase II.

In addition the following suggestions were tabled in the SARDI submission including:

- Explore possibilities to prioritise and rationalise the APG collection in partnership with International pasture and forage Genebanks (CIAT, ILRI and MFGRC) aiming to avoid duplication, and focus and enhance activities around APG strengths.
- Maintain and supply larger seed quantities of priority germplasm to support national and international evaluations programs allowing them to hit the ground running, saving two years' seed increase time and money.
- Explore long term funding models, e.g. endowment funding for Australia's GRC's similar to the Global Crop Trust Fund.

These suggestions have been considered under TOR 4 in section 9 of the review report.

TOR 1 draft recommendations

To build industry confidence in APG transparency and delivery on objectives, the review proposes the following recommendations;

Draft recommendation 1.1

- *That more process and transparency is communicated to external stakeholders on accession regeneration prioritisation in the APG, potentially through delivery of an open prioritisation biennial meeting attached to the TAC*

Draft recommendation 1.2

- *That urgent resolution takes place around deposit of the DAFWA Base collection and is addressed within the agreed APG program timeframe*

Timeframe

- Options for resolution should be timetabled for discussion by the APG SC within 6 months

Implications

- APG KPI 1.2 appears behind schedule - Deposit Agreements developed and executed formalising the transition and receipt of materials from state gene banks into the APG by July 2015. While stated as complete in reports, this is incomplete for DAWFA long term core collection and is due 2 April 2017

Justification

- A number of pre-breeders and breeders would like greater input into regeneration prioritisation of key species

Draft recommendation 1.3

- *That the APG load the currently finalised passport and other database data into GRIN Global ASAP and then update the database again when finalised and that consideration is given to how the previous tropical forages database (formerly www.tropicalpastures.org) can be operationalised into the APG GRIN Global ASAP*

Timeframe

- Options for delivery of these recommendations should be timetabled for discussion by the APG SC within 6 months

Implications

- APG KPI 2.1 appears behind schedule - All Passport, inventory & habitat data cleaned & loaded into GG by Jan 2017. Slippage against the target delivery date of July 2015 - Oct 2015

Justification

- There are likely to be other teething issues with bringing the APG GRIN Global on-line which could delay access further. Commercial breeders are asking when this will be available and there is an opportunity to give some early experience with access to the database, even if incomplete

7. TOR 2 – Review of APG operational alignment within the International Treaty for Plant Genetic Resources for Food and Agriculture

The review indicates that the APG and all partners are currently operating under the International Treaty on Plant Genetic Resources for Food and Agriculture. The APG appears compliant in its obligations under this treaty, however there are specific concerns in regards to the DAFWA Base collection. The Commonwealth government is the contracting Party to this treaty; 'Contracting Parties agree to take appropriate measures to encourage natural and legal persons within their jurisdiction who hold plant genetic resources for food and agriculture listed in Annex I to include such plant genetic resources for food and agriculture in the Multilateral System'. It should be noted that the International Treaty on Plant Genetic Resources for Food and Agriculture is directly linked and builds on the Convention on Biological Diversity;

Article 1 – Objectives¹

1.1 The objectives of this Treaty are the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security.

*1.2 These objectives will be attained by closely linking this Treaty to the Food and Agriculture Organization of the United Nations and to the **Convention on Biological Diversity**.*

Australia ratified the Convention on Biological Diversity in June 1993. The Convention came into force in Australia in December 1993. A detailed review of intellectual property rights and ownership of genetic resources agreed to under this convention² indicated that in effect the only country that can claim ownership rights to accessions are from where they originate;

¹ <http://www.fao.org/plant-treaty/en/>

² The Biodiversity Convention, Intellectual Property Rights and Ownership of Genetic Resources: International Developments. Intellectual Property Policy Directorate Industry Canada 1996.

In 1993, the Commission on Plant Genetic Resources (CPGR) noted that there are fundamentally three possible interpretations of the Legal status of these (ex-situ) collections, considered in the context of the regime established by the Biodiversity Convention:

1. That these genetic resources were outside the Convention, and, since most of them were collected on the general understanding that plant genetic resources were the heritage of humankind, these resources should continue to be freely available, with global compensatory mechanism; Biodiversity, Biotechnology and IPRs: International Developments - It may be anticipated that this could perpetuate the concern expressed by developing countries that having given up their genetic resources to the heritage of humankind in the collection process, they are now denied access to those resources taken from their own country.
2. That these genetic resources were outside the Convention, and therefore that the host country could legislate on ownership and conditions of access; and

In particular, the following was noted;

3. That, since the Parties to the Convention can provide only those genetic resources originating in their own countries, or acquired under the terms of the Convention, that the permission of the country of origin is required for the release of genetic resources from pre-existing collections.

It was noted, however, that, in many cases, countries of origin cannot be identified, and that the collection are widely dispersed (quoted in FAO 1995, Item 8(b), ¶ 31.)

