

# DESERT KNOWLEDGE CRC

The Working Paper Series

Sustainable  
Bush Produce Systems

Progress report 2004–2006

Maarten Ryder  
Fiona Walsh  
Josie Douglas  
Michelle Waycott  
Heather Robson  
Zora Singh  
Maria de Sousa Majer  
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Brian Cheers

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## Shortened forms

ASDP	Alice Springs Desert Park
AIATSIS	Australian Institute of Aboriginal and Torres Strait Islander Studies
CAHREC	Central Australian Human Research Ethics Committee
CDEP	Community Development Employment Projects
CDU	Charles Darwin University
CLC	Central Land Council
CO <sub>2</sub>	Carbon Dioxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DFID	Department for International Development (UK)
DKCRC	Desert Knowledge Cooperative Research Centre
DNA	Deoxyribonucleic Acid
FTE	Full Time Equivalent
HPLC	High Performance Liquid Chromatography
IAF	Indigenous Australian Foods Ltd.
IP	Intellectual Property
JCU	James Cook University
MS	mass spectrum
NPY	Ngaanyatjarra Pitjantjatjara Yankunytjatjara
NPYWC	Ngaanyatjarra Pitjantjatjara Yankunytjatjara Women's Council
NT	Northern Territory
NTFP	Non-Timber Forest Products
NTG	Northern Territory Government
OBF	Outback Bushfoods
PCR	Polymerase Chain Reaction
RCN	Reedy Creek Nurseries
RCBD	Randomised Complete Block Design
RIRDC	Rural Industries Research and Development Corporation
SA	South Australia
SL	Sustainable Livelihoods (approach)
SPSS	Statistical Package for the Social Sciences (when first released in 1968)
SPE	Solid Phase Extraction
SSR	Simple (DNA) Sequence Repeat (microsatellite)
TAFE	(College of) Technical and Further Education
TLC	Thin layer Chromatography
UNDP	United Nations Development Programme
UniSA	University of South Australia
WA	Western Australia
YMC	Yuendumu Mining Company



## 1. Introduction

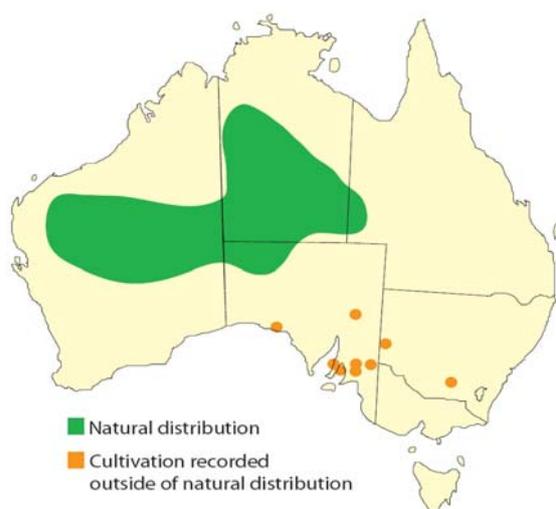
*Solanum centrale* (JM Black) is the focal species of the research reported here because it has an existing commercial value and has provided the bulk of commercial bush food produce sourced from desert Australia. The standard common name in the Northern Territory and Western Australia for *S. centrale* is Desert raisin (Latz 1995, HWA 1998, Albrecht et al. 2007). The fruit resembles a raisin in size and shape but certainly not in taste. The wider native food industry calls this fruit the bush tomato (Robins & Ryder 2004). Note that in central Australia the fruit of other species is commonly called bush tomato (Latz 1995). All Aboriginal dialects have names for the plant, which include *Akalyerr(e)*, *Katyerre*, *Kampurarrpa* and *Yakajirri*. This report consistently uses the Latin species name *Solanum centrale* when referring to the plant or to the fruit of the plant.

*Solanum centrale* is found naturally throughout the central and western desert regions of Australia (SA, WA and NT) that are low rainfall, arid regions (Figure 1 & Photo 1).

*Solanum centrale* has been, and still is, an important food plant for Aboriginal people in desert Australia. It is a plant that requires water (from rainfall or irrigation) for flowering and fruiting; however, it is well able to withstand and survive periods of drought. The plant responds positively to disturbances such as fire and mechanical damage (e.g. roadside grading) (Latz 1995).

In the modern native foods industry, which dates back approximately 30 years, the fruit of *S. centrale* has held an important place. The fruit has been in demand over this period and continues to be sought after as an ingredient for a variety of end uses in the food industry.

The fruit is often allowed to sun-dry on the plant, so that before harvesting it appears shrivelled and dark red-brown in colour (Robins & Ryder 2004); but it is also harvested for customary and commercial use as ripe, yellow fruit, which can then also be sun-dried.



**Figure 1: Approximate *Solanum centrale* distribution**

(Robins & Ryder 2004)



**Photo 1: *Solanum centrale* plant**

Research on native foods in Australia has increased over the past 10–15 years (see research reports published at [www.rirdc.gov.au](http://www.rirdc.gov.au)). This has resulted in a series of reports that have dealt with issues from food safety, toxicology (Hegarty et al. 2001) and market prospects (Cherikoff 2000) to the cultivation of either specific species or a range of species (Ryder & Latham 2004). However, there has been little coordinated effort in native food research across the value chain in a single project, nor has there been such a serious attempt to engage Aboriginal people in the participatory approach undertaken in this project. The research reported here focused primarily on desert native food species with a particular focus on *S. centrale*.

The native foods industry is largely based on traditional Aboriginal knowledge of what is edible from the Australian flora and fauna. The industry also involves Aboriginal people at various levels. However, there are many unresolved issues relating to the roles played by Aboriginal people and subsequent questions about what benefits they may be gaining from the industry. Traditional knowledge and traditional methods are being used, but little is really known about how Aboriginal people may wish to be involved, nor how they are either benefiting from, or being bypassed by other participants in, the industry.

The industry itself is still growing and suffers from the well-known problems of fledgling new crop industries (Fletcher & Collins 2004a, 2004b). These include, for example, matching supply with demand, market development, development of production capacity, and education and awareness. The industry is also based on a small number of small to medium businesses, which are not able to make large investments in research and development. Also, the industry tends to be fragmented, although some industry participants certainly favour cooperative approaches.

In the case of the Australian native food plants we have the added challenge of plant domestication (in the western scientific sense). For many desert food plants there is a wealth of genetic diversity that could be developed appropriately to generate wealth for the people of the desert region from which the plants came.

One of the major goals of the Desert Knowledge CRC (DKCRC) is to facilitate the development of enterprises by Aboriginal communities or interests that will improve their livelihoods. Such enterprises will need to be focused on species that have the potential to provide an income stream for participants. *Solanum centrale* has been identified as a species that has growing market demand and is therefore emerging as an important bush food plant. It is being cultivated in various parts of Australia, including SA, NT and WA, but it is thought that a large proportion of fruit currently going into commercial food products is harvested from the bush.

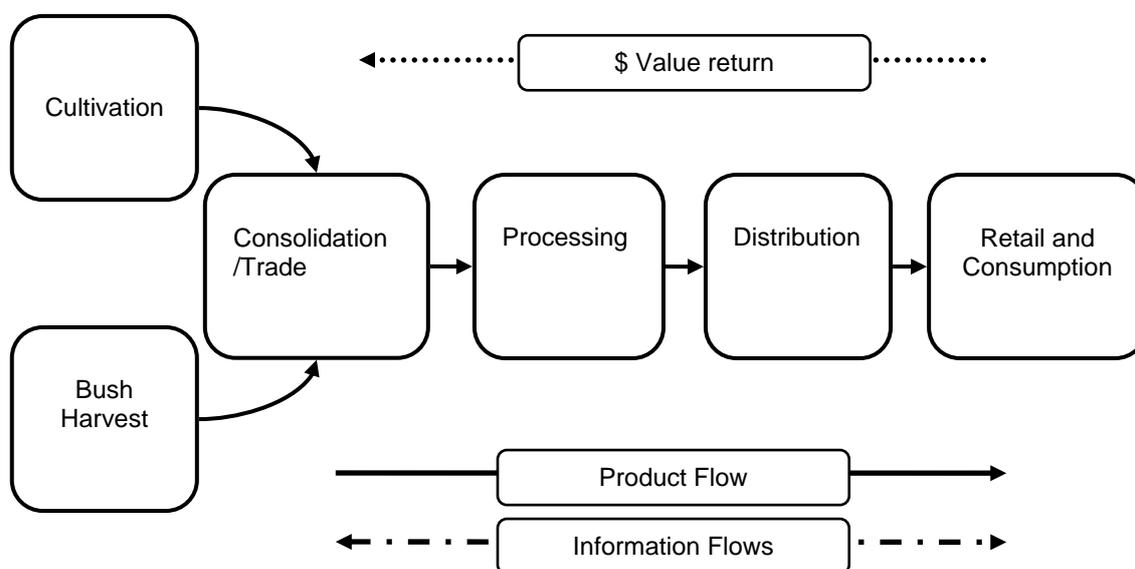
This project aimed to help the native foods industry expand, focusing on desert species, especially *S. centrale*. For example, we aimed to create opportunity through genetic and plant improvement studies, accompanied by the development of appropriate intellectual property–sharing models. We also aimed to facilitate the sustainable development of bush harvest activity and to solve problems in post-harvest storage of produce.

The research team looked to build effective partnerships with Aboriginal people who are involved in both bush harvest and cultivation of bush produce, through cross-cultural learning about the value of traditional methods to the native foods industry. This research intended to address one of the major and ongoing goals of the DKCRC, which is to facilitate the development of enterprises by Aboriginal people or interests that will improve livelihoods by providing an alternative source of income for desert Australians.

## 1.1 Components of the sustainable bush produce systems project

The project is based around a value chain approach (Figure 2) in which the research subprojects are targeted as areas of weakness and where maximum benefit to desert people can be gained.

The set of subprojects that formed the first round of work in this area was developed from a stakeholder workshop held in Adelaide in March 2004. Project proposal development continued through substantial liaison with industry and researchers until October 2004. A second stakeholder workshop was held during the project (October 2005) to report results and to obtain stakeholder feedback.



**Figure 2: Bush foods economic value chain**

The research comprised the following subprojects:

- Sustainable bush harvest
- Post-harvest storage and produce quality
- Horticultural production of *Solanum centrale*
- Genetics and plant improvement
- Steroidal glycoalkaloids in the fruit of *Solanum centrale*
- Aboriginal livelihoods and the emerging bush produce industries.

This working paper documents the research findings from each subproject except that about post-harvest storage and produce quality, which is reported on in De Sousa Majer et al. (2009). Each chapter reports on the context, rationale, results, discussion and recommendations associated with the research undertaken.

### **1.2.1 Sustainable bush harvesting: exchanges between traders and harvesters**

This subproject examined factors that influenced the sustainability of harvest from natural ('wild') populations of bush food seeds and fruits. In central Australia, there has been a small-scale commercial trade in bush produce for more than 30 years. This research focused on exchanges between traders and harvesters, because they were found to be critical to the sustainability of trade within the context of the wider economic value chain. Traders were both Aboriginal- and non-Aboriginal-owned businesses. Subsequent research focuses on bush harvest activity exclusively conducted by Aboriginal harvesters.

The research investigated the nature of trader operations in terms of who managed the businesses and how, what species were traded for what purpose, from where those species were sourced, what tasks and roles the traders fulfilled and what motivated them. The research then identified key sustainability factors that underpinned the exchanges between Aboriginal harvesters and the trader enterprises.

Major findings included identification of the critical roles trader enterprises fulfilled, the influence of rainfall on extreme variations in trade weights for particular species and trade in a suite of species for food and land rehabilitation purposes. Bush resource harvesting and trade has provided a relatively small, highly variable income for traders and harvesters over many years. Traders have developed multiple strategies to accommodate this variation. There appear to be significant non-monetary benefits from trade, but these were insufficient for either traders or harvesters to be reliant upon trade as a sole income. A preliminary assessment of the ecological sustainability indicated low species vulnerability to overharvest and likely secondary ecological benefits from careful harvest management such as monitoring and burning. Assessments of ecological sustainability of the central Australian trade were confounded by extrinsic ecological drivers (rainfall). Furthermore, it was concluded that in central Australia social and economic factors had a more powerful influence upon the sustainability of bush resource trade than ecological factors.

### **1.2.2 Post-harvest storage and produce quality**

This research activity is reported on separately in De Sousa Majer et al. (2009). It focused on post-harvest handling of *S. centrale* fruit. Cultivated and/or bush-harvested fruit can exhibit insect pest infestation, and this has been regarded as a major problem in the industry as it causes economic loss and has implications for food safety. These insect pest species had not previously been identified, nor had research been done to solve this pest infestation problem in stored *S. centrale* fruit. A reliable supply of good quality *S. centrale* fruit is a prerequisite for a sustainable and expanding industry with export potential.

This research sub-project aimed to:

- identify the main stored-product pests responsible for damage to *S. centrale* fruit, and post-harvest treatments and optimum storage conditions that preserve produce quality
- develop post-harvest handling technology that can be used for both the bush harvested and cultivated crop in a variety of situations.

Various post-harvest disinfestation methods were tested, focusing on non-chemical methods. The research in this area evaluated different storage environments, particularly the effect of elevated temperature and altered gas composition on reducing infestation by insect pests. This work is complete and is presented in a separate report (De Sousa Majer et al. 2009).

### 1.2.3 Horticultural production of *Solanum centrale*

While bush harvest activity is important and should remain as a component of the native foods industry, horticultural production of native food plants is also desirable, and is increasing, for several reasons. For crops such as *S. centrale*, supply from the bush is highly variable, with a good crop occurring only every 5–8 years, depending on seasonal conditions. Minor harvests can be expected in between these high yield events, but the key point is that supply is highly irregular and unpredictable.

In order to develop in an organised way, the native foods industry needs to have access to quality produce that is available reliably, in appropriate quantity. Also, while many Aboriginal groups in the desert region do have access to bush harvest activity, not all communities have this option. Aboriginal groups in the urban and peri-urban areas also may wish to participate in the native foods industry and one way to do this is via horticultural production. Indeed, communities that engage in bush harvest may want to cultivate *S. centrale*, for example, to ensure reliable supply when the bush harvest is poor. In addition, western-style crop improvement has begun with some of the desert region native food species (e.g. *S. centrale*, limes, quandong), and these improved plants must be cultivated from nursery-propagated stock plants.

The actual horticultural production systems are in the very early stages of development. It is not known, for example, how *S. centrale* must be managed in horticultural production to ensure a reliable yield year after year. The management of *S. centrale* in cultivation may well be improved by using local Aboriginal knowledge about augmentation or management of the bush harvest (e.g. by soil disturbance, water management, fire management; see Peterson 1979).

In this sub-project, *S. centrale* plants originating from four different locations or regions in central Australia were planted in small horticultural plots in four locations (e.g. on outstations) to help us determine what characteristics have genetic versus environmental origins. We also aimed to find out more about how to produce good quality *S. centrale* crops.

### 1.2.4 Genetics and plant improvement of *S. centrale*

This subproject aimed to examine the development of new food products with a distinctly Australian flavour. New product development and market acceptance requires reliable sources of marketable product, preferably with highly valued palatability. At present, desert bush foods are primarily obtained for market through bush harvest activities, with some efforts to establish plantations. The bush harvest plant material collected is highly variable, both in availability and palatability. Thus, for the benefit of industry development, we need to understand the basis of variability in plant characteristics, both desirable and undesirable.

Plant variability is determined by a combination of genetic and environmental factors. Many key plant traits are controlled by plant genotype. Traits such as palatability are the result of a combination of gene products, usually involved with plant anti-herbivory defences. One of the first steps in the production of cultivated lines is to establish the basis for plant variability in bush populations and identify a desirable plant ‘ideotype’. Taking this approach using morphological, environmental and genetic tools, a detailed understanding of how the plants vary may be established.

The research conducted in this subproject aimed to contribute to the future success of both the bush harvest activity and the cultivation of *S. centrale*. Aboriginal communities in the desert region are interested in cultivation of these native food crops, and some have begun to do so. Given that the produce is, or can be, grown for both local community use and sale to the commercial sector, this research can potentially also benefit the industry as a whole in several ways.

### **1.2.5 Steroidal glycoalkaloids in the fruit of *Solanum centrale***

The fruit of many *Solanum* species contain steroidal glycoalkaloids, which are bitter and toxic compounds. Whether these glycoalkaloids present a problem with food safety and taste in foods derived from *Solanum* depends on the chemical nature of the glycoalkaloids and the levels present in the produce. For example, the outer layer of greened potatoes contains high levels of the compounds  $\alpha$ -solanine and  $\alpha$ -chaconine (Friedman 2006). While the immature green fruits of *S. centrale* are very bitter, the ripe fruits are very often sweet or only slightly bitter. Hegarty et al. (2001) reported that the main glycoalkaloid present in the fruit of *S. centrale* was  $\beta$ 2-chaconine. As a result of their research, Hegarty et al. (2001) recommended that commercial batches of *S. centrale* be monitored for levels of glycoalkaloids.

In this project we investigated the nature and levels of glycoalkaloids present in the fruit of *S. centrale* in an attempt to confirm the results of Hegarty et al. We were unable to find evidence of  $\beta$ 2-chaconine but did find a number of other steroidal glycoalkaloids and closely related compounds in the ripe and in the green fruit. The pattern of glycoalkaloid compounds present appeared to vary between *S. centrale* from obtained different sources.

### **1.2.6 Aboriginal livelihoods and the emerging bush produce industries**

The aims of this PhD project are to generate knowledge of the impacts of involvement in bush produce industries on Aboriginal people and communities using a participatory action research approach. This includes consideration of how Aboriginal people and communities participate, how they prefer to participate, and how they can be involved to maximise the benefits to them.

There are numerous potential benefits from involvement in the industry, but there is also a range of potential negative impacts. This project investigated the underlying assumption that involvement in bush produce industries is inevitably good for Aboriginal people and their communities and aimed to provide a foundation for future developments that maximise the benefits and minimise the negative impacts.

The project uses a 'sustainable livelihoods' framework developed specifically for Australian contexts, and a case study methodology. This subproject began in February 2006. The candidate has engaged with the residents of Aboriginal settlements where case studies and data collection have begun.

## 2. Harvester–trader exchanges: a critical element of sustainable bush harvest to 2006

Fiona Walsh and Josie Douglas

### Acknowledgements

The central Australian bush product traders described in this paper generously shared their time and expertise. Their practice and knowledge forms this basis of this paper. In particular, traders based in Alice Springs – Rod Horner, Jock Morse and Peter Yates – were critical to this research and development of the wider Australian bush products industry.

Members of the *Merne Altyerr ipenhe* (Food from the Creation time) Reference Group suggested subjects for further investigation in this research. They provided inspiration and encouragement in the often challenging cross-cultural environment in which we live. Past and present members of the group are MK (Margaret Kemarre) Turner (Arrernte, OAM); Veronica Perrurle Dobson (Eastern Arrernte); Myra Hayes (Arrernte); Lorna Wilson (Pitjantjatjara); Bess Price (Warlpiri); Rayleen Brown (Kungkas Can Cook), Gina Smith (Warumungu, Kungkas Can Cook); Sandy Marty (CLC representative); Maree Meredith (CLC representative).

Aboriginal harvesters provided initial insights into bush product trade from their unique perspectives, and we look forward to future work with them.

Jocelyn Davies (CSIRO), Michael La Flamme (CSIRO), Tony Cunningham (CDU), Michelle Waycott (JCU), Craig James (DKCRC) and Jenny Cleary (DKCRC) provided constructive feedback on the interpretation and presentation of results that were incorporated into this paper. Administrative, library and technical support was provided by Alice Springs CSIRO staff (Mitchell Jones, Margaret Friedel, Teresa Shanahan, Marita Thompson and Joe Breen). CSIRO Sustainable Ecosystems in Perth provided logistical support during the writing of this report. Thank you to all.

### 2.1 Introduction

Little has been documented about the nature of bush harvesting and trade in native plants for the commercial food industry from desert Australia during the past 30 years (e.g. NTG 2001, Morse 2005).<sup>1</sup> The research reported here was to address the questions:

- What are the drivers of bush harvest activity (market drivers and social drivers)?
- What factors determine who harvests and where?
- There were several ecological questions: are the same plants or same sub-populations of plants stripped of seeds/fruits each year?
- Is this activity affecting soil seed banks, recruitment, survival and longevity of the plant resources?
- Is harvest improving or decreasing the quality and quantity of resource harvested?
- Are traditional management techniques being used to maintain supplies?

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<sup>1</sup> The *Merne Altyerr-ipenhe* (Food from the Creation time) Aboriginal reference group have consistently asked that the term ‘bush foods’ be used rather than ‘wild foods’, as ‘bush foods’ is the term commonly used, it has a clear Aboriginal association, and it does not imply that the plants are ‘wild’ and not cared for. Similarly, they prefer the term ‘bush harvest’ to ‘wild harvest’.

While there are no data available to answer these in western science circles, there may well be traditional knowledge and practice being followed that ensure sustainable harvest is undertaken. It was an initial aim of this research activity to combine the western science perspective with traditional knowledge and management to understand what, if any, problems are being created by bush harvest and to indicate directions for further research and action on these problems.

However, it became apparent very early in the development of the research and engagement in this sub-project that a prior research process was required before the questions above could be answered. While seeking to engage the bush-harvesters in central Australia, the research team began to recognise the importance of traders in the bush harvest process as they related to supply of *Solanum centrale* for the bush foods industry. Consequently, the research questions changed so the team could focus on this initial step in the research process. Foundational research related directly to the process of trading in bush harvest is thus presented in this report. Additional research around sustainability of bush harvest and traditional management techniques will be addressed in the second stage of planned ongoing bush products research.

Trade based on the sale of natural resource products or non-timber forest products (NTFP) has been long established and functional in many parts of the non-western world (e.g. Campbell & Luckert 2001). Natural product sale was the historical basis of monetary economies. Plant and animal products form the backbone of many rural marketplaces. In recent years development agencies and others have encouraged Indigenous and other local groups to form enterprises and harvest and sell local plant and animal resources.

For generations, the economy of Aboriginal people in Australia was based on the subsistence harvest of natural resources. Bush foods, medicines and other products were collected for domestic family use (Latz 1995). Species were selected, manipulated and managed by Aboriginal people in multiple ways (Walsh 1990). Over more than 5000 years, desert Aboriginal people have traded bush foods. Raw and processed products were traded and exchanged through kinship networks that extended across Australia (Akerman & Stanton 1994). It is likely that from early contact with Europeans, bush foods and other products were exchanged for store goods. There are records in central Australia of cross-cultural trade in native tobacco, animal scalps and other products from the 1930s. The monetary exchanges for seed produce began in the early 1970s and were led by Jack Cook, then by Rod Horner in conjunction with Warlpiri and Anmatyerr pickers (Horner 2001).

