PROJECT PHOENIX

MAKING TRACKS

WHERE DOES SEED COME FROM AND WHERE DOES IT GO?

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Across all of our Project Phoenix activities and actions we pay respect to the Traditional Owners and Custodians of the lands and waters on which we work. We honour the resilience and continuing connection to country, culture and community of all Aboriginal and Torres Strait Islander people across Australia. We recognise the decisions we make today will impact the lives of generations to come.

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ACRONYMS

AIM	Assessment, Inventory and Monitoring
ALA	Atlas of Living Australia
ANBG	Australian National Botanic Garden
ASA	Australian Seeds Authority Limited
ASBP	Australian Seed Bank Partnership
ASF	Australian Seed Federation
BLM	Bureau of Land Management
BRAHMS	Botanical Research And Herbarium Management System
DBCA	Department of Biodiversity, Conservation and Attractions
ENSCOBASE	European Native Seed Conservation Database
ENSCONET	European Native Seed Conservation Network
GPS	Global Positioning System
IBRA	Interim Biogeographical Regionalisation for Australia
ISTA	International Seed Testing Association
LLS	Local Land Services
MSB	Millennium Seed Bank
MSBP	Millennium Seed Bank Partnership
PLS	Pure Live Seed
RDE	Rapid Data Exchange
RIAWA	Revegetation Industry Association of Western Australia
SID	Seed Information Database
SOS	Seeds of Success
SPA	Seed Production Area
TERN	Terrestrial Ecosystem Research Network
USDA ARS	United States Department of Agriculture — Agricultural Research Service
USDA	United States Department of Agriculture

EXECUTIVE SUMMARY

Introduction

To restore ecosystems that are degraded or have been cleared, large volumes of native seeds are needed for direct seeding and planting seedlings. This demand may increase in the future.

Information about each seed lot collected is vital for everyone in the seed supply chain, from collection to storage to end use. Seed stores also need to keep records of seed lot information to keep track of the stock they hold, and to easily find appropriate seed lots for clients. End users need to know information such as where the seed was collected from, how old it is, and how many seeds are in the seed lot. Information needs to be passed accurately and efficiently from person to person along the seed supply chain.

Australia does not have a standardised method of collecting and transferring information on native seeds as they pass through the supply chain from collection to end use.

This report:

- investigated if a seed collection tracking app would be an appropriate tool to ensure a consistent methodology in native seed collection for selling seed lots in a national marketplace
- aimed to identify if there are any existing product tracking apps or similar products that could be customised for the seed sector and
- developed recommendations on technology products/services that could be used to improve the data provision of seed lots for sale in Australia in the short to medium term.

Issues

Few issues were encountered in the development of this report. However, there are a couple of limitations to the report. Firstly, the short timeline precluded any collaboration with other authors. Secondly, expert elicitation was used to determine currently used record keeping systems, which involved only a small number of organisations. Not all people responded to requests for information. A larger, sector-wide survey would determine the state of record keeping in Australia.

Key output

The key output is a written report based on sector consultation through expert elicitation and literature review.

Findings

The importance of data collection

- Species from which seed is collected need to be correctly identified, and the species names need to be kept with the seed lot for its entire journey from collection to use.
- Genetic variation within species means that recording the exact source location of the seeds is essential, so that the end user can decide which population best suits their needs.
- Recording population size can provide information about genetic diversity, and whether mixing seeds from different populations may or may not be beneficial.
- Records of collection date, storage date, storage conditions and results of any quality tests must be kept to provide information about the potential viability of the seed lot. Only seed lots containing viable seeds should be used for restoration.
- Record keeping enables seed banks to keep track of their stock and provide information to clients.
- Record keeping enables learning from previous practices, repetition of successful practices and adaptive management.
- Data about species' locations and seed lot characteristics that are good quality and accessible can improve decision making across the seed sector and in the fields of restoration, conservation and taxonomy. Accessible data can also inform policy development and land management.
- Data needs to be recorded in a way that it can be easily transferred. Electronic record keeping systems are therefore preferable to paper-based systems. Electronic record systems need to be compatible to allow automatic and not manual data transfer.

Data collection and record keeping systems for seeds

- It is not known which record keeping systems are used in the native seed industry, and what proportion of the sector uses electronic records.
- There is no standard labelling system for native seeds to transfer information from seller to purchaser.
- Resources from the *FloraBank Guidelines*, 'International principles and standards for native seeds in ecological restoration', ASF, ISTA and RIAWA could be used to develop standardised record keeping and labelling systems for native seed in Australia.

Why does data collection, record keeping and tracking need to change?

- Record keeping databases are needed not only for seed collection, seed production areas, seed storage, and end use, but also in licensing agencies, thus, improving record keeping would have sector-wide benefits.
- Ultimately, by improving data collection, record keeping and seed lot tracking, seed collection could be more sustainable, seed sales more transparent and restoration more effective.

Current systems for seed and data management:

- Currently, there is not a national, standardised system for data management for native seeds.
- Organisations within the sector use different data management systems which they have purchased or developed. These systems are unlikely to be compatible, so if seed lots are transferred from one organisation to another, records cannot be easily transferred, consistently or electronically.
- There is not a national numbering system for seed lots to assist with tracking an individual seed lot from collection to planting.
- Each seed collection needs a unique code.
- Transferring records electronically can minimise human error.
- A national seed collection program for restoration, with a centralised location for processing, testing and storage (or one location per state), with a database that collects and stores information about each collection, may be of benefit to Australia.
- Data management requires resources, in terms of both purchasing or developing systems, and employing a data manager.

Electronic systems available for biological data management

- A contact directory and propagation protocol database would be useful in Australia.

Current systems for data management and sales in other industries

- Other industries provide examples of how the seed sector could improve tracking of seed lots through the supply chain and examples of online sales databases.

Evidence

The data sources include:

- expert elicitation
- peer-reviewed journal articles
- websites
- manuals.

Recommendations

Co-develop mobile & desktop application

Provide user guide & training

Develop national web database for species information

Develop national database of collectors & suppliers

Investigate the potential for an online sales portal

In the short-term, develop a universal spreadsheet

A national seed collecting and tracking app should be developed and provided for free, or for a minimal cost, to those collecting, selling and purchasing native seed, including government organisations, commercial operators and community groups.

The app could potentially be sold or licensed to larger organisations that have greater resources and ability to pay. The app would need several components. The seed collecting component would need to be used on a mobile device such as a phone or tablet. The benefit of such a device is that data could be recorded in the field, and photos and a GPS location could be recorded and linked to the collection record.

The seed cleaning, testing, storage, sale and end use components do not need to be used on a mobile device, and could be used on a desktop or laptop computer.

Records for individual seed lots would need to be exported either in full or in part.

The records should be able to be exported in a way that they are directly imported to the purchaser or end user's app. There should be an option to export all of the information to provide to a client, but also the option to export part of the information, keeping some information as 'commercial in confidence', or to comply with licensing conditions (e.g. not releasing the location of threatened plants). There should be an option to export summary information to the licensing agency for each licence holder.

Essentially, seed banks would need to have a recording system like a financial institution, to show the conditions in which the seed is being stored and to track withdrawals.

Providing everyone with the same app would mean that when seed is bought and sold, all of the information about that seed could be transferred directly into the purchaser's app, negating the need for retyping into the purchaser's system. Hence, the app and database could track seed collections from picking to planting.

It is unknown if a national app/online portal for seed selling would have widespread uptake at the current time. This is due to the fact that a lot of seed is bought on contract (reactive collections), or on demand, and may not be sitting on a shelf waiting to be purchased (proactive collections).

Also, anecdotal evidence suggests that larger seed collectors may not wish to fill orders of only a few grams (although others may — and they may already have their seed list online), and they may prefer to have a conversation with the purchaser so they are able to meet their needs, rather than just having the client buy from a list. Seed collection timing depends on both species and location, which is another reason why clients may wish to consult with seed collectors and may need to put in their orders one year in advance. Hence, further consultation and an investigation into the potential use of an online sales application is required.

A national database of all the seed collectors and seed suppliers would, however, be useful.

The database should be available online, updated annually. Each collector/supplier could list the Interim Biogeographical Regionalisation for Australia (IBRA) sub-regions in which they collect, and the list should be queried, so that purchasers can find collectors in the area in which they would like to source their seed. Each collector could list their licence/s number to give purchasers confidence that the collectors are collecting legally.

INTRODUCTION

The need for seed in restoration

Large-scale, nature-based solutions such as ecological restoration are desperately needed in Australia to prevent species extinctions, mitigate climate change through carbon capture and storage, lower the urban heat island effect, provide fauna habitat, improve ecosystem services, improve resilience to extreme climatic events, and provide public health benefits and economic outcomes. Ecological restoration can also contribute to Australia's Strategy for Nature[1] and Australia's Threatened Species Strategy,[2] as well as fulfil international obligations such as under the United Nations Convention on Biological Diversity.[3]

Ecological restoration approaches include natural regeneration, assisted regeneration and translocation (Box 1). Approaches can address threats such as overgrazing and invasive plants by fencing and weed control, allowing the native plants to regenerate. But, if ecosystems have been heavily degraded and have lost the resilience to regenerate, or land has been mostly or completely cleared of vegetation, then seeds and seedlings are likely to be needed to augment or replace plant populations (Commander and Zimmer 2020).

[1] https://www.australiasnaturehub.gov.au/sites/default/files/2020-11/australias-strategy-for-nature.pdf
[2] http://www.environment.gov.au/biodiversity/threatened/publications/threatened-species-strategy-2021-2031
[3] https://www.cbd.int/intro/

In particular, combinations or approaches are often needed to assist the recovery of all species. In this report, we use the term 'restoration' to encompass all activities on the restorative continuum, including tree planting, mine rehabilitation, threatened plant translocations, carbon farming, offsets, roadside rehabilitation, landcare, coastcare and bushcare. The report focuses on seed-based methods of restoration, such as direct seeding and planting seedlings.

Box 1. Definitions

Ecological restoration: The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Gann *et al.* 2019).

Natural regeneration: Ecological restoration that relies only on increases in individuals following removal of causes of degradation (Gann *et al.* 2019).

Assisted regeneration: An approach to restoration that focuses on actively triggering any natural regeneration capacity of biota remaining on site or nearby (Gann *et al.* 2019).

Translocation: The deliberate transfer of plants or regenerative material from an ex situ collection or natural population to a new location, usually in the wild. It includes reintroduction, introduction, reinforcement, assisted migration and assisted colonisation (Silcock *et al.* 2018).

The importance of data collection, record keeping and tracking for native seed management

The supply of native seed for restoration can be complex, which is why data collection, record keeping and tracking are essential. A diversity of data types needs to be recorded. Given the species diversity across the country and the large land area, correctly recording the species and location is essential.

Firstly, plants from which seeds are collected need to be correctly identified, and the species name needs to travel with the seed lot for its entire journey. If not, the end user may not know what species they are using. Alternatively, the end user may think they are using a different species if the species is mis-identified, or the species name is lost or changed through the supply chain.

Within each species, plants and their seeds exhibit genetic diversity (diversity of different genes within a species). Different populations of a species may exhibit genetic differentiation due to natural selection (which leads to adaptation), random selection (genetic drift), and gene flow (through pollen and seed dispersal) (Commander *et al.* 2018; Harrison *et al.* in press).

Populations that have very different genetic structures due to genetic differentiation are known as 'separate genetic provenances'. These provenances may be adapted to local conditions and, if mixed, could result in outbreeding depression or genetic swamping (Auld *et*

al. 2018; Hufford and Mazer 2003). However, if populations are small and subject to inbreeding depression, mixing provenances could improve genetic diversity.

Secondly, recording the exact source location of the seed lot is important, so that the end user can make decisions about where they would like the seed to come from. They may choose local provenance, or they may choose a mixed provenancing strategy, to attempt to maximise genetic diversity and include genes that may be resilient to, for instance, climate change (Breed *et al.* 2012).

According to one global study, end users had difficulties in obtaining seeds or difficulties finding suitable seed sources, often because material was of an unknow provenance or origin, which resulted in increased costs, decreased species diversity and delays (Jalonen *et al.* 2018). Hence, it is critical that a GPS location is taken every time a seed lot is collected, seed lots are kept separate through the supply chain (but can be mixed at end use), and locations given to the end user, so they can make informed decisions about seed sourcing.

Collecting from very small populations or collecting seeds from few plants can result in insufficient genetic diversity (Broadhurst *et al.* 2008). Hence, third, genetic diversity is why recording the population size, and number of plants collected from is important.

Fourth, seeds are alive, and need to be kept alive from the point of collection, through transport, processing and storage, until they are used. How seeds are dried, the containers that are used to store the seeds, and the temperature of the storage environment, as well as the length of time seeds are stored can all influence seed viability (Merritt *et al.* in press). Hence, records must be kept about collection date, storage date, and any quality parameters tested such as viability and when the test was performed.

Fifth, seed banks need to keep track of their stock. At a minimum, they need to know what they have collected, when it was collected, the weight of the collection, where it is stored, when it was put into storage, if it has been collected for a particular client, and how much of each seed lot has been sold, if it has not been sold in its entirety.

Finally, collecting data and recording it safely can enable learning and adaptive management in seed-based restoration, for instance, recording optimal collection times to inform collection scheduling in future years, and recording the best methods for seed cleaning.

KEY POINTS

- Species from which seed is collected need to be correctly identified, and the species' name needs to be kept with the seed lot for its entire journey from collection to use.
- Genetic variation within species means that recording the exact source location of the seeds is essential, so that the end user can decide which population best suits their needs.
- Recording population size can provide information about genetic diversity, and whether or not mixing seed from different populations may or may not be beneficial.
- Records of collection date, storage date, storage conditions and results of any quality tests must be kept to provide information about the potential viability of the seed lot. Only seed lots containing viable seeds should be used for restoration.
- Record keeping enables seed banks to keep track of their stock.
- Record keeping enables learning from previous practices, repetition of successful practices and adaptive management.

Data collection and record keeping systems for seeds

The *FloraBank Guidelines* (Grose *et al.* in press) and 'International principles and standards for native seeds in ecological restoration' (Pedrini and Dixon 2020) highlight the importance of record keeping, and communicating seed information through labels to everyone in the seed supply chain. While labelling is critical so that the end user can see, for example, the species' name and seed lot weight at a glance, also transferring the information electronically means the end user can quickly look up information on a computer, rather than searching through the printed labels on the seed lots themselves, which are likely to be packed away in storage.

Information can be kept as both hand-written and electronic records (Grose *et al.* in press). However, electronic record-keeping systems are recommended as retrieving and analysing information from electronic records is much more efficient than paper-based systems.

In addition, formulas can be built into electronic systems to perform calculations. For instance, if the total weight of the seed lot and the number of seeds per gram are known, then the total number of seeds in the seed lot can be calculated. Electronic records can be kept in spreadsheets, databases, or Geographic Information Systems. Effective record-keeping systems need to be easy to learn, easy to input data, and easy to retrieve data.

Although the *FloraBank Guidelines* provides an overview of the record-keeping systems that can be used, as well as their concepts and design (Grose *et al.* in press), it is not currently known which record keeping and tracking systems are currently used for native seed information in Australia, and what proportion of organisations use electronic systems.

The recent *Australian Native Seed Survey Report* did not survey the sector for information on record keeping. However, they did ask if there should be a representative industry group that develops best practice standards for testing and labelling, and 80–90% pf participants answered 'strongly agree' or 'agree' (Hancock *et al.* 2020). They also found that 50% of SPA growers and 30% of seed collectors provide seed testing information on the seed they sell, but respondents did not specify how they provided the information.

The Australian Seed Federation[4] (ASF) has a national code of practice for seed labelling and marketing[5] (ASF 2019). The code outlines minimum details required on the label, including species, quality information and mass. They also provide a checklist of what you need to know before you sow.[6] The ASF focuses more on crop seeds than native seeds, but many of the processes are transferrable.

The International Seed Testing Association[7] (ISTA) publishes standard procedures for seed testing, and hence provides methods of collecting standardised data about seed lots. The results from testing can be communicated on ISTA Certificates (ISTA 2021). Only accredited laboratories are allowed to provide certificates.

The Revegetation Industry Association of Western Australia (RIAWA) provides a minimum labelling standard:[8]

- unique collection batch number
- genus and species name
- collection date
- quantity in grams
- location of collection (nearest town/forest block within ten kilometres)
- grade of seed (A, B, C or Conservation).

RIAWA also indicate extra fields for A+ Grade and Conservation Grade.[9]

[4] https://www.asf.asn.au/
[5] https://www.asf.asn.au/wp-content/uploads/2016/06/ASF_Code-of-Practice_WEB.pdf
[6] https://www.asf.asn.au/wp-content/uploads/2021/04/Know_Before_You_Sow_Smart_from_the_Start_Checklist_2021_1304.pdf
[7] https://www.seedtest.org/en/home.html
[8] https://www.riawa.com.au/assets/documents/05-RIAWA-Accreditation-Min-Label-Standard-150520.pdf
[9] https://www.riawa.com.au/assets/documents/01-RIAWA-Seed-Standards-191021.pdf

For A+ Grade:

- number of filled, viable seeds per gram

For Conservation Grade:

- exact location of collection on label
- cut test information provided (% good seed)
- filled/viable seeds per gram data provided
- seed purity data provided (percentage of pure seed in mix)
- germination test/x-ray test results provided
- voucher specimen of species collected supplied
- identification by botanist.

KEY POINTS

- It is not known which record-keeping systems are used in the native seed industry, and what proportion of the sector uses electronic records.
- There is no standard labelling system for native seeds to transfer information from seller to purchaser.
- Resources from the *FloraBank Guidelines*, 'International principles and standards for native seeds in ecological restoration', ASF, ISTA and RIAWA could be used to develop standardised record keeping and labelling systems for native seed in Australia.

Why do data collection, record keeping and tracking need to change?

Without sufficient data attached to the seed lot, the seed lot may be rendered useless (Grose *et al.* in press).

Making record keeping easier and more affordable

The native seed sector faces many challenges. One of these challenges is that many seed collectors do not feel that seed purchasers understand that the cost of seed should reflect record keeping, amongst other variables (Hancock *et al.* 2020). There is a need for more training opportunities, including for plant identification, record keeping, collection, testing and labelling (Hancock *et al.* 2020).

Many organisations and sole traders have developed their own record-keeping systems (Birnie 2021). If record keeping were standardised, and resources provided to collectors and seed banks, costs for record keeping could be minimised.

Improving seed quality information

It is likely that much of the native seed sold in Australia is not quality tested and as such, it is uncommon for seed quality information to be requested or provided (Hancock *et al.* 2020). In fact, there are no mandatory standards for labelling of native seed lots. Without standard labels, seed can be sold with very little information.

Hence, there is no data on seed quality in the native seed sector, and anecdotal evidence suggests that poor-quality seed being purchased and used for restoration is an issue in the sector (Birnie 2021). Essentially, in many cases, purchasers do not what proportion of the seed lot they are buying is live seed.

Without this information on seed quality, seeding rates for direct seeding cannot be calculated. Quality information is essential for production of seedlings in a nursery, as over or under-sowing can result in wasted time or resources. Fundamentally though, if seed quality is not known, there is no way to determine if restoration failures are caused by poor quality seed, or other factors such as adverse weather conditions (Hancock *et al.* 2020).

Improved record-keeping systems would help overcome issues of seed quality (Birnie 2021). Hence, the native seed sector needs a consistent way to present seed quality information, and transfer it from seller to purchaser. Once seed viability is known, then other factors to overcome limitations to seedling recruitment in restoration can be investigated (Commander *et al.* 2020).

Assisting licensing agencies

Record-keeping practices need to change to help address issues in seed licensing. A recent report into seed licensing (Birnie 2021) found:

- data provided to licensing agencies as part of reporting may not be collated to a single source
- the lack of mandatory reporting means that licensing agencies may not receive data on seed collection
- resourcing and staff limitation have been highlighted as a barrier to improving record keeping in seed licensing.

These issues could be addressed by online licence application forms, which would help both with applying for a licence and reporting on collections made under that licence. A user portal would go one step further, allowing licensees to view their applications and report on their collections (Birnie 2021).

Hence, if data was reported in a consistent and compatible manner, then licensing agencies may be able to aggregate and analyse the data in a centralised database for each state/territory. Agencies could also map the data geographically. If this reporting was easy to do, compliance may increase.

The aim of licensing is to ensure that sustainable harvesting is taking place. Making reporting easier to increase compliance, and having a compatible record-keeping system between collectors and licensing authorities, as well as a state/territory database with all licence reports would help licensing authorities achieve their aim.

Improving seed production areas

Databases are seen to be critical to the success of seed production areas (Baker in press) yet, they are not used by all seed production areas. In NSW, a survey of SPAs determined only 26% use databases, 22% use spreadsheets and 33% use paper-based systems (Logie 2020). Also, in a survey of 17 SPAs across Australia, 13 used a database, two used a spreadsheet, one used a paper-based system, and one did not use a record-keeping system but relied on seed collector knowledge (Baker in press).

However, even those SPAs that use a database do not collect comprehensive data — for instance, only 41% of organisations with databases recorded the population size, a factor important in genetic diversity. Researching and creating a database for an SPA may be considered a burden (Baker in press), so developing one that SPAs could use would be of enormous benefit to the industry.

KEY POINTS

- Record-keeping databases are needed not only for seed collection, seed production areas, seed storage and end use, but also in licensing agencies; thus, improving record keeping would have sector-wide benefits.
- Ultimately, by improving data collection, record keeping and seed lot tracking, seed collection could be more sustainable, seed sales more transparent and restoration more effective.

How can data collection, record keeping and tracking change?

Moving to an electronic, nationally consistent and compatible record-keeping system has the potential to improve practices in the sector. The system could consist of a mobile and desktop application. A mobile ‘app’, short for ‘software application’ is an application software or computer program, generally used on a mobile device such as a smart phone or tablet. Desktop applications run on desktop computers and web applications run in web browsers. Applications include software such as word processors, spreadsheets and contact databases.

Aims of this report

This report:

- investigated if a seed collection tracking app would be an appropriate tool to ensure a consistent methodology in native seed collection for selling seed lots in a national marketplace
- aimed to identify if there are any existing product tracking apps or similar products that could be customised for the seed sector and
- developed recommendations on technology products/services that could be used to improve the data provision of seed lots for sale in Australia in the short to medium term.

METHODOLOGY

The information in this report was gathered using a literature review, expert elicitation and web search. The literature review was performed using Google Scholar[10] and the author's personal EndNote library. Individuals from a cross section of the seed sector, both in Australia and overseas, were selected, and emails were sent to them to elicit information. Not all individuals chose to respond.

FINDINGS

Key points, and how this information could be used within a national strategy, are highlighted throughout the review, and summarised in the final section which outlines the recommendations.

Current systems for seed and data management

The seed supply chain

The seed supply chain describes the processes that seed passes through between collection and end use. Figure 1 shows the supply chain and summarises some of the actors who may take custody of the seed lots at various times. Information on the supply chain was compiled through the *FloraBank Guidelines* (Commander in press), and the expert elicitation process below.

Firstly, species and collection locations are selected (Crawford *et al.* in press; Harrison *et al.* in press). The collections may be done opportunistically by seed collectors who think there is likely demand for that species from that area in the future. They may have done reconnaissance trips to check what's in flower and when, and determine seeding potential.

[10] https://scholar.google.com.au/

Alternatively, a client may decide on the species and source location, based on their project aims, and engage a collector. Collectors may be employed through a tender or collectors may have an ongoing relationship with a client. A recent survey found that a slightly greater proportion of seed is pre-ordered, rather than collected opportunistically or bought from opportunistic collections (Hancock *et al.* 2020).