The Convention indicates;

*Article 3. Principle - States have, in accordance with the Charter of the United Nations and the principles of international law, **the sovereign right to exploit their own resources pursuant to their own environmental policies**, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.*

In May, 1992, the Australian Commonwealth, States and Territories adopted the Intergovernmental Agreement on the Environment (IGAE), which defined the roles, responsibilities and interests of all levels of government with respect to environmental matters, to ensure a cooperative national approach to these issues. **The Commonwealth Government has responsibility for foreign affairs and ensuring that international obligations (including the Convention on Biological Diversity) are met** it also has responsibility for the management of living and non-living resources on land it owns or occupies, external territories and marine areas. The States and Territories have responsibility for the policy, legislative and administrative framework within which living and non-living resources **are managed within the State or Territory.**

In consideration of these agreements, this raised questions for the review in regards to integration of the DAFWA Base collection into the APG. It is recognised that DAFWA is the custodian of the Base *Trifolium spp.* collection. GRDC and AWI have historically invested in parts of this collection with intent that these accessions are made available through a GRC. Sale of the DAFWA pasture program could result in a private company having co-ownership of IP (with DAFWA) including the Base *Trifolium spp.* collection. This also could result in more favourable terms for one seed company to access accessions from this collection. The current separately funded MLA and ARC funded *Trifolium* genome mapping and a select panel of cultivars (including 97+ from the DAFWA Base collection) will also deliver significant opportunity for increased use of these accessions for marker assisted selection, which are currently in the DAFWA Base collection.

The review unpacked that risks arising could include:

- Impact on the existing goodwill of other parties contributing to the APG
- That the Convention on Biological Diversity creates uncertainty of DAFWA rights to ownership of accessions collected internationally in the core collection

TOR 2 draft recommendations

To ensure operational alignment of the APG under the International Treaty for Plant Genetic Resources for Food and Agriculture and the Convention on Biological Diversity by the entire APG program as originally agreed by the partners, the review proposes the following draft recommendation;

Draft Recommendation 2.1

- **That the APG seek to secure the DAFWA Base collection under the existing agreement to ensure its physical preservation**

Timeframe

- As a matter of urgency but within no longer than 6 months.

Justification

- There is currently no on-site automated power fail-safe for the DAFWA Base collection and the freezers that store this collection are not suitable for long term storage

8. TOR 3 – Review of value of the APG to Australian industries and global food security

ABS data suggests an increased area of improved pastures production with introduced species in Australia from 2011 to 2015 (Figure 1). ABS statistics from 2001 estimate the area of improved pasture was 22.1 M ha of dryland sown pastures and 1.2 M ha irrigated sown pastures. ABS statistics from 2014/15 estimates the area of improved pasture is 36.8 M ha (down 25.3% from 2013/14) and other grazing land is 279.9 M ha (down 4.4% from 2013/14).

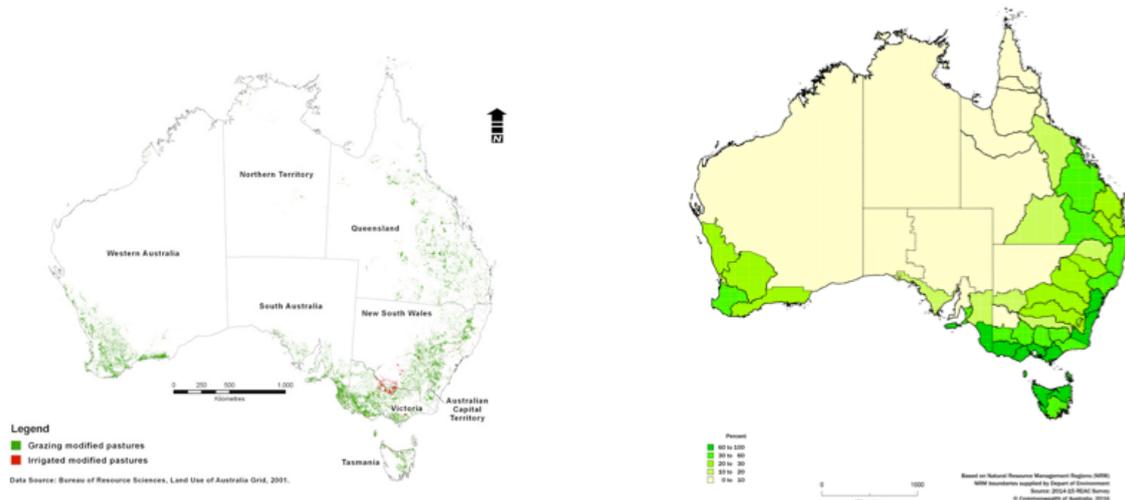


Figure 1. ABS improved pasture production statistics (source ABS)

A series of three case studies were developed through the APG review to consider the potential implications and benefits towards improved pasture production in Australia.

Case study 1 Southern - Red-legged earth mite tolerance/resistance

Red-legged earth mite (RLEM) is a significant cost to industry in southern Australia. There have been significant issues with synthetic pyrethroid insecticide and organophosphate (OP) insecticide resistance for RLEM control in Western Australia and significant risks in eastern Australia³. In addition, there is imminent risk of loss of effective OP chemical controls due to global review of this chemistry group, which has already resulted in the loss of omethoate for crop and pasture use and loss of dimethoate for pasture use except for early establishment due to APVMA regulatory review⁴. In addition there are currently no registered effective alternates and limited miticide discovery⁵.

Noting there has only been limited livestock industry studies on RLEM since 1991⁶ and control costs and resistance impacts have increased since 1991⁷, sheep meat and wool losses estimated at \$56-112 M pa, cattle losses at \$81 M pa and grains losses of \$44.7 M pa⁸, particularly through pasture carry-over impacts.

RLEM resistance/tolerance has not yet been commercially exploited. Resistance/tolerance exists in *Trifolium spp.* and *Medicago spp.* in the APG collection. Phenotyping proof of concept exists.

Potential long-term benefit would be as least as great as the loss/control costs to industry. Based on equivalent seed replacement cost and assuming 50% adoption, this could result in \$119 M pa potentially realised within 10 years post investment delivery.

³ <http://cesaraustralia.com/sustainable-agriculture/latest-news/free-redlegged-earth-mite-resistance-testing-service>

⁴ <http://apvma.gov.au/node/12496>

⁵ Rainbow, R. (2017). The future of the grains industry: a shared responsibility. GRDC Grains Research Update Adelaide 7-8 March 2017.