Customary harvest continues to provide non-monetary benefits to Aboriginal people who live in remote areas of tropical northern Australia, the Western Desert and central Australia. In recent years, there have been few assessments of the significance of this harvest in terms of volume, dietary proportion, nutrients, connection to cultural history or other values. However, observation and descriptive evidence suggests that the use of bush foods, medicines and other resources for family sustenance and/or recreation continue to be of high significance to Aboriginal people.

In tropical environments of the NT, the harvests and commercial sale of plant products for food and medicine has developed only relatively recently. A significant review of tropical species with potential was conducted (Whitehead et al. 2006). Importantly, it canvassed species potential from a variety of criteria that included market potential. Recently, government agencies and others have encouraged the development of natural product enterprises in efforts to secure employment and income alternatives to welfare (NTG 2005, DIA 2005). Research and development has emphasised the compilation of inventories of potential products, the ecological characters of harvest species and their ecological sustainability (e.g. Morse 2005). A key difference between northern and central Australia

appears to be in the presence and active operation of traders (L Alford [Manager, Greening Australia NT] 2005 pers. comm. 22 November).

By contrast to northern Australia, in central Australia there has been established trade in bush produce (NTG 2001). Researchers, harvesters and enterprise managers with an interest in establishing bush food enterprises based on bush harvest have sought to find out how the traders in central Australia operate. There is considerable interest in understanding how to improve the potential opportunities for existing and new bush food enterprises based on bush harvest.

If bush harvest of *S. centrale* and other species in desert Australia grows as market demand increases, questions emerge about the sustainability of the harvest rate coming from the desert region. Studies of other sorts of bush harvesting, and in other countries, have shown that the effect of repeated harvest of plants and plant parts for human use (e.g. commercial trade, personal consumption, medicinal use) has impacts that lower yield and threaten sustainability (e.g. Cunningham 2001). In Australia, possible problems arising from over-harvesting have been highlighted in studies from northern Australia, although most harvesting currently being practised appears to be sustainable (Whitehead et al. 2006). Even plant species with comparatively high economic values and felled for artefact production show evidence of only localised declines (Koenig et al. 2005). In a study by Desmond and Rowland (2000), it was concluded that social and economic factors, rather than ecological ones, had a greater impact upon the sustainability of Aboriginal enterprises based on natural resources.

### 2.1.1 Purpose of this research

No previous research is known to have investigated the roles of bush food, seed and product traders in Australia. The bush harvest research project was conceptualised as one of a number of integrated subprojects of the ‘Sustainable bush produce’ project. This was significant, as rarely had bush food products been researched in a ‘whole of chain’ approach (Figure 2).

While questions about the ecological sustainability of sustainable bush harvest are important, we took a whole-of-chain approach to understand the traders<sup>2</sup> and through them, the harvesters. The first research step was to identify and contact those who traded bush foods, and request contacts for the harvesters from whom they bought. Individual harvesters were invisible to all but those with whom they traded. Three traders were known to project staff, as they had intermittently contributed to the project’s development (Jock Morse and Peter Yates from Outback Bush Foods and Janet Chisholm from Napperby Station/Wimbrandt Pty Ltd). They identified an additional two traders to contact (Frank Baarda from Yuendumu Mining Company Pty Ltd and Rod Horner).

The traders were a critical stepping stone to the harvesters. In early contact with the traders it was apparent that they were experts in the processes of trade that linked Aboriginal harvesters to a wider commercial market. Traders were an important research component because they:

- identify who has traded bush products, where, what, how much and the tasks involved in these enterprises
- document the practices and knowledge of traders who play an essential role in the economic value chain
- document interactions between traders and Aboriginal harvesters
- examine trader opinions of factors that contribute to the sustainability of their enterprises
- recommend how the industry can grow to bring improved benefits to Aboriginal and other desert people.

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<sup>2</sup> People who buy and sell bush products are referred to as ‘traders’. See section ‘What do traders do?’ for further explanation.

Relations and exchanges between traders, processors and retail outlets are not examined here. The focus of this work is upon the exchanges between traders and harvesters; however, to give this context the operations of the traders receives substantial attention. This research is being followed by further research about the activities and interests of Aboriginal harvesters in central Australia, and will be published elsewhere.

Another significant area of project evolution lay in the interpretation of 'sustainable'. As noted above, the original proposal was partially ecological in its orientation; however, an early interview with Aboriginal harvesters and discussions with bush food traders showed that they did not want to focus only on ecological issues. Their accounts and issues of bush food trade were far wider and included historical, economic, social, political and other elements. It was deemed that a broad approach to questions about the sustainability of bush harvest of bush foods was necessary.

The concept of sustainability has evolved over the past two decades. A schematic integration of economic, ecological and social domains was presented in the Brundtland Report (WDEC 1987). This was a landmark and continues to be used as a descriptor of sustainability (e.g. Cunningham 2001). Most significant was the inclusion of the social domain and equitable weighting of it with the economic and ecological domains (Venning & Higgins 2001). It will be the basis for the discussion later in this section.

In central Australia, four main enterprises have bought bush products from Aboriginal people. These enterprises have existed for decades without significant external subsidies (NTG 2001), suggesting a high level of resilience. What are the features of sustainability of these bush product enterprises?

This sub-project report is structured into several parts: the background to this particular project is outlined; research methods are summarised; the main features of bush product trading are described in terms of who traded what, where, when and why; the economic, social, cultural and ecological factors that contributed to the sustainability of the existing enterprises are synthesised; and future opportunities and challenges are considered.

## 2.2 Methods

The ethics framework developed within the project was based on multiple sources, including Australian Institute for Aboriginal and Torres Strait Islander guidelines for ethical research (AIATSIS 2000), DKCRC Ethics Protocols (DKCRC 2003) and Central Land Council Protocols (CLC 2005) as well as the previous experience of researchers. A flyer with a plain language explanation of the project and a project-specific Informed Consent form were compiled and tested.

Approval to conduct the research was obtained from the Central Australian Human Research Ethics Committee (CAHREC) in September 2005 (following literature review, application, correspondence and presentation). An application to the Central Land Council (CLC) for Special Purpose Permit to enter Aboriginal land to conduct research was approved in August 2006.

A combination of participatory, ethnographic and qualitative research approaches from the social sciences has been used in this research. The methods included interviews, text analysis, informal discussion, workplace visits and participant observation on buying trips with bush product traders of central Australia (Table 1). Interviews were conducted with six employees and associates of the four main bush product traders in central Australia. These were Peter Yates and Jock Morse of Outback Bushfoods, Rod Horner, Janet Chisholm of Wirrbrandt

Pty Ltd and Frank and Wendy Baarda of Yuendumu Mining Company PL (YMC).<sup>3</sup> Interviews and informal discussion were also conducted with people who had previously been involved in bush product trade but had withdrawn. This was Thisbee Purich of Ngaanyatjarra Pitjantjatjara Yankunytjatjara Women's Council (NPYWC) and Marilyn Cavanagh of Yalke Products.<sup>4</sup>

A list of potential interview questions was compiled following informal discussion with some of the people listed above. Additional questions were included after informal discussion with CLC staff (David Alexander, Manager, CLC Land Management). The *Merne Altyerre-ipenhe* (Food from the Creation time) Reference Group also added subjects they wanted in the interviews (see Acknowledgements). The questions were trialled with Yates, Morse and Horner, then refined. Appendix 2 lists the interview questions. All interviewees were offered payment of \$40 per hour for the time of their interview and associated discussions.

A project overview, a plain language informed consent form and the interview questions were provided to interviewees beforehand. All interviews were done face to face. The researchers visited the work premises of each trader. Walsh and Douglas undertook trips from Alice Springs to Napperby Station and Yuendumu. Walsh and Mitchell interviewed Horner. Other interviews were conducted by Walsh alone. Interviews were recorded on mini-disc recorder, downloaded and transcribed by a transcription service. The duration of the interviews was from one to two hours. The interviewees were provided with the transcript after their interview.

A keyword list for the interviews was compiled. Initially, two interviews were keyword coded, simply by highlighting key subjects on printed copies and margin notes. Advice from two social scientists was that the sample size, limited as it was by the number of traders, was too small for quantitative analysis using NVivo or similar software. Interview information was synthesised based on the repeated identification of particular topics. Quantitative information was extracted by a finer-detailed coding of particular subjects. The number of times a subject was raised was recorded.

Three staff from the four trader companies voluntarily invited the principal researcher on trading trips. This resulted in two trips to Epenarra to order then purchase Acacia seed and an ordering and buying trip to 12 settlements in the Sandover Highway and River region. These trips were important geographic reconnaissance of the remote settlements and offered the opportunity to observe the traders at work and to make preliminary contact with harvesters and key people (including traditional owners and interpreters) in these settlements. Observations on these trips were recorded in field note books.

Digital photographs of the traders and their workplace premises were taken during visits to the traders' workplaces and on the trading trips. Permissions were sought and granted on most occasions. Requests not to photograph commercially sensitive subjects, such as the amount of produce in storage, were respected.

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<sup>3</sup> Wendy Baarda is not an employee of YMC; she has been a school teacher at Yuendumu for 25 years. Several people recommended that we interview her in respect of her long experience with Warlpiri women who harvest. Also, Wendy had visited Niger with Rosie Nangala Fleming, Freda Napjarri and Jock Morse to demonstrate experiences in the use of *Acacia* seeds for food.

<sup>4</sup> Data from these interviews will also be used in a forthcoming report on harvesters, their activities and perspectives.

**Table 1: Different methods used in research and the outputs from them**

Method	Purpose
Semi-structured interview	Quotes and synthesis
Informal discussion	General information and quotes
Text analysis	Qualitative and quantitative synthesis
Participant observation on trading trips and to workplaces	General information and photos

Informal contact and discussion was also maintained with the Alice Springs-based traders. This was generally by telephone or email contact initiated by the researcher or the trader. The primary purpose of this contact varied (e.g. organising of a course, advice of a forthcoming event). Information about recent bush product trade and associated matters was sometimes exchanged during this contact. Generally, the researchers kept brief notes on the contact. The amount of contact between the researchers and each of the traders varied (Table 2). It ranged from fortnightly to intermittent.

**Table 2: Researcher-trader interview times and frequency of contact**

Trader	Frequency of contact approx.	Interview dates	Trading trip dates
Outback Bushfoods	fortnightly	17/12/04, 8/5/06	15–16/10/04, 2–3/11/04, 7/5/06
Horner	monthly	31/3/05	29–30/11/05
Yuendumu Mining Company (YMC)	bimonthly	3/5/05, 3/8/05	-
Wirmbrandt	intermittent	2/8/05	-
Ngaanyatjarra Pitjantjatjara Yankunytjatjara Women's Council	monthly	14/12/04	-

Traders were invited to relevant workshops and presentations associated with the research. For example, all but YMC attended and contributed to a workshop in October 2005 that reviewed research progress on all the 'Bush Produce' sub-projects.

The research focused on the five-year period from 2000 to 2005. It also sought to synthesise the history and recent operations of the enterprises. Direct quotes from the traders were used to shape and give structure to this report. The traders are highly experienced people who provided considered and articulate reflections on their enterprise operations and motivations. It was critical to keep their voices as strong and accurate as possible.

## 2.3 Results and discussion 1: who, what, where, why did the traders operate

There are four main traders of bush foods and seeds in central Australia. These people buy direct from Aboriginal harvesters (Photos 2 and 3). Each trader is a small company with less than three full-time employees but equivalent to or less than one full-time equivalent (FTE) employed on the bush product component of the enterprise. Bush foods comprise only one of several income sources for each business. Each company is owned and operated in central Australia.



**Photo 2: Anmatyerr women from the Ti Tree region and a researcher search for *Akatyerr* (*S. centrale*) in the southern Tanami Desert**

Traders generally had no direct role in harvesting trips. (Photo by Fiona Walsh)



**Photo 3: Harvesters from Wetengerr (Epenarra) with drums of *Nyterm* (*Acacia sericophylla*) ready to sell to traders**

(Photo by Genevieve O'Loughlin)

Major features of their operation are summarised in Table 3. The four major traders had traded with Aboriginal people for between 8 and 36 years. Two were based in Alice Springs and two in or near remote settlements. They had bought produce from 300–500 harvesters, who were from more than eight language groups and lived dispersed across more than 20 settlements. At least 30 species were traded for food and/or land rehabilitation. Species traded in the greatest volumes were *Solaunum centrale*, wirewood seed (*Acacia sericophylla* ex *A. coriacea* ssp *sericophylla*) and mulga seed (*Acacia aneura*). An average of 7.5 tonnes of seed and fruit products were traded each year from 2000–05. Demand from the food and tourism industry has rapidly increased since 2003.

**Table 3: Summary features of trader operations**

Trader	Time of enterprise operation to 2004	Base	Language groups	Harvester settlements	No. of Aboriginal harvesters involved	Species food and rehabilitation	Purchases 2000–2004 (total tonne)
Horner	mid-70s 35 years	Alice Springs	Eastern Anmatyerr, Alyawarr	> 15 outstations in Utopia/Sandover region, occasional Plenty region	~ 150	<i>S. centrale</i> eucalypt seed (rehab. seed & food)	> 3.5
Outback Bush foods	1998 6 years	Alice Springs	Anmatyerr, Kayteye, Alyawarr	6 Mile, Ti Tree, Stirling, Epenarra	~ 100	<i>S. centrale</i> <i>A. sericophylla</i> <i>A. colei complex</i> <i>A. victoriae</i> (other food spp)	~ 20
Wimbrandt Pty Ltd	1993 11 years	Napperby Station	Central & Western Anmatyerr	Laramba, occasional Aileron, Ti Tree	30–50	<i>S. centrale</i> <i>A. aneura</i>	> 7.5
Yuendumu Mining	1980 25 years	Yuendumu	Warlpiri, Luritja, Pintupi	Yuendumu, Mt Allen, Nyirripi	~ 100	<i>S. centrale</i> <i>A. aneura</i> <i>A. ligulata</i> <i>A. victoriae</i> <i>E. camaldulensis</i> (+ 30 other spp)	> 5.7
Totals	~ 80 years cumulative	3 bases	> 8 languages	>20 settlements	~ 400 harvesters	> 30 spp	36.7 tonne 7.3 per year

Several other people or businesses in central Australia have intermittently bought and sold bush foods as raw produce or processed products. They traded low volumes (kilos rather than tonnes). These included Yalke Products, NPYWC, Kungkas Can Cook and the Centre Bush Bus company. The former two groups stopped trading in 2004; the latter two were intermittent in 2005–06.

Yalke Products was a business owned and operated by an Eastern Arrernte family, Marilyn and John Cavanagh. Their bush food and medicine produce came from a small number of eastern Arrernte suppliers and Outback Bushfoods. Their products were oriented to the tourism market. Marilyn described her family's struggle over more than five years to effectively establish their enterprise. There were many reasons why it was difficult, including small market interest; problems with water quality, fences and equipment at their outstation where a horticultural trial was conducted; insufficient time to undertake all tasks from product

sourcing, packaging, direct marketing and financial management; and the needs of a young family and full-time job. They had a break from trading in 2006.<sup>5</sup>

### 2.3.1 Who were the main traders? Business profiles

#### Horner

Rod Horner trained as a Native Welfare Officer then continued work in community development when employed by the Department of Aboriginal Affairs in the 1970s. In 1975 he began to trade in seed. For 35 years Horner bought direct from Alyawarr and Anmatyerr people in the Sandover (Utopia) region. His business was based at his home premises where there was a cooler room, drying racks and a small packing area. He drove an older model two-wheel drive utility to order and pick up produce.

Horner supplied packaged *S. centrale* (labelled *Akatyerr*) to the Alice Springs Hospital and the Alice Springs supermarkets that had a large Aboriginal customer base. Horner was the smallest of the four companies in terms of volume traded; however, he has the longest period of operation.

#### Yuendumu Mining Company PL (YMC)

This company was based at Yuendumu, an Aboriginal settlement west of Alice Springs with a population of approximately 1000. YMC had a board of nine Warlpiri directors and 302 Warlpiri, Anmatyerr and Pintupi shareholders. YMC was managed by Frank Baarda, an exploration geologist who has lived at Yuendumu for more than 30 years. YMC was a private enterprise company financed by a retail outlet, workshop and contracting. It operated a garage and one of two stores in Yuendumu. YMC diversified its business folio with earthmoving contracts, mineral exploration and the operation of an aggregate quarry. As a sideline it purchased and traded native seeds and bush foods (F Baarda [Manager, Yuendumu Mining Company] 2005, pers. comm. 3 May).

Historically, the major portion of YMC sales were seeds for regeneration (particularly of mine sites); however, these sales had declined in recent years as seed provenance requirements became tighter. YMC had a relatively large non-cooled storage space so it could stockpile bush produce. Produce was also held in the cold room associated with the store. YMC vehicles were used to freight produce to Alice Springs and elsewhere. Packaged *S. centrale* (labelled as *Yakajirri*) products were sold to local people through the YMC store, and through the Lajamanu store 500 km north of Yuendumu.

#### Wirrbrandt Pty Ltd

Janet Chisholm began to trade bush foods in 1993. She bought produce from people who lived at Laramba, which is about five kilometres from Napperby Station homestead. About 300 people lived at Laramba on Anmatyerr land. At Napperby Station homestead and store, two cool rooms with a maximum storage capacity of 2 tonnes were used to store produce. Napperby Station vehicles were used to freight produce.

#### Outback Bushfoods (OBF)

This business commenced around 1998. Its directors were Peter Yates and Jock Morse. Yates trained in anthropology and Morse in botany and forestry. This business was based at a home premise where there was a cooler room, drying racks and a relatively large packing area. There was extra storage space off-site. OBF had additional equipment with a thresher, seed cleaning machine, three one-tonne seed silos, a roaster and grinder (donated by NPYWC).

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<sup>5</sup> In 2007, they resumed in preparation and sale of bush medicine products.

OBF used an old 4WD Toyota Troop carrier and trailer or a personal Hilux for travel to remote settlements and to move produce.

OBF is the only one of the four companies to have a high public profile through electronic means and to conduct online marketing (See <http://www.outbackbushfoods.com.au/default.php>). From 2000–05, the company had grown to be the biggest bush foods supplier in central Australia. It also played a significant role in bush food product development and direct marketing. It preferentially sold produce to the Aboriginal catering enterprise Kungkas can Cook in Alice Springs and collaborated closely with them. Peter Yates of OBF initiated and managed the Alice Springs Bush food/Bush food cooking and recipe competition in 2005 and subsequent years.

Common features of the business outlined above were that they were small or micro-enterprises owned and operated by individuals (with the exception of YMC). All the individuals and/or businesses combined income from multiple sources. This was a classic and effective strategy for survival in highly variable environments, particularly deserts. This strategy was necessary to offset dependence on a single income source that may fail.

### 2.3.2 Aboriginal governance roles in enterprises

In terms of Aboriginal ownership and/or governance of these enterprises, the largest of the four trading companies was wholly Aboriginal owned (YMC). Horner had long investigated options for establishing a cooperative among harvesters in the Sandover River region. Outback Bushfoods had an informal cooperative arrangement with NPYWC. However, this fell through before a Memorandum of Understanding was completed. The arrangement was not pursued, partially because the NPY lands were less productive for the major species OBF were trading in. OBF had specified an intent to share ownership with an Aboriginal group in its business plan. Wirmbrandt Pty Ltd notionally facilitated Aboriginal representation on the national institution Indigenous Australian Foods until at least 2006. Interviewees from two of the four enterprises stated that they had been unable to formalise joint arrangements due to financial constraints, and none of them had been able to pursue external funding or assistance to do so.

### 2.3.3 What do traders do?

The first outcome from this research was to adopt the term ‘trader’ to refer to those who buy and sell bush products as ‘traders’. Previously they were being called ‘wholesalers’ or ‘consolidators’. However, this term was inappropriate. It was a misnomer in relation to the variety of roles fulfilled by those who were also merchants, consolidators, traders, buyers, stock agents, network facilitators and support people. The word ‘trader’ has been settled upon because it seemed the broader role. This was highlighted by Yates from OBF:

*We need to be careful with the word ‘wholesaler’. It greatly underestimates the roles of those people ... It suggests the market has some coherence in its own right and that we’re simply fitting in as a link. What’s really going on is that Aboriginal people are only collecting acacias and akatyerr for family use or in response to our requests, so we’re much more active in making it happen. The entire industry is dependent on ... [Horner, Chisholm or us driving and buying] ... It doesn’t matter how badly somebody in Melbourne wants that thing, without us actually being really active and pursuing the people who want to, can do, and will do the collecting, nothing’s going to happen ... A ‘wholesaler’ is a much more passive player in a well-established supply chain, whereas we’re a more dynamic and reflexive part of that chain ... We’re financing the whole thing as well in that we have to pay up front ... we put the money up, we take the risks. It’s a role that Elders or other big agricultural agents play; we’re not just Campbell’s Cash and Carry ... (P Yates [Director, Outback Bush Foods] 2006, 8 May).*

The traders viewed the harvesters as the primary producers. The varied and complex roles, activities and opinions of harvesters and custodians of food plants and lands has been introduced by (Douglas et al. 2006) and will be investigated in future research.

This study identified and collated the following tasks that were undertaken by traders. The main tasks in which harvesters and traders interacted are denoted by an H-T label.

- order produce from harvesters<sup>H-T</sup>
- long-distance travel to pick up produce<sup>H-T</sup>
- receipt of produce from harvesters<sup>H-T</sup>
- weigh and pay<sup>H-T</sup> (Photo 4)
- clean and sterilise produce (Photo 5)
- roast, grind depending on product
- sort and store (Photo 6)
- package and label produce (Photo 7)
- equipment innovation and maintenance
- direct market of products
- supply to processors or consumers (Photo 8 and 9)
- product value add through brand pack
- product experimentation, research and development
- research in 'new' produce potential
- contribution to industry research and development
- industry promotion
- media responses
- financial investment in capital
- financial, stock and business management
- assistance to harvesters with lifestyle and bureaucratic matters<sup>H-T</sup>
- monitor seeding or fruiting of produce<sup>H-T</sup> (Photo 10)

This is a varied suite of tasks that requires specialist knowledge (e.g. species recognition by Aboriginal and English species names), hard labour (e.g. tonnage transport in >35°C conditions), active marketing skills and wide socio-business networks.