Seeds may be collected by land managers (e.g., volunteer groups, town councils, NGOs, or rural landowners) on the property that they manage (e.g., bushland, conservation reserves, or farms), to be used to restore these properties. These seeds may be retained on the property or sent off-site for nursery propagation and return as seedlings.

Research and conservation institutions may target species for collection, for instance, threatened species, species required for research into conservation techniques or seed dormancy, species required for display in botanic gardens, or species required for horticultural development. In these cases, the seed lot may not change hands (in the case of an individual researcher who may be the custodian of the seed lot from collection to a field trial), or may change hands several times within the organisation (e.g., from collector, to processor to propagator). Seed can also be harvested from seed production areas (Gibson-Roy *et al.* in press-a).

Once collected or harvested, seed is then processed to remove seed from fruits (Errington *et al.* in press). Processing could be done by the collector, or the collector could sell it to a seed bank which processes the seed. Seed can then be tested (Commander *et al.* in press), either in house, or by an external testing laboratory. Then, seeds are dried and stored. Storage time and conditions depend on available facilities and end use and could be short-term (≤5 years), medium-term (5–10 years) or long-term (>10 years) (Merritt *et al.* in press).

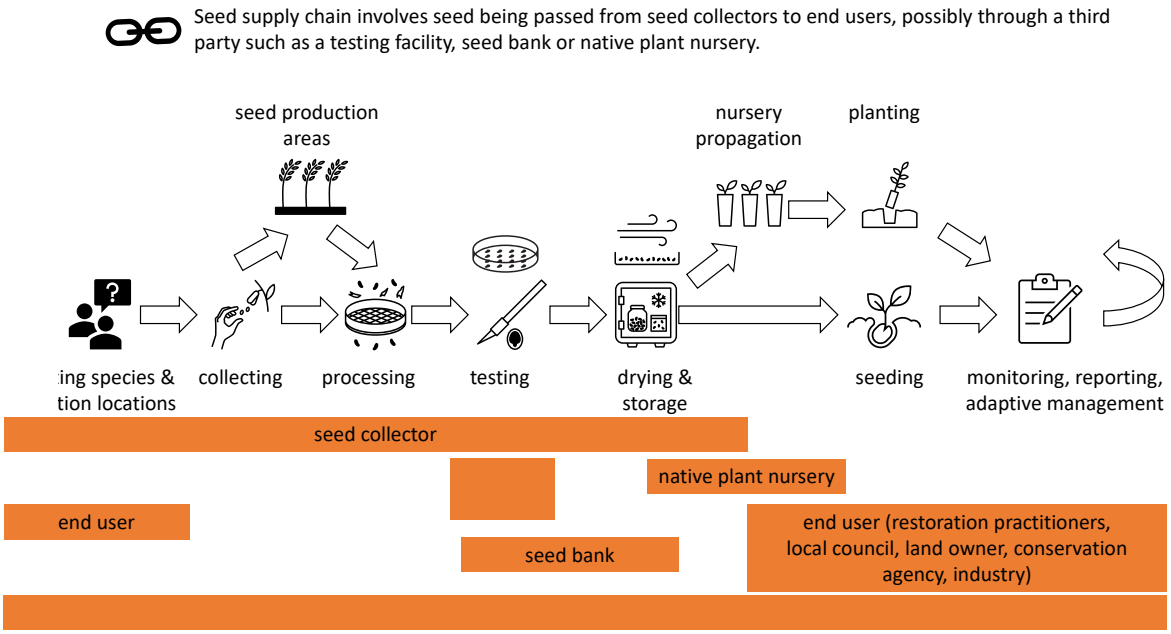
Pre-treating and seed enhancement are options prior to end use, which is typically nursery propagation of seedlings which are then planted (Turner *et al.* in press), or direct seeding (Gibson-Roy *et al.* in press-b).

So, seed lots may remain in the custody of one person, or many people within one organisation. Or they could be passed from a collector, to a processing facility, to a testing facility to a storage facility to a nursery to a restoration practitioner. It is important to understand the various pathways of seed lots along the supply chain, and whether or not the seeds change hands between or within organisations.

As seeds change hands, the information about those seeds needs to change hands too, and with every process, more and more information should be gathered about these processes.

Given the potential number of people and organisations through which the seed lots could pass, it is essential that this information maintains its integrity through the supply chain. However, there is limited evidence on how this critical information about the seed lot is recorded and passed on.

FIGURE 1. REPRODUCED FROM THE *FLORABANK GUIDELINES* MODULE 1 — INTRODUCTION (COMMANDER *ET AL.* (IN PRESS))



How is the data recorded?

Seed collection data has traditionally been recorded in seed collection books, which may have carbon copies which can be detached so the original stays in the book and a copy is attached to the collection. The template in the seed collection book prompts the collector to write down all of the relevant information (Appendix 3).

The information is then generally manually transferred to a spreadsheet or database. Different organisations use different systems. When seed is transferred from one organisation to another, records may be transferred as a print out, an Excel spreadsheet or pdf.

With new technology, forms and templates can now be set up electronically so that information can be captured using a smartphone, tablet or computer. A benefit of electronic recording is that drop-down lists can be created to minimise spelling errors. Also, devices with inbuilt GPS and camera can make capturing locations and photos and linking these to the collection record easier. However, data entry errors can still be made.

Below are some case studies developed using expert elicitation, to show the different ways in which organisations within the industry (state government, commercial, national (US), continental (ENSCONET) and international (MSB)) perform data collection, record keeping and tracking.

Expert elicitation — systems used by seed collectors and seed banks

The following questions were sent to a number of organisations to gain an understanding of current systems for seed and data management.

1. Do you use an electronic data management system?
2. Is it a spreadsheet (e.g. Excel) or database (e.g. *Access*)?
3. Did your organisation develop it, or did you purchase it? Does it have a name? Do you know of any other organisations using the same system?
4. If you collect seeds, do you record information in the field in a paper-based system (e.g. a collecting book) or on an electronic device (smartphone, tablet, laptop)?
5. Do you share your data with others, e.g. purchaser, end user, seed bank, botanic garden, ALA? If so, how (database records, export to a pdf report, export to an Excel spreadsheet)?
6. Do you have any suggestions or recommendations for a national, standardised data management system for seeds?
7. Below is a list of information that could be collected on seeds. Do you have anything to add to it?

Their responses are below. Two respondents were from state government agencies, two were from commercial seed companies, and three were from overseas organisations (national, continental and international).

Murray Local Land Services

Local Land Services is a regional-focused NSW Government agency.[11] Murray Local Land Services (LLS) is one of the 11 LLS regions in NSW.

Murray LLS does all its own seed collecting and has a paper system for field data recording. All the field data sheets are paper and are completed in a carbon copy book. One copy stays with the seed through collection and processing and the other stays in the book which are filed at the seed bank when they are full.

When the cleaned seed is weighed and deposited into the seed vault, the field data is transcribed into the database. Each bag of seed is labelled with the species, weight and collection numbers and the original paper data sheet is placed in a folder and filed for each collection season.

Murray LLS engaged a contractor to develop the Seedbank Database, which is a custom-made *Access* database. It has undergone several revisions over time to make it more workable and improve the ease of operation and reporting capabilities. As they paid for its development, they are the only ones using this system. It is a stand-alone system and is not connected to the internet.

[11] https://www.lls.nsw.gov.au/regions/murray

Murray LLS does share data if requested. Mostly this is information relating to species and weights held in stock and provenance of seed lots for nurseries or other clients wishing to purchase seed. It may be an Excel spreadsheet or PDF.

At a minimum, Murray LLS states that information collected should include species, collection location, population size, number of plants collected from, source of the collection (e.g. planted, SPA, remnant) collection date, vegetation type and whether seed is endemic to the area it is being collected from.

The field data sheets are included in Appendix 3.

Royal Botanic Gardens and Domain Trust, NSW

Royal Botanic Gardens and Domain Trust[12] (RBGDT) is funded by the NSW state government and includes the Royal Botanic Garden Sydney and the Australian Botanic Garden, Mt Annan.[13] The Australian PlantBank is housed at Mt Annan, which stores seed and tissue culture collections as well undertaking plant conservation research. The National Herbarium of NSW is moving to Mt Annan.[14]

The seed collectors currently use a paper-based field collecting book. Royal Botanic Gardens and Domain Trust uses an electronic data management system. The systems differ between groups within the organisation.

The seed collection at PlantBank uses IrisBG[15] (a collection management system used by many botanic gardens worldwide), Herbarium specimen data is on KE EMu[16] (a collections management system, based on the Texpress object oriented database management system), and the seed research data is stored on *Access*.

RBGDT shares data with the Atlas of Living Australia (ALA), Millennium Seed Bank (MSB) and within the department (NSW Department of Planning, Industry and Environment (DPIE)). They share data with other botanic gardens on request.

The expert pointed out that there is a diversity of seed bank operations (commercial and government). A commercial seed bank is managed entirely differently to a government conservation seed bank.

However, there should be at least a minimum standard for seed information to be recorded and kept.

[12] https://www.rbgsyd.nsw.gov.au/
[13] https://www.australianbotanicgarden.com.au/science/australian-plantbank
[14] https://www.rbgsyd.nsw.gov.au/science/national-herbarium-of-new-south-wales; https://www.australianbotanicgarden.com.au/science/national-herbarium-of-new-south-wales
[15] https://www.irisbg.com/
[16] https://www.axiell.com/solutions/product/emu/

Australian Seed Bank online

The Australian Seed Bank Partnership (ASBP) is a partnership of 12 Australian organisations, including botanic gardens, state environment agencies and NGOs. Many of these partner organisations collect and store seed for conservation, as well as conducting research into conservation and restoration.

Most of the partners use paper field books and transcribe to databases on return to the seed banks. The partners use different data management systems (BG Base, IRIS, Excel, BRAHMs etc.) because they have separate governance and financial systems within which they operate. There is one organisation that has transitioned from paper field books to electronic data collection. At Kings Park and Botanic Gardens, the seed collector has a copy of BG Base on the field tablet, so can enter data directly into the database in the field, then export the data to the desktop database upon return from the field.

ASBP has co-developed an online database with the Atlas of Living Australia (ALA). The database, called Australian Seed Bank online,[17] is a compilation of data from the partner organisations.

The system was chosen because of the public/open access nature of the ALA and that many other biodiversity datasets are also available through the ALA meaning there are opportunities for linked data i.e. Australasian Virtual Herbarium. A data analyst from ALA worked with a data working group from ASBP to identify data needs and infrastructure required. The data fields used are based on Darwin Core and the data ingest was mapped according to this and the databases used by partners. The data is exported from their databases and sent to ALA who upload the data to the Australian Seed Bank online. The ASBP is working on an update to the Australian Seed Bank online.

The ASBP secretariat collates subsets of the data provided by the partners. The collated data is then shared with funding organisations, end users, the MSB and ALA. Project-specific data is provided from partners to the ASBP Secretariat in Excel format that is then shared with funders in that form.

> **One point to note is that collections made by ASBP partners are conservation collections, not commercial collections.**

[17] https://asbp.ala.org.au/

Rare Flora Search and Rescue

The Rare Flora Search and Rescue program[18] is a collaboration between the Western Australian Department of Biodiversity, Conservation and Attractions (DBCA), the Wildflower Society of WA and WWF-Australia (formerly World Wildlife Fund). It is a citizen science project which engages volunteers to search for rare and poorly-known flora in the Western Australian wheatbelt region.

The volunteers collected survey information using an app, Flora Collector. The app was developed from ESRI Collector,[19] which can be used to collect any kind of data. The volunteers used the app on either their Android or iOS devices, or were provided with mobile devices for the project.

The data from the project has been uploaded into NatureMap,[20] and will be added to the DBCA Threatened and Priority Flora database.

BioBank Seed

BioBank Seed[21] is a commercial seed collection, storage and testing company based in Uralla, NSW. They collect within about a 250km radius of their facility. Their collectors use triple carbon copy collecting books, i.e. a paper-based system. The top copy goes in the bag with the collection, and the other two copies remain in the book. Back at the base, the collection number is written on a plastic tag. The second copy is used when sampled for testing and is cleaned and bagged. The data is entered manually into their database at the seed store on their return.

They were provided with a custom-made *Access* database, but it did not function effectively, so they employed a database specialised to resolve the issues. The database keeps track of all the seed collections. The database produces a docket and an invoice for all species purchased by a client. It can export data as a pdf.

The company also does seed testing for clients. One issue they have is that they need to develop a new accession number for seed collected by other companies.

> **An important component of testing seed collected by another client is the chain of custody identification, and recording who takes the sample to be tested.**

If someone other than BioBank seed takes the sample, it may not be a representative sample, hence why the sample taker needs to be recorded.

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[18] https://az659834.vo.msecnd.net/eventsairaueprod/production-pecbookings-public/9855ea7d470145f0ba8d690e8666b876
https://www.wwf.org.au/news/blogs/search-and-rescue#gs.1r3m7x
https://library.dbca.wa.gov.au/static/Journals/080341/080341-22.001.pdf
[19] https://www.esri.com/en-us/arcgis/products/arcgis-collector/overview
[20] naturemap.dpaw.wa.gov.au
[21] https://biobankseed.com.au/

Another issue they have is that collections made by others need to be numbered with a different numbering system to the one they use for their own collections. All the testing information is uploaded into the database, and the sample is kept for up to two years.

BioBank seed uses the form published in 'International principles and standards for native seeds in ecological restoration' (Pedrini and Dixon 2020) (Appendix 1).

The company collects both opportunistically and to order. If they are collecting to order, they prefer to be paid an hourly rate, rather than being contracted to collect a set amount of a particular species, in case that species is not seeding. They would prefer to have a conversation with a customer to meet their needs, rather than fill online orders for small quantities.

Tranen Revegetation Systems

Tranen Revegetation Systems[22] is a company providing services in bushland and native vegetation management in and around Perth and the south-west of Western Australia. They offer seed collection, processing, storage and seed banking, pre-treatments, as well as project implementation (seeding and planting).

Data is collected in the field on labels and then input daily into the database system on return to base. The database is a Custom SQL database called SeedTracker, which was developed in-house. There is now one other organisation using it under licence.

Custom reports can be developed from the database for reporting to clients for collection progress and seed bank statements. Reports can be produced in pdf, Excel and Word formats.

They suggest the minimum information to collect:

- at the point of collection
  - location name (i.e. for those working in small reserves)
  - provenance (i.e. nearest town, region, other)
  - topography
  - soil type
- during storage
  - pre-storage treatments (i.e. CO2 gas, insecticide).

A database will also need to have lots of options for user customisation – too complex or too many fields and people will not use it – and if does not allow people to capture the data they usually do they will not either. For instance, they needed to customise their database so that their licensee could capture spatial data.

[22] https://www.tranen.com.au/

Greening Australia

Greening Australia is a not-for-profit environmental organisation with 20 locations across Australia. They conserve and restore landscapes across the country. Several locations store seed until it is used in restoration activities.

Seed collectors use paper forms and electronic recording to document collection records. Information documented includes date, name, collector, plant characteristics, location, GPS etc. They also try to collect a voucher specimen for future reference. The electronic record collects all of the above information, plus has option to take photos of plants being collected and creates a map of collection locations. They use the Fulcrum app[23] for electronic records.

Some locations use a spreadsheet to keep track of their seed lots while in storage. Other locations had previously used the Microsoft Access database. Three locations now use a centralised system, Microsoft NAV Dynamics. The system assigns a seed lot number and the collection data is entered, then labels for the seed bags/containers can be printed out.

The labels contain the following information: species, lot number, collection date, collection provenance, collector name and weight. If seed lots are transferred between the three locations using the system, the information can be transferred too. Permissions can be adjusted to determine who can access or edit the information.

Greening Australia is working towards using Microsoft NAV Dynamics at a national level.

Seeds of Success (SOS)

Seeds of Success[24] (SOS) is the national native seed collection program in the United States (US), led by the Bureau of Land Management (BLM) in partnership with a variety of federal agencies and non-federal organisations. SOS collectors use paper data sheets out in the field (Appendix 3).

Then, the collectors take these data sheets back to the office and enter them into the web portal, which was developed for Seeds of Success by BG-BASE.[25] The fields in the portal match what is on the paper data sheets.

A user guide is provided for the data portal.[26] All the data go into one central database. The web portal connects to the BG-BASE database which is where the data are stored long-term.

[23] https://www.fulcrumapp.com/
[24] https://www.blm.gov/programs/natural-resources/native-plant-communities/native-plant-and-seed-material-development/collection#:~:text=Seeds%20of%20Success%20%28SOS%29%20is%20the%20national%20native,for%20research%2C%20development%2C%20germplasm%20conservation%2C%20and%20ecosystem%20restoration.
[25] http://www.bg-base.com
[26] https://www.blm.gov/sites/blm.gov/files/Data%20Portal%20User%20Guide.pdf

The SOS co-ordinator can access the database through a remote desktop set up and can query and export Excel spreadsheets as needed for big batches.

After collection, the seed is sent to US Department of Agriculture (USDA) Forest Service's Bend Seed Extractory[27] (there are a few partners who do not send their seed there, but this is where the majority is cleaned). Accompanying each shipment is the paper data form associated with the collection. Data sheets printed from the data portal can also be used for seed shipments to Bend. Bend manually enters these data into their own database. Manual entry occasionally results in human error, however, they plan to move to a new database system that will allow direct importation via csv/Excel files.

Portions of each SOS collection also go to partners at USDA Agricultural Research Service (ARS) in Pullman, Washington and Fort Collins, Colorado, for long-term storage. These partners receive electronic files from the coordinator for the relevant collections.

Ideally the data follows the seed.

Each collection has a unique reference number comprised of the collecting team code and the collection number. Each collection has a unique reference number, the format of which is team code, hyphen, and the sequential collection number. For example, the 50th collection made by Chicago Botanic Garden is *CBG-50*. These accession numbers are how they track the collections between partners and for the most part it works.

Of course, there is always human error (someone skips a number or adds an extra zero, etc.) so they are always making little updates and try to communicate those as best as possible between the partners who also track these accessions (Bend, Pullman, Fort Collins). In short, as long as the accession number doesn't get lost or corrupted, then they are easily able to match the seed to the data. SOS has discussed implementing a barcode system in the future, that would allow for better data consistency.

After being cleaned, the first 10,000 seeds go into long-term storage (USDA-ARS), the remainder (which is hopefully many more thousands of seeds) go back to the collector, or to partners for grow-outs, restoration or other end uses (see Figure 2).

Bend works with the laboratory next door at Oregon State University[28] for the seed testing and provides weights (received and clean weight), seed per pound, purity %, tetrazolium tests (a viability test), and estimated pure live seed (PLS). All these results are emailed to the coordinator, who emails the relevant data to the seed collectors.

[27] https://www.fs.fed.us/forestmanagement/vegetation-management/nurseries/index.shtml
[28] https://seedlab.oregonstate.edu/

A few SOS collecting teams have been experimenting with apps over the past few years as tablets become more widely available. SOS is currently running a pilot with a couple of the teams this season using the ESRI apps Survey123,[29] Collector[30] and Field Maps[31] to determine if it would be possible to transition away from paper data sheets almost entirely.

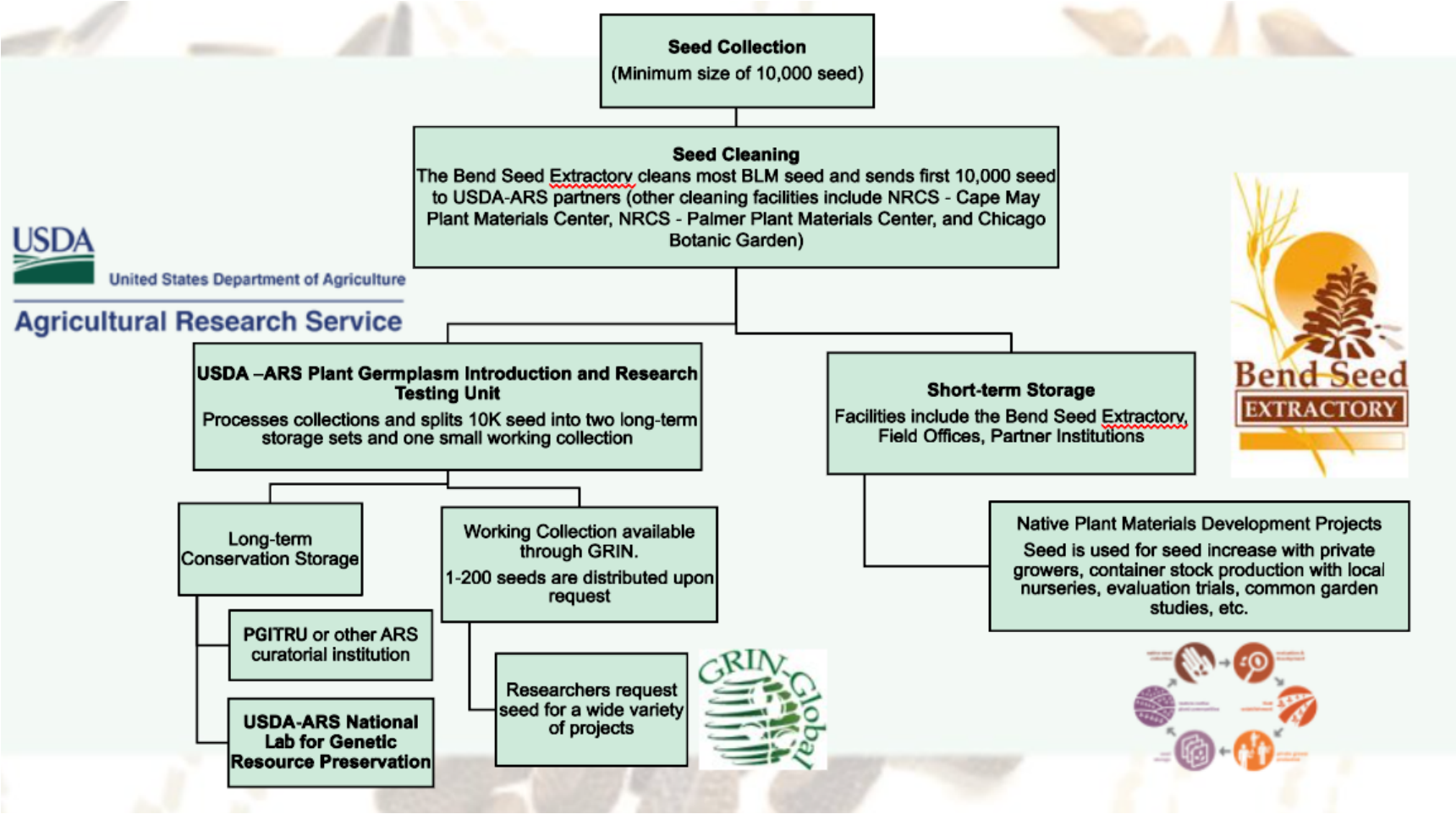
These apps are not meant for long-term, secure storage, so SOS has been working with BG-BASE to develop a cross-walk between the apps and BG-BASE (moving exports from one into the other and vice versa).

This should allow importation of large batches of data from the apps (via csv files) directly into the database, thus eliminating the need for collectors to duplicate their efforts, entering the data twice.

It will also be necessary to ensure that collectors have access to tablets, spare batteries and IT support. Many other BLM programs, like the Assessment, Inventory and Monitoring (AIM) Strategy,[32] use apps for their data collection,[33] including Survey123, Field Maps and Collector.