⁶ Ridsdill-Smith T.J. (1991) A contribution to assessing the economic impact of redlegged earth mite on agricultural production in Australia. In 'Proceedings of a National Workshop on Redlegged Earth Mite, Lucerne Flea and Blue Oat Mite'. (Ed. TJ Ridsdill-Smith) pp. 53–56. (Department of Agriculture: South Perth)

⁷ Ridsdill-Smith T. J., Hoffmann A., Mangano P., Gower J. M., Pavri C. C. and Umina P. A. (2008) Strategies for control of the redlegged earth mite in Australia. Australian Journal of Experimental Agriculture, 2008, 48, 1506–1513

⁸ Murray, D.A.H, Clarke, M.B and Ronning, D.A. (2013) Estimating invertebrate pest losses in six major Australian grain crops. Australian Journal of Entomology 52 (3), 227-241.

Case study 2 Southeastern - Powdery mildew resistance in *Medicago spp.*

Disease evolution and increased summer rainfall impacts has Powdery mildew resistance in *Medicago spp.* There are no cost effective fungicide options for pasture disease management without residue issues. Metrics and assumptions for this case study are based on APG interviews.

Powdery mildew resistance in *Medicago spp.* has not yet been commercially exploited in released varieties. Resistance exists in *Medicago spp.* in the APG collection. Phenotyping proof of concept exists and advanced breeding lines demonstrate resistance and productivity improvement potential.

Potential long term benefit based on a potential impact area of 8 M ha including demonstrated 17% increase in agronomic performance, assuming 50% adoption could result in \$155 M pa benefit potentially realised within 10 years post investment delivery.

Case study 3 North - Anthracnose resistance in *Stylosanthes spp.*

Improved *Stylosanthes spp.* (Stylo) varieties has led to 10-20% increase in pasture productivity. Introduction of Stylo into improved pastures has also resulted in 20-30% increases in live weight gain/head. Evolution and increased incidence and impact of Anthracnose has significant impact on persistence and productivity of this introduced tropical pasture legume. Metrics and assumptions for this case study are based on APG interviews.

Resistance/tolerance exists in *Stylosanthes spp.* in APG collection. Phenotyping and demonstrated selection/breeding potential exists eg PGG Wrightsons V8™ adapted to 1000+ mm annual rainfall or irrigated systems & AP seeds Beefmaker Stylo™ adapted to 500+ mm annual rainfall.

Potential long term benefit based on 20% improvement on the current value of northern improved pastures, assuming 50% adoption could result in \$90 M pa realised within 10 years post investment delivery.

A review of potential industry impacts of the APG

The review through interview surveyed seven Australian pasture breeders. Consensus indicates share of APG contribution to genetic gain of new varieties is between 30-40%. The APG contribution to new pasture varieties released from direct selection from accessions is obviously very high. There has been a significant number of direct accessions from the APG precursor genetic resources centres which have been selected and improved for commercial release. Review interviews with pasture breeders indicate that the APG will continue to contribute significantly to pasture improvement through this way, as high as 70-80% in some species. The impact of the APG on pasture productivity improvement through genetic gain ranges from 0.5-1% pa to 1-2% pa, varying by region with northern Australia improvement at the higher end of estimates. Adoption of new varieties in improved pastures is generally up to max of 30% unless driven by disease or insect control related issues which would drive higher rates of adoption.

While the utilization of APG germplasm by institution (Table 1) indicates limited recent direct use of the APG by Australian pasture breeders, review interviews have highlighted the historic use and value to pasture breeding, both directly and indirectly through pre-breeding and research programs. All the major pasture breeding programs highlighted their intention to increase the use of the APG in the future, particularly when the GRIN Global database and relevant passport information goes live.

The APG review considered the benefit cost (B/C) analysis used for the establishment of the APG⁹. The study presented total present value of estimated benefits was \$6.2 billion over 30 years from improved pastures utilising introduced species from GRCs. This compares with a present value cost of establishing and operating the grains and pastures GRC of \$52 million. Thus, the Benefit/Cost (B/C) ratio is 119 to 1.

On review, a number of these assumptions appear to overreach impact, particularly for the pasture GRC. The report costed the APG operations at \$1.43 M pa. Current costings are \$969 K pa for the APG in 2015/16. It is evident that in-kind institutional costs have not been fully captured so this figure is likely to be at least \$1.2 M pa. Based on this, cost estimates for the APG should have been approximately 34% of the figures used in the study.

⁹ Benefit-cost analysis of the proposed National Genetic Resources Centre: Report to NGRC Steering Committee September 2007. The Allen Consulting Group.

The original 2007 B/C study indicated that 63% of benefit is to crop specialists, 37% livestock/mixed farming benefit. Total factor productivity (TFP) improvement is in the upper range of expectations at 1-2.4%. Public health benefits appear to be overestimated for pastures (figures are focused on gene technologies in grains).

If the assumptions are modified to reflect livestock and mixed farming benefit based on a more conservative producer adoption rate of 30%:

- The revised B/C will be approximately 38:1 and potentially as low as 20:1;
- with TFP growth of 0.5-1%; or
- \$45 M pa or as low as \$24 M pa.