**Photo 4: Harvesters from Epenarra wait while Jock Morse of Outback Bushfoods weighs *Nycterrm* (*Acacia sericophylla*) seed before paying them \$20 per kilo**

(Photo by Fiona Walsh)



**Photo 5: Peter Yates of Outback Bush Foods sorts and does secondary cleaning of *S. centrale* fruit on purpose built drying racks**

(Photo by Fiona Walsh)



**Photo 6: Drums of various seed species for land rehabilitation stored at YMC**  
(Photo by Fiona Walsh)



**Photo 7: Rod Horner weighs cleaned and packaged Akatyerr (*S. centrale*)**  
(Photo by Fiona Walsh)



**Photo 8: Yakajirri (*S. centrale*) for sale on shelves at the YMC store (next to the bubblegum)**  
*Yakajirri* (*S. centrale*) was a popular purchase by local Warlpiri consumers  
(Photo by Fiona Walsh)



**Photo 9: Gina Smith of Kungkas Can Cook caterers preparing *Acacia sericophylla* purchased from Outback Bush Foods**

(Photo by Fiona Walsh)



**Photo 10: Jock Morse checks the phenology and seed viability of a *Kalkarti* (*Acacia cole*) stand**

(Photo by Fiona Walsh)



Wiribrandt had bought and sold almost exclusively *Acacia aneura* (Mulga) seed and *S. centrale*. Among the traders, OBF had led the way with the trade of a diverse suite of *Acacia* species for food. Prior to early 2000s, the industry standard had been *Acacia victoriae*. Since 2000, OBF's *Acacia* stock inventory had shifted to a preference for *Acacia sericophylla* and species of the *Acacia colei* complex. In addition, they had traded smaller quantities of about five other *Acacia* species. To date, consumers had not differentiated *Acacia* species, but this was changing with greater consumer experience of taste and texture variations.

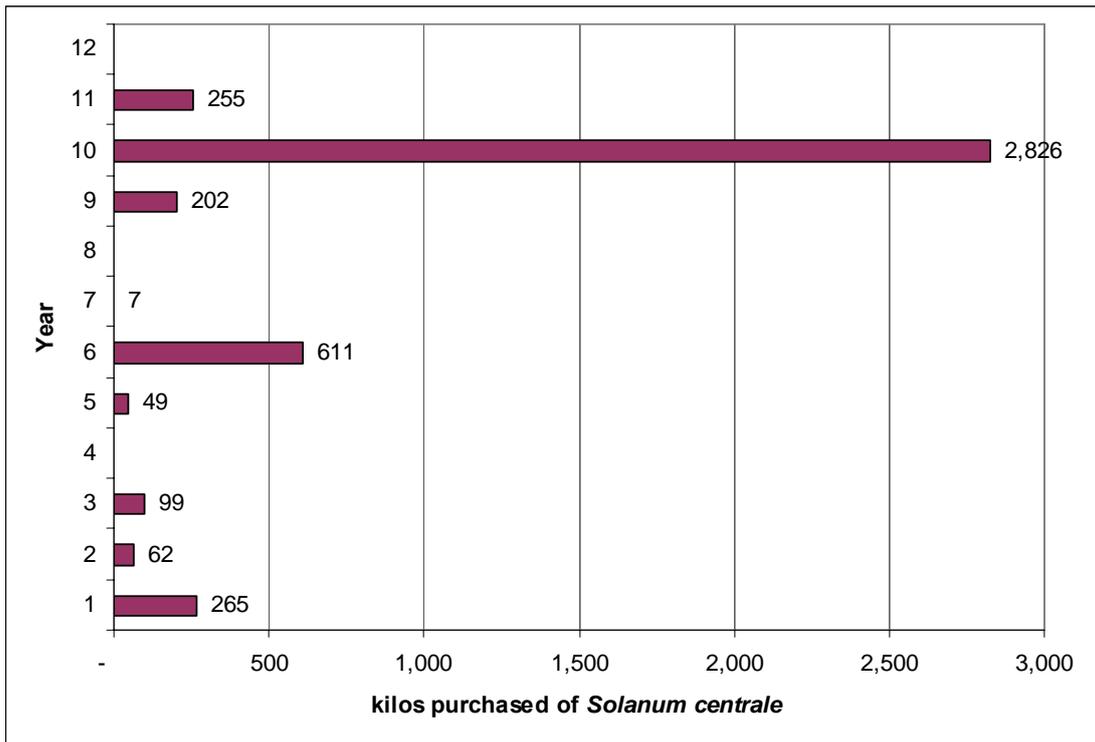
**Table 4: Species or genera traded in largest volumes in central Australia in order ranked by traders**

Warlpiri, Anmaytarr, Pitjantjatjara names	Linnaean name	English standard botanical common names and plant part
Yakajirri, Akatyerr, Kumpurarpa	<i>Solanum centrale</i>	(fruit)
Wakirpirri, Awenth, Kunapuka	<i>Acacia sericophylla</i> (syn. <i>A. coriacea</i> ssp <i>sericophylla</i> )	Wirewood, Dogwood (seed)
Manja, Arteye, Wanari	<i>Acacia aneura</i>	Mulga (seed)
Kalkarti, Alkart	<i>Acacia colei</i> complex ( <i>A. cowleana</i> , <i>A. colei</i> , <i>A. elacantha</i> , <i>A. holosericea</i> )	Kalkardi (seed)
Yarlupu, Arlep, Ngatunpa	<i>Acacia victoriae</i>	Elegant wattle (seed)
Kunjumarra, Aper, Itara	<i>Eucalyptus camaldulensis</i>	River red gum (seed)
various	<i>Eucalyptus</i> spp	(seed)
various	<i>Senna</i> spp	(seed)

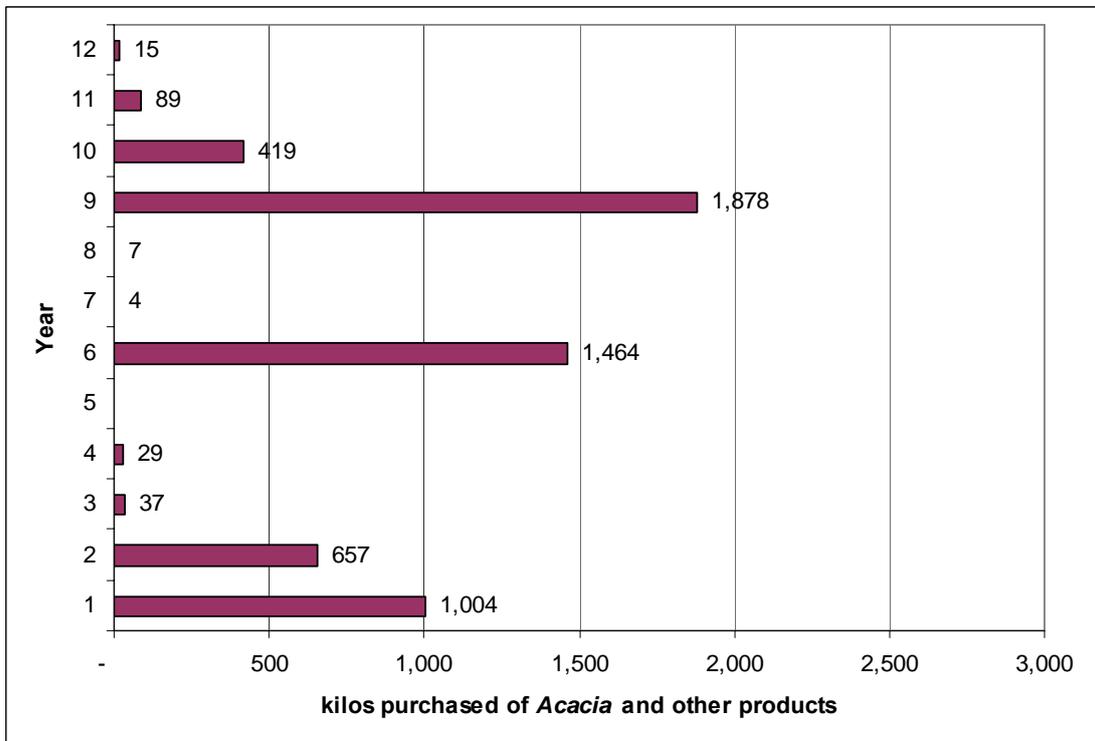
### 2.3.6 Was there inter-annual variation in trade weights?

All harvesters and traders spoke of high variation in the inter-annual weights of species produce that could be harvested or purchased. This was a major challenge in relation to downstream market members who required continuity of supply volume. Harvesters and traders were found to have particular strategies to overcome this inter-annual variation.

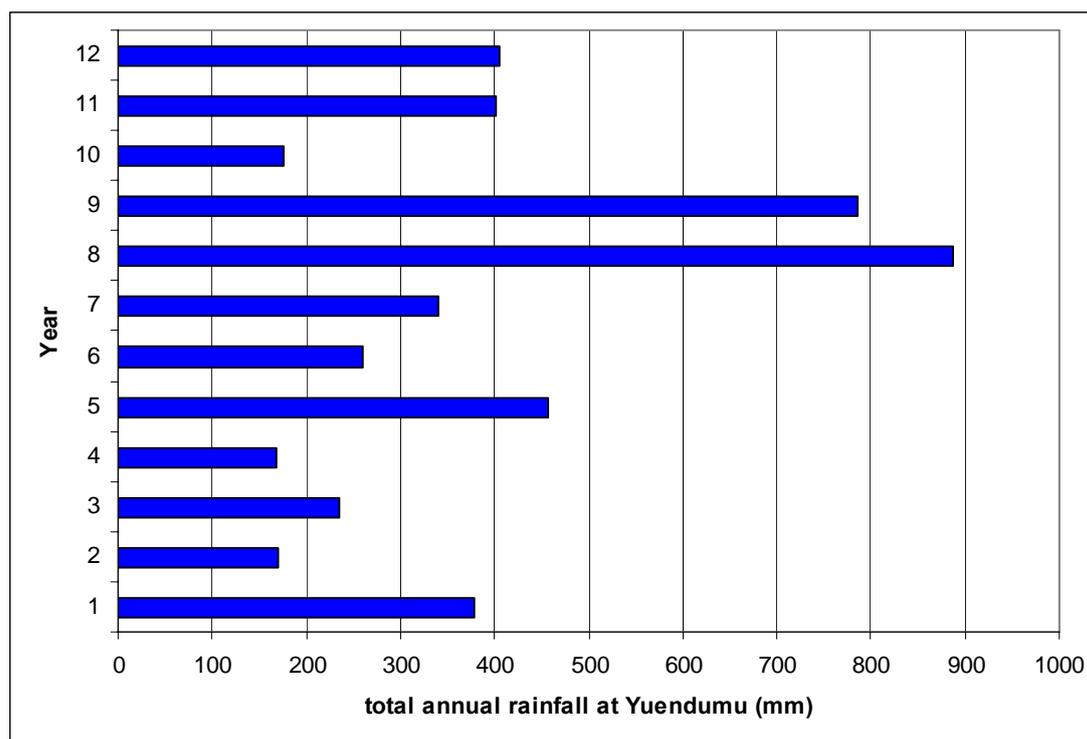
Annual trade volumes for certain species were voluntarily supplied by one trader. This data was for the weights purchased from harvesters over a 12-year period (Figures 4 and 5). Figure 4 describes the volumes purchased of *S. centrale* alone; Figure 5 describes the volumes purchased of all other species combined. The trader requested that their business identity and the years be undisclosed due to being commercial-in-confidence.



**Figure 4: Annual weights of *Solanum centrale* fruit purchased from harvesters by one bush produce trading company over 12 years**



**Figure 5: Annual weights of *Acacia* and other seed species purchased from harvesters by one trading company over 12 years**



**Figure 6: Total annual rainfall at Yuendumu over 12 years**

Figures 4 and 5 demonstrate a wide variation in the weights of *S. centrale* fruit and *Acacia* and other seed species purchased during 12 consecutive years. At its extreme, 2.8 tonnes of *S. centrale* were purchased in one year, and none was purchased two years later. The interviewee and data provider interpreted this variation to reflect variable productivity in the standing crop due to rainfall because, in their recollection, other factors such as the purchase price, potential number of harvesters and their conditions were relatively constant.

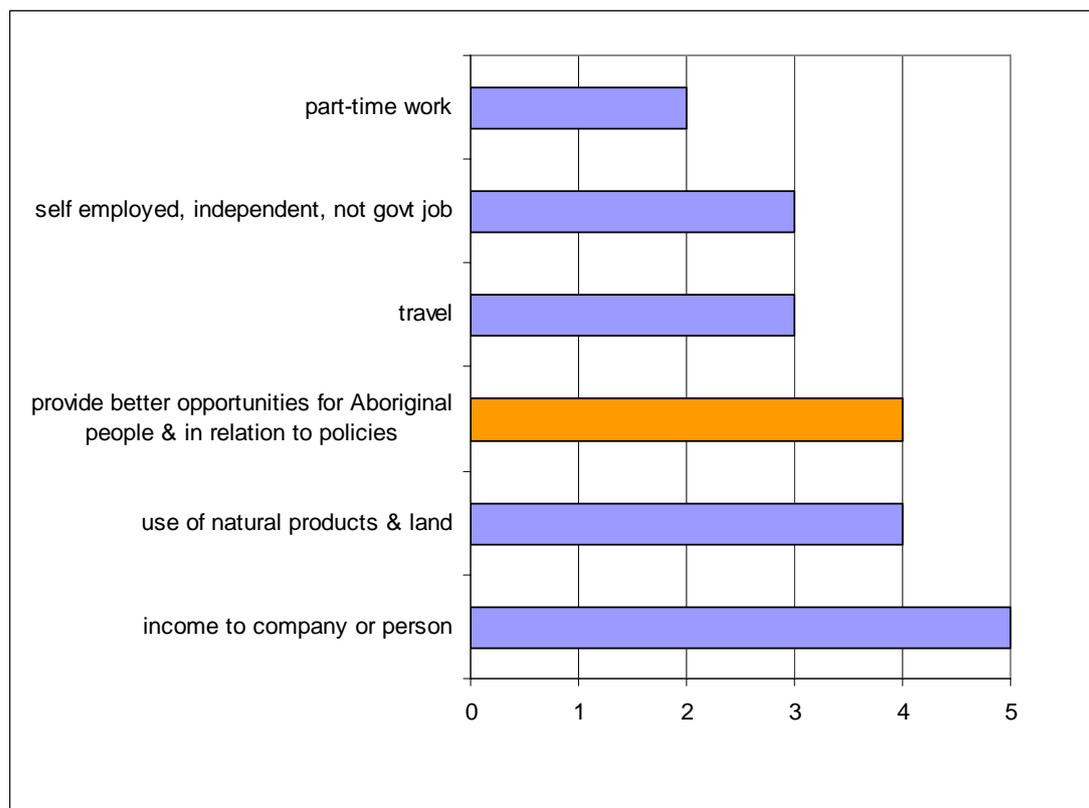
Figure 6 shows the total annual rainfall recorded at Yuendumu (Bureau of Meteorology 2008) for the same years as in Figures 4 and 5. In comparison to Figures 4 and 5, it does indicate a delayed response with larger weights of *S. centrale* and *Acacia* seeds traded after high rainfall periods – for example, in years 6 and 9 after >400mm rainfall. However, it appears that other factors also influence the trade volumes.

In comparing the weights of *S. centrale* fruit and the seeds purchased (Figures 4 and 5), the former was collected in higher weights but not in as many years. All companies had found the *S. centrale* supply to be less reliable than *Acacia* spp. *S. centrale* was a clonal undershrub that reached peak production two to three years after surface disturbance such as burning and grading (Latz 1995); the volume of production was strongly dependent on rainfall, burning and other factors (e.g. Figure 6). *Acacias* include short and long-lived perennial shrubs; some produced seed most at highly predictable times, while others exhibited delayed production responses (Friedel et al. 1994). For example, *A. sericophylla* cropped heavily 2–3 years after high rainfall periods.

Diversification was interpreted, by this study, to be the major strategy by which harvesters and traders overcame this extreme inter-annual variation. This diversification was by different means, including income from multiple non-bush produce sources (all companies), bush produce trade for food and rehabilitation purposes (Horner and YMC), diversification of species traded (all companies) and development of innovative *Acacia* products (OBF).

### 2.3.7 Why do they trade?

The study identified a variety of reasons that motivated traders to undertake their business (Figure 7). The desire to supplement an income was a motivation for all of them. However, the majority of their reasons related to practical actions that provided better opportunities for Aboriginal people rather than a need to earn a high income for themselves or their companies. In total across all the interviews, more than three times the number of motivations (54 vs. 17) related to the provision of better opportunities for Aboriginal harvesters over and above reasons for the benefit of the enterprise or the individual. Traders had a strong philanthropic motivation based on supporting the independence of Aboriginal people who worked to harvest and sell produce.



**Figure 7: Reasons identified by traders for why they trade (number of times cited in five interviews)**

### 2.3.8 Trader reasons for their own benefit

The desire for economic income was a motivation for all trader companies. However, the amount of reliance on this income varied. For some it was a low reliance; as Baarda said:

*[YMC has] a turnover of \$1.2 million per year; the turnover from [bush products is low, for example] ... record sales were in 2002 when we sold \$34 000 worth of seeds and \$20 000 yakajirri ... it is not a big part of our business but it is the most satisfying*

F Baarda [Manager, YMC] 2005, pers. comm. 3 May.

Similarly, the income from bush food sales by Chisholm was said to be 'tiny' (J Chisholm [Wirmbrandt Pty. Ltd.] 2005, pers. comm. 2 August). Both these companies had reasonable income from other sources. The economic imperative to earn from bush produce trade appeared to be higher for Horner and OBF.

All traders had a particular interest in natural ecosystems and land. The use of associated natural resources was a motivation for them. Three of the six traders interviewed came from farming or pastoral backgrounds. They placed a high value on productive land and viewed bush harvest as a form of primary production or a stage before it:

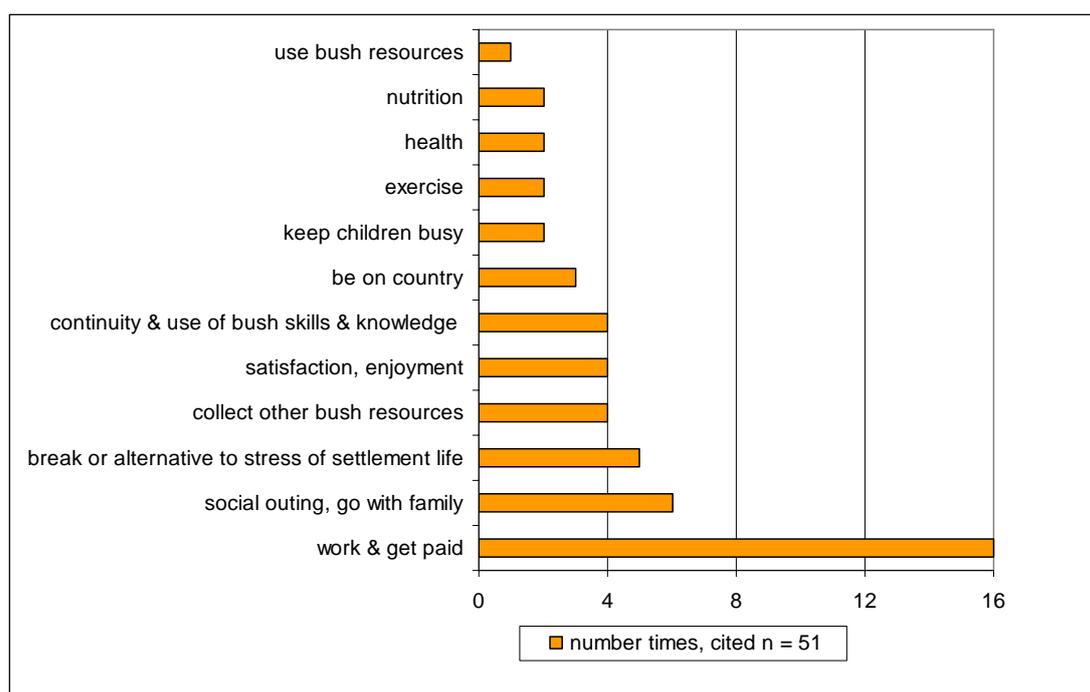
*In the NT, Aboriginal people have more than half of the land area, yet they've got virtually no means of generating wealth or wellbeing from that land ... [Selling bushfoods] allows them to use that land and the resources on it in a way which is culturally appropriate and not artificial, I mean, externally determined and funded.*

J Morse [Director, Outback Bushfoods] 2004, pers. comm. 17 December

This quote also identifies efforts by traders to counter prevailing institutional practices of project imposition upon Aboriginal people and subsequent funding reliance.

### 2.3.9 Trader reasons for the benefit of Aboriginal people

In their interviews, traders spent a lot of time speaking about the benefits of bush harvest to Aboriginal people. Figure 8 gives details of the category 'provide better opportunities for Aboriginal people' that was part of Figure 7. Figure 8 identifies statements made by traders about the benefits they saw for Aboriginal harvesters. Traders were explicit that their roles were in response to historical and present institutions, policies or practices with which they did not agree as they did not genuinely benefit Aboriginal people. Often, these institutions and policies were directed by non-Aboriginal people and systems.



**Figure 8: Reasons identified by traders in relation to Aboriginal harvesters and their families**

Note: number of times cited in five interviews

About 30% of the reasons that traders identified why Aboriginal people harvest and sell to them related to the need of Aboriginal people to earn supplementary income. Social factors that motivated harvesters were seen to be strong by Wendy Baarda, Morse and Yates. For example: 'Groups of women, greatly value the time they get to spend together in the bush

away from the community these are precious times for these women' (J Morse [Director, Outback Bushfoods] 2004 pers. comm. 17 December, see Photo 2). The satisfaction and enjoyment of harvesters was well-recognised by traders.

A very telling comment came from Wendy Baarda:

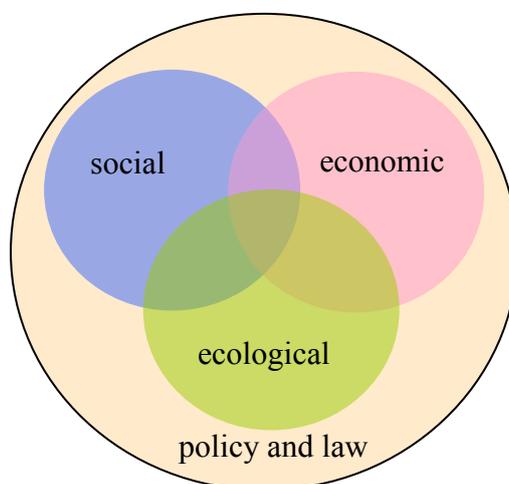
*The old ladies like it [harvesting]. They have a special energy for it. They might have no energy for other things happening here in the community but they have a special energy for getting bush foods. They come alive; they have a new zest for life. It is good for the young people to see that energy.*

(W Baarda 2005, pers. comm. 3 August)

Several traders contrasted the powerful motivation to collect bush foods to the strong disengagement with, even apathy toward, conventional western employment opportunities that some Aboriginal people express. The high level of interest and animation in selling bush foods relative to other activities was described by all traders.

## 2.4 Results and discussion 2: Sustainability of bush produce enterprises: trader–harvester exchanges and trader enterprise characteristics

The previous section provided an overview of bush produce enterprises in central Australia by describing their history, who traded, what they traded, where they traded and why they traded. This section explores factors that have contributed to the sustainability of these enterprises. In particular, it looks at economic, social, cultural and ecological factors associated with trader–harvester exchanges. It also describes some sustainability factors that have contributed to the trader enterprises where harvesters are not directly involved.