[29] https://www.esri.com/en-us/arcgis/products/arcgis-survey123/overview
[30] https://www.esri.com/en-us/arcgis/products/arcgis-collector/overview
[31] https://www.esri.com/en-us/arcgis/products/arcgis-field-maps/overview
[32] https://www.blm.gov/about/how-we-manage/assessment-inventory-and-monitoring-strategy
[33] https://aim.landscapetoolbox.org/data-collection/data-capture-applications/

FIGURE 2. HOW THE SOS SEED IS DISTRIBUTED



The first 10,000 seeds are sent to long-term storage (on the left). Anything that remains, stays at Bend Seed Extractory until requested back by the collector (or if the collector wishes, it can be sent to other partners for grow-outs, research, etc.) Figure provided by Anna Lindquist, SOS.

European Native Seed Conservation Network (ENSCONET)

The European Native Seed Conservation Network (ENSCONET) coordinates native seed plant conservation within Europe.[34] The Network has developed a database[35] (ENSCOBASE) which contains information about seed germination, moisture content and collection location to help improve the use of electronic data for seed conservation. ENSCONET developed the database in-house, in terms of both the structure and fields. The database is unique and runs on a main server, so the partners do not have a copy. They (and anyone) can download their datasets from the website by clicking on links.

The input of data into ENSCOBASE is voluntary and through a template that the database manager provides. ENSCONET did not develop an app. ENSCOBASE can be searched by taxonomy (taxon, genus, family, division), georeferenced (EEA Bio-geographical region, country, institution) and germination data (by taxon).

Data can be analysed, e.g. the total accessions by institutions, country or region, as well as total families and genera. ENSCONET has produced a collecting manual (ENSCONET 2009c), curation protocols (ENSCONET 2009a) and a database manual (ENSCONET 2009b).

Millennium Seed Bank (MSB)

The Millennium Seed Bank (MSB) is part of the Royal Botanic Gardens, Kew, and is located in Wakehurst, UK.[36] Working with its global network, the Millennium Seed Bank Partnership (MSBP),[37] it houses over 2.4 billion seeds from 97 countries across the world.

Along with receiving seed collections from their partners, the MSB receives the associated collection data. The data is housed in the MSBP data warehouse,[38] a database which is curated and published using BRAHMS[39] (Botanical Research And Herbarium Management System) and BRAHMS online.[40]

Generally, they receive the seed collection data electronically through the MSB Data Exchange template. Most MSB partners submit data in Excel files. Sometimes the partners send through RDE (rapid data exchange) files of their seed collections data which can be uploaded into the database very easily. BRAHMS RDE files are the easiest and most efficient way to transfer data between BRAHMS databases. Data can also be downloaded/uploaded as xls, csv files etc, but it's not as efficient, and some data may be lost/corrections required via the latter formats. Germination data can only be submitted via RDE files (rather than xls/csv) for inclusion in the database.

[34] http://ensconet.maich.gr/About.htm
[35] http://ensconet.maich.gr/Database.htm
[36] https://www.kew.org/wakehurst/whats-at-wakehurst/millennium-seed-bank
[37] http://brahmsonline.kew.org/msbp
[38] http://brahmsonline.kew.org/msbp/SeedData/DW
[39] https://herbaria.plants.ox.ac.uk/bol/
[40] https://herbaria.plants.ox.ac.uk/bol/brahms/publishonline/bolkeyfeatures

The MSB has developed the Seed Information Database (SID) (Royal Botanic Gardens Kew 2021) with seed biological trait data from the its own collections and from other published and unpublished sources.[41] It can be searched by clade, order, family genus, species and storage behaviour, and filtered to show only records with storage behaviour, weight, dispersal, germination, oil content, protein, morphology and salt tolerance. In addition, the MSB has published a variety of resources, including seed conservation standards (MSB 2019).

Through expert elicitation, it was highlighted that a national data management system would need dedicated resources to manage the data uploading and display. The MSB's data warehouse, for instance, has a full-time data manager to support the data contributions from <200 partners.

KEY POINTS

- Currently, there is not a national, standardised system for data management for native seeds.
- Organisations with the sector use different data management systems which they have purchased or developed. These systems are unlikely to be compatible, so if seed lots are transferred from one organisation to another, records cannot be easily transferred electronically.
- Each seed collection needs a unique code.
- There is no national numbering system for seed lots to assist with tracking an individual seed lot from collection to planting.
- Transferring records electronically can minimise human error.
- A national seed collection program for restoration, with a centralised location for processing, testing and storage, (or one location per state), with a database that collects and stores information about each collection, may be of benefit to Australia.
- Data management requires resources, in terms of both purchasing or developing systems, and employing a data manager.

Electronic systems available for biological data management

Apps for data collection

Several apps are available for data collection in the field. Most apps reviewed are developed for vegetation surveys and citizen science projects. These can be adapted in some cases for recording data during seed collection. There is one app specifically developed for seed collection and tracking, SeedIT. The apps with the greatest potential for the seed sector are ESRI Collect and ALA BioCollect.

[41] https://data.kew.org/sid/

SeedIT

SeedIT[42] is an app available for Android and Apple which tracks and manages seed collections. The app can be used offline, which is useful in remote locations without internet access. The app can track seed lots from collection to planting (Figure 3).

There is a step-wise process for recording data:

1. Enter collection ID
8. Select a species from the list
9. Select seed, seedling, sapling, tree
10. Type in the number
11. Add an image, either from the library or camera
12. Add notes
13. Review and save
14. The latitude, longitude and altitude will be recorded automatically if the GPS is turned on (if not, the user is prompted to turn it on)
15. The date and time are automatically recorded.

The collections can then be viewed as points on a map or as a list in the store. The languages available are English, Malay, Spanish and French.

The records are uploaded into the cloud console, which is a web application. It allows the user to view all collections (Figure 4). The user can also add names of single species, or multiple species (by uploading a csv file with the column headers 'genus', 'species', and 'local'). By selecting the collection, the map view will be displayed, with the point of collection shown on Google Maps (Figure 5).

Multiple collectors can be added, and they can be arranged into collection groups. The collection data can be downloaded from the web application as a csv file.

The app appears to be fairly easy to use, however, the information that it gathers is less comprehensive than the currently used paper forms in Appendix 3.

[42] https://seedit.io/home

FIGURE 3. VARIOUS SCREENS WITHIN THE MOBILE APP, SEEDIT, SHOWING HOW TO ADD COLLECTIONS, AND FUNCTIONS SUCH AS THE LIST OF STORED SEED AND THE MAP OF COLLECTIONS

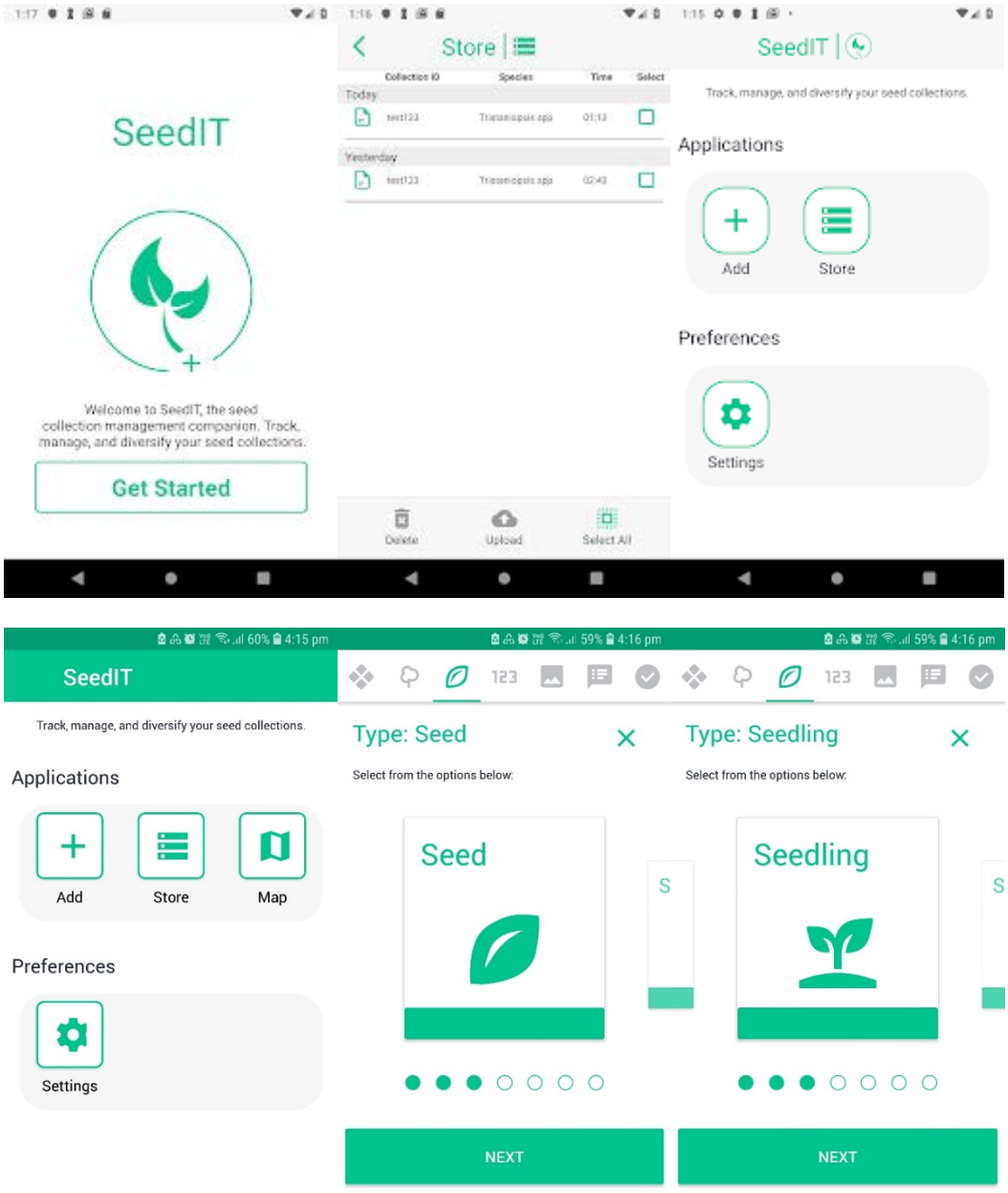
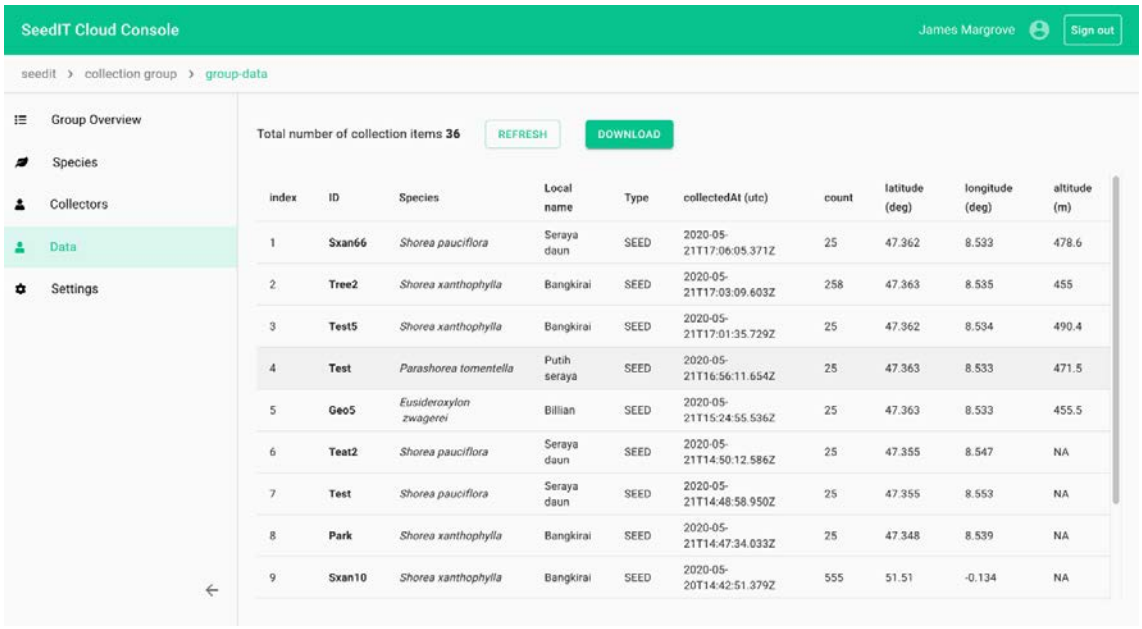
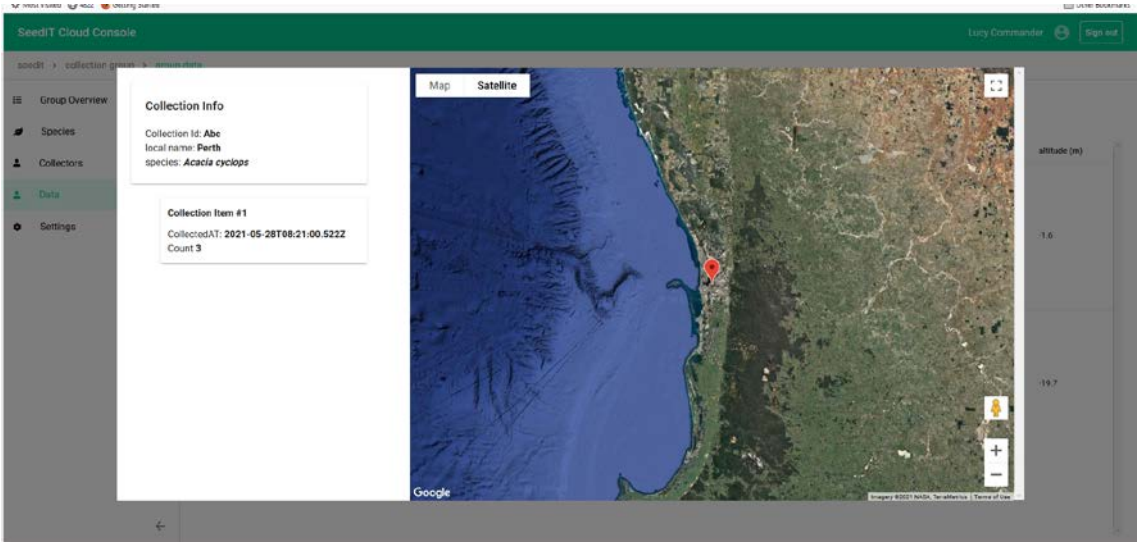


FIGURE 4. SEEDIT CLOUD CONSOLE WITHIN THE WEB APPLICATION, SHOWING THE LIST OF COLLECTIONS



index	ID	Species	Local name	Type	collectedAt (utc)	count	latitude (deg)	longitude (deg)	altitude (m)
1	Sxan66	*Shorea pauciflora*	Seraya daun	SEED	2020-05-21T17:06:05.371Z	25	47.362	8.533	478.6
2	Tree2	*Shorea xanthophylla*	Bangkirai	SEED	2020-05-21T17:03:09.603Z	258	47.363	8.535	455
3	Test5	*Shorea xanthophylla*	Bangkirai	SEED	2020-05-21T17:01:35.729Z	25	47.362	8.534	490.4
4	Test	*Parashorea tomentella*	Putih seraya	SEED	2020-05-21T16:56:11.654Z	25	47.363	8.533	471.5
5	Geo5	*Eusideroxylon zwageri*	Billian	SEED	2020-05-21T15:24:55.536Z	25	47.363	8.533	455.5
6	Teat2	*Shorea pauciflora*	Seraya daun	SEED	2020-05-21T14:50:12.586Z	25	47.355	8.547	NA
7	Test	*Shorea pauciflora*	Seraya daun	SEED	2020-05-21T14:48:58.950Z	25	47.355	8.553	NA
8	Park	*Shorea xanthophylla*	Bangkirai	SEED	2020-05-21T14:47:34.033Z	25	47.348	8.539	NA
9	Sxan10	*Shorea xanthophylla*	Bangkirai	SEED	2020-05-20T14:42:51.379Z	555	51.51	-0.134	NA

FIGURE 5. SEEDIT CLOUD CONSOLE WITHIN THE WEB APPLICATION SHOWING THE MAP VIEW OF COLLECTIONS



Other apps include:

1. **Atlas of Living Australia (ALA)**

   - ALA has developed two apps, BioCollect and iNaturalist.
   - BioCollect mobile app is a data collection tool to assist with collecting field data. It can be used for surveys and activity-based projects (e.g. restoration). Data can be shared to ALA or embargoed. It can be used for seed collection and native nurseries, including recording details of source plants and populations, accession and pre-treatments.

It can be used on a mobile device or computer. The app also uses the camera, clock and GPS to record data. Data collected can be shared within organisations, or made public. It uses international biodiversity data standards. BioCollect can be used as the foundation for a custom app.

https://www.ala.org.au/biocollect/

- iNaturalist is a free app for recoding observations of flora, fauna and fungi. These observations are uploaded to ALA.

https://www.ala.org.au/who-we-are-3/downloadable-tools/ala-mobile-app/

2. Epicollect5

- Epicollect5 is a free mobile app available for Android and Apple and web application. Data can be collected on or offline. GPS and media can also be collected. Data can be exported in csv files.

https://five.epicollect.net/

3. ESRI

- Collector

https://www.esri.com/en-us/arcgis/products/arcgis-collector/overview

- Field Maps

https://www.esri.com/en-us/arcgis/products/arcgis-field-maps/overview

- Survey123

https://www.esri.com/en-us/arcgis/products/arcgis-survey123/overview

4. ODK Collect

- ODK Collect is a free download for windows. It replaces paper forms and also supports location information and images. It can be used offline, then downloaded from the device or sent to a server. ODK Aggregate is a free server which can download the completed forms and generate csv files.

https://into-windows.com/odk-collect/

5. SeedTree Map

- While technically not an app, SeedTree Map is an interactive map that can be used on mobile devices. An experienced botanist maps seed-producing trees on a client's property (Figure 6). Then, the clients can use their map to explore the trees on their property, and click on the interactive map for further information such as fruiting months, fruit and seed characteristics and seed colleting instructions. There is also a recording section where clients can record data and images about flowering, fruiting and seed collection. Clients can use the information to collect seeds to then sell, or to grow their own trees for restoration.

SeedTree Map was developed using Epicollect5, and the end product is viewed in Google MyMaps. It is currently used by around 200 people in the Northern Rivers region of NSW. Further information is provided in Appendix 7.

https://seedtreemaps.com/app/top/main

6. Terrestrial Ecosystem Research Network (TERN)

- TERN has developed a Field Survey app for field data collection. Data can be uploaded to the server.

  https://www.tern.org.au/field-survey-protocols-apps/

  https://www.tern.org.au/tern-observatory/tern-ecosystem-surveillance/

7. vegapp

- vegapp is an app used for collecting data for vegetation surveys, however it can be adapted for seed collection.

  http://vegapp.de/;
  https://play.google.com/store/apps/details?id=edu.kit.ifgg.vegapp

FIGURE 6. A SCREENSHOT OF SEEDTREE MAP SHOWING LOCATIONS OF TREES. TAKEN FROM HTTPS://WWW.SEEDTREEMAPS.COM/APP/TOP/MAIN ON 2/6/2021

Databases for data management

Databases/collection management systems include:

- Access

  https://www.microsoft.com/en-au/microsoft-365/access

- BG BASE

  http://bg-base.com/index.htm

- BRAHMS

  https://herbaria.plants.ox.ac.uk/bol/

- EMu

  https://www.axiell.com/solutions/product/emu/

- Generic plant trait database
  - Kattege *et al.* (2011) has developed a generic database for plant traits (Figure 7).

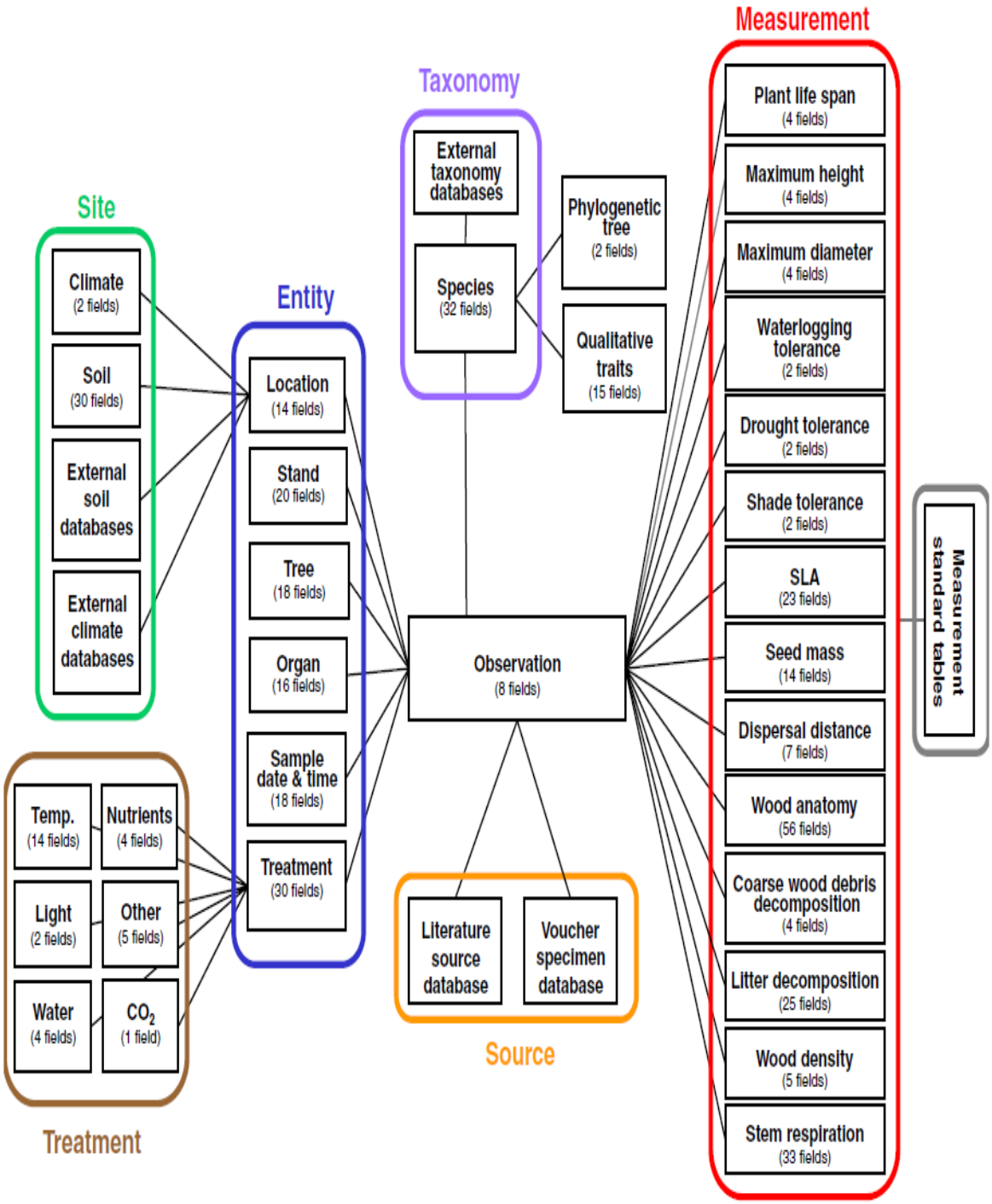
- IrisBG

  https://www.irisbg.com/

- Restor
  - Restor is a hub for information on restoration, scientific data, supply chains and funding. It's a science-based open data platform, where users can record information about their restoration area, such as species and soil characteristics and add photos and notes. Users can publish their sites to share them with other Restore members, and connect with other members doing similar work, or search for members using specific criteria.

    https://www.restor.eco/

FIGURE 7. A GENERIC STRUCTURE FOR PLANT TRAIT DATABASES. REPRODUCED FROM KATTGE *ET AL.* (2011)



For a seed lot database, the 'observation' could be replaced by 'seed lot' and 'measurement' could include quality tests. The link to external taxonomy databases could be a link to the species in ALA.

