Domestication of Australian Acacias for the Sahelian zone of West Africa

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Summary

Multi-purpose Australian Acacias have the potential to form an integral component of Agricultural systems in the Sahelian zone of West Africa. More that a decade of research and domestication has identified well adapted species such as *Acacia colei*, *A. torulosa*, *A. tumida* and *A. elachantha*. These perennial species grow rapidly, are well adapted to infertile soils, they produce seeds that can be easily harvested and processed into nutritious human food. They produce large quantities of fuel wood and construction timber, can be used as windbreaks, improve soil fertility and may have a significant role as multi-purpose trees in sustainable Agroforestry systems. *A. colei* has shown the greatest potential for adaptation and seed production for human food in the Maradi area of Niger. Its main limitations may be overcome by the development of other species such as *A. torulosa*. Present and future research aims to develop *A. torulosa* for Agroforestry systems. The Sahelian eco-farm Agroforestry model will give valuable information on the suitability of *A. colei* in wider areas of Niger. Future research needs to determine the breeding systems of potential Australian Acacias, develop clonal propagation methods and assess their potential for human food. Re-evaluation and domestication of a broader genetic base of these valuable species will be needed for a regional collaborative program that embraces the main agro-climatic regions of the Sahel.

Resume

Les acacias australiens constituent une composante intégrale du système de production au Sahel. Les recherches et les efforts de domestication de ces dernières décennies ont identifiées des espèces prometteuses telles que *Acacia colei, A. torulosa, A. tumida* et *A. elachanta*. Elles ont une croissance rapide et poussent sur des sols les plus dégradés.

Ces acacias produisent des graines facile à récolter. Ces dernières sont utilisées dans l'alimentation humaine. Ils produisent de larges quantités de bois de chauffe et de service et sont aussi utilisés comme brise-vent et dans l'amélioration de la fertilité du sol. Ils jouent de ce fait un rôle important dans les systèmes durables d'agroforesterie. Dans la région de Maradi au Niger, *A colei* s'est révelé plus adapté pour la production des graines destinée à l'alimentation humaine et est pour cela utilisé dans les fermes biologiques sahéliennes. Les limites de cette espèce en agroforesterie ont été relevées par l'émergence d'une autre espèce, *A. torulosa* reconnue pour ses caractéristiques agroforestières. Les recherches futures doivent s'orienter vers la détermination du système de reproduction des espèces, le développement clonal et les méthodes de propagation et l'évaluation de leurs potentiel dans l'alimentation humaine.

La caractérisation, l'évaluation et la domestication d'une large base génétique de ces espèces prometteuses sont indispensable dans un programme de collaboration régionale en prenant en compte les principales zones agroclimatique du Sahel.

Introduction

The Sahelian zone of West Africa and semi-arid tropical regions of the world are under great threat. Climate change, diminishing and unreliable rainfall, traditional mono-culture farming practices, explosive population growth, frequent famines and high deforestation rates have led to severe environmental degradation, impoverished soils, poor crop yields and extreme poverty (Nash, 2000). Food security in these regions is tied to a small selection of mostly annual crops growing under unfavorable agro-climatic conditions (FAO, 1999).

Vietmeyer (1996) has argued that the 'green revolution' that had a dramatic impact on food production in the tropical and sub-tropical world has by-passed the semi-arid zones of Africa. If there is to be a 'green revolution' for arid and the semi-arid tropics, then it needs to come through plants that thrive under such conditions, yield well and require minimum inputs (Rinaudo, *et al.* 2002). Plants need to be domesticated to suit the prevailing environmental conditions, rather than a 'green revolution' to suit the plants by modifying the environment (i.e. via irrigation, fertilizers, herbicides, pesticides).

The seeds of certain Australian Acacias have formed a part of traditional diets of Australian Aborigines and their usage has been well documented (O, Connell *et al*. 1983; Latz 1995; Devitt, 1992). These species generally occur in the hot dry arid semi-arid tropics of Australia and are well adapted to similar regions of the Sahelian zone of West Africa such as at Maradi, Niger.

These multi-purpose Australian Acacias, which also produce highly nutritious seed, have great potential to become a significant component of a new 'green revolution' for the Sahelian zone of West Africa (Harwood *et al*. 1999). More than a decade of positive research and development has now passed in the Maradi area of Niger and elsewhere. It is now time to continue the domestication and wide promotion of these species. Harwood *et al.* (1999) and Rinaudo *et al.* (2002) have called upon appropriate International, national and local Research and Development agencies to work together to ensure these species form an integral component of the agricultural systems of the arid and semi-arid tropical regions of the world.