**Figure 9: Simple sustainability diagram**

Adapted from Brundtland report World Bank, 1992 (in Cunningham 2001)

### 2.4.1 Sustainable to the present

The four main trader enterprises in central Australia have sustained their operations for eight years and longer, which is perhaps the best indicator of their sustainability. Nationally, about 30% of small businesses fail within their first five years of operation (Bickerdyke et al. 2001). Although, as they are micro-enterprises, home-based businesses or subsidiary activities of companies with other income sources, they do not neatly compare to conventional businesses.

Another key indicator of their sustainability is the continued operation of these enterprises independent of external support. They have persisted without subsidies, grants, tax concessions, relief measures or other forms of Australian, State or local government support. For example, the Northern Territory Department of Primary Industries (now Department of Regional Development, Primary Industry, Fisheries and Resources) provides diverse services related to pastoralism, horticulture and forestry, among others, but no services for bush food harvesting from natural populations (see DPIFM 2008). Some of the bush produce traders suggested that the lack of government support may have contributed to their longevity (Horner, F Baarda, Yates). Others raised the possibility of external support strengthening their expansion (Chisholm, W Baarda, Morse), but all were wary about the possible consequences of it.

A third indicator of sustainability was the large number of Aboriginal people who have voluntarily harvested and sold bush produce to the traders. This is exceptional in a regional context where Aboriginal people in remote settlements rarely choose to or are able to actively engage with conventional labour markets or western economic systems through state or private sectors (Taylor 2005, Tonkinson 2007). As observed:

*Most people have the perception that Aboriginal people are very unwilling to work. And that it's very hard to get people to engage in any sort of activity that earns money. We've found precisely the opposite. Bush food collecting has something about it that capitalises their energy, interests and passion in a way that you don't see in any other Aboriginal industry.*

(J Morse [Director, Outback Bushfoods] 2004, pers. comm. 17 December)

It can be interpreted that bush food harvest and sale was, from Aboriginal viewpoints, a logical extension of customary harvest. Thus one economic sector (the customary one) is extended to engage with the market sector as typified in the hybrid economy concept by Altman (2005).

The incremental growth of these enterprises and the interdependence between harvesters and traders was emphasised by all who were interviewed. Their comments are typified in these by comments, first by Horner, then Morse:

*[The Sandover area] that's where I had contact with people. It's grown, my business was growing with their business ... I've experimented with buying seed and they're the people that experiment with me and it's grown from there*

(R Horner [Trader] 2005, pers. comm. 31 March).

*A most important aspect of the industry in terms of our success is that Aboriginal people who are involved in it won't benefit from it unless we [OBF] benefit from it because our ability to buy seed depends on us being commercially viable and profitable. And conversely we can't benefit from it unless we've got the full confidence of people who are doing the harvesting* (J Morse [Outback Bushfoods] 2004 pers. comm. 17 December).

The following sections examine the economic viability, social acceptability and ecological capacity of bush produce trade. Importantly, it was found that each enterprise applied factors that were seen to be consistent with the cultural practices of remote area Aboriginal people. In summary, it appears that the enterprises operated effectively across each of these domains. The integrated approach would appear to have a 'triple-bottom line'<sup>6</sup> balance or even better with the explicit incorporation of the cultural domain. The main elements within each of these

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<sup>6</sup> Technically 'triple bottom line' accounting requires the identification of monetary equivalents to measure the value of human, natural and economic capital (Hamblin 2001).

domains that have contributed to the sustainability of harvester–trader exchanges are summarised in a schematic diagram and expanded upon below.

### 2.4.2 Economic viability between traders and harvesters

Traders paid harvesters on a per kilo basis. Each trader reported paying cash or cheque to the Aboriginal sellers or harvesters on receipt or delivery (e.g. Photo 4); they did not delay payments to harvesters. The maintenance of good relationships with individual Aboriginal sellers relied on immediate payment. Processes for delayed payments (e.g. bank deposits) were limited, as few harvesters had details of their bank accounts readily available. There were no institutionalised arrangements among harvesters to receive or manage funds (e.g. no companies, trusts or cooperatives), and payment was to individuals. Immediate payments were valued because harvester incomes were low and money was often in short supply, even for daily necessities such as staple foods. This payment system engaged harvesters in a market economy, but one where they do not receive benefits associated with salaried jobs, such as leave and superannuation. This transaction system was similar to that for most artists or workers paid at rates per piece of product.

### 2.4.3 Paradoxes in perceptions of payment and income

There were paradoxes in the perceptions and realities of money earned from the bush produce enterprises. Fair payment to harvesters was the objective of all traders interviewed. A decent personal income was another objective. Those not involved in trade but interested in the welfare of Aboriginal people, such as staff of Central Land Council and members of *Merne Altyerr-ipenhe* Reference Group, were concerned that harvesters might be ‘getting ripped off’.

At least two harvesters with whom there have been preliminary interviews felt they were not paid enough for their labour; however, more than ten others accepted the payment prices. It can be assumed that all Aboriginal people who regularly sold produce made deliberate decisions to harvest and accept the offered prices for their produce. Table 3 shows that from 2000–2004 more than 7 tonne per year of seeds and fruit were traded for rehabilitation and food. Based on a minimum of \$12/kg this resulted in more than \$90 000 per year directly injected into remote area Aboriginal incomes. This equated to about six CDEP position equivalents or 2.5 salary equivalents (at \$30 000) per year. Significantly, these injections came with no start up, capital or recurrent costs to government or other organisations except to the traders.

Trader incomes were low compared with national averages. The highest annual personal gross income a trader received directly from produce sales was reported to be about \$20 000 in 2005. Additionally, at least two of the trader enterprises, like other small businesses, had invested personal funds into infrastructure and working capital. As Yates said:

*Outback Bush Foods got to where we are now, which is barely economically viable, only because Jock Morse put up a lot of money, risked a lot of money up front and I was willing to work for almost nothing in the last six years.*

P Yates [Director, Outback Bushfoods] 2006, pers. comm. 8 May.

One company had also sought and used investor funds to buy stock.

The paradox lies in the annual incomes of traders being higher than the average annual incomes of the harvesters but low on a national scale. Harvesters could increase their income by trading larger amounts of produce when available. Yet they were still in one of the lowest income groups in Australia.

#### 2.4.4 Work, not welfare

The collection and sale of bush produce provided harvesters a return, independence and a purpose:

*There's all this unearned money, unemployment benefits, royalty money which is given out. Us white people control the means of production, the mine, the citrus farm, whatever. and give Aboriginal people a little bit of cash but no employment. With this bush food industry they are the producers, they control the means of production.*

R Horner [Trader] pers. comm. 31 March 2005.

A key ingredient that underpinned the effectiveness of trade in bush produce was the opportunity for harvesters to work and be paid. This was work and income independent of government- and agency-based welfare and royalty systems; the debilitating effect of this 'sit down money' upon people's initiative and morale has been widely recognised (Pearson 1999, Mitchell 2002). By contrast, all traders were motivated to reduce Aboriginal people's economic dependence upon these government-controlled systems. In their interpretation, Aboriginal people valued the work that built on their social relations and bush skills (Figure 8).

#### 2.4.5 Bush products are more than economic commodities

Many bush foods continue to be eaten by Aboriginal families in central Australia. Of the species with commercial value, particularly *Yakajirri*, *Akatyerr* (*Solanum centrale*) and *Nyterrm* (green seeds of *Acacia sericophylla*, wirewood) continue to be eaten. Some commercial species are also key characters in *Jukurrrpa* and ceremony, are frequently portrayed in art, are significant cultural features – for example, are often listed in dictionaries – and many are considered a significant part of the family history of individuals. *Akatyerr* and *Ntyerrm* have characteristics of 'cultural keystone species'. Aboriginal people identified these values to varying degrees or in different ways.<sup>7</sup> For example, senior Aboriginal women placed a strong emphasis on them. Certain Aboriginal people consider themselves to be the custodians of these resources. They do not consider them to be public property, property of the commons or to belong to non-Aboriginal people or their legal systems. These matters have been noted by Douglas et al. (2006) and will be expanded upon in future research.

#### 2.4.6 Cultural consistency of trade

Elements of the economic domain of sustainability overlapped with the cultural domain and vice versa. It was found in this research that bush produce traders recognised, appreciated and worked into the cultural domain of Aboriginal harvesters. The degree varied among the traders. The major aspects of the cultural system the traders recognised included the local nomenclature for bush food species, specific knowledge associated with species, practices surrounding the collection of bush foods on country, harvesting techniques, high skill levels among harvesters and harvesters' expectations inherent in their exchanges and relationships with traders. For example, the traders knew that harvesters undertook other cultural activities while they went on collecting trips, as noted by Morse:

*Selling seed lends legitimacy to their existing motivations to undertake other activities. Those [middle aged and older] women will be out collecting bush tucker, goannas, sugar*

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<sup>7</sup> We have learned from preliminary talks with past harvesters that there have been recent and intense discussions among Anmatyerr people about the appropriateness or other of selling bush foods. After these discussions, some harvesters chose to stop selling, while others did not. Apparently, views differed between individuals, possibly on a generational basis. Further, we have been told by several individuals, independent of each other, that certain species must not be sold because of the significance of their *Jukurrrpa*. Presently these species have no commercial value. Herein is a common dilemma for Aboriginal custodians of land and resources – to inform non-Aboriginal people of cultural values or to retain the secrecy or appropriate disclosure protocols.

*bag ... all the time, if they could. They take the kids out bush, they have time together. Because there are so many other pressures on their lives, they don't get much opportunity.*

J Morse [Director, Outback Bushfoods] 2004, pers. comm. 17 December.

Wendy Baarda reflected on some of the other cultural factors:

*When it's a really good season, older women see all the trees are dripping with seed, all the kalkarti and mulga; it inspires them to go collecting. The money is not really important for some – it is only later, when those first harvesters come back with money that it then attracts other people to go out collecting.*

W Baarda 2004, pers. comm. 3 August.

Implicit in her explanation was the interpretation that collecting resources helped Aboriginal people to maintain the integrity, interaction and productivity of their lands. This was felt by people who had grown up reliant on bush foods, hunting and gathering for their sustenance. Also important was Wendy's observation of different stimuli for different people, in particular with younger generations responding to the economic stimuli.

However, traders gave different weights to the importance of cultural factors; for example, in Chisholm's view:

*People do it for the money, good money. Deeper cultural meanings are limited, a bit of bush tucker, take kids out; they might have a picnic as well ... better to do something they enjoy.*

J Chisholm [Wirmbrandt Pty. Ltd.] 2005, pers. comm. 2 August.

Importantly, this identified a whole domain that needs to be incorporated into understanding the trader enterprises and the ways they operated. It was insufficient to simply include these elements into the social or other domain; although special cultural elements also sit within other domains. The cultural elements were very unique features of bush food harvest and trade. This cultural system has been found to be highly complex and will be investigated in future research among bush food harvesters and Aboriginal knowledge holders.

## **2.4.7 Existing skills developed**

Each of the interviewees identified the expertise of the harvesters as a critical cultural advantage. Specialised skills were required to locate, harvest and clean bush produce from Aboriginal lands. Several of the traders contrasted this to the limited recognition by non-Aboriginal people of an existing skill and knowledge base in Aboriginal settlements. As Wendy Baarda said, in speaking of the monetary payment and appreciation of Warlpiri harvesters who sold produce to YMC:

*Collecting bush foods is something that Aboriginal people like; they can do it, and their skills have value. It makes people feel useless when their skills are not valued.*

W Baarda 2005, pers. comm. 3 August.

This poignant comment was volunteered by Wendy in a discussion about the potential of bush foods in horticultural production. She followed with some comments about the repeated offers or demands by agencies for Aboriginal people to attend training in a multitude of skills, including horticultural production. She said that while Aboriginal people appreciated some of the benefits of training, her point was that people had existing skills that were rarely

recognised and utilised by external agencies. In her view, the lack of recognition of these skills demoralised people.

#### **2.4.8 Social acceptability of trade to Aboriginal harvesters**

The success of bush food trade has depended on many factors associated with its social acceptability to Aboriginal people. This social domain has made a major contribution to the sustainability of these enterprises. It has many dimensions. These relate to social aspects of engagement between the traders and the harvesters, and to social interactions between the harvesters themselves.

The importance of the latter was noted by all traders; quotes above from F Baarda, W Baarda and Morse refer to them. Figure 8 identified the social aspects of collecting trips as a major factor that was thought to motivate harvesters. These were distinguished in two ways: positive aspects, where harvesters actively sought the company of family or complementary skin groups or other groupings; and as a response to negative social conditions of settlements where interpersonal stresses and tensions were high. For example:

*The whole family come here with buckets of seeds to sell, they get it weighed and walk out with cash in their hands. They've just spent a whole weekend out bush with their family away from the hassles that might be happening in Yuendumu.*

F Baarda [Director, Outback Bushfoods] 2005, pers. comm. 3 May.

Yates also interpreted bush food collection as being a choice by harvesters for a simpler bit of life: 'remote communities these days are often very troubled places' (P Yates [Director, Outback Bushfoods] 2006, pers. comm. 8 May).

#### **2.4.9 Ecological capacity of regions to support trade**

Questions have been raised about the ecological capacity of areas in central Australia to sustain trade in bush products. This was an aspect of the original research proposal (see above). Some of these questions have been raised by ecologists and horticulturalists, with the latter sometimes arguing for a shift to horticultural production as a means to reduce pressure on bush populations. Also, 'occasionally, consumers of bush food products have asked about the ecological effects of harvest; however, they were commonly more interested in cultural practices behind harvest' (P Yates [Director, Outback Bushfoods] 2006, pers. comm. 8 May). It is critical to consider the capacity of bush populations to sustain demand in any natural resource-based enterprise (Cunningham 2001, Whitehead et al. 2006).

All traders held the view that the ecological capacity of the central Australian region to sustain trade was high, with rainfall being the most significant limiting factor. Five of the six traders interviewed asserted that ecosystem degradation, particularly by stock grazing and clearing for infrastructure and rural development, was far more damaging than the effects of commercial bush harvest. For example:

*The total number of seeds removed from this area is minimal compared with what's out there. Bush harvested bush foods are far less environmentally damaging than running cattle or building settlements. It's a drop in the ocean.*

F Baarda [Manager, Yuendumu Mining Company] 2005, pers. comm. 3 May 2005.

A simple comparison between the exported biomass of cattle and commercial bush products from central Australia was made. At least 70 000 head of cattle per year are exported from the Alice Springs region (NTCA 2007). At an average of 500 kg per head, this equates to 35 000 tonnes of biomass. The export of about 7.3 tonnes of bush produce per year (Table 3) is tiny by comparison to annual cattle exports from central Australia.

Four of the six traders believed that there were positive eco-cultural consequences of bush harvest that may have outweighed the risk of negative ecological impacts. While it might be argued that the traders could have had a vested interest in identifying low ecological impacts of bush food harvesting, all identified the sustainability of their trade as reliant upon ecosystem production. Also, three individuals in the four trading companies had a long history of ecological research, had been active in conservation programs, appeared to be particularly sensitive to the ecological impacts of their enterprises, and/or made close observations of the lands, habitats and species traversed in the course of buying trips (Photo 10).

Morse, a botanist, was emphatic that, in the context of these enterprises:

*Ecological sustainability is not an issue. [The species are] extremely widespread, very abundant. People will only harvest them when there's an abundant crop, in very localised areas of high density stands that they can get access to. The rest of the time it's left alone and 99% of the population is beyond the reach of harvesters.*

J Morse [Director, Outback Bushfoods] 2004, pers. comm. 17 December.

Independently, Thisbe Purich observed:

*[The women] don't go in there and work flat out or get as much as they can ...one person collects, then another, then they have a rest, someone diverts to get a goanna, another break ...this stops an area being depleted, makes harvest a lot more sustainable.*

T Purich [NPYWC] 2004, pers. comm. 14 December.

Both quotes indicate that harvesting strategies reduce the potential for over-harvest. These strategies are influenced by the need for localised efficiency. Also, harvesters are motivated by multiple factors, not solely by the desire to procure a maximum yield.

#### **2.4.10 Susceptibility of species to over-harvest**

None of the species traded were listed as threatened under Northern Territory or national legislation. There were no approved or proposed management plans for any of the traded species. In the NT, there were proposed programs related to commercial utilisation for cycads, timber harvest from native vegetation and several animal species (NTG 2007) but none of these programs were for central Australian traded species.

Preliminary assessments of the vulnerability of two of the main species that were traded were conducted during this study. These were for *Solanum centrale* and *Acacia sericophylla* (Table 5). These assessments used criteria that predict species vulnerability or susceptibility to over-harvest. The criteria were identified by Cunningham (2001:148) and Whitehead et al. (2006:15).

**Table 5: Ecological and harvest features that predict susceptibility/vulnerability of plant species to commercial harvest – preliminary assessments of two major central Australian species**

Criterion	<i>Solanum centrale</i>	Rank	<i>Acacia sericophylla</i>	Rank
Distribution	Widely distributed (WA, NT, SA, Qld)	low	Widely distributed (mid-latitudes northern Aust: WA, NT, Qld)	low
Habitat	Strongly associated with particular, sparsely available habitat: Dunefields, sand plains and sandy rises; recent burns (<2 years old)	mod.	Strongly associated with widely available habitat: Dunefields, sand plains and sandy rises (low)	mod.
Abundance	Common	low	Common	low
Growth rate	Rapid	low	Slow	high
Plant part harvested	Many small fruits produced annually	low	Medium-sized fruits, periodic	mod.
Single vs. multiple use	Single	low	Few uses	mod.
Other threats	Substantial and potentially partially ameliorated by harvest - land clearing - stock disturbance - insufficient appropriate burns - ? climate change: may be more vulnerable as clonal species; however survives under increased CO <sub>2</sub> (below)	low	Minor and independent of harvest - land clearing - stock disturbance - wildfire - buffel grass - ? climate change	low
Impact of harvest on individual plants	Slightly reduced recruitment	mod.	Slightly reduced recruitment	mod.
Importance for fauna	Significant for many species, including culturally significant fauna Fruit eaten by bustard, red kangaroo, ants, others	mod.	Significant for keystone species Shade; green seeds eaten by galahs and other birds Dry seeds eaten by ants, weevils, insects and other	high
Ranked totals of criteria	4 of 13	low enhanced by harvest mgmt	6 of 13	low
Species rank for criteria identified by Whitehead et al. 2002	6 of 10 criteria ranked low susceptibility		4 of 10 criteria ranked low susceptibility	
Species rank for criteria identified by Cunningham 2001	3 of 10 criteria ranked moderate susceptibility		3 of 10 criteria ranked moderate susceptibility 2 of 10 criteria ranked high susceptibility	

Note: Mod = moderate

Table 5 shows that the overall susceptibility of *Solanum centrale* and *Acacia sericophylla* to over-harvest was likely to be low based on the identified criteria. For the majority of criteria, the species were ranked as having low susceptibility, with only 2 of 10 criteria ranking as high. *A. sericophylla* was more vulnerable to overharvest than *S. centrale*. The principle reasons for their apparent resilience under recent harvesting conditions were that only seeds or fruit were taken (harvest was not fatal to the plant), and they were a common, widely distributed species. There was consistency between these findings and the observations of the traders.

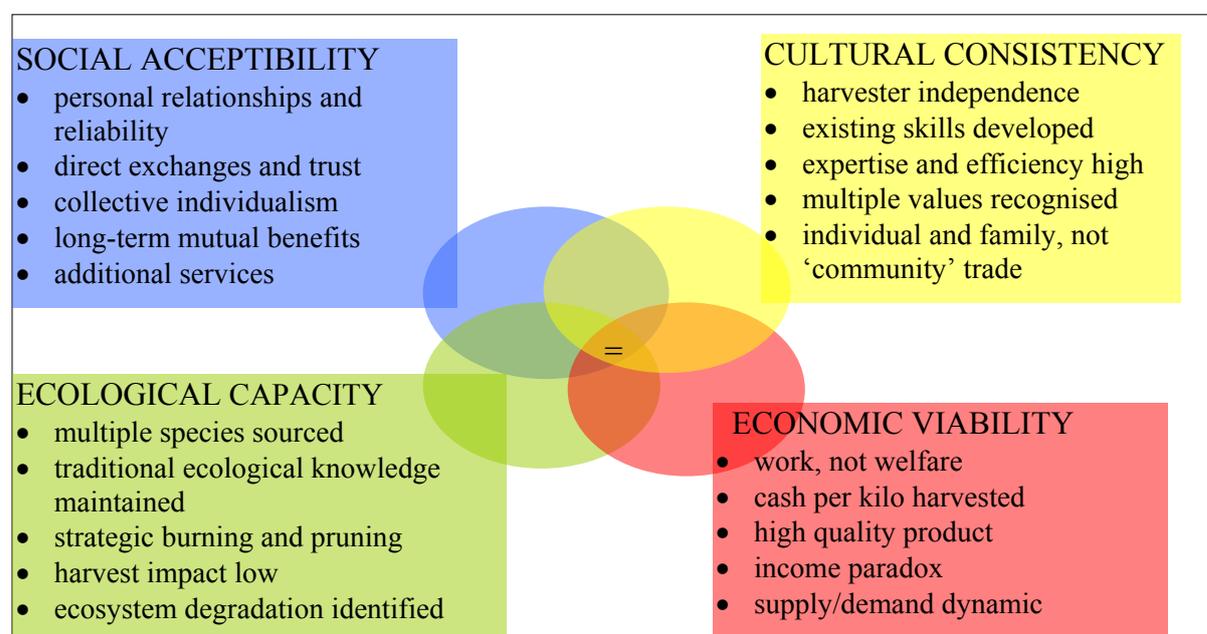
By contrast to the susceptibility of species to harvest, there was preliminary evidence that Aboriginal harvesting activities may have reduced the vulnerability of certain species. These activities included strategic burning regimes by Aboriginal people which promoted the regeneration and production of *Solanum centrale* and short-lived perennial *Acacia* species.

Also, low intensity removal of branches may have acted as a pruning effect in stimulating foliage and seed production. The existence of positive feedback effects from harvesting management methods requires future investigation.

### 2.4.11 Synthesis of the main elements that contributed to sustainable trade

In sum, four main domains contribute to the broad sustainability of trade in bush produce from central Australia to 2006. Many elements that contributed to the effectiveness and durability of trade have been identified in this research. These existed in a complex, flexible and dynamic way suited to the desert and cross-cultural environments of central Australia. Figure 10 synthesises the elements that were described in the above section.

In the operation of trader enterprises, there appeared to be a balance between these domains. Importantly, the economics of trade was not dominant. Strong philanthropic factors motivated the traders. Harvesters appreciated many non-monetary benefits. However, all sought to supplement their personal or business incomes. Cultural and social elements were unique features of the bush produce trade.