Online databases with public or registered user access to plant and seed information

Seed information

Online databases with information about seeds are listed below. There is no single database with information on all Australian species – databases have generally been set up by individual organisations. The exception to this is the ASBP database, which receives information from partner organisations across the country. Also, the MSB's Seed Information Database contains information on Australian seeds. In the US, there is a good example of a propagation database, providing information on how to grow plants from seeds.

- ANBG

  Seedbank database — Australian National Botanic Gardens (anbg.gov.au)

- ASBP

  https://asbp.ala.org.au/

- Native Plant Network Propagation Protocol Database
  - The database shares information on how to propagate native plants of North America. Registered users can also add new protocols and edit existing protocols using the protocol interface, are credited for the entry, and have the opportunity to add their company logo to the protocol.

    https://npn.rngr.net/npn/propagation
  - The database is searchable by genus and species, family, state, product type (bareroot, container, seed), organisation, company/nursery. Search results can be exported as an Excel spreadsheet. An example of the information provided in each protocol is given in Appendix 5.
  - Practical advice for growing and planting North American plants is also published in the *Native Plants Journal*.

    http://npj.uwpress.org/.

- Revegetation Industry Association of Western Australia (RIAWA)
  - RIAWA has developed a purity and viability database. The minimum purity % is available to the general public. The database for members has recommended dormancy breaking method, photographs, viability and germination data (Figure 8).

    https://www.riawa.com.au/accreditation/purity

- Royal Botanic Gardens, Kew – Seed Information Database (SID)

  https://data.kew.org/sid/

- Royal Tasmanian Botanic Gardens, germination database

  https://gardens.rtbg.tas.gov.au/conservation/tsccgerminationdatabase/

- Seeds of South Australia

  https://spapps.environment.sa.gov.au/seedsofsa/

- SylvanSeeds
  - SylvanSeeds is an online database of germination of seeds from temperate broadleaf and mixed forests. It includes species from eastern Australia. The data was gathered using a literature review (Fernández-Pascual 2021) and the web application was made using shiny – an open-source R package.[43]

    SylvanSeeds: Germination database of temperate broadleaf and mixed forests (shinyapps.io)

FIGURE 8. SCREENSHOT OF THE ONLINE RIAWA SEED PURITY DATABASE

	Purity				Viability			Germinability				
Scientific Name	Minimum Purity % A,B Grade	Commercial (A,B) Grade Photo	Seeding (C) Grade Photo	Purity Comments	Range (%)	Mean (% ± sd)	Test Method	Max (%)	Range (%)	Max / gram	Mean (% ± sd)	Recomm Dormanc Break M
Allocasuarina huegeliana	99%							55		297.5		
Allocasuarina humilis	99%			Occasional small twig. Less than 1%	60-65	62.0%±1.5 from one seed lot	X-ray	25		77.4		No treatr required
Allocasuarina lehmanniana	99%			Occasional small twig. Less than 1%		90% from one seed lot	X-ray	22		220		No treatr required
Alyogyne huegelii	95%				50-52	51±1	X-ray					Hot wate

Seed purchasing

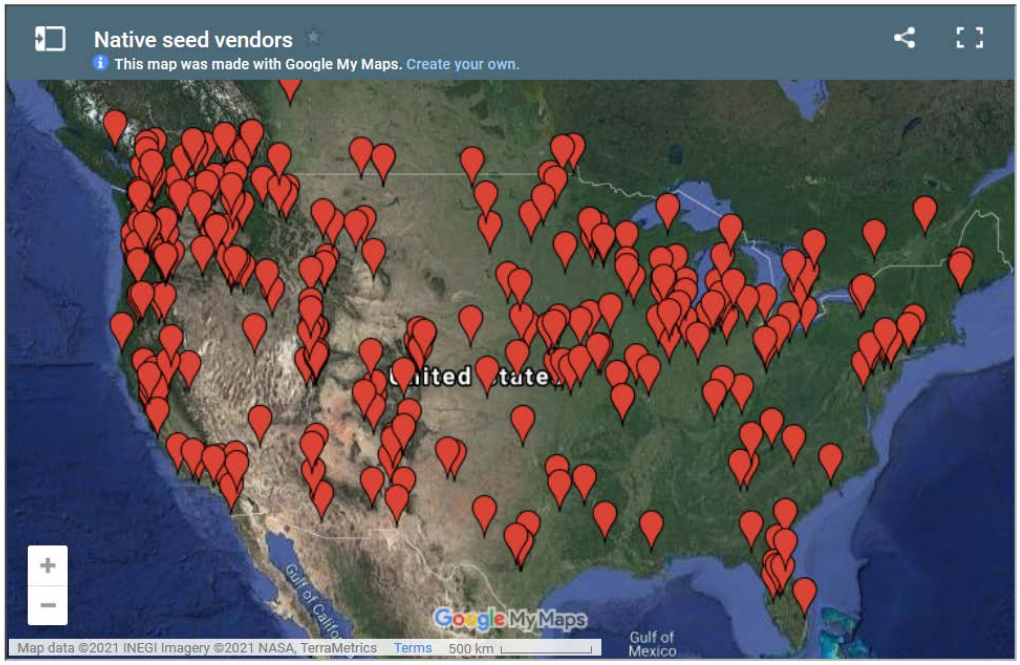
There is not currently a central location for purchasing native seeds in Australia. However, some organisations have online catalogues or databases, and there are some North American websites that provide examples of what could be implemented in Australia. The Australian Tree Seed Centre (CSIRO), for example, has an online database. Customers can order seeds directly from the seed database.[44]

The Australian Seeds Authority has a contact directory, however, this appears to be limited to those working with crop species.[45]

The Native Seed Network, coordinated by the Institute for Applied Ecology, provides a map with seed vendors in the US and Canada[46] (Figure 9). They are currently upgrading their database with information on native seed and vendors. This type of map would be fairly simple to set up for Australia, however, it only shows where the seed vendor is located, and not the regions in which they collect. An Australian vendor database would need to be searchable using IBRA bioregions, as some collectors may have a large area in which they collect.

[43] https://www.rstudio.com/products/shiny/#:~:text=Shiny%20is%20an%20open%20source%20R%20package%20that,in%20minutes.%20This%20opens%20in%20a%20new%20window
[44] https://treeseeds.csiro.au/atscordering/
[45] https://aseeds.com.au/industry-directory-view/
[46] https://appliedeco.org/restoration/nativeseednetwork/find-seed/

FIGURE 9. MAP OF NATIVE SEED VENDORS IN THE US AND CANADA ON THE NATIVE NETWORK WEBSITE HTTPS://APPLIEDECO.ORG/RESTORATION/NATIVESEEDNETWORK/FIND-SEED/ 27 MAY 2021



Reforestation, Nurseries and Genetic Resources (RBGR) supplies people in the US who grow forest and conservation seedlings with the latest technical information. They provide resources including a contact directory. RNGR.net is sponsored by the USDA Forest Service[47] and Southern Regional Extension Forestry[48] and is a collaborative effort between these two agencies. RNGR has a national nursery and seed directory.[49]

The directory can be searched by keyword, state (US and Canada), product (plants, seeds, services), nursery type (federal, forest industry, not for profit, private, state, tribal). There is also a map view, a list in alphabetical order, and the list can be downloaded as an Excel spreadsheet. The spreadsheet contains the business name, contact information and product.

Plant information

Several online databases have been published which contain information about plants and plant traits. A trait is a characteristic of a plant, like leaf shape; seed traits include seed size, seed mass, germination speed and dormancy class (Jiménez-Alfaro *et al.* 2016). These databases may or may not include seed information. They provide examples of how an online database containing information on seeds could be set up. Also, any database on Australian seeds could link to these databases for users to find out additional species information.

[47] http://www.fs.fed.us/
[48] http://www.sref.info/
[49] https://www.rngr.net/resources/directory

International experts have called for standardised collection of seed traits and a seed trait database, like those already in place for plant traits (Saatkamp *et al.* 2019).

- Atlas of Living Australia (ALA)

  www.ala.org.au

- BioFlor
  - A plant trait database containing 66 traits (including five seed traits) of species native and naturalised in Germany (Kühn *et al.* 2004)

    https://www.ufz.de/biolflor/index.jsp

- FloraBase
  - Database of the Western Australian flora

    https://florabase.dpaw.wa.gov.au/

- NatureMap
  - Maps, lists and reports of Western Australia's flora and fauna diversity

    https://naturemap.dbca.wa.gov.au/

- LEDA
  - LEDA provides information on plant traits of Northwest European flora (Kleyer *et al.* 2008)

    https://uol.de/en/landeco/research/leda
  - Data standards (https://uol.de/en/landeco/research/leda/standards) could be used to develop data standards for Australia. Information is available on how to do measurements. Mostly for ecologists, but seed weight and seed shape, in situ seed longevity, diaspore type, seed structure, would all be useful to have in an Australian seed information database, and having measurements consistent with international standards would mean data could be compatible.

    https://uol.de/f/5/inst/biologie/ag/landeco/download/LEDA/Standards/Leda-S3-5_seed_traits.pdf

- National Herbarium of NSW on Amazon Web Services
  - High resolution images of the preserved plant specimens from the National Herbarium of NSW for biodiversity assessment, systematic botanical research, ecosystem conservation, policy development, for educational and other outreach tools.

    https://www.rbgsyd.nsw.gov.au/science/national-herbarium-of-new-south-wales/national-herbarium-of-nsw-on-amazon-web-services
  - NSW BioNet database (NSW Department of Industry, Planning and Environment)

    http://www.bionet.nsw.gov.au/

- NSW Saving our Species database

  https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/saving-our-species-program/saving-our-species-database#:~:text=The%20Saving%20our%20Species%20%28SoS%29%20database%3A%20stores%20strategies,in%20your%20local%20area%20that%20you%20can%20support

- Restore and renew
  - A science-based open data platform which provides a webtool for genetically-informed species restoration, and a site matching tool to help match restoration sites to potential seed collection locations.

    https://www.restore-and-renew.org.au/

- TRY Plant Trait Database
  - TRY is a global database of curated plant traits. It has integrated more than 400 datasets, including SID. TRY has definitions of several seed traits, and many more definitions are under development. The database is mostly used by vegetation scientists, but having an Australian database compatible with and that could feed into TRY would be useful to research.

    https://www.try-db.org/de/TabDetails.php

Definitions and standards for databases

These definitions and standards can be used when developing fields for an app or database, and also used in a user manual.

- Biodiversity Information Standards (TDWG) Darwin Core — TDWG
  - Darwin Core 'includes a glossary of terms intended to facilitate the sharing of information about biological diversity by providing identifiers, labels, and definitions. Darwin Core is primarily based on taxa, their occurrence in nature as documented by observations, specimens, samples, and related information.'
- National Seed Laboratory Dry Branch, GA, USDA
  - Provides a price list and definition of seed tests

    https://www.fs.usda.gov/nsl/; https://www.fs.usda.gov/nsl/nsl_seedtesting.html
- ISTA (ISTA 2020)
- *FloraBank Guidelines* (Commander in press)
- 'International principles and standards for native seeds in ecological restoration' (Pedrini and Dixon 2020)

KEY POINT

A contact directory and propagation protocol database would be useful in Australia.

Current systems for data management and sales in other industries

Tracking

Tracking or tracing products along the supply chain is important for many reasons:[50]

- supports claims about products (e.g. organically grown)
- improves competitiveness
- provides quality assurance for customers
- ensures products were legally obtained
- provides information on provenance (i.e. source location) and authenticity
- provides integrity of systems
- provides transparency
- provides information so customers can make ethical purchasing decisions (Agrawal *et al.* 2021).

Other markets have sophisticated tracking and sales systems. For instance, Blockchain is a technology that is used in a number of industries.[51] Blockchain is a list of records that are added to and linked together. The records are called blocks, and they are linked together with a security code (hash). As each successive block is added, they form a chain.

The blocks are records of transactions, and as each one is published, it is time stamped. The blocks are recorded in an electronic database, and the data can only be read by users with access to the database. Hence, each record is traceable and transparent.

Blockchain has been used in supply chain management. The records are continually added on to, and therefore allow anyone in the supply chain to be able trace their product. The seafood industry[52] is using blockchain technology to improve traceability and transparency and overcome issues such as illegal fishing. Fish are registered on the blockchain network by entering information such as species, time, location and weight. The data then follow the fish through the supply chain.

There is potential to use blockchain technology in the seed sector to be able to trace seed lots back to the source. However, it may be an expensive and complex system to implement. The concepts of blockchain could possibly be adopted, for instance, each time seed lots are transferred from one organisation to another, that organisation could add its unique code onto the accession number, and the accession number would then grow, so the end user could track the seed lot back through all the organisations that have handled the seed lot.

[50] https://www.agriculture.gov.au/market-access-trade/traceability-project#why-is-traceability-important
[51] https://blockchainaustralia.com.au/what-is-blockchain/
[52] https://www.blockchain-council.org/blockchain/how-blockchain-is-transforming-seafood-industry/; https://fishcoin.co/

If each organisation kept records about each seed lot, then the end user may be able to directly ask for records from the collector or testing facility, rather than relying on the supplier, for example. And with the accession number starting with the seed collector's unique code, end users may be able to ascertain whether or not the seed was collected legally.

Australia ran a National Traceability Project[53] between 2017 and 2019. It resulted in reports 'Enhancing Australia's systems for tracing agricultural production and products' and 'National Traceability Framework'.[54] As part of the project, the Traceability Grants Program[55] provided funding to support projects to enhance agricultural supply chain traceability, including technologies to digitise information flow. The program will run over four years, from 2019/20 to 2022/23, and funding was allocated in two rounds, the second of which closed on 21 January 2021.

One of the successful projects in the second round is 'Seed and Plant Traceability Platform and Framework' which is creation of a traceability platform and framework for Australian seeds industry, including digitisation of certifications' information with Australian Seeds Authority Ltd (ASA) as the lead recipient. The ASA is a not-for-profit company which provides quality standards and manages seed certification, and is primarily concerned with crop and pasture seeds.

Some examples of tracking in the agricultural industry are wool and cotton. In the wool industry, organic woollen clothing can be traced back to the place where the sheep was born. This is achieved by assigning each property with a unique number, and tagging every sheep that is born with a physical or electronic tag. At sale, information changes hands electronically.

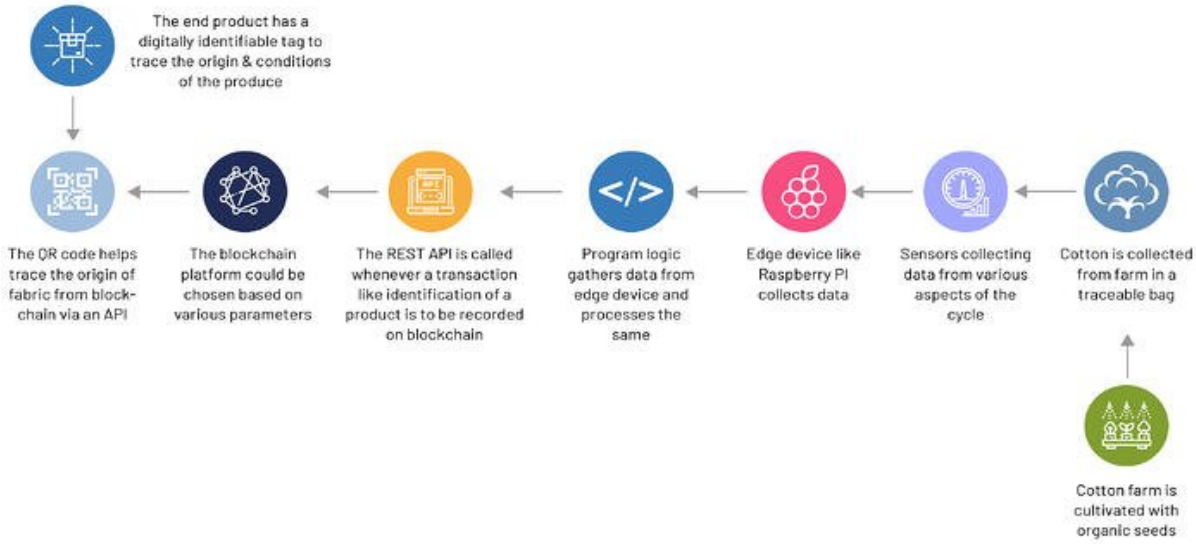
Tracking is important for the wool industry to protect quality and provide authenticity, market differentiation, corporate social responsibility, biosecurity and transparency (Australian Wool Innovation Limited 2021).[56] Australian Wool Innovation Limited (AWI) is developing an Electronic Chain of Custody Tool (ECCT) in partnership with Everledger, using blockchain technology, which aims to track wool though the supply chain from sheep to shop. Hence, the retailer or consumer will be able to access the information about the source of the wool and its processing.

Organic cotton can be tracked from 'farm to fashion', or 'seed to shelf' (Figure 10). This tracking has been developed due to the need to have greater transparency along the supply chain.[57] The system can detect and minimise fraudulent claims of using organic cotton. The

[53] https://www.agriculture.gov.au/market-access-trade/traceability-project
[54] https://www.agriculture.gov.au/sites/default/files/documents/national-traceability-framework_0.pdf
[55] https://www.agriculture.gov.au/market-access-trade/traceability-grants-program
[56] beyond-the-bale---march-2021.pdf (wool.com)
[57] https://fashionforgood.com/our_news/successfully-tracing-organic-cotton-with-innovative-technologies/

former systems were paper-based and there were multiple separate systems along the supply chain;[58] however, tracking is now digital.

FIGURE 10. THE PROCESS BY WHICH ORGANIC COTTON IS TRACED ALONG THE SUPPLY CHAIN (HTTPS://WWW.NAGARRO.COM/EN/BLOG/BLOCKCHAIN-ORGANIC-COTTON-TRACEABILITY)



Online sales

Purchasing online from a centralised system can save time for the purchaser, as it negates the need to visit multiple websites, or use phone or email to contact multiple suppliers. An online system also assists suppliers who could increase their visibility by having an online presence. It could assist them to sell opportunistic collections and would save resources as they could upload the information about their collections to a website and therefore not need to develop their own website or online catalogue. Examples of potential systems can be found in other industries.

Online sales in other industries

Websites have been set up in a variety of industries to allow individuals and organisations to list products. These products range from cars and houses to handmade items and unwanted household goods. Some examples are Gumtree,[59] Airbnb,[60] Facebook marketplace,[61] Etsy,[62] Carsales[63] and Realestate.com.au.[64] There is not currently such a system for native seeds.

[58] https://fashionforgood.com/our_news/successfully-tracing-organic-cotton-with-innovative-technologies/
[59] https://www.gumtree.com.au/
[60] https://www.airbnb.com.au/
[61] https://www.facebook.com/marketplace/
[62] https://www.etsy.com/
[63] https://www.carsales.com.au/
[64] https://www.realestate.com.au/buy

EvergreenConnect[65] is an online database to connect businesses in the green life industry. The database lists plants from many wholesale growers in Australia. These wholesale growers list their stock directly, and can update their list via an Application Program Interface (API), directly from their inventory management system. Retail nurseries, local councils and landscapers can search the database to find what they need. Access to the database costs $90 ex-GST per year.

Online seed sales

While many seed collectors source seed directly for a client, others collect opportunistically (and some may do both), and those with opportunistic collections may wish to have an outlet to sell their seed. Some publish their inventory and prices on their individual website (e.g. Nindethana),[66] some will post out a printed catalogue (e.g. Seed West),[67] whereas others may publish a list of species that they commonly have (e.g. Tranen revegetation systems).[68]

For a purchaser, however, searching on numerous different websites may be time consuming, so having a facility whereby seed suppliers upload the seed they currently have in stock, may be useful. The online sales database would need to be searchable by species, and IBRA sub-region, so that customers could select seeds from their preferred source location.

However, to be sure that end users obtain the species that they need from the locations that they select, they may need to commission a collection.

If an online sales database was set up, then it should be compatible with the seller's own database, so they can upload the information about each seed lot directly, and not need to type information into an online form. EvergreenConnect appears to have such a system.

KEY POINT

Other industries provide examples of how the seed sector could improve tracking of seed lots through the supply chain and examples of online sales databases.

Potential for a national seed app, database and tracking system for seed sales

There are three separate, yet complementary electronic products, that could be developed to benefit the seed sector.

1. National seed tracking system using a mobile app and compatible desktop database to collect and manage seed lot information and track seed from source to site. The database could be used in all parts of the seed supply chain so that

[65] Evergreen Connect
[66] https://www.nindethana.net.au/seed-list-html.aspx
[67] http://seedwest.net.au/prices.html
[68] https://www.tranen.com.au/services/seed/seed-sales/

data from the tracking system can be passed from seller to purchaser through a database, rather than through Excel or pdf output.

2. National seed information database with information about seed processing, storage and propagation, for families, species and genera.
3. National suppliers' database, or national sales database for suppliers to upload to and purchasers to select from.

Information would need to be transferred easily from each product. For example, suppliers would need to upload information from their seed tracking system easily into a national sales database. End users would need to have links from their seed tracking system to a national seed information database to quickly gain information on, for instance, processing and pre-treatments for individual species.

There are a number of issues with data collection and sharing that will need to be addressed. Some information may be confidential, for instance, GPS locations of threatened species.

Location information of the seed source could be provided in several formats. The GPS location could be provided, however, anecdotal evidence suggests that some collectors do not always wish to provide that information. Another option is to provide the IBRA regions and sub-regions. These regions are possibly more useful than using local government areas as biogeographical units are more environmentally relevant than administrative units (Cevallos *et al.* 2020). Alternatively, a grid reference number could be supplied. GPS location, however, would be the ideal type of location data.

If a desktop database to store seed lot information could connect with ALA, then the seed source could potentially be placed on the species distribution map to determine where population is located with respect to the species range, i.e. if it's in the middle or at the northern or southern end of its range. Also, with a GPS location, and a mapping component, it may be possible to determine environmental parameters of the source location, such as average rainfall.

If clients wished to purchase seed from a specific location, or radius from their restoration site, the database could be searched according to IBRA sub-region, or if all collection locations were placed on a map, those within a search location could be selected. As well as providing links to species information in ALA, the database could link to an Australian Seed Information Database, and Native Vegetation Guides (e.g. Kent *et al.* 2002).

Although having an online seed sales database may assist with determining supply and demand trends, it will not provide a full picture, as seed is also sourced on contract or through tenders. Furthermore, seed may be stored for a number of years prior to sale, so it may be difficult to see patterns in supply and demand given that seed may be sold several years after collection.

However, collection trends could be ascertained through licensing reports. Supply trends could be elucidated through amalgamating records of all seed lots purchased in a given year, either by a government department or as part of a grant program, although this would not provide a picture of the whole industry.

Licensing agencies would need to develop a standardised electronic form for submission of information of seed lots collected with a collecting licence. Some compulsory fields are suggested below (see Benefits for licensing departments).

1. App and record management system for seed lots

A national seed app and record management system would be an innovation for the seed sector, restoration sector and government departments.