This paper summarizes the past and present development and domestication achievements of the Australian Acacias in the Sahelian zone of West Africa, gives current research activities, proposes future research directions and a long term collaborative approach to ensure these species are domesticated and their long recognized potential becomes a reality.

Domestication of Australian Acacias in Niger

Past achievements
Australian Acacias were first introduced and trailed in the Sahelian region of West Africa in the 1970's and 1980's by a number of research organizations, with the aim of finding tree species for fuel wood and windbreaks. (Cossalter, 1987). Initial interest in Australian Acacias began in the early 1980's in the Maradi area of Niger when it was realized that the traditional farming practices, which relied on annual crops in an uncertain environment, was unsustainable. Famine could occur in any year so long as farmers relied on these annual crops. Experiments by the Serving in Missions (SIM) Maradi Integrated Development Project (MIDP) with a wide range of indigenous and exotic plants with human food potential were assessed and clearly identified the Australian Acacias as stand out performers for a range of wood products and human food (Rinaudo, et al 2002). This collaborative work by the MIDP over the last decade was supported by the CSIRO Forestry and Forest Products Australian Tree Seed Centre (ATSC), Ohafemi Awololowo University in Nigeria, local communities and the Nigerian Government.

The primary focus of this work has been to improve food security by identifying, developing and promoting new human food sources for the Maradi region of Niger. Whilst a wide range of Australian Acacia species with potential for Human food were evaluated (e.g. *A. colei, A. coriacea, A. elachantha, A. torulosa, A. tumida, A. victoriae*), *A. colei* was chosen as the key species to develop and promote in rural villages.

The main advantages of *A. colei* include:

- Perennial habit.
- Adaptation to infertile soils.
- Nutritious seed for Human food.
- Seed easy to harvest and process.
- Seed can be stored for long periods.
- High seed production from the second year.
- Provides other products and services.
    1. Fuel wood products.
    2. Construction timber.
    3. Windbreaks.
- Improved soil fertility via Nitrogen fixation and organic matter via mulch.
- Reduction in the risk of famine.
- Foliage not eaten by livestock.

Details of these advantages with research results are given by Rinaudo *et al.* (2002).

The silvicultural methods to maximize seed production from *A. colei* have also been identified and include:

- Propagation in tree nurseries.
- Tree spacing in the field (10 x 10 m) or field borders.
- Cultivation 3-4 x in the dry season.
- Fertilizer at planting (Compost, Rock Phosphate)
- Pruning in 3rd year (April/May) to 1.0-1.5 m height, then every 2nd year thereafter.

- Harvesting and processing of coiled pod type in March/April.

For details of these methods and instructional guide see Harwood *et al.* 1999; Evans *et al.* (2001).

Widespread planting and use of *A. colei* has occurred in over 90 villages in the Maradi area over the last decade. Recent estimates indicate that people in over 55 villages harvest and eat Acacia seed. (T. Abasse *personal communication*, 2004). This field exposure has also highlighted numerous disadvantages of *A. colei* that have adversely affected the promotion and uptake of *A. colei*. These disadvantages will need to be overcome if widespread adoption is to be achieved and include:

- Severe competition with Agricultural crops.
- Short lifespan (5-10 years).
- Susceptibility to wind damage.
- Dieback beginning in the 3rd year.
- Seedless years.
- Seed eaten as a food additive (25% acacia flour mix with traditional foods).
- No market for seed.
- Propagation via tree nursery.

Current MIDP recommendations for *A. colei* include: Use only in field borders, reclamation of barren land and in/around compound houses.

In order to continue the domestication and use of *A. colei*, more recent studies with *A. colei* have concentrated on understanding its Flowering biology (Abasse, 2003a). This has also led to the selection of superior seed producing provenances of *A. colei*