**Figure 10: Sustainability of trader-harvester exchanges: major contributing domains and elements**

## 2.4.12 Enterprise that is sustainable in the future? How?

*It is very difficult to identify the future sustainability [of bush food trade]. We can only really know our past, we can describe the present, we can plan for five years, but beyond that it is a guess. This is a highly variable, stochastic natural environment; add that to vagaries associated with Aboriginal harvesters and commercial markets and you will see why we cannot look too far ahead. We have a vision for our business, but we cannot know how it will play out.*

J Morse [Director, Outback Bushfoods] 2005, pers. comm. 17 October.

As Morse stated, the sustainability of trade in bush-harvested produce was uncertain because it was subject to multiple external unpredictable factors. These included high variation in natural production of bush food plants due to rainfall variability and other climatic conditions, variable patterns of harvest and trade by Aboriginal collectors of bush produce, and unpredictable markets. While the trade had been sustainable at small scale and intermittent production over more than two decades, its long-term sustainability remained uncertain.

Frank Baarda detailed a challenge in terms of priorities among harvesters:

*It will remain a peripheral income for people unless there is a crash in the art industry. Last year we bought \$20 000 of seeds; Warlukurlangu [Art Centre] sold almost \$1 million dollars of art.*

F Baarda [Manager, Yuendumu Mining Company] 2005, pers. comm. 3 May.

Yates held a concerned view:

*Overall I'm quite worried [about the future] ... We have certain advantages in central Australia in terms of climate, plenty of space, not much opportunity cost and so on. But there are a whole lot of farmers down there [southern Australia] who are looking to diversify. As soon as we prove bush foods is viable there's a real danger that they'll be able to step in and by virtue of better capitalisation they'll be able to do it better than us. We could find that what we've done is laid down the carpet for somebody else to walk up and that wouldn't be very good. I think there's a real danger of it and I'm half prepared for that outcome.*

P Yates [Director, Outback Bushfoods] 2006, pers. comm. 8 May.

By contrast, Horner maintained a regional focus and was less concerned by the challenges:

*Nothing else is going to replace it. [Younger] Aboriginal people are going to stay on the dole so this [trade] is a sideline, where \$100 represents a 1% increase in their income. They'll supply whatever market we can get.*

R Horner [Trader] pers. comm. 31 March 2005.

Wendy Baarda recognised the realities of Warlpiri life in Yuendumu. Of the future she saw:

*There are two or three different [future scenarios]. In twenty years, there might be no seed collecting. Or it could be the same as now. Or if it was encouraged it could be flourishing ... Warlpiri need someone to encourage and support them. Each of the projects, programs or whatever are dependent on the next white person who comes along. But if there was policy to buy bush harvest and support it then people might [get more involved].*

W Baarda 2005, pers. comm. 3 August.

She identified three future scenarios that, by contrast to Yates, did not recognise horticultural production. Views of the future varied from trader to trader: from optimistic, to steady, to pessimistic. This variety reflected a complex fledgling industry that faced regular uncertainties on many fronts.

### **2.4.13 Growth in demand – shortfall in supply**

All traders reported growth in demand for their bush food produce since 2000. OBF argued that this demand was increasing significantly. Horner was more circumspect; rather than make a bold statement on growth, he cited the example of two tonnes of *S. centrale* that was sold over three years (2000–03), and in 2004 one and a half tonne was sold in only 12 months (R Horner [Trader] 2005, pers. comm. 31 March). In 2005, all traders were cautious about the size and durability of demand. Concurrently in 2005, supply was low due to rainfall. Then in 2006, all stocks of *S. centrale* were sold out in central Australia. Demand had increased dramatically; supply shortfalls of at least two tonne were reported by one trader in 2007. The growth was too recent and variable to provide reliable forward projections on its rate of change. It brings with it many questions: most critical is the matter of how to ensure that bush harvest activity continues to thrive while horticultural production grows. In summary, there were very different perspectives on future growth of their enterprises and the wider industry.

### **2.4.14 Trader views of horticultural bush food production**

Horticultural production of bush produce has a long but very intermittent history in central Australia (Pechey 2001). It has been applied because it is the standard western production system, in the expectation that native bush species could be adapted to horticultural production and the belief that horticulture based on bush foods would be more suited to Aboriginal involvement. Yet there have been many failed horticulture projects on Aboriginal settlements (F Baarda [Manager, Yuendumu Mining Corporation] 2005, pers. comm. 3 August) and town camps in Alice Springs (G Miers 2004, Director, Geoff Miers Garden Solutions, Alice Springs, pers. comm. 26 October).

More recently, horticulture has been promoted as a means to provide a better continuity of supply to expanded markets. Furthermore, it has been advocated for conservation reasons. It has principally been non-Aboriginal people who have been the main drivers of horticultural production of bush foods in central Australia, but there have been, and are, Aboriginal families or individuals who have been interested in horticulture. On the Pitjantjatjara lands in South Australia, small-scale horticultural plots of bush foods have been established over the past decade. This has been instigated and managed by Gail and Mike Quarmby (Outback Pride 2005). They have plots at Mimili, Pukatja and Amata that were established and operated with funds from the Indigenous Land Corporation, SA TAFE and other agencies.

The study found that the views of central Australian traders of horticultural production varied from negative, to ambivalent, to recognition of the need to trial this production system. These views were partially informed by their perspectives on benefits to Aboriginal bush harvesters, particularly women. It was Horner's view that bush-harvested stock had at least a short- and medium-term advantage over horticultural produce. He believed the high skills of bush harvesters that produced clean, quality produce had a significant advantage over horticultural products. Independently, Chisholm and OBF also believed that bush harvest would yield better quality and cleaner fruit than horticultural production. Further, it was Horner's view that the high economic costs of horticultural production (capital and operational) would prohibit investment by conventional horticultural producers. Yuendumu Mining Company and Horner had no specific interest in being involved in horticultural production, whereas OBF and Chisholm had considered getting involved in it.

The interests of the latter two enterprises were to secure a more reliable supply, to have a niche in the prospective horticultural development of bush foods and to adapt horticultural

conventions so that they brought improved benefits and took advantage of the skills of local Aboriginal people.

The variety of views is apparent in the following quotes:

*Growing bush foods would be disastrous (to bush harvest). Collecting bush foods [from the bush] is something that Warlpiri people like, they can do it, and their skills have value. It makes people feel useless when their skills are not valued. It is essential that people's skills are valued. They are not natural gardeners. To try growing bush foods would (undermine) Warlpiri people. Outsiders would need to come and do the work. It might also be a waste of money [because it would fail].*

W Baarda 2005, pers. comm. 3 August.

Yates provided a commentary on bush harvest and horticulture:

*Government seems to be falling over itself to support horticulture, and yet there has never been an iota of support for bush harvest in any direct sense so it isn't a level playing field. It turns out that because bush harvest deals with the bush it's hard to measure, it happens below the horizon of the statistic keepers; they're not interested in it. But because horticulture fits into a domesticated white fella frame of the world, they feel they can measure productivity, output, therefore it's worthy ... In the process of throwing money at one paradigm of production you may well be destroying another and a whole lot that goes with it.*

P Yates [Director, Outback Bushfoods] 2006, pers. comm. 8 May.

Yet Yates flagged the need for a change in perspective on bush harvest:

*So they were the arguments against it, against the horticulture, and I still feel that with some passion. But a strange thing has happened where the market has grown to a point where bush harvest can no longer supply enough and I'm faced with a situation where other people downstream in the industry have made big investments: they have developed products, got them into shops, supermarkets, export and now if we, the suppliers – and it's not just Outback Bush Foods, it's all of us – if we can't supply to those people, then those products, all that investment goes belly up, and it'll take five to ten years to get back to the same position ... we're up against the vagaries of climate and of people's ability to get out there and get what is there.*

P Yates [Director, Outback Bushfoods] 2006, pers. comm. 8 May.

A tension exists for traders between production from bush harvest and production from horticulture. All traders wanted to maintain support to bush harvest because of the complex benefits it brings to Aboriginal people and desert ecosystems. However, OBF and Wirmbrandt saw the need to maintain consistency of supply. Table 6 synthesises the points raised by traders in response to a question on their view of horticultural production.

**Table 6: Comparisons between the advantages and disadvantages of production from bush harvest and horticulture as outlined from the trader responses**

Method of production	Advantages	Disadvantages
Bush harvest (past and existing production system)	<ul style="list-style-type: none"> <li>- low capital costs</li> <li>- existing skill base</li> <li>- no training required</li> <li>- improved care of country</li> <li>- maintenance of Aboriginal ecological knowledge and associated cultural practice</li> <li>- many women and children benefit</li> <li>- marketing advantage (Aboriginal, fair trade, green)</li> </ul>	<ul style="list-style-type: none"> <li>- fluctuating supply</li> <li>- low volume production</li> <li>- access constraints (vehicles)</li> </ul>
Horticulture (experimental and speculative production system)	<ul style="list-style-type: none"> <li>- continuity of supply</li> <li>- consistency of raw product</li> <li>- large volume production</li> <li>- few young men may benefit</li> <li>- cultivation and operations lessons</li> </ul>	<ul style="list-style-type: none"> <li>- high capital costs</li> <li>- non-Aboriginal support substantial</li> <li>- intensive training required</li> <li>- high labour costs</li> </ul>

In synthesis, it was the view of the central Australian traders that greater benefits for more Aboriginal harvesters, particularly women, lay in the continuation of harvest based on a bush harvest production system rather than a horticultural production system. It was the trader's view that horticultural production would require substantial external subsidy and could diminish Aboriginal benefits from bush harvest and commercial bush product development. Two of the four trader companies considered there to be potential in horticultural production, but all saw risks in it too.

### 2.4.15 Research and development priorities identified by traders

In interview traders were asked to name what they considered were the main priority topics that research and development could address. They were not asked to identify a priority order, and these are not listed in any order.

Applied research and development topics identified by traders:

- views of younger Aboriginal people
- links to youth and community programs
- patch burning and production
- identify and develop products known to Aboriginal people 'new' to western markets
- expand involvement of Aboriginal enterprises and value adding
- cooperatives or other joint arrangements
- storage facilities
- changes to permit and licensing systems

## 2.5 Conclusions and future

This research found that the exchanges between bush harvesters and traders were essential in linking bush produce to wider markets. Without these exchanges, developments of the wider industry based on central Australian produce would not have occurred. To the present, bush

harvest trade in central Australia has operated for multiple purposes and principally to provide work and income opportunities for Warlpiri, Anmatyerr and other Aboriginal people on remote lands in central Australia, and to provide income supplements to the desert-based enterprises of trader companies. These enterprises also operated for secondary purposes that were intended to improve social conditions and ecosystem management in central Australia. The largest of the four trading companies was wholly Aboriginal-owned. Two companies had actively investigated partnerships or cooperatives with Aboriginal groups or organisations but had been unable to formalise them due to financial constraints. One company notionally facilitated Aboriginal representation on a national institution (IAF) at least until 2006.

Traders and harvesters exchanged produce in Aboriginal settlements remote from Alice Springs. Two trading companies were based in these settlements, and two travelled long distances to order and purchase produce. Extensive travel was one of many jobs undertaken by the trader enterprises. The cleaning, storage and packaging of produce were also essential jobs that required infrastructure and capital investment. Interstate and overseas marketing and sales were other major jobs undertaken by traders. This work required particular combinations of commitment, skills, labour and knowledge that have been rare in central Australia.

The trade volume in bush produce has been small at approximately 7.3 tonne per year, and the total gross economic value low, at an estimated minimum of \$90 000 per year based on wholesale figures (produce purchased from harvesters) from 2000–2004. However, public investment costs have also been small to negligible, and the non-monetary benefits to Aboriginal harvesters have appeared to be high. These benefits include health, social and educational benefits and the maintenance of cultural practice and traditional ecological knowledge.

Extremely high variability in trade volumes was identified in this study. Rainfall volumes had a major influence upon traded weights. This presents a major challenge to traders and downstream market members. Most harvesters and traders accommodated this variability by diversification of the species they harvested or bought (respectively) by trading up to 30 species for food and rehabilitation purposes. Significantly, they also had income streams from other sources. The trading companies that had greater reliance upon bush food produce and/or single species were more vulnerable to variations in natural production. This has especially been the case for reliance upon the highly seasonal species, *Solanum centrale*. The extreme inter-annual variations reported in this study (and subsequent declines in trade noted in 2007 and 2008) indicate that the study occurred after a high production period, which followed a high rainfall period that may have been exceptional on a decadal scale.

This study found little evidence for the vulnerability of species to over-harvest. Indications were that *Solanum centrale* production increased because of burning by prospective harvesters and others. There were also suggestions that *Acacia* harvest was promoted by the pruning of plants. Traders and harvesters indicated that rainfall and ecosystem degradation due to other land uses had far more profound negative effects upon production. This was based on ethnographic and desktop assessments that could be tested under experimental harvest conditions in the future.

As consumer demand from products increases, there are major challenges in the development of harvester–trader exchanges at local and regional scales. One response to these challenges has been greater research and development investment in horticultural production of bush foods (see other sections of this report). The means of realistically securing long-term Aboriginal benefits from these alternative production systems through employment and other returns still needed to be determined. Table 7 identifies some of the polarities that exist between these different production systems and the development of one (horticulture) with little or no investment in the other (bush harvest).

**Table 7: Polarities to weigh up in longer-term bush produce enterprise-industry development in central Australia**

Note: comparing bush harvesting to 2006, and dominant commercial development scenario to circa 2010

Prior to 2006		Future
bush harvest production	↔	horticulture production
integrated sustainability	↔	economic sustainability
livelihood, non-monetary values	↔	economic values
Aboriginal harvesters	↔	increased non-Aboriginal involvement
cultural resource	↔	commodity
supply-driven	↔	demand-driven
ecosystem management	↔	plot management
desert	↔	non-desert
individual dominated enterprises	↔	agency dominated enterprises
small-scale, family focused	↔	large scale, 'settlement-focused'

To date and in the future, there are different models for horticultural production that bring differing returns to Aboriginal groups. There is a need for investigation of these models among Aboriginal groups. This and other recommendations to support bush harvest production systems and trade have been made in Appendix 2. There may be moderate risks that bush harvest will be displaced by horticultural production, with these risks exacerbated by the nature of research and development investment. It is appropriate to conclude with the same sentiment as Rod Horner ended his bush food article, which remains pertinent. It is similar to the Hippocratic Oath taken by doctors, and reads:

*In your deliberations on bush tucker, be careful that you do not harm people [the present Aboriginal collectors].*

Horner 2001

## **2.6. Recommendations to support increased bush harvester and trader production and exchanges**

This section does not provide recommendations in relation to horticultural production or its potential interplay with bush harvest. Research attention to this area is already substantial.

A major challenge lies in the determination of which are the most important priorities and how to go about them. This question needs to be asked of traders and others actively involved.

### **2.6.1 Social and cultural**

- Facilitate links to more non-Aboriginal people in remote settlements who can arrange connections between harvesters and traders and provide additional transport and freight.
- Undertake research and greater engagement with harvesters to identify their opinions and ideas for expanded involvement.
- Ascertain motivations, views and interests of younger Aboriginal people in bush harvest collection and sale opportunities.
- Record Aboriginal ecological knowledge associated with traded species and provide documented knowledge to schools in appropriate media.
- Active promotion of opportunities for harvesters to trade bush foods. Do this promotion through schools, health programs and in stores. Employ effective promotion means including individual contact, 'walk through the value chain' workshops and events.
- Develop and provide promotional information about bush product trade in photo-based, plain language format. This would include species, the traders, how to contact them and other details.
- Intensify and initiate links between ranger groups, their coordinators and harvesters. Encourage the integration of commercial bush harvest into on-country ranger programs for improved land management, resource monitoring and capacity building.
- Advocate for the integration of commercial bush produce harvest with youth and other community-based programs.
- Support intergenerational training that facilitates the transfer of skills and knowledge from older people to younger. This should be experiential, based on country and extend to supply to buyers.
- Support expanded involvement of Aboriginal people in enterprises. One area is in value-adding such as the use of a grinder.

### **2.6.2 Economic and technological**

- Arrange updates of species produce lists currently sought by traders and others that are accessible in plain language and with language names; possibly available on-line for access by people who collaborate with harvesters.
- Collaborate with traders to identify suitability and options for centralised storage facilities that can be used in periods of high volume production and to overcome existing storage constraints of the traders.
- Facilitate discussions with traders on advantage of regional labelling that identified bush harvested produce collected by Aboriginal from lands of central Australia.
- Investigate the workability of potential criteria that could be used in cultural branding and certification schemes.
- Ascertain pay rates to harvesters (per kilo per hour per species) that include time spent cleaning. Ideally, non-monetary values would also be estimated, but these are difficult to quantify.
- Identify mechanisms to increase or at least maintain pay rates to harvesters, to increase number of active harvesters and weights collected. The market mechanism for this will require increases in prices paid by consumer and processors.

- Extend on past trials that allow harvesters or other Aboriginal people to use threshing, other cleaning and additional machinery that could be used to supplement manual skills.

### 2.6.3 Ecological

- Investigate custodial management measures that support long-term harvest, for example, custodial tenure, and spatially dispersed use.
- Improve fire management: trials of burn regimes to promote *S. centrale* in known locations where production had ceased or was low.
- Encourage incorporation of bush food production into regional fire management plans.
- Document species biology and ethnobiology for those with commercial value to understand roles in ecosystem processes.
- Recognise that at present, the need for bush produce species resource management plans appears to be low relative to other priorities.
- After desktop assessments, conduct experimental harvests to assess the ecological sustainability of species identified as vulnerable to over-harvest.
- Give recognition and constructive support to the existing bush produce traders who operate in central Australia.
- Give greater constructive support to the existing bush produce harvesters who are active in central Australia.
- Facilitate decision making among traders as to the most appropriate cooperative or other model that allows better representation of trader and harvester interests to external agencies and to the wider market and to improve continuity of supply through low production periods.
- Contribute to reviews of laws and regulations at Territory and Australian Government levels so they are suited to small-scale operations and sustainability of existing enterprises.

### 2.6.4 Other

- Provide resources to a position that provides direct, practical support to facilitate connections between Aboriginal harvesters and traders.
- Support small steps and incremental development in Aboriginal enterprises, private–public cooperatives and other arrangements. Do not allow development to be too rapid.
- Be consistent for more than three years where any additional non-government or government staff and resources are brought in to support harvester activities
- Investigate potential of plant products known to Aboriginal people and ‘new’ to western markets. These could include but not be limited to gums and resins and medicinal plants.
- Produce developments must ensure assessment and return to Aboriginal people that are commensurate with background intellectual property contributed. Further, wide consultation with people who have custodial associations with the species.
- Research comparative economic costs and returns (inclusive of various government subsidies and support) between major enterprises, especially pastoralism, that compete for overlapping land areas and natural resources on Aboriginal lands.
- Compare research and development investment into bush harvest production systems with horticultural production systems

### 3. Preliminary results of horticultural production trials of *S. centrale*

Maarten Ryder

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- Alice Springs Correctional Facility, NT, for hosting a *S. centrale* field trial.

### 3.1 Introduction

The development of a commercial supply chain for *S. centrale* was initiated on the basis of bush harvested plants. Today, the majority of the *S. centrale* sold comes from bush harvest stocks. Variability in supply and quality associated with bush harvest will hinder industry growth as consumer demand increases. While bush harvest needs to continue to supply the market in certain instances, horticultural production is needed to become the mainstay of a high volume market needs.

The selection of ‘highly valued’ *S. centrale* for development in breeding programs in the western scientific sense is in its infancy. Reedy Creek Nurseries (RCN) have begun the process of selection for desirable characters and are applying this knowledge commercially in the ‘Outback Pride’ value chain. However, because there is a lack of selected or genetically improved *S. centrale* plants in the industry outside the Outback Pride value chain, there is a market opportunity to provide enhanced capacity to produce *S. centrale* crops and to improve the quality of the product to the consumer.

In the ‘Bush produce’ project, our medium-term aim is to work with Aboriginal people in the selection of *S. centrale* for cultivation. This is built into future research as a ‘participatory domestication’ project. To support this aim, we decided to make our own selections of *S. centrale* by collecting plants from roadsides or government land, and to initiate scientific work with those plants. This approach has limited scope for expansion given available plant resources that exist in these locations, and we need to make partnerships with Aboriginal people to fully develop the research. However, in this initial phase of the project we have begun the important and essential process of developing technical expertise and tools for later use with the ‘participatory domestication’ project.

The initial aims of the horticulture component of the bush produce project were:

1. to collect *S. centrale* (*Akatyerr*) from different geographic locations and to propagate these clonally
2. to plant these different ‘selections’ in different locations in small drip-irrigated trial plots (at least two trial locations)
3. to assess plant performance (survival, growth, yield) and analyse genotype x environment interaction where possible.

### 3.2 Materials and methods

#### 3.2.1 Plant material

*Solanum centrale* plants and seeds were sourced from four locations/regions.

Plants from Kuyunba (Hatt Road, near Alice Springs) (23° 48’ S, 133° 44’ E) and the Alice Springs Desert Park (ex Stirling NT, 21° 44’ S, 133° 45’ E) were propagated clonally at the Alice Springs Desert Park. This genetic material was not completely identical, but progeny were much more uniform than the plant material raised from commercial seed lots.

Dry conditions in the summer of 2004–05 resulted in little *S. centrale* growing in the bush. Additional plant material required for our work was sourced from bush harvest–collected commercial batches of *S. centrale* fruit. This material was not clonal and was therefore highly variable from one plant to the next. However, to maximise our potential for learning, we purchased fruit that had been collected from two distinct, non-overlapping collection regions: Napperby Station/Laramba people, north-west of Alice Springs (at 22° 32’ S, 132° 46’ E) and

Utopia region, north-east of Alice Springs (at approx 22° 14' S, 134° 34' E) and propagated seed from these.

The sources of plant material are named according to the region from which they came as follows:

- Kuyunba = Arrente
- Stirling (from plants grown at the Alice Springs Desert Park) = Central Anmatyerr
- Utopia = Eastern Anmatyerr
- Napperby = Western Anmatyerr.

Plants were approximately 10 cm tall when planted, except for the Central Anmatyerr plants which were mostly 25 cm tall and flowering.