The app would need to have separate forms to enter information on collection of the seed lot, and another one for collection location. For instance, when collecting several species in the one location, it is inefficient to repeatedly put in the same information about the associated species, geomorphology and soils. So, for each collection location, one GPS reading and one site description could be entered, then a unique site code linked to all seed lots collected in that location. A new GPS reading and a new location description would need to be entered if seeds are collected at a new location, even if within the same property or general area i.e. a riverbank or rocky outcrop.

The desktop database would need to have information about each species that is not unique to each seed lot. The species information could contain photos of the seed, photos of dissected seeds, photos showing the difference between seed and chaff, information on embryo morphology, dormancy class, and optimal conditions for germination.

There could also be a link to more information on the species in ALA, or an online Australian Seed Information Database (see below). In addition, formulas could be built into the database, to enable auto calculation of seeds per gram, total seeds in the seed lot, price per 1000 seeds etc. once key data has been entered.

The database should have some ability to display spatial information, that is, display all seed lots collected at a particular location, or all collection locations for a particular species. That information would assist with collection planning.

It would assist the seed collector to know where to go should a request for that species come in, and also easily look up collection dates to know when to go. And, by looking at total collection weight and date, the collector may be able to determine the ideal collection time, or if the collection amount was affected by environmental factors such as rainfall.

Therefore, the app would require (at least) three forms — seed lot, location and species (Grose *et al.* in press).

Having a standardised, compatible electronic system in which to store the information about seed lots would make data transfer between supplier and purchaser, testing company and client, collector and licensing agency, grant recipient and funding body, and different locations of a single organisation, much easier and more efficient.

The provision of seed data in market transactions and traceability of seed lots will provide benefits for the industry. Firstly, the end user will have the information on where the seeds were collected to make an informed decision about selecting seed source locations. This information will enable them to select either locally sourced seed, or choose a provenancing strategy which mixes local with non-local seed.

Secondly, the end user can be provided with quality information such as purity, seed fill and seed viability. They will know how the seed has been stored, and how long since it was collected. This may provide information about its quality, as seed viability can decline over time, particularly under sub-optimal storage conditions (Commander *et al.* in press; Merritt *et al.* in press).

Thirdly, the end user may be able to provide feedback through the supply chain. For instance, if a species has been mis-identified, a nursery manager could inform the seed collector, or if seed testing reveals low viability, the seed store could be notified, and they may assess their storage procedures, or test any remaining seeds from that seed lot.

Finally, seed collectors who wish to use the restored site as a seed collection resource will know the source location of the seeds, and they can make informed decisions as to whether or not to collect there.

If restoration plantings are not performing as expected, information on the seed source may be able to provide some insights, for instance, did the source population have low genetic diversity? Do the climatic parameters of the source population match the planting site?

The information on seed source needs to be kept securely and for long time periods so that it is not lost during staff changes. The seed lot accession numbers could also be reported, for instance in a project report, or through a reporting tool such as the Monitoring Evaluation Reporting and Improvement Tool[69] (MERIT), used for reporting projects funded by the Australian Government.

Easily exporting data on seed collections for compliance under licensing conditions would be a huge benefit to both collectors and licensing agencies. An investigation into the information required by licensing agencies, and also the information that seed collectors are willing to provide, would enable a data transfer form to be developed. Annual summaries of reports made on seed collection under licence could be made available.

Voluntary reporting could also be done easily through a standardised system. For instance, those collecting on their own property who do not

[69] https://fieldcapture.ala.org.au/

need a licence could also report to licensing agencies if they wish, for states and territories to gain an understanding of the capacity of private land to supply seeds.

A mobile app and desktop database could be provided to users in various ways:

- available for free to all users
- provided for free to those who apply for a seed collection licence or receive a grant for purchasing seed for restoration or are a registered community group
- provided for a fixed price to all users
- provided with a pricing tier and hence provided for a minimal cost to sole traders and small businesses with <5 employees, with increasing costs for increasing business sizes.

Ideally, there should be no financial barrier for users to adopt the system, as it will work most effectively if it is used by the majority in the sector.

2. An Australian Seed Information Database

A national, online database with information on seeds has great potential in Australia. The database could contain information on seed weights, which would help purchasers to calculate how much seed they may need to order.

Propagation protocols for families, genera and species as well as general information about propagation of species from certain ecosystems or climatic regions (such as optimal germination temperature) would be useful for nurseries and volunteer groups.

Photos of cross sections of dissected seeds would be useful for organisations that test seeds. Summarised information from the peer-reviewed literature on dormancy type and pre-treatments to overcome dormancy would be relevant to those without access to research publications. Photos of immature and mature fruit would help collectors harvest seeds at the ideal level of maturity. Information on storage behaviour (i.e. whether or not seeds can be dried and frozen) would inform seed stores on best ways to store seeds of each species to maintain viability.

The database could list fire-related seed traits, to assist with post-fire recovery and fire management decisions (Jiménez-Alfaro *et al.* 2016). For instance, useful traits include regeneration strategy (resprouter or obligate seeder), seed bank type (canopy stored or soil stored seed bank), age at which plant starts seeding, germination response to smoke, ability to germinate after heat shock, pre-fire seed bank availability and post-fire seed survival (Auld *et al.* 2020; Miller *et al.* 2020).

Organisations that develop information on seeds are best placed to assist with populating an Australian Seed Information Database. For instance, Australian Seed Bank Online, SID and RIAWA have much of this information already.

Several books have comprehensive information, which could be amalgamated, including *Australian Seeds* (Sweedman and Merritt 2006), *Pilbara Seed Atlas and Field Guide* (Erickson *et*

al. 2016) and *Australian Rainforest Seeds* (Chapman *et al.* 2020). Knowledge gaps could then be identified to direct further research.

A customised collection, processing or propagation manual could be developed for each collecting trip or project, by selecting all of the relevant species and making the information available offline (either printed or downloaded onto a mobile device).

3. National online seed procurement database or seed supplier database

An online database would be a one-stop-shop for end users looking to purchase native seed.

There are two options for an online database: either a database that lists seed lots that are for sale, or a seed supplier database, where seed collectors and seed stores are listed. Both have advantages and disadvantages. Having a supplier database would be useful for clients who pre-order their seed, and those who need seed collected on contract from a particular location. However, having an essentially online seed shop would suit end users who need seed immediately. Seed collectors too may either prefer to be contacted for contract orders, or prefer to collect opportunistically and sell later, or may do both.

A potential benefit of an online shop is that suppliers could be required to list the collection licence number along with each seed lot, and that may encourage compliance with licensing as well as assurance to the purchaser.

A drawback of an online shop is that it would rely on seed suppliers regularly updating the lists of species that they have available for sale. They would also need to provide information about the source location of the seed, but may not wish to publish the GPS locations of all of their collections online.

The database would need to be searchable by location, and not just the location of the supplier's business address, but all the locations in which the collectors are able to collect from. This search function could be using IBRA sub-regions, where suppliers specify the sub-regions in which they collect, and purchasers can filter search results by the sub-region from which they would like their seed to be sourced.

Sector benefits

Benefits for government departments

One of the largest benefits would be for state government departments, who purchase and use large volumes of seeds for restoration projects. A recent survey found that 48% of the seed purchasers responding to the survey were from local or state government (Hancock *et al.* 2020). If all of the information about all of the seed lots that changed hands through government was contained in a single database, then the departments could:

- cross reference with licensing to ensure the seed was obtained legally
- compare seed quality between years and suppliers

- aggregate and analyse data to determine which species and how much seed is being used where, to help forecast seed needs and enable advance ordering
- show which seed lots are surplus to needs, or in storage, and could be used by other projects
- feedback information into research organisations on the most commonly used species, or species for which insufficient seed is collected, or species for which propagation protocols are not known/optimised
- more easily share information between employees about suppliers and where to source seeds
- know who in the department is collecting, purchasing or using seed to enable better communication and collaboration. For instance, bulk orders may attract a discount, or multiple collections from the same location for several different projects may make a collection trip more worthwhile for the collector
- know which species may be easy to source in large quantities, and which may be difficult to source in large quantities to help inform seed ordering
- collate and build on information, for instance to determine which species can be direct seeded, and which should be grown in a nursery and planted as seedlings
- look up optimal collection times to help with timing of seed ordering or collection.

Benefits for licensing departments

With a standardised data collection app, seed collectors could easily submit their collection records to licensing departments to report on collections made under their licence. Electronic submissions would save licensing staff time as they would not need to retype information from paper forms. Licensing departments could then aggregate collection information, to better understand where seeds are being collected, and how much is collected. Ultimately, this would provide information to prevent unsustainable collection. Minimum information provided to licensing departments could include:

- licence number
- licence date/time period
- collector name and organisation
- collection location (GPS, property name, property tenure, nearest town)
- collection date
- accession number (unique number identifying seed lot)
- species name (scientific name)
- approx. number of plants collected from
- weight of collection before processing
- wild collection / salvage harvest / seed production area harvest

- part of plant taken (i.e. seed)
- photograph of the plant, fruit or seed.

Benefits for organisations spread across multiple locations

A standardised record-keeping system for seed would benefit organisations with multiple locations, for instance, if a state restoration seed bank was established, similar to the SOS program in the US, which could receive seed lots from multiple collectors, and may process, test and store seed in separate locations. One centralised database would help keep track of all the seed lots and enable staff in different locations to add to the information about the seed lot.

If multiple staff are contributing to the information about the seed lot, then it is essential that the data is gathered in the same way and recorded in a centralised location. A database would give an organisation the ability to scale up their business. It would also enable an organisation to produce summary statistics across all of its locations to elucidate supply and demand trends across the whole business.

Benefits for sole traders

Several larger seed collectors and seed banks already have a data management system (e.g. botanic gardens, Murrary LLS, Biobank seed, Tranen). However, these systems can be expensive and time consuming to purchase and set up. Sole traders may not have the resources for these systems.

Having a universal data management system would benefit small companies in particular because they would not need to invest in developing their own system. Increasing efficiency within the business will save both time and financial resources. It would also lift the standard of those smaller organisations and enable them to compete for business with larger organisations.

Benefits for Indigenous groups

Data collection apps have been used with success by Indigenous groups, for instance the Tracks App, developed by ALA and the Central Land Council, enables rangers to track threatened species such as bilbies.[70] The app is available in both English and Warlpiri, facilitating its use by the Warlpiri rangers. As the tracking data is recorded in a standardised way, trends over time can be analysed.

An app for seed collection, particularly if translated into First languages, would be of enormous benefit for Indigenous seed collection groups and plant nurseries. Making data collection easy and enabling information transfer to the purchaser would improve the ability of Indigenous groups to participate in the seed sector and gain economic benefits through the sale of seed.

[70] https://www.ala.org.au/blogs-news/the-tracks-app-a-bi-lingual-mobile-app-exploring-biodiversity-in-an-indigenous-context/

Groups collecting bushfoods would also benefit by being able to prove authenticity and enable traceability back to the individual who made the collection.

A national seed information database could include traditional ecological knowledge, as long as the knowledge is in the public domain. Recording traditional ecological knowledge about seeds and seed collection would help preserve the knowledge and make it available for future generations, work towards a more inclusive sector and break down barriers between Indigenous and non-indigenous seed collectors and end users.

An online supplier database could highlight Indigenous seed suppliers for those wishing to employ Indigenous collectors. It would also enable collectors who may not have a web presence to be more visible and gain business.

Benefits for landholders

Landholders could map populations of native species on their property, and use this either to collect seeds themselves, or allow collectors on their land, perhaps for a fee, such as SeedTree Maps (Appendix 7). It would be simple for the landowner to alert a collector if there is a mass flowering event, for instance, to give the collector advance warning of a potential high yield of seed.

Benefits for restoration practitioners and native nurseries

An Australian Seed Information database would be invaluable to restoration practitioners and native nurseries. Information on seed pre-treatments, for instance, could be immediately downloaded, rather than looking up information in multiple books, or collating from various web sources. A report on all species in the restoration area could be easily generated to inform planning and implementation.

A record management system would help keep track of seed lots in a nursery and at planting, and enable reports for clients and funding bodies to be quickly generated. An online seed procurement database or supplier database would save time and resources for practitioners and nurseries to source seeds.

Benefits for environmental managers and the research community

Improved data on species distributions through mapping seed collection locations would assist environmental managers and the research community. Range extensions would be of particular interest, that is, locations of populations at the highest altitude, most southern location, driest location, for instance. Researchers such as taxonomists, community ecologists, modellers, and those undertaking meta-analysis of ecological data would all benefit. It would improve biodiversity assessments and vegetation classification.

Having access to more data through compatible and easy-to-use record-keeping systems will improve decision making, as environmental mangers could make more informed decisions about seed sourcing locations, protected areas and restoration aims.

RECOMMENDATIONS

Use of technology to improve seed tracking in Australia

Overall recommendation

Seeds (and germplasm such as cuttings) need to be traced from the point of collection all the way through the supply chain to the point at which they are planted – whether they are direct seeded or planted as tube stock. At every point in the supply chain, information needs to be collected about the seed lot, and transferred to the next user (Figure 11). This tracking should be done using an electronic, not paper-based system.

A National Seed Information Database would benefit not only the seed sector, but the restoration sector more generally, as well as ecologists, and those propagating native plants for interest or profit.

This database would need to be established in collaboration with state and national data aggregators and funders, and consistent with international standards, to ensure that it is compatible, or is housed within, existing databases. These organisations include ALA, Australian Seed Bank Partnership, the MSBP Data Warehouse, TERN, NSW BioNet, Australian Research Data Commons,[71] and the National Collaborative Research Infrastructure Strategy (NCRIS).[72]

[71] https://ardc.edu.au/
[72] https://www.dese.gov.au/ncris

FIGURE 11. HIGHLY SIMPLIFIED SEED SUPPLY CHAIN, ELECTRONIC PRODUCTS REQUIRED AND DIRECTION OF INFORMATION FLOW OF SEED INFORMATION

Seed supply chain summary

All of the products will need to be compatible with each other to allow easy transfer of information. The mobile app is shown in green, the desktop application (database) is shown in blue, the online sales database is shown in black and the national seed information database (containing information on species, not on seed lots) is shown in purple. Data could be entered into the mobile app during seed collection in the field, then transferred to the desktop application on return from the collecting trip. A subset of this information could be sent to the licensing agency to comply with licensing conditions.

All information should be transferred to the seed store, and additional information added, including information from outsourced testing (if undertaken). All information can be transferred to the end user (perhaps via other users in the supply chain, not shown). A subset of information could be uploaded to an online sales portal, alternatively, an online database of seed collectors and suppliers could be developed.

The national seed information database could have information on how to collect, process, store and propagate families, genera and species. This database could be populated using data from the literature, global databases and the Australian Seed Bank Online. It could also be populated by registered users.

Specific recommendations

1. **Co-develop a mobile app and desktop application, for data collection, record keeping and tracking, so that the mobile app is essentially an extension of the desktop application, and data transfer between them is simple.**

2. **The mobile app for recording seed collection data in the field needs to:**

   - record information including (but not limited to) species name, habitat, date, collector's name and licence number
   - be able to link photos to records
   - be able record GPS locations and
   - be able to function without access to the internet, so it can be used in remote locations.

3. **The desktop application which can download data directly from the mobile app must:**

   - have several modules to store information including:
     - processing
     - quality
     - germination, dormancy, pre-treatments
     - storage and
     - seed production
   - be able to transfer data to another organisation with the same app, i.e. when the seed lot or part thereof changes hands
   - be able to transfer a subset of the data to the licensing organisation e.g. collector name, licence number, species collected, collection region and total seed weight collected
   - be able to be accessed by multiple computers within an organisation, because there may be several locations for data entry, or different people responsible for different parts of the process (processing room, storage location, dispatch), or for large organisations like national NGOs or state government departments, many different offices or seed stores.

4. **Provide a user guide and training to all app users, including training on the importance of record keeping. Training could be a mandatory component of seed licensing.**

   - Develop specialised training programs for Indigenous Australians in accordance with relevant national guidelines and appropriate consultation.

5. **Develop a national database (web application) for seed information including, but not limited to, average seed weights, seed morphology, embryo morphology, processing protocols, dormancy class, pre-treatments, propagation protocols, photos of fruits, seeds and dissected seeds. The database would need entries for each species to record species level information (e.g. seed weight) and also entries for genera to record information such as processing and propagation protocols, which may be common to all species within a genus.**

   - Use existing knowledge or software to develop the database, and partner with organisations with existing databases, for example, the Australian Seed Bank Partnership (Australian Seed Bank Online), ALA, BGCI, botanic gardens, the MSB (SID, MPSP data warehouse).
   - Undertake a survey of the seed and restoration industry to determine the fields required in the database (i.e. information they need to know). Ensure that all parts of the sector are consulted, as collectors, purchasers and research may all have slightly different needs.
   - Base the fields and field codes within the database on the traits, tests and field codes in TRY, Darwin CORE and SID, and seed tests outlined by ISTA (International Seed Testing Association).[73]
   - Ensure that the information in the database may be compared with other global databases to enable global comparisons (i.e. consistent methodology for trait measurements, ability to export information as a .csv).
   - Initially populate the database with information gathered from the scientific literature, then add to regularly (quarterly or annually) with new information, either directly from research partners, or gathered from the scientific literature.
   - Investigate the possibility of a Wikipedia-style database, where registered users can add their own information. However, it is important that the source of the information is displayed, so other users can make a decision about its potential accuracy.

6. **Develop a national database (web application) of native seed collectors and suppliers and native plant nurseries.**

   - Investigate the potential to develop an **online marketplace**, ensuring ease of uploading seed lot information from the desktop application for record keeping.

[73] https://www.seedtest.org/en/home.html

7. **In the short-term, develop a universal spreadsheet with information currently contained in seed collection sheets (see appendices) and using field codes (i.e. column heading) from Darwin Core, SID or Australian Seed Bank Online (where possible), and provided for free to all collectors and end users.**

    - Then, when collectors sell seed, they can export the records for those seed lots, and the purchase can import the records into their spreadsheet, without having to retype the data, or saving the data in multiple different spreadsheets.

Collecting data on seeds — what is required

ALA states that:[74] '*A high quality record contains the minimum mandatory fields plus as many of the following fields as possible:*

- *precision and accuracy fields:*
  - *coordinate precision, coordinate uncertainty*
  - *taxon rank, identification qualifier*
- *verification information:*
  - *survey methodology*
  - *geodetic datum*
  - *identification information (by, protocol, references, date)*
  - *verbatim values*
- *other:*
  - *precision and accuracy*
  - *verification details*
  - *related records and taxa*
  - *multimedia'*

[74] https://support.ala.org.au/support/solutions/articles/6000197140-what-fields-are-needed-for-a-high-quality-record-

National tracking app and database — baseline data requirements

This list is a starting point to develop the fields for data collection for a national app and database:

- Reconnaissance trip
  - Family, Genus, Species
  - Location
  - Description of phenology (buds, flowers, immature fruit)
  - Photo of flower
  - Pressed specimen
- At the point of collection
  - Family, Genus, Species*
  - Common name (optional)
  - Landscape context (roadside population, scattered paddock trees, degraded small remnant, large area of continuous vegetation)
  - Natural population or seed production area*
  - Whether or not the area has previously been seeded or planted
  - Collection date*
  - Collection licence number*
  - Licence type*
  - Licence renewal date*
  - Collector(s) name(s)*
  - How many plants were collected
  - How many plants are in the population (approx.)
  - Location: coordinates and datum*
  - State*
  - Site description
  - Plain language locality
  - Unique accession number or seed lot number*
  - Description of the level of maturity of the collection (immature, point of natural dispersal, seeds had mostly dispersed, seed was bagged for later collection)
  - Site tenure
  - Site contact person
  - Site permission*
  - Photograph of the plant, with close up of any flowers, leaves, and fruit / seeds
  - Voucher specimen reference

- During processing
  - Total weight of the seed lot before processing*
  - Equipment/technique used process the seeds
  - Total weight of the seed lot after processing
  - Storage conditions (temperature and humidity) during processing, post-harvest drying conditions
- During quality assessment
  - Name of the person/organisation taking the sample
  - Purity
  - Seed fill
  - Seed viability
  - Seed germination
  - Seeds per gram or weight of 100 seeds
- During storage
  - Pre-storage drying conditions
  - Pre-storage treatments (insecticide / carbon dioxide)
  - Storage date
  - Storage location
  - Storage container (glass, plastic bag, foil bag, woven bag)
  - Storage conditions (temperature and humidity)
- Prior to end use
  - Date taken out of storage
  - Viability test (if undertaken)
  - Pre-treatment (if applicable)
  - Seed enhancement (if applicable)
- In the nursery
  - Sowing method (directly into pots, in punnets then pricked out)
  - Sowing date
  - Emergence %
  - Temperature conditions following sowing

- In direct seeding
  - Seeding rate
  - Seeding date
  - Site preparation (fencing to exclude grazing, ripping)
  - After-care (irrigation)
- Whenever bought and sold
  - Purchase date
  - Transport time and conditions (temperature and relative humidity)
- During monitoring
  - Emergence (for direct seeding)
  - Survival

*This information should be provided to licensing organisations as part of reporting requirements.

Data collection needs to take into account the size of the collection and also its end use. Hence, although all information gathered about the seed lot needs to be recorded, not all information needs to be gathered. For instance, for very small seed collections of threatened species, there may be insufficient seeds to perform certain quality tests.

The intent on data collection and transfer should be to capture and communicate information and especially to ensure that the seed source location is known. It should not become a technological or financial barrier to market participation (see also Abbandonato *et al.* 2018; de Urzedo *et al.* 2019).

CONCLUSION

A national seed lot tracking app and database would be an innovation for the seed, restoration, landcare and conservation sectors, as well as licensing and environmental management. Having seed collection data that is consistently gathered, and easily transferred with the seed lot through the seed supply from picking to planting, will ensure transparency and accountability within the sector. End users will be able to check that seed has been legally obtained, even if it has changed hands several times through the supply chain. Comprehensive information provided on source location and quality will enable better management decisions to be made and could prevent unsustainable over-collection.

A seed lot tracking app that can be used on a mobile device (e.g. smartphone or tablet) would be of benefit to the seed industry. The tracking app could be used in the field during seed collection, to replace paper forms, and enable photographs and GPS location to be attached to the seed lot data.

The information collected by the app would need to be transferred to a desktop database. The desktop database would also need to store information on seed processing, drying, storage, quality, and germination, as well as weight and price. The software would need to be able to export information about each seed lot. Calculations would need to be automated within the database, such as calculating seeds per gram. Also, it would need to keep track of the current weight of seed from the seed lot, if withdrawals are made and the seed lot is not sold or used in its entirety.

The benefit of the app and database is that a seed lot could be assigned a unique code, which would stay with the seed lot through the entire supply chain, and provide a link between the seed lot and its associated data (i.e. source location, quality, collection date etc). Labels for each seed lot (especially if there are multiple containers, or if withdrawals are made) could be printed directly from the database, and could even display a barcode or QR code to link back to the data.

Industry consultation may be required to come to a consensus on how to develop the standardised format of the unique code. For instance, the code may contain the collector's code, date, location, as well as a unique number. So, for example, the 345th collection made by Lucy Commander in 2021 could have the code: 21LCOM345. If that seed lot is transferred to another organisation, e.g. the Whyalla Seed Bank, the unique code for that organisation could be added to the seed lot: 21LCOM345WSB.

The database would need to be able to determine the IBRA bio-region from the GPS location of the collection. So, another option is to include the source location in the unique code, such as the IBRA sub-region e.g. BBN01, which is the code for the Townsville Plains sub-region within the Brigalow Belt North region.

Alternatively, the IBRA sub-region could be a mandatory piece of information on the seed label, along with the code and the scientific name of the species.