The three case studies combined if successful would deliver a combined benefit to industry realised after 10 years post investment of 364 M pa (\$281 M present day value @3% discount rate) if all deliver on technical outcomes, in commercial varieties with an expected high rate of adoption due to the high industry impact of the biotic stress issues. There may however be lower present day value benefit in an alternative higher discount rate is used. While if successful, these outcomes derived from APG accession access are likely to deliver a B/C well in excess of 38:1, a detailed study of industry delivery costs, including commercial breeding is however required to provide a net present value of benefit. It should be recognised that delivery of these case study outcomes would be very difficult without the ease of industry access and availability of a large pool of accessions in the APG, if not at least significantly delayed in delivering industry benefit via international GRCs.

A benefit cost return of 20:1 or more from the APG is an exceptional return for industry and RDC investment. This is compared with an example of one of the highest rates of return on investment, the cereal rust control program at 23:1¹⁰, indicating that industry should have a high level of confidence that the APG program will return significant value to pasture based industries.

Cost to industry from no future APG

The estimated impact of the APG on pasture productivity improvement through genetic gain ranges from 0.5-1% pa to 1-2% pa, based on review interviews. The current estimated total value of improved pastures of \$12.3 billion pa (Table 1). Based on these values, the potential loss of value to pasture improvement and resulting production from no future APG would be between \$62.5 to \$250 million pa.

Table 1. APG estimated contribution to improved pasture value

Industry	Region	Contribution value of improved pasture \$ Billion	Assumption based on the off-farm value of production	Source
Livestock(53.65%)	Northern	0.9	30% from improved pasture	MLA estimate 2015
	Southern	5.7	2009 estimate	MLA 2011 Feedbase Investment Plan
Wool (6.7%)	National	0.82	32.5% from improved pasture	ABS 2013-14
Dairy (21.1%)	National	2.6	70% from improved pasture	Dairy estimate 2015
Seed (0.8%)	Southern	0.1	100%	RIRDC estimate 2015
Fodder (4.9%)	Southern	0.6	% Lucerne, medic & clover	ABS 2012-13
				MLA 2011 Feedbase Investment Plan
Cropping (9.3%)	Southern	0.84	refer Gout & Jones 2006	MLA estimate 2015
	Northern	0.3	refer Lloyd 2009	MLA estimate 2015
Pork	National	0.004	0.5% from free range pastures	SARDI estimate 2015
Poultry	National	0.01	0.5% from free range pastures	SARDI estimate 2015
Horse	National	0.36	90% of expenditure horse feed	AHIC 2014-15
Total		12.3		

From: AUSTRALIAN PASTURES GENE BANK STEERING COMMITTEE Meeting 1 ACTION ITEM 3c

¹⁰ An Economic Analysis of GRDC Investment in the Australian Cereal Rust Control Program 2007 GRDC Impact Assessment Report Series.

Value to global food security

Current international access to the collection is 22% of APG use (Table 2) , noting that a number of the international institutions could be utilising accessions for variety improvement as well as research purposes (Table 3). Assuming an equivalent international opportunity cost benefit per \$ spent to the revised Australian B/C of 38:1 and APG operating cost of \$1.2 M pa, based on consideration of the international use of the APG compared to Australia, the current international value from APG contribution to food security value would be approximately at least \$10 M pa.

Table 2. APG accessions dispatched by country 2015-16

Country	# Accessions Dispatched
Argentina	113
Australia	899
China	18
France	6
Tanzania	81
United Arab Emirates	39

From: APG Annual Progress Report 2015-2016

Table 3. Utilisation of APG germplasm by institution in 2015-16

Institution	Country	# Accessions
AgriBio	Australia	10
Australian National University	Australia	1
Department of Agriculture Queensland	Australia	117
CSIRO	Australia	62
Chinese Academy of Science	China	11
Department of Economic Development, Jobs Transport & Resources	Australia	5
DAFWA	Australia	155
GeneGro	Australia	2
Crumpton & Sons	Australia	3
Hebei Institute of Coastal Agriculture	China	7
James Cook University	Australia	19
Private	Australia	17
PundaZoie	Australia	1
SARDI	Australia	153
University of Queensland	Australia	202
University of Tasmania	Australia	132
Laboratoire des Symbioses Tropicales et Méditerranéennes	France	6
University of Western Australia	Australia	10
University National del Litoral	Argentina	113
Nelson Mandella Institute	Tanzania	81
Ministry of Presidential Affairs	United Arab Emirates	39
Western Sydney University	Australia	10
Total	11	1,156

From: APG Annual Progress Report 2015-2016

Value proposition for the APG

There are many components in considering the value proposition for future APG investment. Building on the value to productivity improvement, returns from future specific trait development and global contribution to genetic improvement, the estimated cost to industry from no access to an APG is significant, particularly if there is a lack of ability to rapidly respond to future risks of biotic and abiotic loss. The public value of the APG is difficult to account for. While the 2007 B/C study indicated public health benefits focused on gene technologies in grains, there are likely to be public benefit from public amenity, habitat retention, plus reduced environmental erosion and salinization impacts from improved pastures (Figure 2). The elements of a combined value proposition detailed in this review should form the basis of key messages for an APG communications strategy.