### **3.2.2 Field site locations**

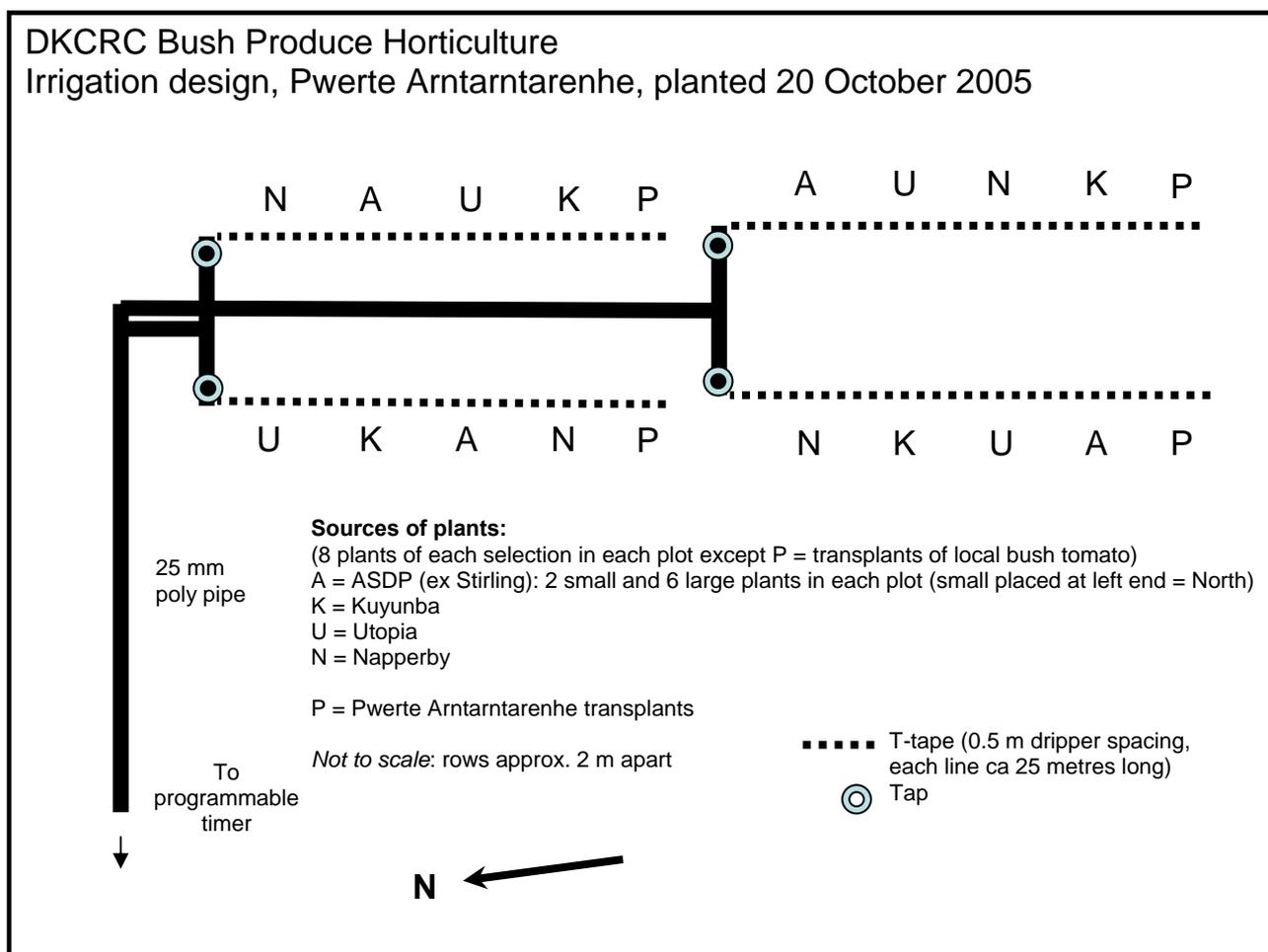
- Pwerte Arntarntarenhe (24° 20' 12.19" S, 133° 42' 31.89" E)
- Oak Valley NT (24° 23' S, 133° 56' E)
- Areyonga (24° 4' S, 132° 16' E)
- Alice Springs Correctional Facility (near Alice Springs 23° 41' S, 133° 52' E)

### **3.2.3 Trial design**

Trials consisted of four replicates in which the four treatments (plant 'selections', in plots) were randomly arranged (randomised complete block design, RCBD). At one site, Pwerte Arntarntarenhe, there were eight plants per plot. At other sites, due to restrictions on the numbers of plant selections available, there were sometimes different numbers of plants per plot. The trial at the Alice Springs Correctional Facility was planted as a RCBD; however, the arrangements at the other two sites (Oak Valley and Areyonga) were set up with replication but not as RCBD, and the results were not analysed statistically. Means per plot and overall trial means were nevertheless calculated.

### **3.2.4 Trial establishment and maintenance**

Trials were set up with drip irrigation systems and battery-operated programmable timers. Netafim® techline® was used to deliver water at a rate of 4 litres per hour. Plant spacing was 1 metre within the row, and distance was 2 metres between rows. The trial design at Pwerte Arntarntarenhe is presented in Figure 11.



**Figure 11: Trial layout at Pwerte Arntarntarenhe (John Holland North)**

Sites were established on 18 October 2005 (Pwerte Arntarntarenhe), 2 November 2005 (Oak Valley), November 2005 (Areyonga) and December 2005 (Alice Springs Correctional Facility).

Organic fertiliser (GroMor<sup>®</sup>) was applied at planting at the rate of approx 50 g per plant. At the Alice Springs Correctional Facility the fertiliser was applied two months after planting.

Local management of trials consisted of weeding (by hand or mowing) and extra watering where it was deemed necessary in extreme heat conditions by the local site operator.

### 3.2.5 Data collection and analysis

Data were collected approximately every two months (December 2005 and February, March and June 2006).

Exact dates of collection are given below:

- Alice Springs Correctional Facility Areyonga (13/1/06, 20/3/06, 14/6/06)
- Areyonga (1/12/10, 12/1/06, 13/6/06)
- Oak Valley NT (11/1/06, 15/3/06, 24/5/06)
- Pwerte Arntarntarenhe (11/1/06, 15/3/06, 24/5/06)

Plant height and width were measured, as well as vigour (0–100 scale, where 0=dead; 25=poor vigour, possibly with some nutritional deficiency, or pest or disease problems; 50=moderate vigour with no major setback or problem; 75=good vigour with no major problems; 100=very healthy and vigorous new growth).

Spininess and leaf colour were recorded at each sampling time. Notes were also made on plant damage (from insects and other causes).

Plant data for Pwerte Arntartarenhe were analysed statistically using ANOVA (Genstat version 9.1).

Yield data were collected only at Pwerte Arntartarenhe. At other sites, no fruit yields were available. At Pwerte Arntartarenhe, three plants per plot were tagged for yield measurement. Fruit was harvested three times (February, March, June 2006). The fruit was sun-dried and weighed. Data for each plant were combined to give a total yield, which was analysed statistically using ANOVA (Genstat version 9.1).

### 3.3 Results

#### 3.3.1 Plant establishment: survival and vigour of surviving plants

Plant survival is presented in Table 8. *Solanum centrale* plant survival after planting and through the growing season was generally very good for all selections at all locations, usually above 75%. The one exception was at Areyonga in June 06, where the survival fell to low levels for all selections after good survival rates had been recorded in January and March 06. Whether this decrease in June is due to a specific problem or due to seasonal conditions is not known. For example severe plant damage is caused by frost in winter but plants then recover in the spring or summer when there is sufficient moisture.

**Table 8: Proportion of plants surviving by site and plant origin over time**

Site	Plant origin	December	January	March	May–June*
Alice Springs Correctional Facility	Central Anmatyerr (Stirling)		0.95	0.9	0.9
	Arrente (Kuyunba)		0.79	0.79	0.79
	Eastern Anmatyerr (Utopia)		0.77	0.75	0.73
	Western Anmatyerr (Laramba)		0.88	0.88	0.88
Areyonga	Central Anmatyerr (Stirling)	0.75	0.75		0.58
	Arrente (Kuyunba)	0.92	0.92		0.24
	Eastern Anmatyerr (Utopia)	0.88	0.81		0.40
	Western Anmatyerr (Laramba)	0.98	0.85		0.38
Oak Valley	Central Anmatyerr (Stirling)		0.83	0.83	0.67
	Arrente (Kuyunba)		1.00	1.00	0.92
	Eastern Anmatyerr (Utopia)		1.00	1.00	1.00
	Western Anmatyerr (Laramba)		0.95	0.93	0.88
Pwerte Arntartarenhe	Central Anmatyerr (Stirling)	1.00	0.88	0.75	0.75
	Arrente (Kuyunba)	0.97	0.81	0.75	0.75
	Eastern Anmatyerr (Utopia)	0.81	0.81	0.81	0.78
	Western Anmatyerr (Laramba)	1.00	1.00	0.97	0.97

\* Measurements were taken at Alice Springs Correctional Facility and Areyonga in mid-June, and at Oak Valley and Pwerte Arntartarenhe in late May.

## Plant vigour

Data for vigour of surviving plants by selection and location are shown in Table 9. At the Pwerte Arntartarenhe site, vigour was always over 50. For cutting-grown material, vigour decreased a little over the season, whereas for seedling material vigour remained at the same high level (60–80 range). At Oak Valley, similar high levels of vigour were seen, except in February 2006, when average vigour was assessed as poor to moderate. This may have occurred during a period of extreme hot weather and less than optimal water application. All selections had similar vigour.

At Areyonga, vigour was also reasonably high, but declined at the end of the growing season. The Central Anmatyerr (Stirling) selection seemed to do better than the Arrernte (Kuyunba) selection. Vigour of *S. centrale* at the Alice Springs correctional facility showed a pattern similar to that seen at Oak Valley. Vigour was generally quite good (60–70), except for a dip to 30–50 in March 06.

**Table 9: Plant vigour (0–100 scale) by site and plant origin over time**

Site	Plant origin	December	January	March	May–June*
Alice Springs Correctional Facility	Central Anmatyerr (Stirling)		72	40	70
	Arrernte (Kuyunba)		61	29	61
	Eastern Anmatyerr (Utopia)		66	52	64
	Western Anmatyerr (Laramba)		60	49	71
Areyonga	Central Anmatyerr (Stirling)	66	85		64
	Arrernte (Kuyunba)	34	54		25
	Eastern Anmatyerr (Utopia)	46	64		47
	Western Anmatyerr (Laramba)	46	60		51
Oak Valley	Central Anmatyerr (Stirling)		70	35	75
	Arrernte (Kuyunba)		63	31	50
	Eastern Anmatyerr (Utopia)		61	40	57
	Western Anmatyerr (Laramba)		64	44	58
Pwerte Arntartarenhe	Central Anmatyerr (Stirling)		80	56	57
	Arrernte (Kuyunba)		72	48	52
	Eastern Anmatyerr (Utopia)		72	72	78
	Western Anmatyerr (Laramba)		71	65	72

\* Measurements were taken at Alice Springs Correctional Facility and Areyonga in mid-June, and at Oak Valley and Pwerte Arntartarenhe in late May.

## Plant growth

*Solanum centrale* plant growth (height) during the 2005–06 growing season is shown in Table 10.

At Pwerte Arntartarenhe, the seedling plants (seed from Eastern and Western Anmatyerr, Utopia and Napperby respectively) grew larger (especially wider) than the plants grown from cuttings (Central Anmatyerr and Arrernte, that is, Stirling and Kuyunba respectively), and the plants at this site grew much larger than at the other three locations.

At the Oak Valley site, plants grew particularly well later in the season. The cutting-grown plants from Stirling performed the best and the cutting-grown plants from Kuyunba showed the least growth.

The growth of the cutting-grown *S. centrale* (Central Anmatyerr and Arrernte, that is, Stirling and Kuyunba respectively) at Areyonga was poor, with reduction occurring through the

season. On the other hand, the seedling plants showed a positive growth, though not as large as at other sites.

The growth of *S. centrale* plants at the Alice Springs Correctional Facility, which were planted well after the other three sites, was reasonably good and was consistent through the season across three of the four selections. The cutting-grown plants sourced from the Arrernte region (Kuyunba) showed the lowest growth rate.

**Table 10: Plant height (cm) of *S. centrale* from different origins over time at four field sites**

Site	Plant Origin	December	January	March	May–June*
Alice Springs Correctional Facility	Central Anmatyerr (Stirling)		23.30	24.48	31.28
	Arrernte (Kuyunba)		18.27	13.98	13.60
	Eastern Anmatyerr (Utopia)		13.71	24.08	26.74
	Western Anmatyerr (Laramba)		12.66	20.89	24.77
Areyonga	Central Anmatyerr (Stirling)	30.50	21.58		27.04
	Arrernte (Kuyunba)	17.29	13.99		13.50
	Eastern Anmatyerr (Utopia)	13.29	18.71		20.90
	Western Anmatyerr (Laramba)	13.11	15.95		22.43
Oak Valley	Central Anmatyerr (Stirling)		24.31	24.42	33.17
	Arrernte (Kuyunba)		18.18	17.25	19.29
	Eastern Anmatyerr (Utopia)		18.96	21.65	29.90
	Western Anmatyerr (Laramba)		20.53	23.13	27.64
Pwerte Arntarntarenhe	Central Anmatyerr (Stirling)	24.84	37.28	31.22	32.16
	Arrernte (Kuyunba)	17.29	32.31	30.06	35.25
	Eastern Anmatyerr (Utopia)	22.40	37.76	41.65	49.10
	Western Anmatyerr (Laramba)	18.84	34.69	36.12	41.16

\* Measurements were taken at Alice Springs Correctional Facility and Areyonga in mid-June, and Oak Valley and Pwerte Arntarntarenhe in late May.

## Fruit yield

Fruit yield data was only obtained from the Pwerte Arntarntarenhe site. At this site, three plants of the eight in each plot were tagged for sequential harvest of fruit. Fruit yields from the three sequential harvests made between mid-January and late May were measured separately and the weights were then combined for the analysis. The fruit from the remaining plants was left for the use of the site owners.

Total dry weight of fruit per plant is presented in Figure 12. The average yields per plant differed significantly at  $P = 0.001$ . The yield from the Central Anmatyerr plants was two to three times higher than from plants from other locations. This difference may be explained in part by the fact that the Central Anmatyerr plants were more advanced at planting (larger and flowering).

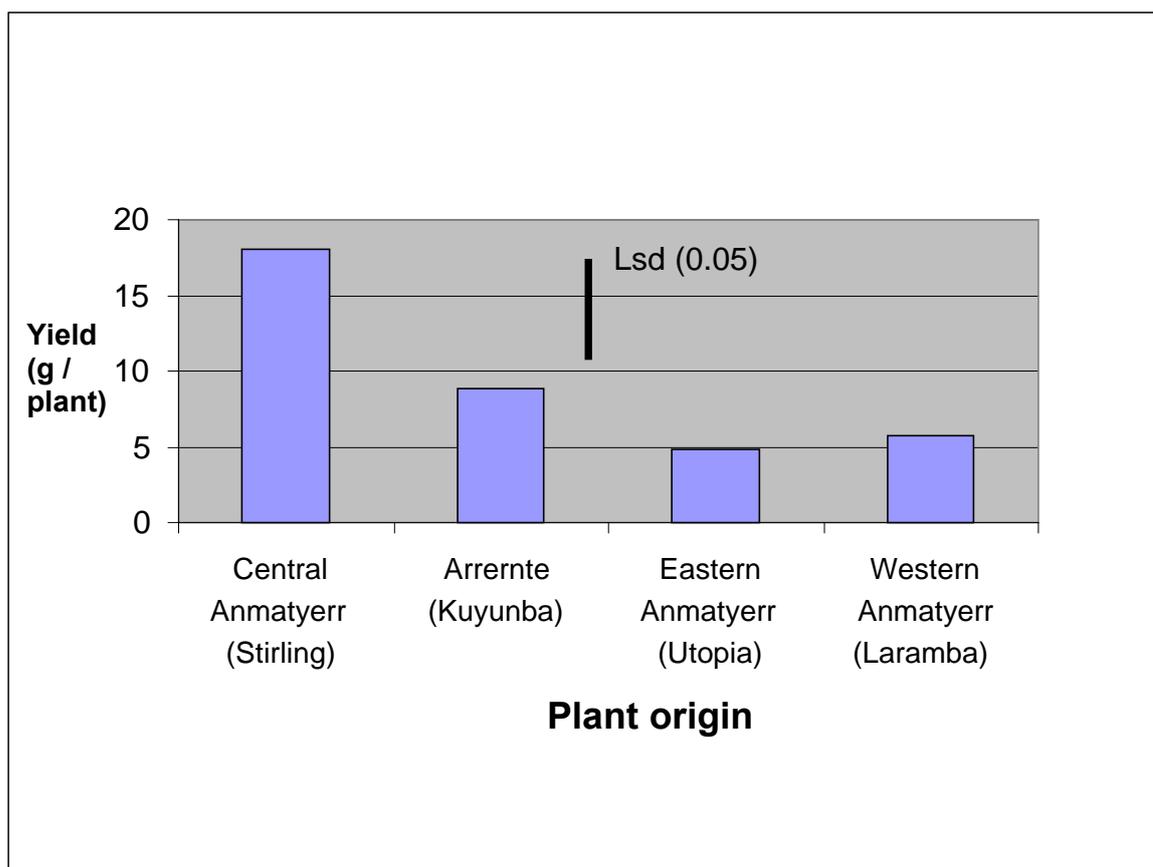


Figure 12: Total harvested fruit yield, Pwerte Arntarntarenhe, 2006

The yield data were converted into yields per hectare and these are presented in Table 11. The data were then re-calculated as if all plants had yielded as much as the highest yielding plant. These data are presented in Table 12.

Table 11: Average fruit yield for 4 sources of plant material and gross return per hectare

Selection	Average Yield (g/plant)	Yield (kg/ha)*	Gross return/ha+	Gross return/ha++
Central Anmatyerr (Stirling)	18.0	360	\$4320	\$8640
Arremte (Kuyunba)	8.8	176	\$2112	\$4224
Eastern Anmatyerr (Utopia)	4.8	96	\$1152	\$2304
Western Anmatyerr (Laramba)	5.7	114	\$1368	\$2736

\* assuming 20 000 plants/ha, which can be done with 1 m row spacing, 0.5 m plant spacing. This is a tight spacing (distance between rows, 10 km of drip irrigation/ha)

+ At \$10 per kg ++ At \$20 per kg

Table 12: Calculation of yield and gross return per hectare based on yield of the highest yielding plant (assuming all plants had given the same high yield)

Selection	Yield (g/plant)^	Yield (kg/ha)*	Gross return/ha+	Gross return/ha++
Central Anmatyerr (Stirling)	40	800	\$9600	\$19 200
Arremte (Kuyunba)	20	400	\$4800	\$ 9 600
Eastern Anmatyerr (Utopia)	15	300	\$3600	\$ 7 200
Western Anmatyerr (Laramba)	25	500	\$6000	\$12 000

^ Calculation based on 'Best plant'

\* assuming 20 000 plants/ha, which can be done with 1 m row spacing, 0.5 m plant spacing. This is a tight spacing (distance between rows, 10 km of drip irrigation/ha)

+ At \$10 per kg ++ At \$20 per kg

### 3.4 Discussion

*Solanum centrale* establishment was generally extremely good at all sites. Survival rates were high (over 75%) until late autumn, when there was a decrease at one site (Areyonga). At the Pwerte Arntarntarenhe site, all the plants in the two plots at the southern end were killed (at the right end of the plot layout presented in Figure 11) progressively during the summer. This was very likely to have been caused by salt build-up in the soil. Soil analyses show that salt levels in the soil at the southern end were very much higher than at the northern end of the trial. In early 2006, the average electrical conductivity of soil at the north end of the trial was 0.09 dS/m, and at the south end it was 0.78 dS/m. Chloride (salt) levels in soil at the north end were 45 mg/kg soil and at the south end were almost 20 times higher, at 880 mg/kg. It was very interesting that a *S. centrale* plant that had been transplanted to the southern end of the trial from only 100 metres away on the property survived and grew well in the saline soil at the southern end of the trial, despite the adverse conditions which killed plants originating from Stirling and Kuyunba. It is possible that the local plants from the clay pan have a level of salt tolerance. This could be investigated further, and we are planning cooperative action to validate and develop the salt-tolerant plants.

The ground preparation (rotary hoeing), water and fertiliser applications at Pwerte Arntarntarenhe ensured excellent plant growth, which then resulted in harvest of fruit in January, March and May 2006. At Oak Valley, plant growth was somewhat restricted partly because the site was exposed and windy, and there had also been less ground preparation compared with the Pwerte Arntarntarenhe site.

At the Areyonga site, there was good establishment in the early phase, but there were some problems and no harvest was recorded. The two main constraints were thought to be (1) severe insect damage problems due to galls and leafhoppers, which were possibly made worse by insect infestations in an adjacent citrus orchard; and (2) maintenance problems such as lack of timely irrigation repair, weed competition and possible plant losses due to mowing.

The trial at the Alice Springs Correctional Facility was planted last in December 2005. In June 2006 there was a lot of fruit on the bushes, but it was still green and was therefore not harvested. The late planting time probably contributed to the lack of harvest despite good plant establishment and growth.

When conditions are good, it is clear that *S. centrale* can grow very rapidly. For example, at Pwerte Arntarntarenhe, within 6 weeks of planting, the spreading root systems from which *S. centrale* regenerate (Dennett 2006) had emerged at a distance of 40cm from the planting position.

Average yields of *S. centrale* per plant at Pwerte Arntarntarenhe, from vigorous, healthy plants, varied from 4.8 to 18 g per plant (dry weight). The differences between selections were large and were statistically significant. However, the yield differences may have been due to the type and developmental stage of the planting material rather than genetic differences between the selections. The highest yielding plants, from Stirling, were propagated from cuttings and were also the most advanced at planting time: they were larger and were flowering, whereas the other three selections were not yet at that stage.

The average yields per plant were lower than have been reported by other growers of *S. centrale* (quoted in Robins & Ryder (2004)). For example, yield estimates of 25–100 g per plant have been obtained from others. Compared with the 25 g per plant estimate, the 18 g per plant average recorded for the highest yielding plants and the 5 g per plant for the lowest yielding are slightly lower and much lower, respectively. It should also be noted that the

yields from this trial are for the total fruit harvest, and do not account for losses that would occur when poor quality fruit is culled. There were clearly fruit present in the harvest that should be removed for a quality product.

As stated earlier, it will be important to obtain a second season of yield data to see what changes will occur, and whether the yields will increase substantially.

During a site visit to Pwerte Arntarntarenhe in March 2006, it was noted that there were many flowers but very few fruit on any plants, whereas usually there is a range of flowers and green to ripe fruit present in mid-season. It is possible that an extended period of very hot weather (several weeks in January 2006 of over 40°C maximum temperatures) may have interfered with some aspect of pollination and fruit set, leading to lower yields.

## 4. *Solanum centrale* genetics and plant improvement

Michelle Waycott, Heather Robson, Jon Luly, Joseph Holtum and Tim Collins

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### 4.1 Introduction

The aim of this project is to understand the link between genetic diversity and plant origins to recognise and/or develop improved market-demanded characteristics such as flavour and size. The result would be capacity development to identify new varieties that could attract Plant Varietal Rights for communities involved, thereby protecting intellectual property, and generate royalties while also recognising regional characteristics for market branding of bush harvest product.