The codes, with any other required information from the database, such as collection location, collection date, and total seed lot weight, could be provided annually to the licensing authority as a condition of the licence. Then, anyone along the supply chain could check the code with the licensing authority to ensure that the seed lot has been legally obtained, or licensing authorities could randomly audit seed banks or end users by cross referencing the unique codes.

The main databases that are being used in the seed industry are ALA, BRAHMS and BG-BASE. Two custom databases have been developed especially for the commercial sector. These existing databases could be used as a basis for developing a specialised system, or a custom database could be built from scratch.

Significant sector consultation from Conservation Seed Banks, the ASBP, commercial seed collectors, licensing agencies and end users will be required to develop the fields, as each stakeholder group may collect different data, and have different data requirements.

To support the app and desktop database, a national seed information database, providing information about seed collection, processing, storage, and propagation, would be beneficial.

It could be an online database, but easily linked to the desktop database to enable users to quickly find the information they need. It would not contain information on individual seed lots, but provide information about each species, similar to the international database, SID.

However, unlike SID, records should be able to be downloaded into or linked to seed lot record keeping databases to enable users to quickly look up information about the species with which they are working. Also, information about genera could be provided, similar to the page for each genus provided in FloraBase,[75] as often seed collecting and processing information is common to many species within a genus. This national database would require resources and support to develop. The development of this database will need to be undertaken with consultation from key data aggregators such as ALA.

Sales of opportunist collections of native seed (i.e. not seed ordered through contracts or tenders) could be better enabled in one of two ways. Either, an online database of seed collectors and suppliers could be set up, or an online portal for seed sales, using information uploaded from the desktop database used by each seed store, could be established.

Further investigation and industry consultation is required to determine which option is preferable.

Stakeholder consultation and consensus, as well as app and database development or customisation could take time. So, in the short-term, a universal spreadsheet with all of the possible fields could be developed and provided for free, so that those without an electronic record-keeping system can use one immediately, and records (i.e. information on each seed lot) can be shared between sellers and buyers.

Those who already use custom databases may be able to set up their databases to export records in the format of the universal spreadsheet, so that buyers can import the records directly into their spreadsheet.

[75] https://florabase.dpaw.wa.gov.au/browse/profile/21511

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APPENDICES

Appendix 1. Seed lot accompanying information

This information sheet is reproduced from Figure 2 in Pedrini and Dixon (2020). It can be used as indicated or modified depending on local conditions, for labelling of native seed batches prior to sale. This template is divided in three sections based on the seed supply chain key steps: seed sourcing/provenance, seed quality testing, and seed enhancement.

Species: _____

Seed lot#: _____ ☐ Wild-collected

Seed batch weight: _____ ☐ Cultivated

Company logo, name address, contact

Seed Source

Date of collection: *month/year*

Location: *state/province, municipality, seed zone*

Site: *gps coordinates (WGS 1984 datum)*

Collector: *name of the person/company*

Notes:

Managed seed production (If cultivated)

Date of harvest: *month/year*

Location: *state/province, municipality, seed zone*

Number of generations: *1-5*

Producer: *name of the company*

Notes:

Seed storage condition after collection/harvest RH%_____ T°_____

Date of treatment: *month/year* **Seed quality test** Performed by: *name of person/company*

Purity

Pure Seed Unit PSU: _____ %

Other seeds[2]: _____ %

Inert material[3]: _____ %

Notes:

1000 Pure Seed Units PSU weight: _____ (g).

Viability

Viable Seed Unit VSU: _____ %

☐ Cut test ☐ X-ray ☐ TZ ☐ Other

Notes:

Germinability

Germinable Seed Unit GSU: _____ %

Notes:

Dormancy (if required)

Dormant Seed Unit DSU: _____ %

Notes:

Dormancy type (if known)
☐ Physical
☐ Physiological
☐ Morphological
☐ Morpho-physiological
☐ Combinational

Pure Live Seeds PLS: %

Pure Germinable Seed PGS: %

Pure Dormant Seeds PDS: %

Date of treatment: *month/year* **Seed enhancement** Performed by: *name of person/company*

☐ Dormancy release*

☐ After-ripening:

☐ Stratification: *warm, cold, dry...*

☐ Scarification: *abrasion, acid...*

Notes:

☐ Chemical: *GA$_3$, KNO$_3$, smoke...*

☐ Seed priming

☐ Hydro ☐ Osmo ☐ Solid-matrix

☐ Chemo ☐ Other

Notes:

☐ Promoters: *hormones, chemical ...*

☐ Seed coating

☐ Film ☐ Encrust ☐ Pellet ☐ Other

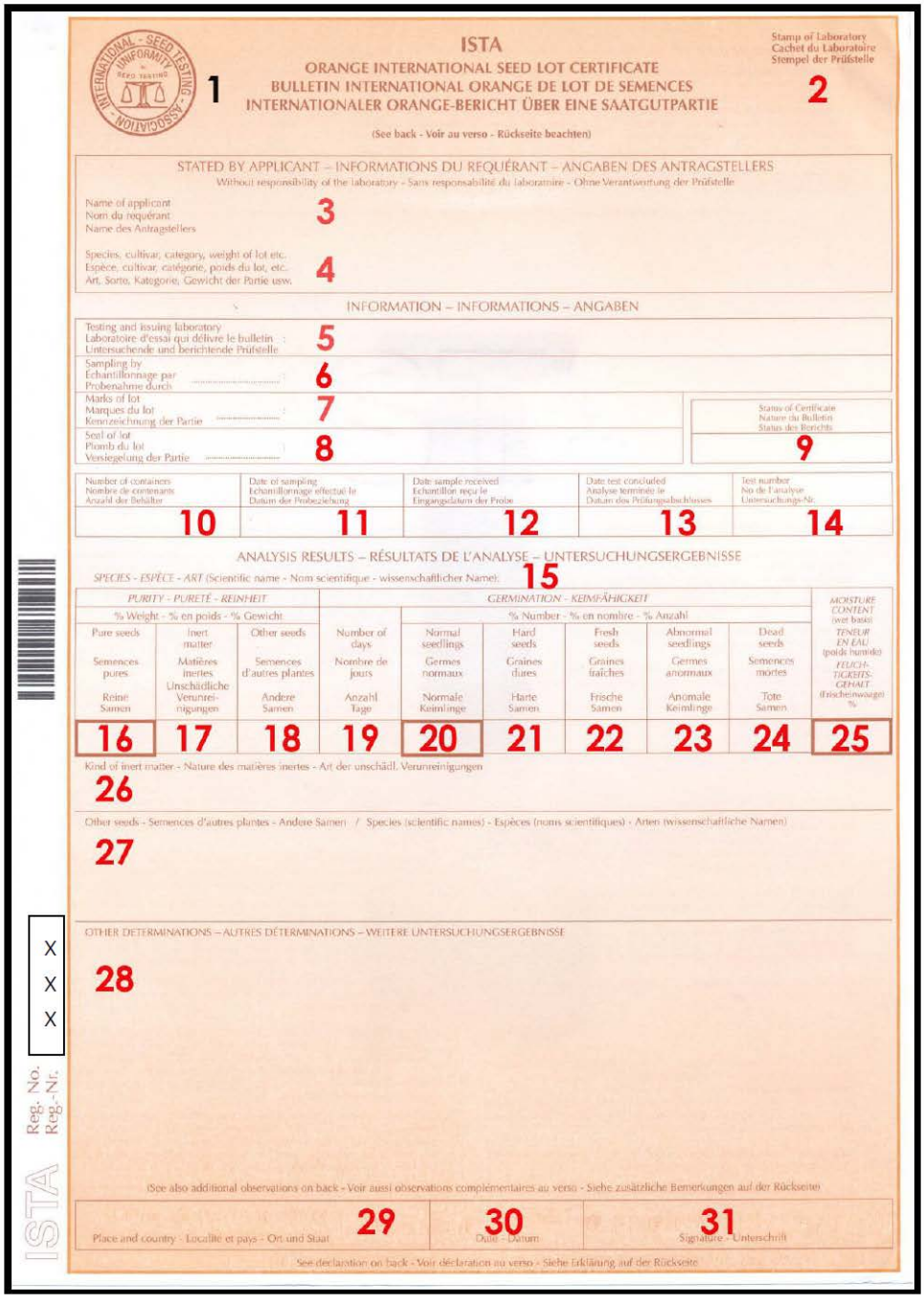
Notes:

☐ Promoters: *hormones, chemicals ...*

☐ Protectants: *fungicide, pesticide...*

Appendix 2. ISTA Certificates

Annex 1: Orange International Seed Lot Certificate with reference numbers added



ISTA

1

ORANGE INTERNATIONAL SEED LOT CERTIFICATE
BULLETIN INTERNATIONAL ORANGE DE LOT DE SEMENCES
INTERNATIONALER ORANGE-BERICHT ÜBER EINE SAATGUTPARTIE

Stamp of Laboratory
Cachet du Laboratoire
Stempel der Prüfstelle
2

(See back - Voir au verso - Rückseite beachten)

STATED BY APPLICANT – INFORMATIONS DU REQUÉRANT – ANGABEN DES ANTRAGSTELLERS
Without responsibility of the laboratory - Sans responsabilité du laboratoire - Ohne Verantwortung der Prüfstelle

Name of applicant
Nom du requérant
Name des Antragstellers
3

Species, cultivar, category, weight of lot etc.
Espèce, cultivar, catégorie, poids du lot, etc.
Art, Sorte, Kategorie, Gewicht der Partie usw.
4

INFORMATION – INFORMATIONS – ANGABEN

Testing and issuing laboratory
Laboratoire d'essai qui délivre le bulletin
Untersuchende und berichtende Prüfstelle
5

Sampling by
Echantillonnage par
Probenahme durch
6

Marks of lot
Marques du lot
Kennzeichnung der Partie
7

Seal of lot
Plomb du lot
Versiegelung der Partie
8

Status of Certificate
Nature du Bulletin
Status des Berichts
9

Number of containers Nombre de contenants Anzahl der Behälter	Date of sampling Echantillonnage effectué le Datum der Probeziehung	Date sample received Echantillon reçu le Eingangsdatum der Probe	Date test concluded Analyse terminée le Datum des Prüfungsabschlusses	Test number No de l'analyse Untersuchungs-Nr.
10	11	12	13	14

ANALYSIS RESULTS – RÉSULTATS DE L'ANALYSE – UNTERSUCHUNGSERGEBNISSE

SPECIES - ESPÈCE - ART (Scientific name - Nom scientifique - wissenschaftlicher Name): 15

PURITY - PURETÉ - REINHEIT			GERMINATION - KEIMFÄHIGKEIT						MOISTURE CONTENT (wet basis) TENEUR EN EAU (poids humide) FEUCHTIGKEITSGEHALT (frischeinwaage) %
% Weight - % en poids - % Gewicht				% Number - % en nombre - % Anzahl					
Pure seeds Semences pures Reine Samen	Inert matter Matières inertes Unschädliche Verunreinigungen	Other seeds Semences d'autres plantes Andere Samen	Number of days Nombre de jours Anzahl Tage	Normal seedlings Germes normaux Normale Keimlinge	Hard seeds Graines dures Harte Samen	Fresh seeds Graines fraîches Frische Samen	Abnormal seedlings Germes anormaux Anormale Keimlinge	Dead seeds Semences mortes Tote Samen	
16	17	18	19	20	21	22	23	24	25

Kind of inert matter - Nature des matières inertes - Art der unschädl. Verunreinigungen
26

Other seeds - Semences d'autres plantes - Andere Samen / Species (scientific names) - Espèces (noms scientifiques) - Arten (wissenschaftliche Namen)
27

OTHER DETERMINATIONS – AUTRES DÉTERMINATIONS – WEITERE UNTERSUCHUNGSERGEBNISSE
28

X
X
X

Reg. No.
Reg.-Nr.

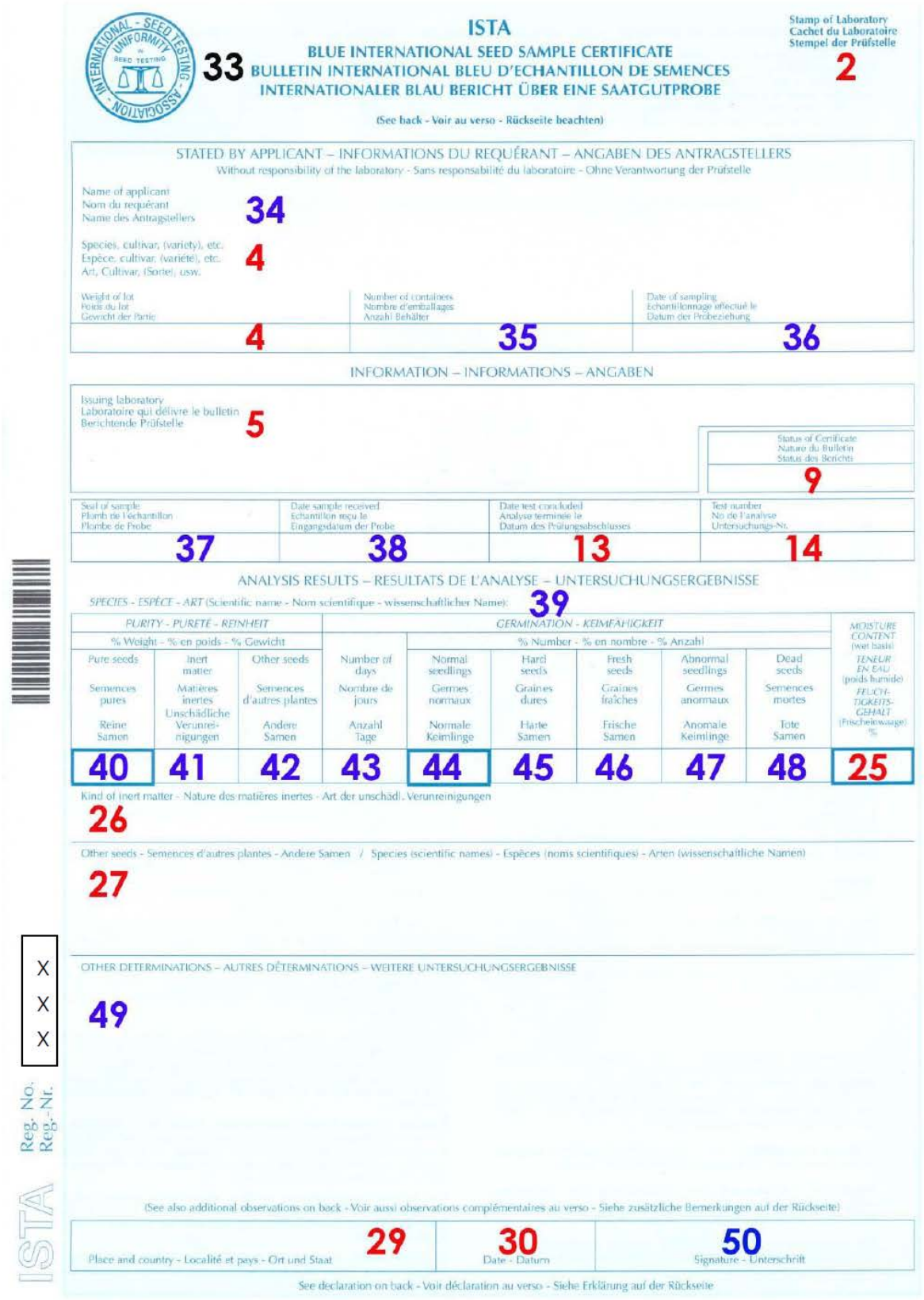
ISTA

(See also additional observations on back - Voir aussi observations complémentaires au verso - Siehe zusätzliche Bemerkungen auf der Rückseite)

Place and country - Localité et pays - Ort und Staat	Date - Datum	Signature - Unterschrift
29	30	31

See declaration on back - Voir déclaration au verso - Siehe Erklärung auf der Rückseite

Annex 2: Blue International Seed Sample Certificate with reference numbers added



ISTA

33

BLUE INTERNATIONAL SEED SAMPLE CERTIFICATE
BULLETIN INTERNATIONAL BLEU D'ECHANTILLON DE SEMENCES
INTERNATIONALER BLAU BERICHT ÜBER EINE SAATGUTPROBE

Stamp of Laboratory
Cachet du Laboratoire
Stempel der Prüfstelle
2

(See back - Voir au verso - Rückseite beachten)

STATED BY APPLICANT – INFORMATIONS DU REQUÉRANT – ANGABEN DES ANTRAGSTELLERS
Without responsibility of the laboratory - Sans responsabilité du laboratoire - Ohne Verantwortung der Prüfstelle

Name of applicant
Nom du requérant
Name des Antragstellers
34

Species, cultivar, (variety), etc.
Espèce, cultivar, (variété), etc.
Art, Cultivar, (Sorte), usw.
4

Weight of lot Poids du lot Gewicht der Partie	Number of containers Nombre d'emballages Anzahl Behälter	Date of sampling Echantillonnage effectué le Datum der Probeziehung
4	35	36

INFORMATION – INFORMATIONS – ANGABEN

Issuing laboratory
Laboratoire qui délivre le bulletin
Berichtende Prüfstelle
5

Status of Certificate
Nature du Bulletin
Status des Berichts
9

Seal of sample Plomb de l'échantillon Plombe der Probe	Date sample received Echantillon reçu le Eingangsdatum der Probe	Date test concluded Analyse terminée le Datum des Prüfungsabschlusses	Test number No de l'analyse Untersuchungs-Nr.
37	38	13	14

ANALYSIS RESULTS – RESULTATS DE L'ANALYSE – UNTERSUCHUNGSERGEBNISSE

SPECIES - ESPÈCE - ART (Scientific name - Nom scientifique - wissenschaftlicher Name): 39

PURITY - PURETÉ - REINHEIT % Weight - % en poids - % Gewicht			GERMINATION - KEIMFÄHIGKEIT						MOISTURE CONTENT (wet basis) TENEUR EN EAU (poids humide) FEUCHTIGKEITS-GEHALT (Frischeiswaage) %
				% Number - % en nombre - % Anzahl					
Pure seeds Semences pures Reine Samen	Inert matter Matières inertes Unschädliche Verunreinigungen	Other seeds Semences d'autres plantes Andere Samen	Number of days Nombre de jours Anzahl Tage	Normal seedlings Germes normaux Normale Keimlinge	Hard seeds Graines dures Harte Samen	Fresh seeds Graines fraîches Frische Samen	Abnormal seedlings Germes anormaux Anomale Keimlinge	Dead seeds Semences mortes Tote Samen	
40	41	42	43	44	45	46	47	48	25

Kind of inert matter - Nature des matières inertes - Art der unschädl. Verunreinigungen
26

Other seeds - Semences d'autres plantes - Andere Samen / Species (scientific names) - Espèces (noms scientifiques) - Arten (wissenschaftliche Namen)
27

X
X
X

OTHER DETERMINATIONS – AUTRES DÉTERMINATIONS – WEITERE UNTERSUCHUNGSERGEBNISSE
49

Reg. No.
Reg.-Nr.

ISTA

(See also additional observations on back - Voir aussi observations complémentaires au verso - Siehe zusätzliche Bemerkungen auf der Rückseite)

Place and country - Localité et pays - Ort und Staat	Date - Datum	Signature - Unterschrift
29	30	50

See declaration on back - Voir déclaration au verso - Siehe Erklärung auf der Rückseite

Appendix 3. Data forms

Murray Seed collection field data sheet

Murray CMA Seedbank — **Seed Collection Field Data Sheet**

COLLECTION SITE LOCATION:

Vegetation type: Remnant / Planted / SPA

Site registered ? Yes No ?

MCMA Site Registration Number: (if planted or a SPA)

Land ownership: Public Private

Site name (eg. Joe's Swamp, or property name & paddock):

Closest road:

Closest town:

Shire:

Landholder (if applicable):

Subcatchment / Subregion: (see local Reveg. Guide)

MCMA Mgmt. Unit: (eg. Berriquin or Culcairn)

COLLECTION SITE VEGETATION:

Dominant species (at or adjacent to site):

Species abundance at site:
Dominant Abundant Common
Uncommon Rare Solitary

Population size at site (if ≤10, enter actual number):
11 - 25 26 - 50 51 - 100 101 - 500 501 +

Number of plants collected from (if ≤10, enter actual number):
11 - 25 26 - 50 51 - 100 101 +

Collection timing:
Early Peak Late

Seed crop quantity:
Light Medium Heavy

Additional notes:

SEEDLOT DETAILS:

Species name:

Vegetative form:
Tree Shrub Grass / Rush / Sedge Other

Date/s collected:

Collection number: 1309

Allocated project/s (if known):

Seed payment req'd: Yes No

COLLECTION SITE COORDINATES:
(Please record GPS coordinates in GDA 94 mode)

Coordinates from: Map GPS

Scale:

Map number: Map date:

MGA zone: 54 55

Easting:

Northing:

Elevation (m):

OTHER SITE DETAILS:

Aspect (circle main option only):
N NE E SE S SW W NW N/A

Position in landscape:
Watercourse Floodplain Depression
Plains / Flat Sandhill Crest
Lower slope Mid slope Upper slope

Surface soil colour:

Surface soil description:
Sand
Clay Loam

COLLECTOR DETAILS:

Main collector:

MCMA SB supervisor:

Total no. collectors:

Additional collectors: (eg. IOs, Landcare, GreenCorp)

MAIN COLLECTOR'S SIGNATURE:

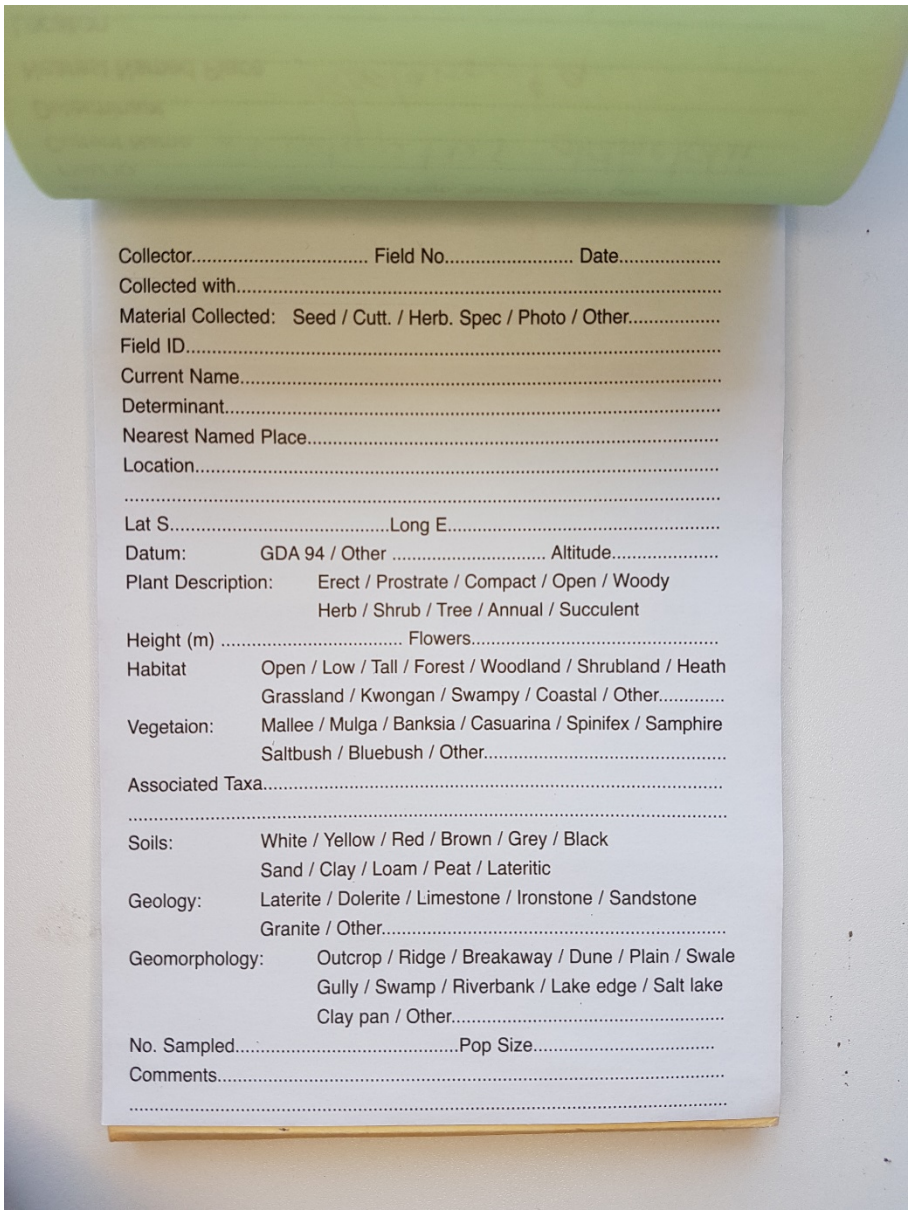
I declare that this seed has been collected in an ethical and sustainable manner, in accordance with MCMA Seed Collection Guidelines (see inside cover)

SEED PROCESSING DETAILS:

Seed quality:	Poor	Average	Good	Date delivered	
Seed rating:	Low value sites	Medium value	High value only	No. bags delivered	
Processing: (as applicable)	Date or N/A:	Processing: (as applicable)	Date or N/A:	Deposit weight (g)	
Hand cleaned:		Floated:		Additional deposits to seedlot (g)	
Threshed:		Gassed (CO_2):			
Sieved:		Dryacide:		Database entry complete	
Seed graded:		Other:			

OFFICE USE ONLY:

Kings Park collecting book



Collector..... Field No..... Date.....
Collected with.....
Material Collected: Seed / Cutt. / Herb. Spec / Photo / Other.....
Field ID.....
Current Name.....
Determinant.....
Nearest Named Place.....
Location.....
.....
Lat S.....Long E.....
Datum: GDA 94 / Other ..... Altitude.....
Plant Description: Erect / Prostrate / Compact / Open / Woody
Herb / Shrub / Tree / Annual / Succulent
Height (m) ..... Flowers.....
Habitat Open / Low / Tall / Forest / Woodland / Shrubland / Heath
Grassland / Kwongan / Swampy / Coastal / Other.....
Vegetaion: Mallee / Mulga / Banksia / Casuarina / Spinifex / Samphire
Saltbush / Bluebush / Other.....
Associated Taxa.....
.....
Soils: White / Yellow / Red / Brown / Grey / Black
Sand / Clay / Loam / Peat / Lateritic
Geology: Laterite / Dolerite / Limestone / Ironstone / Sandstone
Granite / Other.....
Geomorphology: Outcrop / Ridge / Breakaway / Dune / Plain / Swale
Gully / Swamp / Riverbank / Lake edge / Salt lake
Clay pan / Other.....
No. Sampled.....Pop Size.....
Comments.....
.....