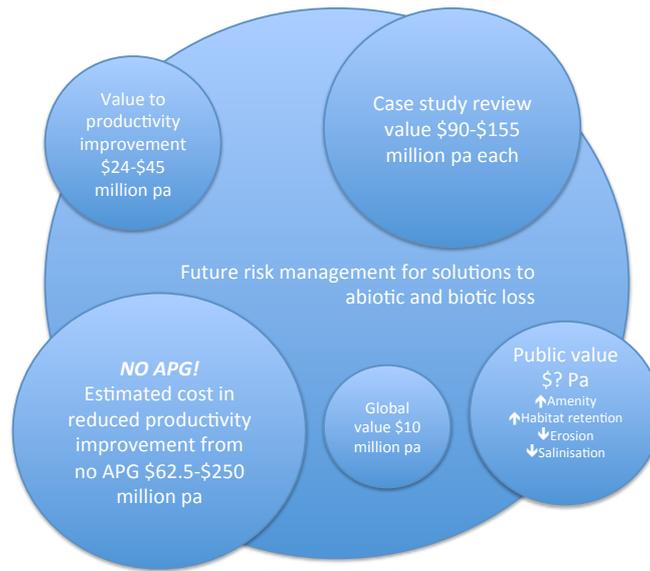


Figure 2. Value proposition components for future investment in the APG

TOR 3 Recommendations

To build industry confidence in APG return on investment, the review proposes the following draft recommendations;

Draft recommendation 3.1

- ***That the APG program reviews its current cost model including all in-kind contributions to fully account for the current and future cost of operations***

Draft recommendation 3.2

- ***With difficulty in accessing current detailed pasture investment impact studies, APG partner RDCs should jointly consider commissioning a new impact study including detailed survey of the research/producer community to build confidence and value in not only the APG investment, but associated pre-breeding and production systems investment***

Draft recommendation 3.3

- ***All RDCs give consideration to a second phase of investment of at least the current levels plus CPI accounting for matching in-kind investment from partners with RDCs committing to a review of contribution for a phase III investment following a re-evaluation of cross industry benefit***

Implications

- Revised APG return on investment will deliver not only future strategic risk management for industry RDCs but a very high rate of return to RDCs on industry investment and broader public benefits of pasture based agriculture outputs
- Long term cost savings through limited capital equipment investment will offset future costs
- All APG operations will be fully accounted for

Justification

- More conservative assumptions in the B/C model highlight very high return on investment of between 20-38:1
- The x3 case studies if all successful would combined potentially deliver a B/C return well in excess of estimates
- Breeding programs, marker assisted selection and extension and adoption programs will all contribute to the delivery of industry productivity benefit, however they all rely on the pivotal role of the APG in providing foundational accession access.

9. TOR 4 – Identify future opportunities including goals and ways to ensure APG sustainability for the longer term

Drivers for consideration of change to APG business delivery models

The review notes potential future budget constraints for the APG program. It is estimated that between 25 to potentially greater than 30% in-kind FTE labour contribution to the APG is not fully accounted in the operations report. In addition it is anticipated that a x2 fold Australian and x4 fold international increase in demand for APG accessions will occur following live activation of the GRIN Global database. This view has been supported by breeders and the Global Crop Diversity Trust (GCDT).

There are options to increase resources and time spent on strategic seed regeneration prioritisation and submission to GCDT *Svalbard* for removal from the APG, estimated by some stakeholders to deliver a potential long term saving of 25+% through reduced long-term demand on APG resources for seed quality maintenance and collection curation. In addition, there is a recognised need to speed up the delivery of a 20% increase in seed regeneration rate for the next 10 years for the APG to be in both good order and achieve a steady state of operations.

The review has considered needs and options including field relocation to increase seed regeneration capacity and efficiency improvement through reduced travel and access to improved infrastructure and resources. The review has also recognised significant future opportunity for increased use of molecular markers for key traits in the APG collection e.g. as demonstrated from the separately funded MLA and ARC funded *Trifolium* genome mapping and a select panel of cultivars (including 97+ from the DAFWA core collection). There will be significant opportunity for increased use of APG accessions for marker assisted selection as separate investment programs allow this resource to be exploited. It is recognised however that the commercial drivers are difficult in Australia for genetically modified (GM) pasture programs in Australia. While there is technical potential for the APG to have a role in delivery of biotechnology and GM plant development opportunities in the future, commercial opportunity will be limited for the foreseeable future to existing unregulated breeding technologies. This does not however prevent potential pasture biotechnology research opportunities.

A number of strategic, operational and political issues have been considered by the review;

Strategic

- There is significant industry value in being a global citizen and contributing to the greater global good in return receiving access to potential useful genetic resource accessions in return from other international parties
- There are also potential long term cost savings and opportunity for increasing APG access to new accessions through collaboration
- There has been concern raised by commercial breeders that requests for accessions which require regeneration can lead to leakage of commercial intent

Operational

- The APG is in an interesting situation in being the largest repository of accessions for a number of pasture species in the world, creating a unique strategic role for international germplasm access
- A major resourcing challenge for the APG will be to manage an expected x4 fold increase in international demand for accessions when the APG GRIN Global comes on-line

Political

- Australia has collected accessions in the collection under agreement with foreign governments and has obligations as a signatory to the Biodiversity Convention
- As the APG is funded through industry RDC levy (recognising co-investment by the Federal government) there will be an industry buy-in challenge if expected international demand accounts for >30% of the program delivery, particularly supporting competing countries for international trade and market access
- Building a user pays system for the APG would be an international precedence and may potentially result in an international backlash impacting on Australian public and commercial access to overseas genetic resources centres

Current and projected future utilisation of the APG

The review has considered the current use of the APG and projected future use (Table 4). The key issue is that the international use for the APG is likely to increase to more than 30% in the next Phase II. This is likely to cause industry investor concern, as the industry APG investment will be making a significant contribution to international competitors and potential export market displacement.

Table 4. Total APG use by sector (% current use to % projected % future use post GRIN Global access)

User sector	Current Use of accessions	% current to % projected future use of accessions
Australia research/government	876	(76% to 62%)
Australia commercial	23	(2% to 1.5%)
Signatories to treaty - International research/government	238	(20.5% to 34%)
Non-signatories to treaty - International research/government	18	(1.5% to 2.5%)
International commercial	0	

The APG has a number of levers that could be considered for a sustainable and equitable business model, ranging from increased RDC investment with co-government contribution, increased operational efficiencies and prioritisation as well as increased levels of international collaboration and consideration of increased cost recovery through a user pays co-investment (Figure 3).