The specific aims of the genetics and plant improvement work in this phase of the project were:

1. to screen and identify genetic markers for *Solanum centrale* for use in plant improvement in order to understand genotype x environment variability
2. to collect *S. centrale* from different geographic locations to establish baseline genetic variability
3. to establish variability in a variety of plant traits: germination, morphology, alkaloids, growth
4. to begin the development of an ideotype for *S. centrale*.

#### 4.1.1 Background to genetics and plant improvement approaches for *Solanum centrale*

*Solanum centrale* exhibits characteristics suggesting considerable scope for improvement of planting material through selection and breeding. Prior to western cultures' interest in native foods, plants such as *Akatyerr* (*S. centrale*) had already been selected for over many centuries through Aboriginal traditional land management practices. A recognition and contribution of both Aboriginal knowledge and scientific experimentation may be the most beneficial approach to both enhancing commercially desirable plant traits this species possesses and preserving the natural resource present in bush populations still harvested by Aboriginal peoples for food and for sale to commercial suppliers.

*Solanum centrale* is known to have a high degree of genetic and morphological variability based on field observations (Johnson et al. 2003) and various attempts at horticultural plantings for fruit production over the past couple of decades. Attempts at horticultural plantings had been primarily focused around planting seedlings for cropping within a two-year period with limited success after this. To our knowledge, seedlings were typically sourced from bush-collected fruits, and as a result plants grown were from variable locations

and of variable quality. One of the first steps in the production of recognisable cultivated lines is to establish the basis for plant variability in bush populations and to identify a desirable plant, or 'ideotype'. To do this, and to pave the way for the development of any Plant Varietal Rights (legally binding recognition of unique varieties), baseline information on plant trait variability are required.

A workshop consisting of people from the bush foods industry and researchers in October 2005 identified larger fruit size, sweeter fruit taste, production of more synchronous crop and lower spinniness as desirable. Ongoing market research will aid in the development of a more refined set of desirable traits; however, at present, baseline variability in any plant trait awaits testing for genetic versus environmental component. In addition, germination of *Solanum centrale* has been found to be generally low (e.g. Johnson et al. 2003, Ahmed et al. 2006), and tissue culture techniques have been developed for *in vitro* generation of clonal material. However, the average land holder wishing to plant out *S. centrale* is unlikely to have access to such facilities. Practical tools for plant production systems are required for adequate application of new varieties that are established.

One component of the plant variability that is being focused on is the presence of glycoalkaloids in the fruit. The main glycoalkaloid present in the fruit was reported to be a solanine-family compound called  $\beta$ 2-chaconine (Hegarty et al. 2001). Hegarty et al. (2001) also reported that 'levels were much higher in green fruit compared to ripe fruit with the concentration in green fruit at >10 mg/100 g close to the 15 mg/100g reported as being a high solanine level in potatoes'. In their conclusions, they stated that 'levels are below the accepted threshold levels for potato but need some monitoring; the levels of solanine in green and dried *S. centrale* would thus seem to warrant a monitoring system for commercial material'. Solanine-like compounds are important to assess because of food safety issues (high levels can make people ill). In addition, these compounds make fruit bitter, and if we can detect and select plants with low glycoalkaloid levels in the fruit when selecting *S. centrale* for horticultural production, 'sweeter' fruit may be the result.

The first phase of research in this project has focused on developing genetic tools (markers) that can be used to document variation and also, later, to protect new IP (selected or improved plants). A methodology for measuring the bitter tasting toxin solanine that occurs in *S. centrale* fruit has been established. This will aid in the selection of *Solanum centrale* for use in horticultural production which have a lower natural concentration of solanine. We have begun establishing natural variation in plant traits based on plants grown under identical conditions and will use material from these plants in future verification of the genetic markers identified by this study.

## 4.2 Materials and methods

### 4.2.1 Plant material

There was very little *S. centrale* growing in the bush in the 2004–05 summer due to very dry conditions; the plant material available from field-collected living plants was limited. As a result, plant material was sourced from commercial batches of *S. centrale* fruit. This material was not necessarily from a precise geographic location; however, suppliers were able to provide general sources as outlined below.

**Table 13: Locations from which samples were obtained for using in the genetics and plant improvement study**

Location		Latitude °S	Longitude °E	Number of samples analysed with SSRs
Arrente Kuyunba (same as Hatt Rd)	*	23.48	133.47	1
ASDP-Stirling	^	21.44	133.45	17
Central Anmatyerr (Outback)	*	22.80	133.16	7
Jamestown (same as Utopia)	*	22.14	134.46	3
John Holland	^	24.20	133.42	30
Hatt Rd	^	23.48	133.47	35
Murray Bridge (same as Outback = Central Anmatyerr)	*	22.80	133.16	5
Pine Hill	^	22.23	133.30	31
Tanami Rd	^	21.55	133.15	31
Western Anmatyerr (= Napperby)	^	22.46	132.47	60
Eastern Anmatyerr (= Utopia)	*	22.14	134.46	18
OzTukker	*	unknown		3

\*=commercially sourced seed, ^=field collected plants

## 4.2.2 Germination studies

Methods for germinating the seed were developed by DKCRC researchers. Final testing included a range of concentrations of smoke water, gibberellic acid, 0.1% potassium nitrate, surface burning of soil, and simple soaking in distilled water. Trials were carried out in shade house conditions at Alice Springs Desert Park, James Cook University and CSIRO (Adelaide).

## 4.2.3 Genetic analysis

### Marker screening

The identification of highly polymorphic genetic markers for the purposes of DNA fingerprinting was based on simple sequence repeats (SSRs). DNA is first extracted from fresh or dried leaves using Plant Tissue DNA Extraction Kit (Qiagen™, Epoch™). DNA is then quantified using spectrophotometry, and the DNA amount is standardised to 25 ng/μL and stored at -20°C until use. DNA fingerprints are generated using fluorescent tagged primers (Geneworks™) and Polymerase Chain Reaction (PCR) conditions to ensure consistency.

A total of 16 different primers were screened for amplification efficiency. A final set of six different amplification primers were used to determine individual plant genotypes.

Final screening across samples was conducted.

## 4.2.4 Method of DNA fingerprinting *Solanum centrale* using simple sequence repeats

DNA was extracted from silica-dried leaf material using a SDS-Silica extraction method based on Elphinstone et al. (2003) developed for this project to allow higher throughput screening. Six fluorescent tagged SSR primers were used in single-primer PCR reactions: 818-hex, 826-hex, 889-tet, 855-tet, 888-fam, and Or-fam. Reagents used were Immolase Taq (Bioline, 5u/ml), 100x BSA (New England Biolabs) with 2 μl of DNA (20 ng) in a total 30 μl volume.

Primer sequences used in final screening:

818 5'-CAC ACA CAC ACA CAC AG-3'

826 5'-ACA CAC ACA CAC ACA CC-3'

889 5'-DBD ACA CAC ACA CAC AC-3'

855 5'-ACA CAC ACA CAC ACA CYT-3'

888 5'-BDB CAC ACA CAC ACA CA-3'

OR 5'-GRTRCYGRTRCACACACACACA-3'

A polymerase chain reaction using a MJ Research Peltier thermal cycler with an incubation step of 95°C for 10 minutes was used to activate the Immolase Taq, followed by 15 cycles of 3 minutes at 94°C, 30 seconds at 94°C, 30 seconds at 64°C decreasing by 1°C per cycle. This was followed by 7 cycles of 30 seconds at 94°C, 30 seconds at 50°C, and 30 seconds at 72°C. Final incubation was at 72°C for 5 minutes and the program was then held at 12°C indefinitely. PCR products were visualised on a 1.5% 1x TBE agarose gel. Products were quantified, multiplexed (889, 888 and 826 in one set, 818, 855 and Or in the second set) and cleaned using ethanol/ammonium acetate precipitations. Dehydrated products were sent to the Genetic Analysis Facility at James Cook University for genotyping.

Electropherograms were analysed using the Megabace Fragment Profiler V1.2 software. Peaks were scored for 97 loci (= unique fragment lengths for each primer and 1 = peak present; 0 = peak absent) for all samples. Genetic analysis was conducted using GenAlEx6 program (Peakall & Smouse 2005).

#### 4.2.5 Glycoalkaloid content

Separation of standard compounds ( $\alpha$ -chaconine and  $\alpha$ -solanine) was conducted using thin layer chromatography (TLC) and high pressure liquid chromatography (HPLC) using the method of Jonker et al. (1992). Results were compared with standards:  $\alpha$ -chaconine was partially hydrolysed in acid (Friedman et al. 1993) to generate a family of breakdown products that includes  $\beta$ 2-chaconine. The two common glycoalkaloids present in green potato, alpha solanine and alpha chaconine, were isolated following the method of Jonker et al. (1992).

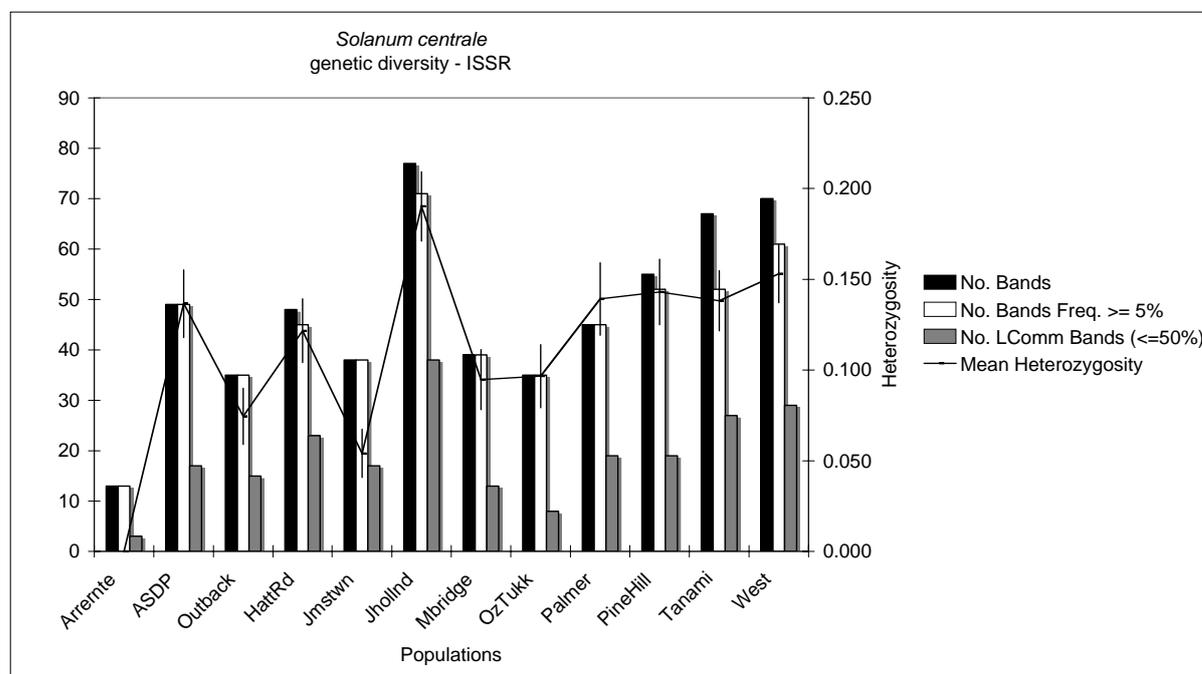
#### 4.2.6 Morphometric variation among shade-house grown *Solanum centrale*

Seedlings raised during germination trials were grown to flowering under standard shade-house conditions at James Cook University in Townsville, Qld. Plants were sourced from fruit obtained in Tanami Road, Kuyunba Road, Pine Hill, Alice Springs Desert Park, Outback Bushfoods, Oztukka and Utopia. *S. cleistogamum* was sourced from the Alice Springs Desert Park. The plants were grown in 2.6 L pots containing the following ratio – 4 coarse sand: 1 loam: 1 vermiculite: 1 perlite. The pots were fertilised with dilute Miracle Grow (1.25 mL in 2 L) monthly and treated with Fongarid fortnightly while plants were small, and then monthly. Morphological characters of plants were measured over a period of 1 week and measurements were taken before temperatures were stressful to plants in the morning. Characters measured were leaf angle ( $^{\circ}$  to vertical), leaf area (mean of 3 replicates on the 4<sup>th</sup> leaf and below from the main growing shoot), leaf length (on the 4<sup>th</sup> leaf from the apex of the main growing shoot), leaf breadth (as for leaf length), number of spines in 1 cm span below (on the 4<sup>th</sup> leaf from the apex of the main growing shoot), spine length (the longest spine in the area scored for spine number), reflectance (using an integrated sphere), % reflectance.

## 4.3 Results and discussion

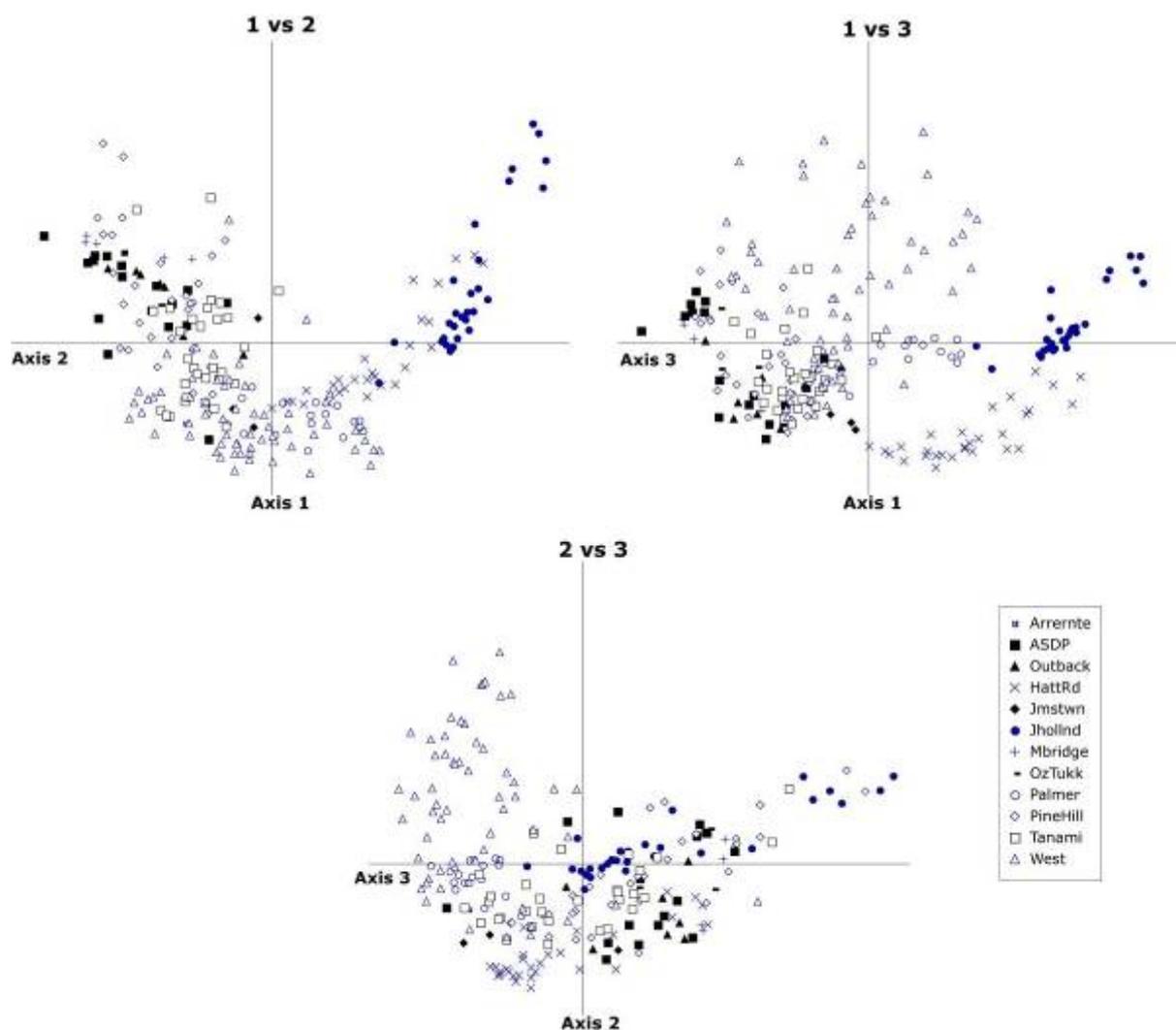
### 4.3.1 Genetic analysis

Genetic analysis of 241 plant samples across 97 loci revealed a high degree of genetic polymorphism (diversity), both within and between the populations studied (Figure 13). The level of genetic diversity detected was sufficient to verify genetic identity (i.e. individual fingerprints). Among the 241 samples, 217 genotypes were detected. Among the samples with shared multilocus genotypes, a high level of consistency was observed and we assign these as putative clones. Clones are only found among samples within a geographic location and nearly all clones detected were found in samples collected in the same location, on transects. The larger clones detected were at the John Holland and Hatt Road locations. At these sites up to 8 samples were observed to have shared genotypes. The samples collected were over larger spatial scales (tens of metres) and as such support field evidence that plants can achieve substantial vegetative colonisation using below-ground structures.



**Figure 13: Genetic diversity of populations and seedlings from commercially sourced fruit based on SSR variation across six primers.**

The genetic relatedness among the sets of samples collected suggests continuous variability and moderate degrees of connectivity (Figure 14). Some degree of population identity is emerging from the samples analysed. However, additional discrete population sampling is needed before a more robust interpretation of population identity can be made. If the observation of population structure is borne out across a wider population sampling, the likelihood of regionalised germplasm resources being identified is increased.



**Figure 14: Principal coordinates analysis of genetic distance among all samples based on 97 SSR loci across 12 different sets of samples**

Refer to Table 13 for sampling locations. The analysis is presented as two-dimensional plots of a three-dimensional analysis. The proportion of variation explained by each axis were 25.06% axis 1, 11.68% axis 2 and 10.19 axis 3.

### 4.3.2 Glycoalkaloid content

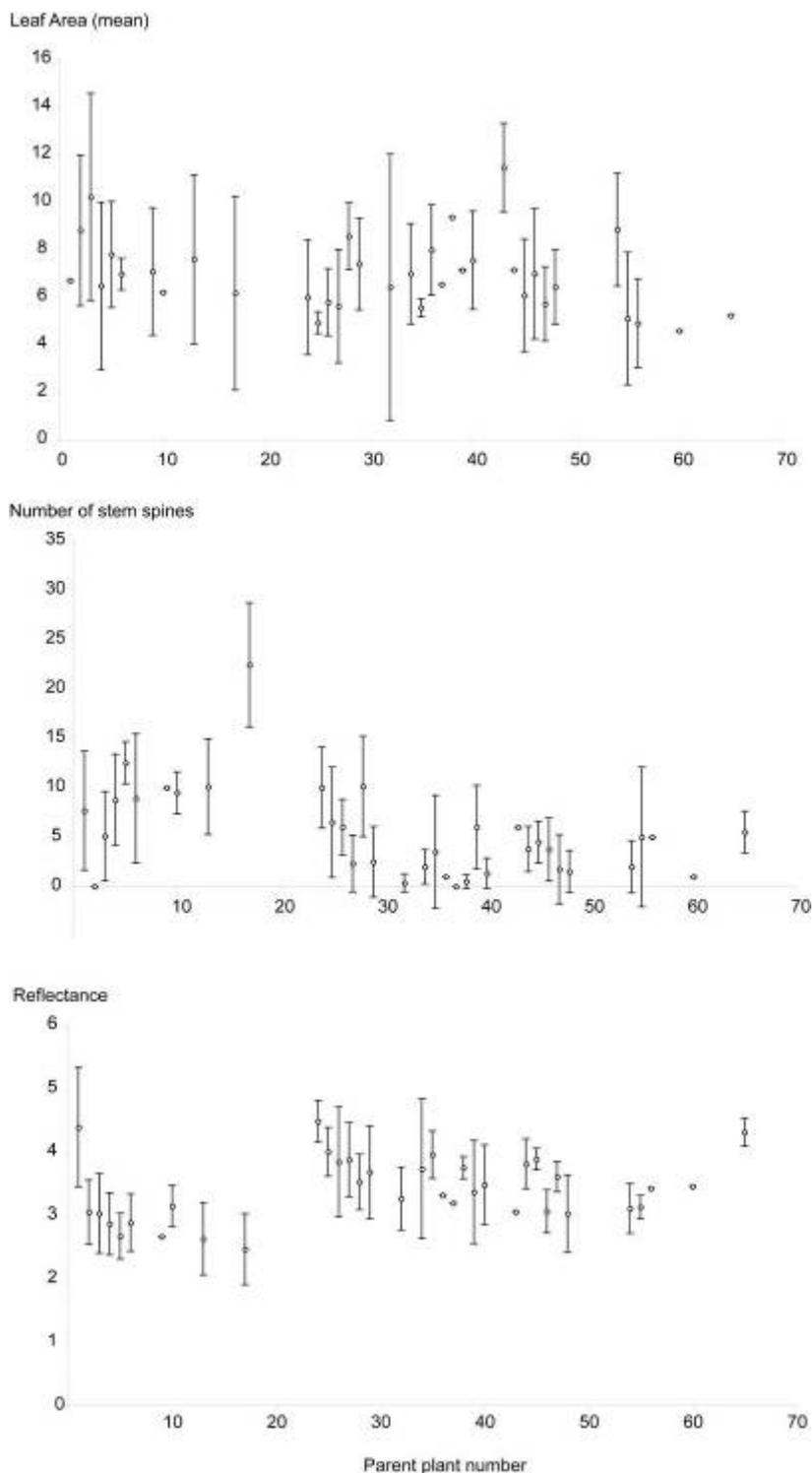
Glycoalkaloid extractions have been made from *S. centrale* fruit (green fruit and ripe fruit, collected from different locations, e.g. Napperby station NT and Jamestown SA).

Glycoalkaloids were detected in samples of green potato, and methods are working. In a variety of sample extraction and chemical analyses, more recently involving some mass spectrometry, no  $\beta$ 2-chaconine has been detected in any *S. centrale* fruit samples. The identity of the glycoalkaloids present in *S. centrale* is the subject of ongoing investigation.

### 4.3.3 Morphometric variation among shade-house grown *Solanum centrale*

Assessment of morphological variability revealed high levels of plasticity among the 237 plants surveyed from 35 fruits from fruit sourced in eight locations (Figure 15). Sample Sc17 was germinated from fruit collected off *Solanum cleistogamum*. This sample was obviously different, for example, was more spiny and had smaller sized leaves. Among all traits measured, the variability was as great within fruits as between them. Some between-fruit differences were significant for leaf reflectance. This is a measure of how much light is

reflected from the surface of leaves and corresponds with leaf pubescence (hairiness) and the reflective quality of the hairs and leaf surface (colour). These characteristics correspond with leaves that had copper-coloured hairs versus silver hairs.