Seeds of Success (US) field data form

Seed Collection Ref. Number:		**Collector Code:**	
Date(s) Collected (MM/DD/YY):		**Collector Name(s):**	
		Collection Number:	
		Alt. Collection Number:	

COLLECTION DATA

Family:		**No. of Plants Sampled** (min. 50):	
Genus:		**No. of Plants Found** (approx.):	
Species:		**Area Sampled** (acres):	
Subspecies/Variety:		**Seeds Collected From:**	*Plants Ground Both Unknown*
Plant Habit:	*Tree Shrub Forb Succulent Grass/Grasslike*	**Plant Height** (feet):	
Field Notes to assist in identification of pressed specimen (e.g. flower color):			
Common Name(s) of Plants:		**NRCS PLANTS Code:**	

LOCATION DATA

Ecoregion (Omernik Level III):		**State:**		**County:**	
Subunit (BLM area, park name, etc.):		**Area within Subunit** (trail name, etc.):			
Land Owner:		**Non-BLM Permission Filed:**	Y N		
Location Details:					
Source Used:	*GPS Map None*	**Accuracy:**	*GPS Within 5km 6–20km More than 20km*		
GPS Datum:	*NAD83 NAD27 WGS84 Other:*				
Latitude (dg/min/sec) (ex: 40˚ 34’ 19.5” N):	N	**Elevation:**			
Longitude (dg/min/sec) (ex: 107˚ 36’ 51.54” W):	W	**Unit** (ft or m):			

HABITAT DATA

Associated Species (Scientific Name):	

Ecological Site Description, Habitat Type and/or National Vegetation Classification :				
Modifying Factors:	*Mowed Burned Grazed Flooded Seeded Trampled Other:*			
Land Form:		**Slope** (degrees)**:**		
Land Use:		**Aspect:**	*N NE E SE S SW W NW*	
Geology:				
Soil Texture:	*Clay Silt Sand Other:*	**Soil Color:**		
HERBARIUM VOUCHERS				
Number of pressed specimens:		**Date Voucher Taken:**		
Herbaria Names (Smithsonian, Regional, Local):				
SPECIALIST IDENTIFICATION				
Identified by (name and organizational affiliation):				
Material Identified:	*In Field From Pressed Specimen on Day of Collection* *From Pressed Specimen on Another Date From Photograph*	**Date Identified** (MM/DD/YY):		

PRE-COLLECTION CHECKLIST

This section is for your reference only and not required as part of the data collected by the SOS National Coordinating Office. The conditions indicated in **boldface** *describe ideal population size and seed dispersal stage for seed collecting.*

Assess Population and Seed Dispersal Stage
Approximate area of population: x (feet, yards, miles……)
Approximate total number of individual plants present and accessible: *0–50 50–500 500–5000 > 5000*
Evidence of disturbance or damage: *Resown Burnt Sprayed* **No damage**
Readiness of population for collecting: give percentages or circle the most frequently occurring: *Vegetative In flower Immature seeds* **Around natural dispersal** *Post dispersal*
Estimate the number of individual plants at natural dispersal stage: *<50* **>50**
Is the population: ***A single population*** *A population with distinct sub-populations* (Can you sample separately or from the most suitable?)

Assess Seed Quality and Availability
On a typical individual, where on the plant/branch/fruit is the seed at natural dispersal stage: **Recognized**
Using a cut test on the seeds at this stage, give percentages or circle the most frequently occurring: **Healthy** *Insect-damaged Empty Moldy Malformed/other damage*
Estimate the number of healthy seeds per fruit:
Estimate the number of fruits per individual plant:

Should Seed Be Collected On This Trip?
Using the above information, if you only collect 20% of the healthy seeds available today, will this result in a collection of **>10,000** healthy seeds?

ESCONET (ENSCONET 2009c)

Appendix 1 Passport (Collecting) Data Form

FIELDS IN GREY ARE MANDATORY

Accession ID						**Collection Number** *(same as bag number)*	
Collection date		YYYY	MM	DD			
Main Collector Surname & First Name *(CAPITALS)*						**Institution**	
Other collectors Names and Institutions							
Taxon name							
Vernacular name(s) (+ language)							
Herbarium Voucher	Yes/No Number:	**Number of mature plants found** (tick one)	1..... 2-5..... 5-10..... 10-25.... 25-50.... 50-100.. 100-1000..... 1000+...		**Number of plants sampled** (tick one)	1..... 2-5..... 5-10..... 10-25.... 25-50.... 50-100.. 100-1000..... 1000+...	**Phenology status** *(tick one)*
Soil sample	Yes/No Number:						More flowers than fruits..... More fruits than flowers..... Only fruits..... Fruits already dispersed.....
Sampling Method *(tick one)*	Random..... Regular..... Transect (linear).... Core of population. Edge of population. Other.....						
Sampling area visited (m x m)					**Seeds / fruits collected from ground?**	YES NO Partially	
Photos *(give references)*							
Country					**Primary subdivision**		
Secondary subdivision *(council, municipality…)*							
Locality							
Latitude Y		**Longitude X**		**Units** (tick one)	Degrees Meters	**EPSG Code** (see codes)	
Altitude (m)		**Water depth** (aquatics) (m)				**Altitude Accuracy** (m)	

Geocode pro-vided by collector?	**Geocode Method** *(tick one)*	**Altitude Method** *(tick one)*	**Prevalent Aspect** *(tick one)*	**Slope** *(tick one)*	**Soil texture** *(tick one)*	**Soil pH** *(tick one)*
Yes	GPS	Altimeter	N	Level 0-5%	Gravel	Acidic
No	DGPS	DEM	N-E	Undulating 6-10%	Sand	Alkaline
	Estimate	GPS	E	Rolling 11-20%	Sandy loam	Neutral
	Map	Estimate	S-E	Moderate 21-31%	Loam	
	Google Earth	Map	S	Steep >30%	Clay loam	
			S-W		Clay	
			W		Peat	
			N-W		No soil	

EUNIS Habitat Code *(see codes)*		**Land Use Code** *(see codes)*	**Threats**

Site Notes
(observations or any relevant information)

Associated species
(SPECIFY 3-5 rare or abundant species)

Collecting Notes
(e.g. problems encountered, collecting method, estimate of seed nos., flower colour etc)

Appendix 2 Codes for use in Passport Data Form

I. EPSG (European Petroleum Survey Group) CODES

The EPSG registry (http://www.epsg-registry.org/) holds all codes and descriptive information relating to each one. All EPSG codes can be returned by running a blank search. Codes relating to a particular country can be retrieved from this database using searching by area.

II. EUNIS HABITAT LAND CODES – for Europe

For key and descriptions – see http://eunis.eea.europa.eu/habitats-code.jsp

A: Marine habitats	
A1	Littoral rock and other hard substrata
A2	Littoral sediment
A3	Infralittoral rock and other hard substrata
A4	Circalittoral rock and other hard substrata
A5	Sublittoral sediment
A6	Deep-sea bed
A7	Pelagic water column
A8	Ice-associated marine habitats

B: Coastal habitats	
B1	Coastal Dunes and Sandy Shores
B2	Coastal Shingle
B3	Rock cliffs, ledges and shores, including the supralittoral

C: Inland surface waters	
C1	Surface standing waters
C2	Surface running waters
C3	Littoral zone of inland surface waterbodies

D: Mires, bogs and fens	
D1	Raised and blanket bogs
D2	Valley mires, poor fens and transition mires
D3	Aapa, palsa and polygon mires
D4	Base-rich fens and calcareous spring mires
D5	Sedge and reedbeds, normally without free-standing water
D6	Inland saline and brackish marshes and reedbeds

E: Grasslands and lands dominated by forbs, mosses or lichens	
E1	Dry grasslands
E2	Mesic grasslands
E3	Seasonally wet and wet grasslands
E4	Alpine and subalpine grasslands
E5	Woodland fringes and clearings and tall forb stands
E6	Inland salt steppes
E7	Sparsely wooded grasslands

F: Heathland, scrub and tundra	
F1	Tundra
F2	Arctic, alpine and subalpine scrub
F3	Temperate and mediterranean-montane scrub
F4	Temperate shrub heathland
F5	Maquis, arborescent matorral and thermo-Mediterranean brushes
F6	Garrigue
F7	Spiny Mediterranean heaths (phrygana, hedgehog-heaths and related coastal cliff vegetation)
F8	Thermo-Atlantic xerophytic scrub
F9	Riverine and fen scrubs
FA	Hedgerows
FB	Shrub plantations

G: Woodland, forest and other wooded land	
G1	Broadleaved deciduous woodland
G2	Broadleaved evergreen woodland
G3	Coniferous woodland
G4	Mixed deciduous and coniferous woodland
G5	Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice

H: Inland unvegetated or sparsely vegetated habitats	
H1	Terrestrial underground caves, cave systems, passages and waterbodies
H2	Screes
H3	Inland cliffs, rock pavements and outcrops
H4	Snow or ice-dominated habitats
H5	Miscellaneous inland habitats with very sparse or no vegetation
H6	Recent volcanic features

I: Regularly or recently cultivated agricultural, horticultural and domestic habitats	
I1	Arable land and market gardens
I2	Cultivated areas of gardens and parks

J: Constructed, industrial and other artificial habitats	
J1	Buildings of cities, towns and villages
J2	Low density buildings
J3	Extractive industrial sites
J4	Transport networks and other constructed hard-surfaced areas
J5	Highly artificial man-made waters and associated structures
J6	Waste deposits

X: Habitat complexes

B. LAND USE CODES

L1: Agriculture	
L1.1	Pasture
L1.2	Fallow
L1.3	Crop
L1.4	Grassland
L1.5	Forest
L1.6	Woodland
L1.7	Protected enclosure

L2: Commercial	
L2.1	Draining
L2.2	Dumping
L2.3	Aquaculture
L2.4	Quarrying / Mining
L2.5	Industrial
L2.6	Peat cutting

L3: Grazing	
L3.1	Light
L3.2	Moderate
L3.3	Severe

L4: Leisure	
L4.1	Walking
L4.2	Fishing
L4.3	Hunting
L4.4	Golf
L4.5	Sports pitch
L4.6	Camping
L4.7	Horse riding
L4.8	Cycling

NAME .....

LOCATION .....

.....

.....

.....

State ..... **Subdivision** .....

Special Geographic Unit .....

Lat .....°.....'.....'.....''S **Long** .....°.....'.....''E

Altitude .....m **Datum** ..... **Precision** ± .....m

Native:	Natural	Naturalised	Unknown
Source:	Wild	Introduced	Cultivated

COLLECTOR .....

No. ..... **DATE** ...../...../.....

Vegetation Type .....

Landform .....

Habitat Notes .....

.....

.....

Associated Sp. .....

.....

.....

Soil/Geology .....

Disturbance/Threats .....

.....

Appendix 4. ALA occurrence data template simple

These are column headers from a spreadsheet, but have been presented as rows for ease of reading.

http://rs.tdwg.org/dwc/terms/index.htm#catalogNumber	ID — Use a record identifier from the source data set if one exists, if not leave blank	catalogueNumber
http://rs.tdwg.org/dwc/terms/index.htm#basisOfRecord	Observation | Specimen | Still Image | Moving Image | Sound	basisOfRecord
http://rs.tdwg.org/dwc/terms/index.htm#recordedBy	The name of the observer, collector, photographer etc, can be a group or organisation name if individuals do not want their name shared	recordedBy
http://rs.tdwg.org/dwc/terms/index.htm#scientificName	scientific name of the organism	scientificName
http://rs.tdwg.org/dwc/terms/index.htm#vernacularName	Common name for the organism, not required if you have a scientific name	vernacularName
http://rs.tdwg.org/dwc/terms/index.htm#identificationqualifier	How certain the identification is	identificationQualifier
http://rs.tdwg.org/dwc/terms/index.htm#eventDate	Date of the occurrence, indicate precision in the value, use '/' to separate start and end dates	eventDate
http://rs.tdwg.org/dwc/terms/index.htm#stateProvince	NSW | VIC | TAS | SA | WA | NT | QLD | ACT	stateProvince
http://rs.tdwg.org/dwc/terms/index.htm#locality	a description of the location	locality
http://rs.tdwg.org/dwc/terms/index.htm#decimalLatitude	latitude in decimal degrees	decimalLatitude
http://rs.tdwg.org/dwc/terms/index.htm#decimalLongitude	longitude in decimal degrees	decimalLongitude
http://rs.tdwg.org/dwc/terms/index.htm#coordinateuncertaintyinmeters	The radius of a circle providing the uncertainty of the coordinates (includes all potential error introduced by datum shift, extent and precision of coordinates). Leave blank if unknown.	coordinateUncertaintyInMeters
http://rs.tdwg.org/dwc/terms/index.htm#individualCount	number of individuals in the occurrence	individualCount
http://rs.tdwg.org/dwc/terms/index.htm#associatedMedia	Indicate a URL for an associated photo, movie or sound recording or, if they are in an attached zip of media files indicate the specific file name	associatedMedia
http://rs.tdwg.org/dwc/terms/index.htm#occurrenceRemarks	any comments	occurrenceRemarks

Appendix 5. Native Plant Network Propagation Protocol Database

These two propagation protocols have been taken from the Native Plant Network Propagation Protocol Database https://npn.rngr.net/renderNPNProtocolDetails?selectedProtocolIds=lamiaceae-acanthomintha) access date 27/5/2021

Native Plant Network
Propagation Protocol Database
Protocol Information

Acanthomintha (ilicifolia)

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Family Scientific Name:	Lamiaceae
Family Common Name:	Mint Family
Scientific Name:	*Acanthomintha ilicifolia* (A. Gray) A. Gray
Common Name:	San Diego thornmint
Species Code:	ACIL
Ecotype:	Coastal Sage Scrub
General Distribution:	Southern California and Baja California
Known Invasiveness:	None known
Propagation Goal:	Seeds
Propagation Method:	Seed
ProductType:	Propagules (seeds, cutings, poles, etc.)
Stock Type:	Wild Collected Seeds
Time To Grow:	6–8 months
Target Specifications:	To produce as many seeds as possible from available wild collected seeds for reintroduction purposes.
Propagule Collection:	We collected seeds along maternal lines from two wild populations of San Diego thornmint in San Diego County: Mission Trails Regional Park and Dennery Canyon.

Propagule Processing:	Wild collected seeds clean with sieves and air winnower (blower).
Pre-Planting Treatments:	Directly planted — no pretreatment
Growing Area Preparation/ Annual Practices for Perennial Crops:	We directly planted seed in two 4 x 4 ft raised beds (~250 seeds per bed) with a string grid installed above the bed to track seed production by maternal lines.The grid divides each box into 56 cells, each of which is plant with 5 seeds. The beds contained native clay soil that we amended with one cup of organic fertilizer. We installed an 8" tall hardware cloth cage on top of the raised bed to prevent mammal herbivory.
Establishment Phase:	Raised beds were watered daily until germination was observed, then seedlings were maintained evenly moist until established. Seeds germinated within two-three weeks, and seedlings were well-established by six weeks.
Length of Establishment Phase:	6 weeks
Active Growth Phase:	Once plants were established, plants were watered about once a week (unless seasonal rain occurred). We allowed the top inch of soil media to dry between waterings. We maintained the beds weed free. We applied Sluggo to deter herbivory by slug pests.
Length of Active Growth Phase:	12–16 weeks
Hardening Phase:	As plants begin to flower, watering is reduce to allow the medium to dry in between waterings. As plants begin fruiting, watering is reduced to once every two weeks. Pollinators were observed visiting the flowers so there was no need for hand pollination.
Length of Hardening Phase:	8 weeks
Harvesting, Storage and Shipping:	Plants were allowed to dry down in the raised beds and seeds were harvested using scissors along maternal lines. Seeds are ready to harvest once plant have stopped flowering and plant biomass appears dry. The plants were fairly productive, producing 3–4,000 seeds per bed. Seeds were cleaned using sieves and the air winnower. Seeds were stored in a cool dry environment in our seed bank until the land manager picked them up a few months later.
Length of Storage:	6 weeks
Outplanting performance on typical sites:	Land managers directly planted seed into a fenced area at Mission Trails Regional Park on a clay lens soil habitats. Land managers performed extensive weed management at the site before reintroduction of seed. From the first direct seeding, 50 plants were established at the site.
Other Comments:	This species has an unpleasant after smell for a mint.

Citation:

Anderson, Stacy; Weatherson, Tobin. 2020. Propagation protocol for production of Propagules (seeds, cutings, poles, etc.) *Acanthomintha ilicifolia* (A. Gray) A. Gray Seeds Wild Collected Seeds; San Diego Zoo Institute for Conservation Research Escondido, California. In: Native Plant Network. URL: http://NativePlantNetwork.org (accessed 2021/05/26). US Department of Agriculture, Forest Service, National Center for Reforestation, Nurseries, and Genetic Resources.

Sphaeralcea (parvifolia)

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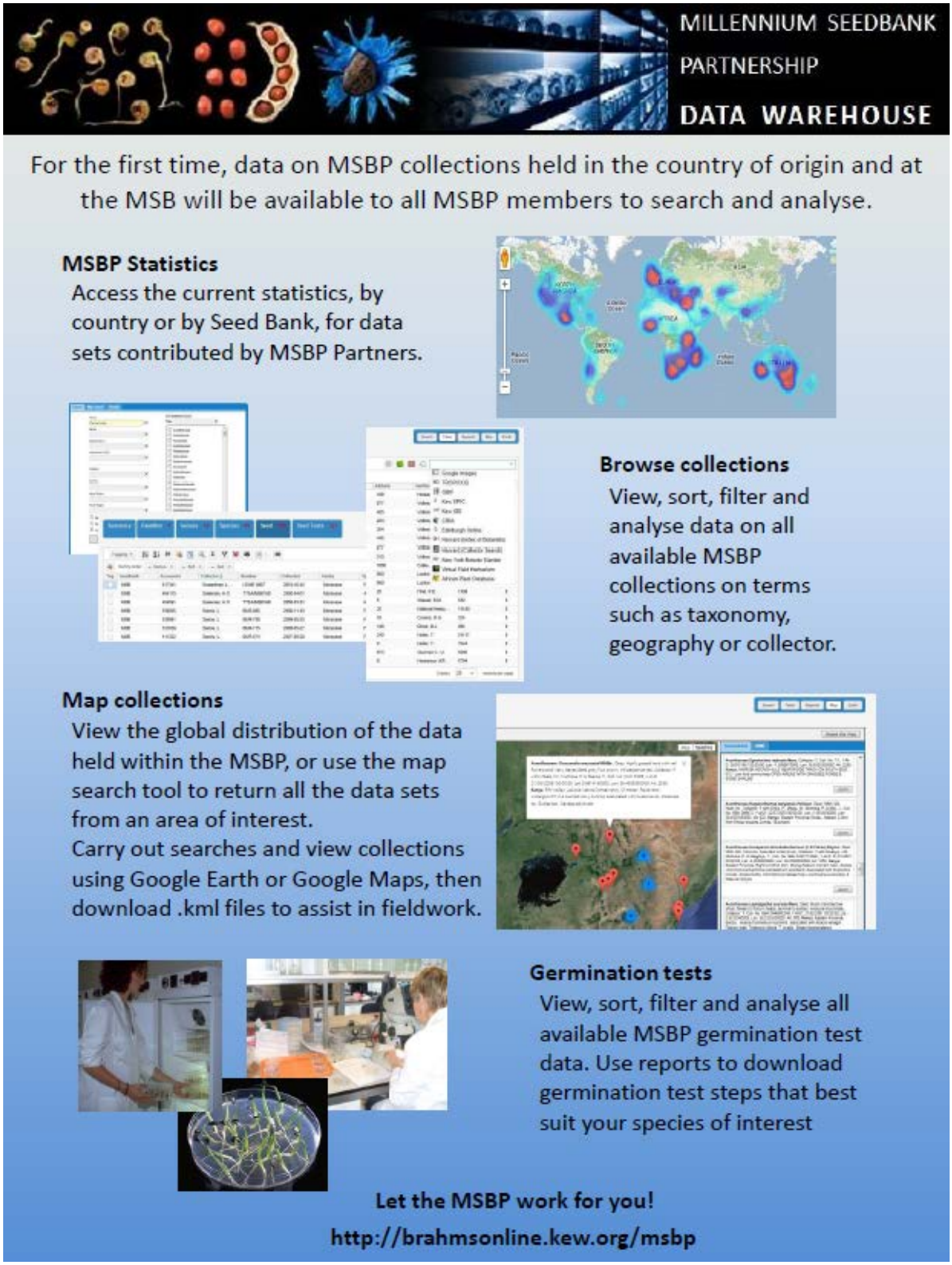
Family Scientific Name:	Malvaceae
Scientific Name:	*Sphaeralcea parvifolia*
Species Code:	SPPA
Ecotype:	wild collected from Uinta County, Utah
Propagation Goal:	Seeds
Propagation Method:	Seed
ProductType:	Propagules (seeds, cuttings, poles, etc.)
Pre-Planting Treatments:	APPROACH: This project aimed to determine optimal germination conditions for species currently used in restoration in the Colorado Plateau, as well as other priority forb species that may be beneficial to include in future restoration efforts. For this study, seeds were plated on 1.5% agar in petri dishes (4 replicates of 25 seeds per treatment) and incubated in growth chambers at Chicago Botanic Garden using six temperature treatments intended to represent different seed sowing times and locations in the Colorado Plateau (treatments are shown as day/night temperatures respectively, using a 12h/12h light/dark cycle): TREATMENTS: 1) early-spring (4 weeks at 52°F/34°F) NOT SCARIFIED 2) early-spring (4 weeks at 52°F/34°F) SCARIFIED 3) winter (12 weeks at 34°F) and early-spring (4 weeks at 52°F/34°F) NOT SCARIFIED 4) winter (12 weeks at 34°F) and early-spring (4 weeks at 52°F/34°F) SCARIFIED 5) mid-spring (4 weeks at 59°F/41°F) NOT SCARIFIED 6) mid-spring (4 weeks at 59°F/41°F) SCARIFIED 7) winter (12 weeks at 34°F) and mid-spring (4 weeks 59°F/41°F) NOT SCARIFIED 8) winter (12 weeks at 34°F) and mid-spring (4 weeks 59°F/41°F) SCARIFIED 9) late-spring (4 weeks at 68°F/50°F) NOT SCARIFIED 10) late-spring (4 weeks at 68°F/50°F) SCARIFIED 11) winter (12 weeks at 34°F) and late-spring (4 weeks 68°F/50°F) NOT SCARIFIED 12) winter (12 weeks at 34°F) and late-spring (4 weeks 68°F/50°F) SCARIFIED

Establishment Phase: RESULTS: Almost all viable seeds from this Seeds of Success collection from Uintah County, Utah germinated to relatively high levels (70% or more) when scarified AND subjected to temperatures at 34°F (treatments 2, 4, 8, 12). If temperatures were not cold enough, scarification was not sufficient to support germination over 30% (treatments 6 and 10). And winter temperatures alone were not sufficient to support germination above 35% if seeds were not scarified (treatments 3, 7, and 11). Additional research is needed to identify whether these results are representative of the entire species. The figure at http://tinyurl.com/CBGSeedGerminationSPPA shows the average percent germination and standard deviation of viable seeds for each treatment.