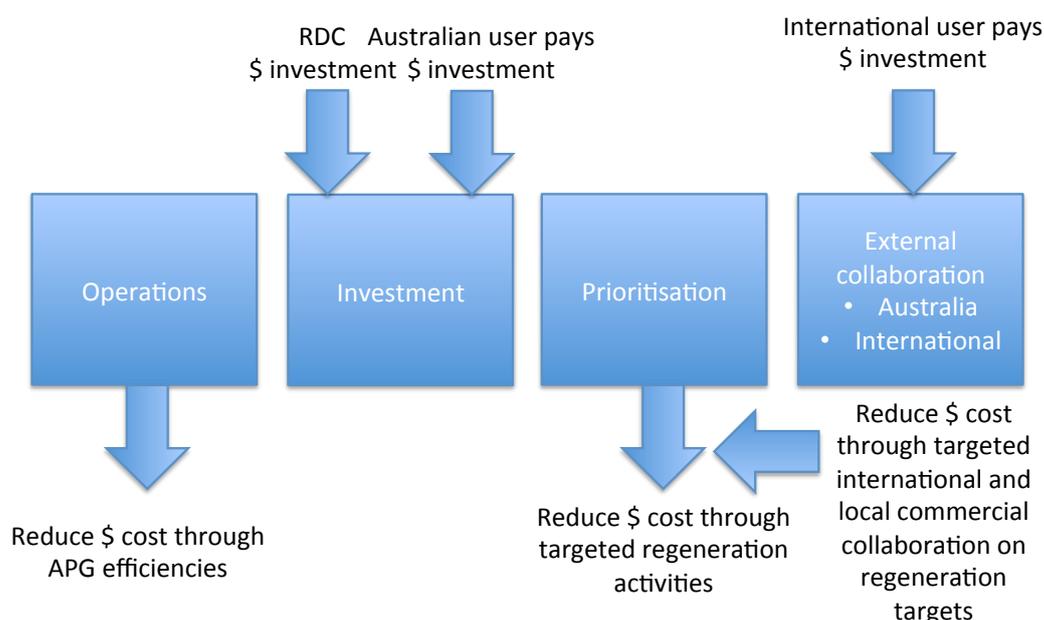


Figure 3. Key levers for the APG

Discussions with the Global Crop Diversity Trust suggest that recovering costs for maintenance and distribution of accessions is within the scope of the International Treaty on Plant Genetic Resources for Food and Agriculture and Convention on Biological Diversity – This creates options to do the following (Table 5);

Table 5. Options for new APG revenue sources

Australia	International • Signatory to treaty	International • Non-signatory to treaty
Research institutions Target @ current APG seed delivery cost	Research institutions @current APG seed delivery cost plus regeneration costs	Research institutions @current APG seed delivery cost plus regeneration costs plus overheads costs
Discounted cost to commercial breeders < current quarantine costs	Commercial breeders Full APG cost recovery plus overheads costs	Commercial breeders Full APG cost recovery plus overheads costs

The review considered the role of the APG in providing secondary services including supply of larger seed quantities of priority germplasm to support national and international evaluations programs, plus additional support for marker development of core collections. The review considered that these were service programs that should be funded separately by RDCs and other investment sources on a case-by-case basis. These services would impact on the transparency and simplicity of a cost recovery model detailed to investors and users of the APG. The review also considered endowment type funding models for the APG similar to the Global Crop Trust Fund, however there first needs to be industry clarity around the current value of the APG and support needs to be built for continued investment by key industry investors before this type of approach could be considered.

APG internal and external communications

The current APG communication goals address many key priority areas including:

- Promote the Australian Pastures Genebank
- Maximise the effectiveness of the collection to users
- Increase teamwork and develop partnerships
- Engage effectively with RDCs, State and Australian governments to
 - keep them informed of developments,
 - consult opportunities to strategically develop the collection, and
 - address issues;
- Develop strong partnerships with the national and international genetic resource and scientific community, the seed industry and other potential funding bodies to
 - keep them informed of key developments,
 - discuss opportunities to strategically develop the collection, and
- Deliver communications in a targeted, effective, timely, accurate and appropriate manner

The review recognises the very effective and detailed internal communications within the APG operations, with the deliver partners and also reporting to the steering committee. The current approach however does not include a detailed communication strategy for the each of the stakeholder segments, particularly lacking communications with key APG end user stakeholders including breeders and producers. There is a risk that a focus on communications around the anticipated GCDT Svalbard deposit in 2018 may indicate to stakeholder that the APG role is completed. There is a clear need for communication to stakeholders of the APG current and future value to industry and its role in mitigating future productivity risks from biotic issues.