<u>Understanding the reproductive biology of *A. colei*</u>

The reproductive biology of six provenances of *A. colei* (Maslin& Thomson) obtained from the Forest Products Australian Tree Seed Centre (CSIRO) was studied at the National Agricultural Research Institute of Niger Republic. Flowering occurred in all the provenances at ages 10-12 months. Onset of flowering in *A. colei* was usually in August or September with duration of 120 days. In 1999, frequency of flowering ranged from 17.5% in Windjana to 46% in Purnululup provenance. The inflorescence of *A. colei* is in a spike and andromonoecious. The mean number of spikes per tree ranged from 1,020-+2.03 in Mtisa to 6,470-+4.7 in the Leopold downs provenance. Flowering intensity ranged from 125,069-+1.61 in Mtisa to 657,816-+2.03 in Leopold downs. The highest mean number of male flowers was observed in the Purnululup provenance with a value of 71.1-+3.64 (53%) and lowest number of male flowers of 58.5-+5.23 (47.9%). The number of hermaphrodite flowers ranged from 43.3-+5.22 (35%) in the Mtisa provenance to 53.8-+5.39 (41.6%) in the Port hedland provenance. Sex ratio ranged from 1:1 in Windjana provenance to 2:1 in the Mtisa provenance with an overall mean ratio of 1.5:1 (male: female flowers). The peak of anthesis was attained on the third day, thereafter the number of opened flowers started to decrease on the 4th day and complete anthesis occurred on the 5th day. In general, *A. colei* had a basipetal flower. The number of fruiting spike per twig ranged from a minimum value of 7.6-+0.3 (13%) in the Mtisa provenance to 11.2-+0.5 (19%) in the Leopold downs provenance. The number of fruit set per hermaphrodite spike ranged from a minimum value of 12.2-+0.4 (14%) in the Purnululup provenance to a maximum of 18.2-+0.7 (21%) in the Port headland provenance. The longest fruit of 10cm-+0.16 was observed in the Mtisa provenance while the shortest fruit length with value of 5.5 cm-+0.10 was observed in the Windjana provenance. The fruit width of *A. colei* ranged from a minimum value of 0.38mm-+0.03 in both the Port hedland and Leopold downs provenances to a maximum of 0.39mm-+0.04 in both the Bungle Bungle road and the Windjana provenances. *A. colei* is self-compatible and cross pollinated. Fruit set under selfing ranged from 6.5% in Windjana to 9% in Bungle Bungle road. Fruit set under cross-pollination ranged from 4.8% in Leopold downs provenance to 13.9% in the Mtisa provenance. Mean seed yield per tree ranged from 0.09-+0.26kg in the Windjana provenance to 5.0-+1.14kg in the Port hedland provenance at 18 months of age (Abasse, 2003b).

Coppicing system of *A. colei*

Trials to assess the response to various coppicing regimes of *A. colei* were carried out at the INRAN Maradi research station. These have aimed to improve the longevity of *A. colei* and understand the seed production of *A. colei* (Abass, 2003a). The results showed that pruning in May at 1m with a saw gave the best results.

The Sahelian Eco-farm concept was also established in 2003 and is a systems approach aimed at providing solutions to the main constraints to the rain-red agricultural systems of the Sahel. Australian acacias (particularly *A. colei*) are a central component of this system and provide, seed, wood production, reduce wind erosion and give valuable mulch for soil restoration (Pasternak, personal communication, 2003)

Animal production trials

Trials were conducted to determine if *A. colei* seed could replace fishmeal, the main protein source in Broiler chickens diets. The results showed that ground A. colei seed could replace between 50-70% of the fishmeal in a broiler chicken's diet without reducing the weight gain of the chickens. This is a very important finding because it will give a market value to *A. colei* seeds of at least 200F CFA / kg (Abasse *et al*. 2004).

Present activities

At Maradi, the MIDP has now turned attention to a thorough evaluation of *A. torulosa*, another promising Australian Acacia that appears to overcome many of the constraints found with *A. colei*. (Doran and Turnbill, 1997). *A. torulosa* has grown well in windbreaks at the ICRISAT Sahelian Centre in Niger (Rinaudo *et al*, 2002) and provenance trials with six seedlots were established at Maradi in 1998 (Table 1) and 30 ha of field borders were planted to these *A. torulosa* provenances at Danja (20km E Maradi). Comparative trials between *A. torulosa* and *A. colei* were established in 2001 at two sites in the Maradi area. A larger provenance trial aimed at broadening the genetic base of *A. torulosa* was established at Danja in 2002 and included 14 provenances of *A. torulosa*, three provenances of *A. plectocarpa* and *A. eriopoda* (Both closely related species to *A. torulosa*)(Maslin and McDonald, 1996). In addition progeny seed from superior *A. torulosa* trees (from 4 years old field border trees) from erect tall wood producing trees and more branched high and wood producing types were planted in trees blocks in 2002.

Preliminary results from these trials show that *A. torulosa* displays broader genetic variation and that there is great potential to select tall growing, high wood producing trees ideal for Agroforestry systems and more branching higher seed producing types for windbreaks in Agroforestry systems. Table 1 gives comparative data for six provenances of *A. torulosa*. Note two distinct types, tall erect types with few branches and more open multi-stemmed types with potential for high seed and wood production.

Table 1. Performance of *Acacia torulosa* provenances at Danja, Niger after 3 years and 4 months of growth.