**Figure 15: Morphometric variability within fruits for three measures**

Each point represents the average data for all plants from a particular mother plant (i.e. fruits were collected from one plant); error bars are standard deviations. Note parent plant number 17 was *Solanum cleistogamum*; all others are *Solanum centrale*.

## 4.4 Conclusions

The outcome of these investigations has been to screen and identify genetic markers for *Solanum centrale* that identify genetic individuals. These markers will be able to be used in plant improvement experiments to assess genotype x environment variability. Techniques for the screening of glycoalkaloids in fruit have been established.

The baseline genetic diversity of *S. centrale* is high. These markers also reveal that genetic diversity may be partitioned into regional groups.

The variability in a variety of plant traits measured was high, as was variability in plant morphology. Between-plant differences were as great as within-plant differences for the traits measured. The extensions of this study to measure traits of value to the bush foods industry are underway based on field trials.

It is clear from these studies that the development of an ideotype for *S. centrale* will be able to take advantage of the high level of character variability, differences in fruit size, bitterness, spininess and growth form. This work will be conducted in stages of work to come.

## 5. Steroidal glycoalkaloids in the fruit of *Solanum centrale*

Maarten Ryder, Marie O'Hanlon, Bruce Hawke and Michael Karkkainen

### Acknowledgements

We thank the Alice Springs Desert Park, Jamestown Community School, the Narungga Aboriginal Progress Association and Reedy Creek Nurseries for supplying or granting permission for the use of fruit samples.

### 5.1 Introduction

The fruit of *Solanum centrale* is a part of the traditional diet of Aboriginal people in Australia's arid zone (Latz 1995). The dried fruit and dried and ground fruit are increasingly used in the commercial food industry in Australia. The fruit is used to flavour a range of value-added food products from pasta to chutneys and dukkahs (Robins & Ryder 2004).

Many of the Australian *Solanum* species produce edible fruits, but these are usually only harvested when the fruit is fully ripened. There are also a number of species of *Solanum* which grow in the same regions that produce toxic fruits and are avoided by Aboriginal people (Latz 1995).

As is the case with many solanaceous fruits, there are reports that the fruit of *S. centrale* contain toxic, bitter steroidal glycoalkaloids (Hegarty et al. 2001). Earlier, Aplin and Cannon (1971) reported the occurrence of a 'moderately strong positive test for [unspecified] alkaloids' possibly by analysis of the foliage of *S. centrale* only, and Collins et al. (1990) reported a positive reaction with an alkaloid test of leaf tissue.

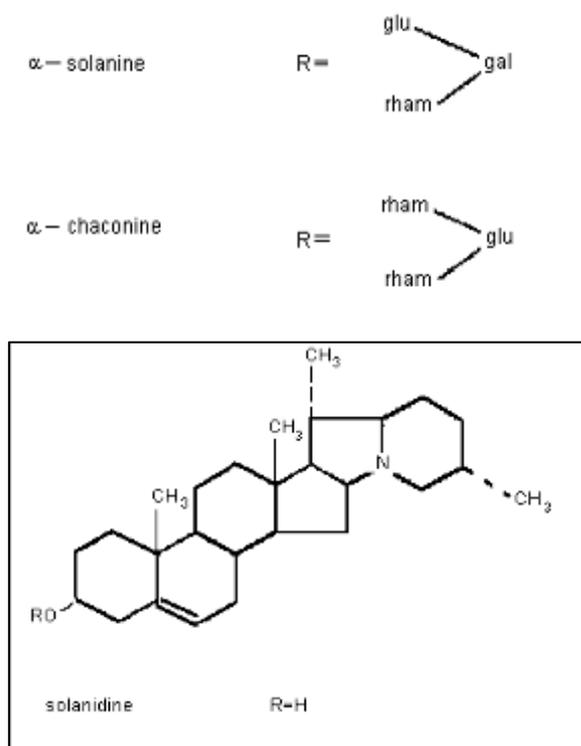
Hegarty et al. (2001) analysed several different fruit samples of *S. centrale* for solanine-related compounds, using acetic acid/sodium bisulphate extraction followed by alkaline precipitation and then separation by thin layer chromatography (TLC) and subsequently high performance liquid chromatography (HPLC). They analysed whole frozen green and ripe fruit and also dried fruit, both whole and ground, and found evidence of solanine compounds in all samples. They reported that the main steroidal glycoalkaloid present was  $\beta$ 2-chaconine at 550 mg/kg dry weight (green fruit), 110 mg/kg dry weight (ripe fruit) and 140 mg/kg dry weight (dried fruit). The levels of glycoalkaloids in green fruit were reported to be close to high levels found in green potatoes. They concluded that commercial batches of fruit should be monitored for levels of solanine-related compounds, because although the levels decreased as fruit ripened, they became more concentrated again during the final drying process. Fruit is normally traded dried and whole or dried and ground.

This study was initiated to build on the previous work (Hegarty et al. 2001) and to establish a method for monitoring steroidal glycoalkaloids in commercial batches of *S. centrale* fruit.

## 5.2 Materials and methods

### 5.2.1 Authentic glycoalkaloids

Authentic samples of  $\alpha$ -solanine and  $\alpha$ -chaconine (Figure 16) were purchased from Sigma, St Louis, Missouri, USA. These standards were dissolved in methanol and used for comparison in the chemical analysis of samples by TLC, HPLC and mass spectrometry. In addition, authentic glycoalkaloid samples were partially hydrolysed in acid (0.2N HCl in methanol, 65°C for up to 2 h; Friedman et al. 1993) to generate the related  $\beta$ - and  $\gamma$ -solanine and chaconine compounds as well as the solanidine steroid (Figure 16).



**Figure 16: Chemical structures of  $\alpha$ -solanine,  $\alpha$ -chaconine and the steroid solanidine**

*Solanine and chaconine are composed of solanidine with sugar molecules attached at position 'R'. Solanine has a branched three-sugar portion that contains glucose (glu), rhamnose (rham) and galactose (gal); chaconine has a branched three-sugar portion that contains two units of rhamnose and one of glucose.*

### 5.2.2 Plant material

Fruits of *S. centrale* were obtained from (a) plantings at Murray Bridge SA, Jamestown SA, Moonta SA and Palmer SA; and (b) natural stands of *Solanum centrale* at Napperby Station, NT, collected in December 2005. Green fruits were stored at -20°C, and dried fruits were stored under desiccation at room temperature.

Fruit samples from *Solanum orbiculatum* sub-species *orbiculatum* were obtained from the Alice Springs Desert Park, June 2006.

Potatoes (*S. tuberosum*) were purchased from a local supermarket and were allowed to turn green by storing them in sunlight.

### 5.2.3 Protocols for sample extraction and clean-up

#### Initial protocol

Fruit samples of *S. centrale* were processed following the method of Jonker et al. (1992) which was developed originally for potato. Samples were ground (Ultra Turrax, IKA) for 1 minute in distilled water and a sub-sample was homogenised a second time in methanol/acetic acid/water (94:1:6, v/v/v).

Samples were partially purified by adsorption on to solid phase extraction columns (SPE CN Bond-Elut, Varian Inc.) which were washed with water and then eluted with 50% aqueous methanol.

#### Later protocol (Alt et al. 2005)

After homogenisation as above, samples were partially purified by passing through Waters Oasis HBL SPE columns and washing with HCl, ammonia solution and then methanol/ammonia before elution with methanol.

In a later modification of the method, lipids were removed in the early stages of extraction by homogenising samples in chloroform/methanol (2:1, v/v), and taking the methanol phase formed after addition of KCl, before proceeding to the SPE partial purification step.

### 5.2.4 Separation of glycoalkaloids

#### Thin layer chromatography (TLC)

TLC of authentic compounds and partially purified fruit extracts was performed using silica gel 60 chromatography plates (Merck). The solvent mixture used most often was chloroform/methanol/2% ammonia (65:35:5, v/v/v; Friedman et al. 1993). Glycoalkaloids were visualised using iodine vapour (Friedman et al. 1993).

#### High performance liquid chromatography (HPLC)

After partial purification using SPE columns, authentic compounds and samples were dissolved in acetonitrile/0.01M Tris HCl pH 7.8 (3:2, v/v) and separated by HPLC on a C18 column (Alltech Alltima 5u, 250mm x 4.6 mm type) using an Agilent model 1100 HPLC. The solvent used was acetonitrile/0.01M Tris HCl pH 7.8 (3:2, v/v), flow rate 0.5 ml/min, 30°C and peaks were detected at 205nm using a Diode Array detector.

#### Chemical identity of glycoalkaloids

Authentic glycoalkaloids and selected partially purified plant extracts were analysed by mass spectrometry using a Thermo Electron TSQ Quantum. The MS conditions were full scan mode in Q1, source: positive Electrospray Ionisation; spray voltage 3200V; sheath gas pressure (arbitrary units) 11; capillary temperature 270°C; sample infusion at 5µL/min. Positive Ionisation gives molecular weight of the molecular ion (m/z) + 1 unit.

## 5.3 Results and discussion

### 5.3.1 Establishment of methods

The methods for extraction, partial purification and separation of the glycoalkaloids from fruit of *S. centrale* were adapted and improved in the initial phase of the work. At first we used methods that had been developed for the analysis of potato tissues for solanine and chaconine compounds. Solanine and chaconine are the two main glycoalkaloids that cause health problems from eating green potatoes. The methods (e.g. Jonker et al. 1992) worked very well for potato tissues, and compounds corresponding to both  $\alpha$ -solanine and  $\alpha$ -chaconine were easily detectable by TLC and HPLC.

For fruit of *S. centrale*, we modified the method to that published by Alt et al. (2005). We tested different washing procedures for the solid phase extraction cartridges, as done by Alt et al. (2005), and optimised the procedure using their 'combination' wash. Following this modification, we improved the method by changing to a new type of solid phase extraction cartridge, and then further modified the procedure to remove lipids as an early step (B Siebert September 2006, Visiting Research Fellow, University of Adelaide, pers. comm.).

The published methods for potato usually rely upon extraction of glycoalkaloids from up to 50 g or so of potato tissue. We scaled down the extraction procedure so that we could extract and separate the glycoalkaloids from a single green, ripe or dried fruit of *S. centrale*. This is highly desirable for research work, where the number of fruits available from our source material is often limited.

The methods were refined, as described, to make it easier to extract and detect compounds from *S. centrale*. Extracts of *S. centrale* fruit appeared to contain many more compounds that had HPLC retention times that were similar to  $\alpha$ -solanine and  $\alpha$ -chaconine and their  $\beta$ - and  $\gamma$ -relatives. Spiking *S. centrale* extracts by adding authentic  $\alpha$ -solanine and  $\alpha$ -chaconine to fruit extracts before analysis was helpful, and confirmed that we were capable of extracting and separating out these compounds using the techniques we had developed.

In addition to using TLC and HPLC separation, where we compared the mobility of compounds in plant extracts to those of authentic standards, we were able to use mass spectrometry to determine the molecular weights of authentic and unknown compounds. This was critical to our success because of the presence of many compounds in fruit extracts that had retention times similar to the authentic standards. Without the mass spectrometry it would not have been possible to make definitive assignments of compounds from the HPLC traces.

### 5.3.2 Solanine and chaconine glycoalkaloids

We were not able to purchase or obtain  $\beta_2$ -chaconine or other solanine and chaconine family glycoalkaloids, other than  $\alpha$ -solanine and  $\alpha$ -chaconine. We therefore generated the families of solanine and chaconine compounds from the authentic samples by partial acid hydrolysis. The molecular weights of these compounds are shown in Table 14. We have separated these compounds by both TLC and HPLC and the  $R_f$  (relative mobility, TLC) and retention time (HPLC) data are shown in Table 14.

**Table 14: Molecular weights and separation of solanine and chaconine compounds**

Compound	Formula	Molecular Wt	Rf*	Retention time+
$\alpha$ -solanine	C45H73NO15	868.06	0.19	6.702
$\beta$ 1-solanine	C39H63NO10	705.92	(not detectable)	
$\beta$ 2-solanine	C39H63NO11	721.92	0.28	
$\gamma$ -solanine	C33H53NO6	559.78	0.38	
$\alpha$ -chaconine	C45H73NO14	852.06	0.23	7.261
$\beta$ 1-chaconine	C39H63NO10	705.92	0.29	
$\beta$ 2-chaconine	C39H63NO10	705.92	0.36	9.744
$\gamma$ -chaconine	C33H53NO6	559.78	0.42	
solanidine	C27H43NO	397.64	0.57	

\* Mobility of compounds relative to the solvent front, using the system described in Materials and methods.

+ Retention time in HPLC separation system, in minutes.

### 5.3.3 Glycoalkaloids in fruit of *S. centrale*

Using the techniques outlined in the methods section and described further under 'Establishment of methods', we made extracts of *S. centrale* fruit that were obtained from a number of different sources. These included cultivated plants at Jamestown SA, and commercial batches of material that had been harvested from the bush in central Australia. We also made extracts from the fruit of *S. orbiculatum* subspecies *orbiculatum*. This species is known to produce bitter fruits, which are eaten only by certain groups of Aboriginal people, such as the Warlpiri (Latz 1995).

We looked for, but were unable to confirm the presence of,  $\beta$ 2-chaconine as the main glycoalkaloid in fruit of *S. centrale*. In the work reported by Hegarty et al. (2001), the chemical separation techniques used were TLC and HPLC. Our work shows that when only these two separation methods are used, it is extremely difficult to make an unequivocal identification because of the presence in HPLC traces from *S. centrale* extracts of a number of other compounds with similar retention times to the authentic solanine and chaconine family of compounds. These other materials may or may not be glycoalkaloids.

Using mass spectrometry of partially purified fruit extracts, we were not able to detect the characteristic molecular weight of  $\beta$ 2-chaconine in *S. centrale* ( $m/z + 1 = 706.35 - 706.48$  for standard compounds). We did, however detect evidence of at least one other glycoalkaloid in the solanine/chaconine group.

We processed many samples to reach this conclusion: 102 fruit extract samples were tested by HPLC and 18 of those were analysed by mass spectrometry. Both green and ripe fruit were analysed. In addition, 8 samples from potato were analysed by HPLC and some of these were also analysed by TLC.

Fruit of *S. orbiculatum* contained a compound that was not distinguishable from  $\alpha$ -solanine by TLC and HPLC, compared to authentic  $\alpha$ -solanine, and extracts contained a clear molecular weight signal expected of  $\alpha$ -solanine by mass spectrometry ( $m/z+1 = 868.5$ ).

We have not yet been able to quantify the glycoalkaloids in fruit of ripe *S. centrale*. At this stage it appears that the levels of solanine and chaconine compounds are not high, compared with concentrations in green potato; the detection of compounds in *S. centrale* extracts was much more difficult than for potato extracts, with the signals being much lower in mass spectrometry for example.

## 5.4 Summary and conclusions

Methods were developed and adapted for the extraction and chemical separation of glycoalkaloids from the fruit of *S. centrale*. The main separation methods used were thin layer chromatography (TLC) and high performance liquid chromatography (HPLC). Mass spectrometry was used to confirm molecular weights of authentic compounds and compounds in plant extracts.

The solanine and chaconine families of compounds were generated by mild acid hydrolysis of authentic  $\alpha$ -solanine and  $\alpha$ -chaconine. These families were separated by both TLC and HPLC and their behaviour in these separation systems was confirmed.

Extracts of green potato were shown to contain compounds that behaved as expected for  $\alpha$ -solanine and  $\alpha$ -chaconine, in easily detectable amounts.

The glycoalkaloid  $\beta$ 2-chaconine was not detectable in extracts of fruit of *S. centrale* (both green and ripe). Another member of the solanine/chaconine family of compounds was detected, but not in all fruit samples analysed. The conclusion of Hegarty et al. (2001) that  $\beta$ 2-chaconine is the main glycoalkaloid in *S. centrale* is not supported.

Levels of glycoalkaloids present in fruit of *S. centrale* are yet to be quantified, but appear to be low compared with levels in green potato tissue.

Extracts of the fruit of *Solanum orbiculatum* subspecies *orbiculatum* contained a substance that was not distinguishable from  $\alpha$ -solanine.

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## Appendix 1: Progress report on Livelihoods PhD

### **Indigenous livelihoods and the emerging bush produce industries – recent experiences from Australia’s arid zone**

Final report to June 2006

This sub-project started in February 2006 when Janelle White commenced her PhD candidature. Another candidate had enrolled in March 2005, but officially withdrew in October 2005 having made little progress. The scholarship could not be re-advertised until after the first candidate had officially withdrawn, which explains the delay in Janelle’s commencement.

Janelle has progressed well. She has received satisfactory progress reports in the mid-year minor review and end-of-year major review (just completed) and UniSA has approved her study plan for the next 12 months. She has also submitted her PhD proposal, which is currently being reviewed by the UniSA Centre for Regional Engagement Research Degree Review Panel, completed a good draft of Chapter 1, reviewed relevant research and theory, and is working on a research ethics proposal with the advice of Juanita Sherwood and in consultation with her other supervisors.

Janelle has done extensive work in exploring possible study sites and next week will commence three field trips to discuss participation with a number of Aboriginal communities. She has developed a matrix as a tool for describing community characteristics based on previous research. This will assist with site selection and, eventually, data analysis. Janelle has established a good understanding of relevant communities and other stakeholders and is establishing sound relationships with them. She has done an excellent job in generating support for her project.

As expressed in the thesis proposal (White 2006, pp.1–2):

*This research aims to significantly expand our understanding of socio-cultural issues around Aboriginal people’s involvement in the emerging bush produce industries in Australia, and to help identify fresh ways in which benefits can be maximised (and costs minimised) to ensure the development of a socio-culturally fair and equitable industry. In order to achieve this, this study will look at how and why Aboriginal people are choosing to engage in the industry, and will identify some of the positive and/or negative effects this engagement is having on people’s livelihoods, well-being and life opportunities.*

The concept of ‘(sustainable) livelihoods’ will be further defined and explored, drawing on recent information and research conducted predominantly within international contexts. This will help to identify the complex nature of such livelihoods and emphasise the need for a multi-level, people-centred approach in Australia. Such an approach could help to ensure that Aboriginal people are not only more willingly involved in the development of the bush produce industries, but that they could also receive more substantial benefits to the quality of their lives from such involvement – including their social and cultural condition.

More specific aims are to:

- investigate the underlying assumption that involvement in bush produce industries is good for Aboriginal people and their communities
- better understand the reasons why Aboriginal people have chosen to participate (or not) in the bush produce industries and establish whether they have (different) aspirations for future involvement

- identify the nature of socio-cultural indicators important to Aboriginal people to help establish more appropriate research and development approaches within the industries
- establish what impacts involvement (or non-involvement) has had on people's livelihoods and wellbeing to date, including social and cultural effects
- contribute to future developments that maximise the benefits and minimise the negative impacts of industry involvement and development, through modification and further development of an Aboriginal Australian model of sustainable livelihoods
- ultimately help empower more individuals and communities to develop and participate in bush produce industries that maximise benefits to their livelihoods and wellbeing, and that allow people to retain control over their traditional knowledge. (White 2006, p.2)

The thesis is located within the 'Bush foods economic value chain' developed by DKCRC (refer Figure 2). It also uses a 'sustainable livelihoods' framework, which Janelle is building from existing livelihoods approaches (e.g. Chambers 1987, p.1; Chambers 1997, p.11; Chambers & Conway 1992, p.7; Carney 1998; Scoones 1998; Cahn 2002), recent work incorporating the concept 'cultural capital' (e.g. Glavovic et al. 2003), and recent work at the Centre for Appropriate Technology. The concept 'sustainable livelihoods' is defined as follows:

*A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living. (Chambers & Conway 1992; p.7)*

*A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base. (Carney 1998; Chambers 1997, p.11; Scoones 1998)*

As Janelle states in her thesis proposal:

*The above definition of 'sustainable livelihoods' has been generally adopted as a basis for rural development research and practice by a number of government, non-government and multi-lateral organisations in recent years (including the Department for International Development (UK) (DFID), the United Nations Development Programme (UNDP), OXFAM and CARE) (Cahn 2002). It is at the basis of a relatively new approach to poverty reduction known as the 'Sustainable Livelihoods' or 'SL' approach. This approach has been used as a tool for planning, reviewing and evaluating projects, as well as researching, analysing and developing policy (Cahn 2002). It is aimed at maintaining and building stocks of various assets (often referred to as 'capital') to which people have access, in order to achieve a set of livelihood outcomes and to provide for future generations.*

The draft thesis structure and timelines are presented in Attachment 1. This project is well on track and Janelle is adhering to timelines to ensure that it is completed and her project is submitted by February 2009. An industry supervisor has not yet been appointed and we will do this as soon as possible.

## Appendix 2: Guiding questions to ask traders of bush harvested products (Chapter 2)

### Opening

Fiona to explain joint CSIRO – DKCRC project.

Fiona to explain consent form

### General (past and present)

What is the history of your bush food business?

How do you describe your business now?

What is the organisational structure of your business?

Why are you involved in this business? [e.g. income/local employment/country travel]

Is the present harvest of bush resources for sale sustainable? (in economic, social &/or environmental terms)

### Social/personnel

Where do the people from whom you buy live?

Who are the main people from whom you buy?

Where do they collect from?

What are the main benefits of this business?/Why do you think harvesters are involved in it?/How motivated are they?

What are the main constraints to harvesting?/What makes it hard for harvesters?

How could these constraints/problems be overcome?

Do you work in a cooperative way with other buyers?

Would you want other people to be involved?

Would you promote bush harvest as a business for more people to get involved with?

Do you employ Aboriginal people in roles other than harvesters?

### Economics/market

How has your business developed over time?

Are your markets growing or stable or declining?

Are you making money/breaking even/losing money?

Who do you sell too?

Do you sell to local people, Aboriginal and other?

## **Resource species**

What are the main species you buy?

What species and volumes were purchased in 2004, 2003, ... in the past?

Do harvesters provide you with the species worth the most? or easiest to collect?

What species have sale potential but are not used?

## **Environmental**

What issues are there with the ecological sustainability of bush harvest from past to present?  
What about the future if harvest rates were to increase?

How do harvesters and other Aboriginal people 'manage' or care for the land and the species they collect?

What affects has harvesting had on plant populations? on country?

What affects has pastoralism, burning, weeds and other land use changes had on commercial bush food plants?

Have there been species you couldn't get because they had been over-collected in the region?

Do you contribute to the environmental management of resources and/or the country?

How should environmental management be improved?

## **General questions on the future of your business**

What future do you see for your business?

Would it be sustainable if there were a 2x increase in product demand?

Would you encourage other people (especially Aboriginal groups) to get more involved in selling bush resources? In what roles?

What do you imagine the Bush Produce industry will be like in 5 and 10 years time?

Have you written about your business (articles, papers, books etc.) Could I have a copy?

What research questions should this CSIRO bush harvest project address?

In relation to the wider Bush Produce industry what questions should be addressed in the future?

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