TOR 4 draft recommendations

To ensure sustainability of the APG in the longer term, the review proposes the following draft recommendations;

Draft recommendation 4.1

- ***The APG SC should oversee an audit of all in-kind research partner contributions to the APG to quantify the actual current and potential future costs of APG operations***

Draft recommendation 4.2

- ***The APG should develop a table of revised costs based on seed delivery and regeneration, with revised activity based cost structures***

Draft recommendation 4.3

- ***Consideration be given to the development of commercial options for ‘trusted’ commercial companies or breeding companies to conduct seed regeneration under contract agreement with associated APG protocols and inspection requirements (costs paid by the company), enabling more timely access to accessions and reducing confidentiality conflicts to third parties***

Draft recommendation 4.4

- ***The APG increases resources for strategic prioritisation of seed increase in collaboration with other international GRCs (e.g. CIAT, ILRI and MFGRC) to reduce longer term resource requirements***

Draft recommendation 4.5

- ***The APG develop and implement a targeted communication strategy to its stakeholders, local and international, but in particular end user producers detailing the value, impact and risk management of the APG program, incorporating a new impact study detailed in recommendation 3.2. This communication strategy should provide the rationale and benefits for any change to the APG business model***

Draft recommendation 4.6

- ***Any changes the SC recommend to the APG business model and cost recovery model should be first discussed with the Australian Grains Genebank and then formally presented to the Global Crop Diversity Trust members for discussion under the plant treaty. Increased Australian government participation in the international GCDT***

meetings on behalf of the APG will be required to ensure effective carriage and support for any changes

Draft recommendation 4.7

- *RDC investors should consider continued investment in APG Phase II based on the indicated ROI and broader industry and public benefits of at least the current APG commitment plus CPI and a consider matching of any in-kind commitment when fully detailed through an APG audit*

Draft recommendation 4.8

- **Changes to APG business and cost recovery models should be fully implemented within the first 3 years of a phase II investment. Following a review which demonstrates a sustainable APG investment model has been achieved, Consideration to a rolling 5 year APG investment cycle should be considered (Figure 4)**



Figure 4. The APG requires a transition Phase II

Draft recommendation 4.9

- *The APG steering committee consider inviting representative breeders and end user producers onto the steering committee plus consider and conduct a biennial seed regeneration prioritisation meeting open to all interested parties and stakeholders to increase buy-in on APG strategic management and investment*

Timing

- Any changes to the business structure and future cost recovery model the APG SC implements should be at tabled to the global community at the same time the APG GRIN Global data goes live and timing for implementation should be carefully coordinated so as not to cause a rush or bottleneck for international accession access
- Implementation of any changes to the business model and cost recover models should be fully implemented prior any initiation or RDC commitment for a Phase III APG investment

Implications

- A business model that will self fund the anticipated 30+% cost of the ongoing APG program and will self adjust to any increase or decrease in international demand will offset RDC and Australian producer concerns around the operational costs of the program
- There is still an underlying concern that a precedence of Australia increasing cost recovery charges for access to accessions may result in longer-term challenges and collaboration in access to international germplasm pools. This risk can be offset through high level engagement and clear communication to members of the Global Crop Diversity Trust and attendance at meetings of signatories to the plant treaty

Justification

- The current model requires options to balance income and costs in light of review of undocumented in-kind costs and anticipated increases in demand for APG accessions following activation of the APG GRIN Global database

10. TOR 5 – Assess potential risks to APG operations and consider mitigation measures

There is a recognised need for the APG to increase output of the regeneration program by at least 20% over the next 10 years to achieve sustainable management in delivery of quality accessions to users of the program, including the research community, pre-breeders and commercial breeders. This will put a strain on available land and other resources. The review has given consideration to particular risks to the APG program and also options for mitigating these plus options for improved delivery efficiency. It should be noted that availability of suitable land resources, access to irrigation infrastructure, travel time efficiencies have been considered. At a number of sites seed cleaning, sorting and processing equipment requires upgrading to offset significant labour costs and inefficiencies. For states with

moratoria on genetically modified (GM) organisms, the role of the APG in providing pasture seed industry, the APG provides industry confidence in maintaining GM free status through sourcing local accessions for pasture variety improvement. There is however risks of introduction from international sources through adventitious presence that may be seen to compromise the GM free status of the APG.

TOR 5 draft recommendations

Following review assessment of APG risks and mitigation measures the following draft recommendations are proposed;

Draft recommendation 5.1

- ***Consideration be given to relocation of the TAS seed regeneration site***

Timeframe

- Initiate trials within 12 months – transition within 3 years before completion of an APG Phase II investment

Implications

- Relocation close/in Launceston will increase operational field efficiency potentially by >20% per FTE due to reduced travel time

Justification

- The current site is prone to waterlogging and potential inundation in very wet seasons and irrigation infrastructure for dry seasons is inadequate. Consideration of land access adjacent to the proposed new city campus site should be explored.
- Relocation of seed increase and use of pollination exclusion tents as used in NZ should be trialled as an intermediate step at the Mount Pleasant site to reduce land demand and operational efficiency in combination with improved dripper irrigation infrastructure

Draft recommendation 5.2

- ***Consideration be given to relocation of the WA seed regeneration site and explore long term arrangements for APG service provision***

Timeframe

- Within the next 3 years before completion of an APG Phase II investment

Implications

- Relocation through negotiation with UWA facilities at Shenton Park Field Station would increase available field space for seed regeneration and alleviate current complications with soil disease and herbicide carryover management

Justification

- The current site has limited space available for necessary expansion of the APG seed regeneration program plus there is considerable available capacity for utilisation of bird protected plots, glasshouse and plant/seed processing
- The proposed sale of the DAFWA pasture breeding program is likely to result in a long term challenge for maintaining expert service delivery capacity to the APG
- Relocation to UWA Shenton Park facility in combination with other pasture program activities could deliver increased operational efficiencies and utilisation of equipment and facilities

Draft recommendation 5.3

- ***That RDC and partner consideration is given to capital investment particularly focussed on seed cleaning, sorting and processing to offset future labour costs at SARDI; UTAS/TIA; QDAF. Additional infrastructure for land, irrigation and pollen houses should be explored by UTAS/TIA. A business case for future cost savings should be developed for each state program and presented this to the APG investment partners for consideration in offsetting future costs***

Draft recommendation 5.4

- ***The APG adopts the implementation of bar coding of accessions through the entire process and resources this for inclusion into the annual operational plan***