Citation:

Kramer, Andrea T; Foxx, Alicia. 2016. Propagation protocol for production of Propagules (seeds, cutings, poles, etc.) *Sphaeralcea parvifolia* Seeds Chicago Botanic Garden — Research Glencoe, Illinois. In: Native Plant Network. URL: http://NativePlantNetwork.org (accessed 2021/05/26). US Department of Agriculture, Forest Service, National Center for Reforestation, Nurseries, and Genetic Resources.

Appendix 6. Millennium Seed Bank Partnership Data Warehouse



Exploring Millennium Seed Bank collections from North America- a case study

The Royal Botanic Gardens Kew (Kew) in UK maintains seed collections from over 4800 US plant populations at the Millennium Seed Bank (MSB). We are developing tools to analyse the quality of these collections so that Kew and our partners can identify gaps in coverage and respond to problems that may require training or research support.

Our questions:

1: Which US native seed collections meet fieldwork data standards?

2. Which seed collections meet current viability targets?

3. Which families are typically not supported by comprehensive field passport data?

The resources that we used:

(1) The MSB Data Warehouse on line

(2) Seed accessions data from Kew's Seed Bank Database.

(3) A standards assessment tool for evaluating collections data quality, including field (passport) data, developed using BRAHMS software.

(4) Tableau Public© software to create data visualisations. These can be embedded in a website to enable user interactivity, or downloaded as standalone graphics (Task 3).

What is the MSB Data Warehouse?

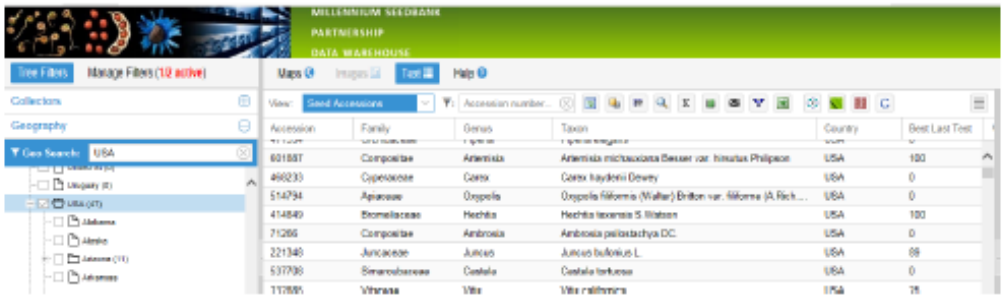
It is an online tool to explore and analyse regularly updated collection data shared by participating seed banks worldwide. It helps users with the planning of seed collection programmes and in improving their seed germination testing.

Access is restricted to MSBP partners and native seed banks that provide data on their collections. The locality data of sensitive species can be withheld as specified in a Data Provider Agreement with Kew.

The MSBP Data Warehouse is powered by an underlying BRAHMS database which is compiled and managed on our secure servers at Kew. The amount of data available on the MSBP Data Warehouse continues to grow as more partners share their data within the MSBP community

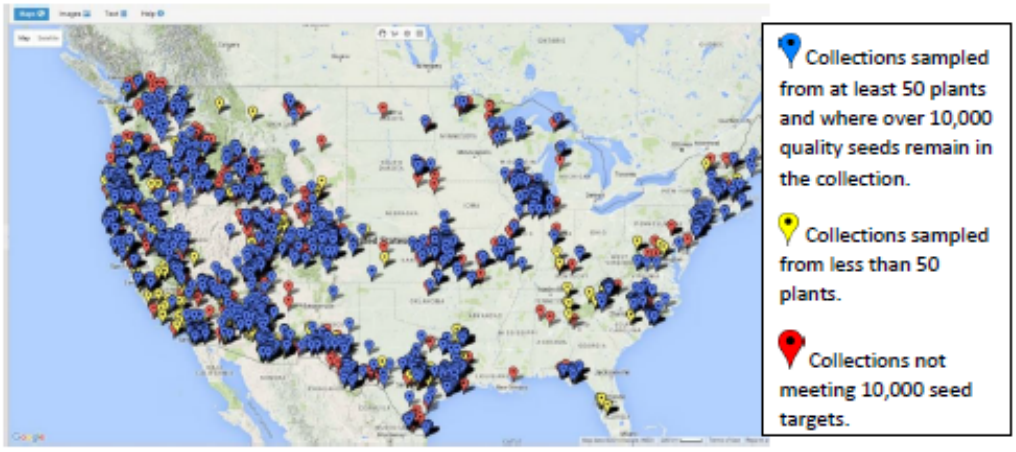
Visit: http://brahmsonline.kew.org/msbp

Using the geographical filter to explore collections in the MSB Data Warehouse



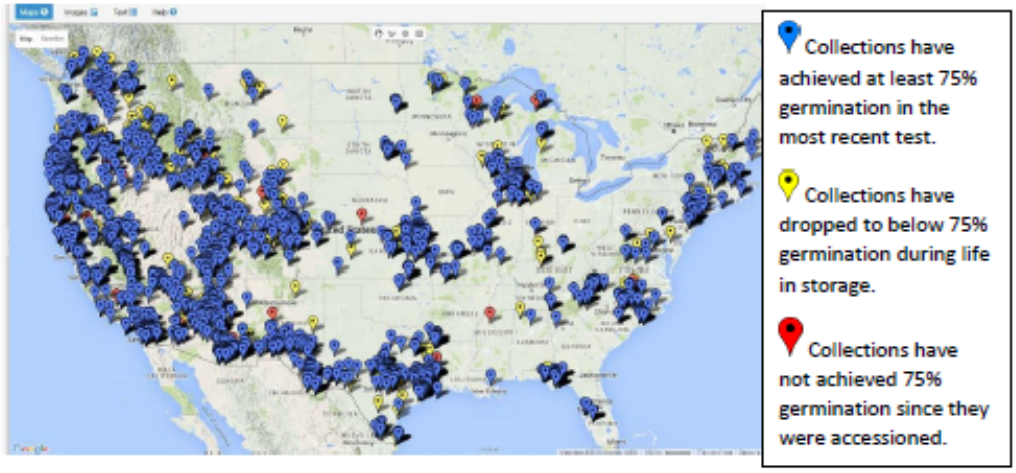
1. Which US native seed collections meet fieldwork standards?

Collectors have been trained to sample from large plant populations, to maximise the genetic diversity of the collection and to ensure that sufficient seed is available for research and conservation. We filtered collections that met sampling targets and exported these as kml files to be viewed either in Google Earth or within the Data Warehouse as blue pins (image 1 below). Collections not meeting targets for seed number are shown in Red and for sampling are in Yellow.



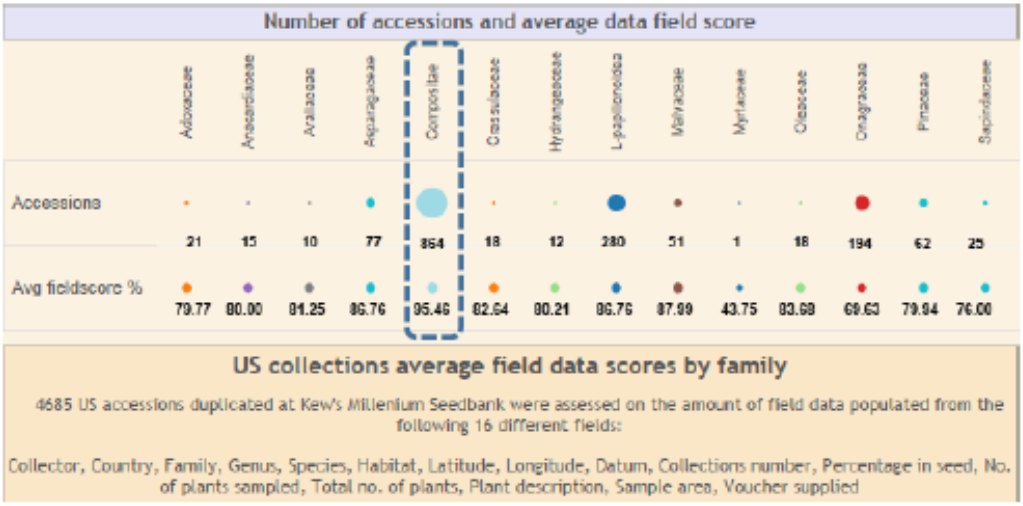
2. Which seed collections meet current viability targets?

MSB Seed Collections receive an initial viability test and are monitored at intervals to ensure that samples can continue to be distributed. For this task we filtered collections for which at least 75% of the seed tested in the most recent test had successfully germinated (Blue pins). Yellow and Red pins show respectively collections which have not achieved that threshold, or which have dropped below 75% during their life in seed bank storage.



3. Which families are typically not supported by comprehensive field data?

Seed Collectors are trained in recording comprehensive field (passport) data that is available for subsequent users of the collections. We wished to know if some families tend to have incomplete data (i.e. from the sixteen data fields that are analysed) and thus only partially meet the MSB field data standards. From the table below we can see that the 864 Compositae accessions (the most well represented family), has an average field (passport) data score of 95.46%.



Conclusions

We have shown that existing collection data can be easily transformed for in depth analysis of collections' quality, including highlighting potential areas for future improvement. By harnessing new technologies readily available these analyses can be given greater impact through online mapping and interactive data visualisations. The techniques used in this study can be adapted to reveal many other insights, for example by filtering on year of collection or collecting organisation.

Acknowledgements

Thankyou to data providers including Bureau of Land Management and associated Seed of Success partners.

Department of Plant Sciences, University of Oxford. © 1985 - 2015 Botanical Research And Herbarium Management System (BRAHMS). Version 7. Available from: http://herbaria.plants.ox.ac.uk/bol/brahms/ (November 2015)

Study authored by Naomi Carvey n.carvey@kew.org and Michael Way m.way@kew.org

May 2016

Index to links for further testing

USA MAP 1

HIGH QUALITY COLLECTIONS – High adjusted seed quantity AND high sample size

http://brahmsonline.kew.org/Content/Projects/msbp/resources/kml/HighQualityUSA.kml

LOW SAMPLE SIZE < 50 plants

http://brahmsonline.kew.org/Content/Projects/msbp/resources/kml/LowSampleUSA.kml

LOW ADJ SEED COUNT < 10,000

http://brahmsonline.kew.org/Content/Projects/msbp/resources/kml/LowAdjSeedCountUSA.kml

USA MAP 2

BEST LAST TEST HIGH > 74

http://brahmsonline.kew.org/Content/Projects/msbp/resources/kml/HighBestLastUSA.kml

BEST LAST TEST LOW < 75

http://brahmsonline.kew.org/Content/Projects/msbp/resources/kml/LowBestLastUSA.kml

BEST LAST TEST DECLINING where best last < 75 AND best ever > 74

http://brahmsonline.kew.org/Content/Projects/msbp/resources/kml/DecliningBestLastUSA.kml

NATIONAL PARK BOUNDARIES

YOSEMITE

http://brahmsonline.kew.org/Content/Projects/msbp/resources/kml/YOSEMITE.kml

CRATER LAKE

http://brahmsonline.kew.org/Content/Projects/msbp/resources/kml/CRATERLAKE.kml

BRECON BEACONS

http://brahmsonline.kew.org/Content/Projects/msbp/resources/kml/brecon_beacons.kml

BRECON BEACONS Tree preservation order areas

http://brahmsonline.kew.org/Content/Projects/msbp/resources/kml/Brecon_Tree_Preservation_Orders.kml

Appendix 7. SeedTree Maps Information Sheet

SEEDTREE MAPS provides a mapping service that informs clients about the native trees on their property and enables them to participate in community-based reforestation and conservation and potentially benefit financially at the same time. Specialising in subtropical rainforest species, **SEEDTREE MAPS** is at the forefront of using technology to popularise tree identification, seed collecting and community-based restoration of the critically endangered 'Lowland Rainforest of Subtropical Australia' in the Northern Rivers.

Based on the understanding that many subtropical rainforest seeds are recalcitrant and therefore may not survive the drying and/or freezing processes required to be stored in the Australian Plantbank's Seedbank, **SEEDTREE MAPS'** main aim is to support a decentralised seed storage, seedling storage and living collection of a diverse suite of quality seed-producing species on private property.

The Experience Botanists and mapping consultants take clients on a **SEEDTREE TOUR** of their property, mapping GPS locations of quality seed-producing trees. During the tour, an overview of where the property sits in the context of the landscape is given, ecological questions are answered, and a clear understanding of the responsibilities and legalities of sustainable seed collecting is provided.

The Map Clients then receive an interactive digital **SEEDTREE MAP** that can be opened on any device, that provides accurate, well-researched information about their trees, simply by clicking on the tree icon. Information can be customised to client interests and will include scientific and common names, conservation status, distinguishing ID features and two images. Optional information may include botanical name derivations, fruiting months, fruit and seed features and simple seed collecting instructions. The latter information is available to those clients that show an interest in seed collecting and have purchased the recently published guide, *Australian Rainforest Seeds: A guide to collecting, processing and propagation* (CSIRO Publishing, 2020) of which Michelle Chapman, founder of SEEDTREE MAPS, is co-author. In addition, the map includes a **MY RECORDS** section where clients can record data and upload extra images to support observations about flowering, fruiting, seed collecting, fauna sightings, tree height and dbH. Clients can use the **SEEDTREE MAP** to connect with their trees, enjoy showing their friends the trees on their property, engage their children with nature, collect seeds to grow their own trees for restoration, harvest bush tucker foods, give or sell the seeds to nurseries, or sell trees to the public.

SEEDTREE MAPS is the first commercial tree identification and mapping service of its kind, and was created in July 2019 by the founder, Michelle Chapman. Intellectual property includes the concept of engaging landowners in purchase of an educational tree tour and tree identification map, the map function of attaching customised research about seedtrees to a waypoint that can be updated by the creator, using information from a co-authored guide to seed collecting to engage users in seed conservation and restoration, and the model of providing a platform for clients to upload data for scientific research about seeds. It was developed using a generic data collection app, Epicollect5. Several steps are required before the end-product can be viewed and edited in Google MyMaps, a well-known and user-friendly mapping application in Google Maps.

SEEDTREE MAPS is not an app, and probably never will be, as the purpose of the service is to connect clients with their land by taking a **SEEDTREE TOUR** with a qualified botanist and mapping consultant. This walk and talk with passionate naturalists is the key to engaging landholders with how important the stewardship of their trees, and sustainable seed collecting, is. An app that simply provided information on species' location and seed collecting instructions would be prone to irresponsible seed handling practices. Currently, the SEEDTREE MAPS website is developing, with a seedtree database and membership database and networking capability planned for 2022. Also, an offline mapping app for Android may be used at a later date.

The technology continues to develop as the business grows and financial investment increases, with the eventual aim being a network of members that can communicate to swap and share data, seeds, and seedlings. Currently, each map is developed and customised individually, uploaded to Google My Maps. At present, around 200 people enjoy using **SEEDTREE MAPS.**

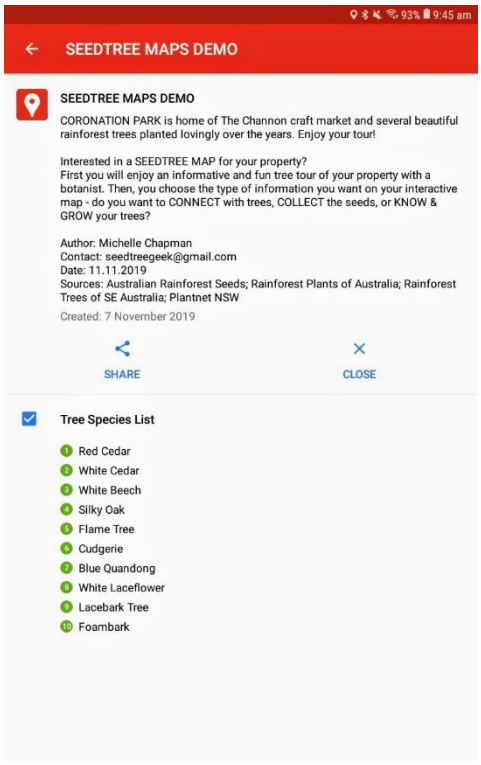
www.seedtreemaps.com

Selected images from SeedTree Maps

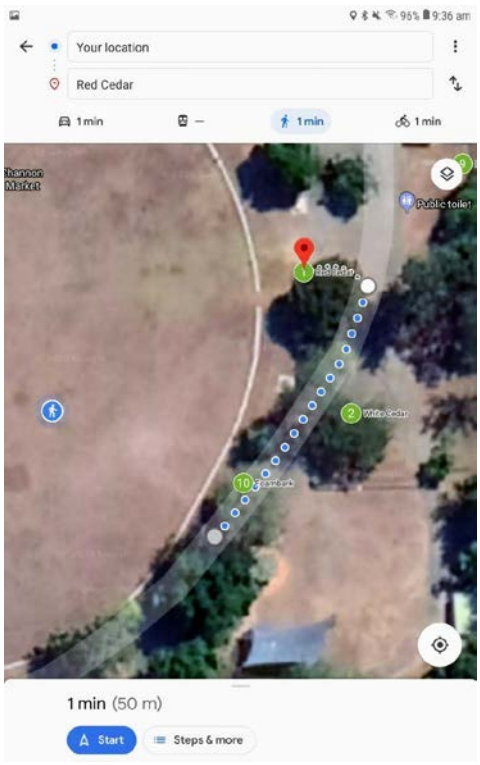
1. Map of Northern NSW

2. Coronation Park location

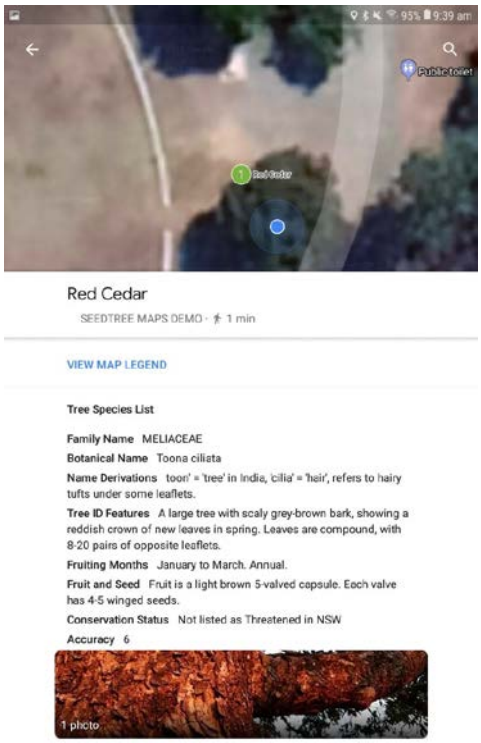
3. Click on legend species list



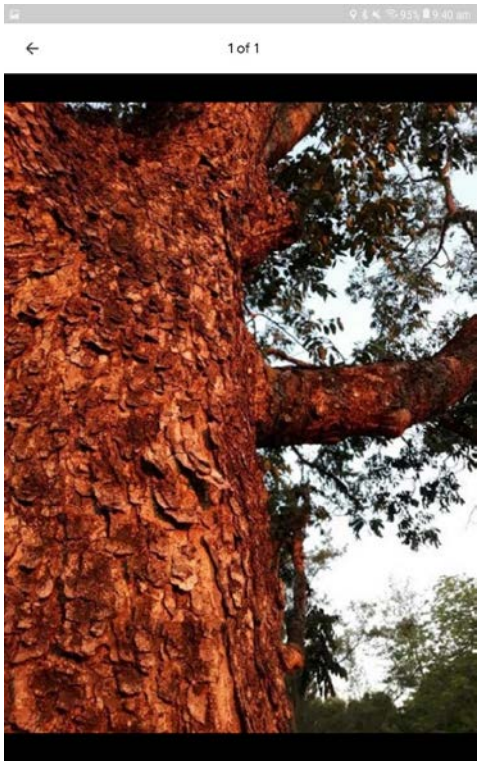
4. Walk to Red Cedar



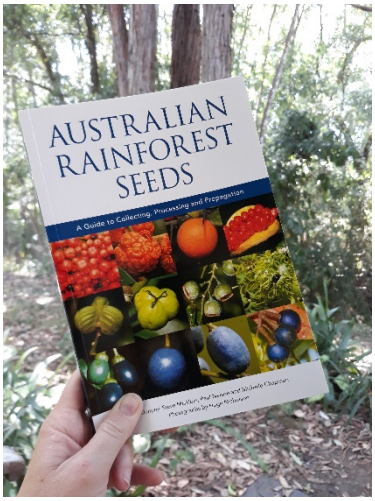
5. Click on Red Cedar Info



6. Click on Red Cedar image



7. Australian Rainforest Seeds book



8. Red Cedar in book