Timeframe

- Within the next 12-18 months before completion of the current Phase 1 APG investment cycle

Implications

- Barcoding will improve both operational efficiency and risk of misidentification
- Long term improvements in seed cleaning, sorting and processing efficiency is likely to result in significant savings in labour saving between 0.5-1 FTE per year per operation, allowing additional capacity for a 20% increase in the regeneration program output

Justification

- Equipment cost and lifespan would be significantly less than the long term labour costs the efficiencies would offset
- WA relocation to Shenton Park in combination with other pasture program activities could deliver increased operational efficiencies and utilisation of currently adequate equipment and facilities

11. Concluding review comments

The internal intent and commitment from the APG delivery team is clear. APG operations have been assembled well in the initial operations however there is room for some operational improvement. While pasture breeders see value in the APG, producers have limited understanding of the existence and role of the APG and are yet to be convinced of its value.

The APG must develop and implement a targeted communication strategy to its stakeholders, local and international, but in particular end user producers detailing the value, impact and risk management benefits of the APG program. This communication strategy should provide the rationale and benefits for any change to the future APG business model.

There are a number of levers available to improve the sustainability of the APG. Any changes the APG steering committee ultimately recommend to implementing change to the business model must be first clearly communicated with the rationale and transparent detail of operational costs and tabled for discussion with key national, international and partner stakeholders to address political risks. There is also a need for Increased Australian participation in the international Global Crop Diversity Trust and plant treaty meetings to ensure effective carriage and support for any changes. Any changes to APG business and cost recovery models should be fully implemented within the first 3 years of a phase II investment.

The estimated impact of the APG on pasture productivity improvement through genetic gain ranges from 0.5-1% pa to 1-2% pa, based on review interviews. Based on these values, the potential loss of value to pasture improvement and resulting production from no future APG would be between \$62.5 to \$250 million pa.

The return on investment derived from APG accession access is likely to deliver a benefit/cost well in excess of at least 20:1, and likely up to 38:1. A detailed study of industry delivery costs, including commercial breeding is however required to provide a net present value of benefit. A benefit cost return of 20:1 or more is an exceptional return for industry and RDC investment, indicating that industry should have a high level of confidence that the APG program will return significant value to pasture based industries.

The review recommends that RDC investors should consider continued investment in APG Phase II based on the indicated ROI benefits of at least the current APG commitment plus CPI and consider matching of any in-kind commitment when fully detailed through an APG audit. Importantly, it needs to be recognised that public and commercial investment in pasture breeding and production system improvement is required for any benefit of the APG to be realised. The elements of a combined value proposition for return on investment detailed in this review should form the basis of key messages for an APG communications strategy.

Background on Crop Protection Australia

Dr Rohan Rainbow, Managing Director of Crop Protection Australia, a wholly owned business of Rainbow & Associates Pty Ltd established in 2001, has over 25 years of experience in industry leadership in the fields of agronomy, agricultural engineering, precision agriculture, farming systems development, crop protection technology, breeding for biotic traits and biosecurity preparedness. Dr Rainbow has extensive experience in leadership, strategic planning, management and delivery of new agricultural technologies resulting in industry practice change. With established relationships at senior levels of government, machinery, technology and chemical manufacturers, research and grower organisations, Dr Rainbow has significant experience in the delivery of reforms to national programs, technology development, agricultural industry practice change and technology adoption.

Dr Rainbow has significant experience in the delivery of reforms to APVMA pesticide minor use, emergency use and Category 25 industry initiated registration programs, was instrumental in the establishment of the cross industry National Working Party on Pesticide Applications and has recently facilitated the establishment of a cross industry AgVet Collaborative Forum. Dr Rainbow has recently supported CropLife Australia in delivery of chemical stewardship programs.

Dr Rainbow has overseen the development and implementation of a number of industry strategies in plant breeding, crop protection, biosecurity, food and feed safety, farming systems, precision agriculture, robotics and automation and data. During his 7.5 years as the GRDC senior plant health manager including Theme leader - Protecting Your Crop, Dr Rainbow has overseen the delivery of a number of reviews including the Australian Cereal Rust Control Program, Australian Centre for Necrotrophic Fungal pathogens, Australian Herbicide Resistance Initiative and National Pathology Review. In his role with the ACRCF and other biotic pre-breeding programs, Dr Rainbow has overseen GRDC engagement in the Global Rust Initiative and Russian Wheat Aphid pre breeding programs, which have operated under the International Treaty for Plant Genetic Resources for Food and Agriculture.

Dr Rainbow is also currently consulting to:

- GRDC Consulting Manager Future Farm automation and robotics program
- CRDC as the project leader for the cross RDC/industry Accelerating Precision 2 Decision Agriculture Big Data program
- RIRDC Facilitator AgVet Collaborative Forum – cross RDC/industry program
- Grain Producers Australia consulting advisor to on pesticide and crop protection related issues

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Background on Spiegare Pty Ltd

Cameron Begley is a Director of Spiegare Consulting Pty Ltd. Cameron has experience in senior level management, business development and commercial executive with extensive experience in technology commercialization in public and private sectors. Proven background delivering technical and commercial operations in local and globally networked teams delivering sustainable and profitable technologies to industry. Cameron brings expertise in the areas of:

- Commercial Management
- Technology Commercialization
- Identification and delivery of technologies to market
- Strategy development and implementation in complex operating and external environments
- Leadership in complex problem-solving

Cameron Begley has overseen the delivery of numerous reviews of research and commercialisation programs on behalf of CSIRO, GRDC, RIRDC and Australian Centre for Plant Functional Genomics.

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