Provenance/ Seedlot[1]	**Survival rate** %	**Mean tree height** (m)	**Mean tree width** (m)	**Growth habit**[2] (1-9)	**Number of main stems**[3]
16959	75	3.9 (2.7-5.3)[4]	2.6	7.8	2.2
19044	67	2.5 (1.2-4.0)	3.1	4.9	4.8
19037	77	2.4 (1.5-4.0)	3.0	4.5	4.4
18451	78	3.2 (2.4-4.3)	2.9	5.9	3.0
19930	77	5.0 (3.8-6.3)	4.1	7.3	2.7
Sadore	93	3.6 (1.8-4.8)	4.3	5.6	6.9

[1]Australian Tree Seed Centre Numbers. [2]Visual score: 1= Prostrate, 9 = Erect.
[3]Number of main stems originating < 0.25 m above ground level.
[4]Range of tree heights. All data is mean of 17-26 trees per provenance/seedlot.

The comparative trial between *A. colei* and *A. torulosa* at Danja showed that two year old *A. colei* trees planted at optimal spacing (10 x 10 m) produced 3-4 kg of seed per tree whereas *A. torulosa* trees of the same age planted at 5 x 5 m spacing produced 0.5 to 1.1 kg seed per tree (Note that with the closer spacing there are 2.5 x more *A. torulosa*. trees per unit area than *A. colei*, so that seed production per unit of land area was similar for both species). Seed production in the third year (2004) appears to be poor for both species.

Four year old *A. torulosa* trees when grown in field borders with 5 m spacing between trees have given seed yields of up to 14 kg and also produce significant quantities of wood. These same trees also display excellent coppicing and regrowth attributes. The tall erect growing types appear to have excellent potential for Agroforestry (Table 2.)

Table 2. Seed and wood production from *A. torulosa* trees grown in field borders at Danja, Niger after 4 years of growth.

Tree type/ Number	**Mean weight of Pods and seed** (kg)	**Mean weight of pods** (kg)	**Mean weight of seed** (kg)	**Dry weight of wood** (kg)
Branching types (39)[1]	9.7	5.4	4.0	
Branching types (25)	12.5	7.0	5.2	
Tall types (19)	4.9	2.4	1.7	
Branching tree No. 222	27.0	14.0	12.0	117.0
Branching tree No. 241	21.0	13.0	7.5	30.0
Branching tree No. 62	18.0	9.0	7.7	14.0
Tall tree No. 313	12.0	5.0	3.5	49.0
Tall tree No. 300	8.0	4.0	3.5	25.0
Tall tree No. 305	8.0	4.0	3.0	38.0

Table 3 shows the wider range of *A. torulosa* provenances and two new species of Acacia (*A. plectocarpa*, A. *eriopoda*) under trial at Danja and Maza Tsaye. Some of these provenances have now grown to over 6 metres in height in just 18 months and are beginning to display significant seed and wood production.

Table 3. Acacia species/provenances planted in field trials in the Maradi area (Danja and Maza Tsaye) in 2002.

Acacia species/provenance	No. of parent trees	No. of trees being evaluated Danja	Maza Tsaye	Seed produced in 2004	Mean tree Height (15months) (m)
Bauhinia reticulata	1	27	-		0.6
A. colei (Leopold downs)	1	27	5	√	2.8
A. torulosa 222	1	54	50	√	1.9
A. torulosa 313	1	54	30	√	2.7
A. torulosa Bulk A[2]	5	45	15	√	2.5
A. torulosa Bulk B[3]	5	27	15	√	2.9
A. torulosa 15964[1]	20	27	-		2.9
A. torulosa 16959	3	27	-		2.0
A. torulosa 18420	5	27	5		2.5
A. torulosa 18442	6	27	10		2.2
A. torulosa 19044	10	27	5	√	1.6
A. torulosa 19930	10	27	15	√	2.2
A. torulosa 19978	40	27	-		2.5
A. torulosa 20078	40	27	-	√	2.0
A. torulosa 20360	25	27	-		3.6
A. torulosa 20364	10	27	-	√	2.8
A. plectocarpa 18800	5	27	-	√	3.0
A. plectocarpa 18443	5	27	5		2.5
A. plectocarpa 16957	2	27	-	√	2.7
A. eriopoda 19183	40	54	-	√	2.1
A. eriopoda 18665	10	27	-	√	1.4
A. eriopoda 17164	40	27	-	√	2.2

[1] ATSC numbers.
[2]Bulk seed from 5 best branching *A. torulosa* trees (Field border trees planted in 1998).
[3]Bulk seed from 5 best tall *A. torulosa* trees (Field border trees planted in 1998).

The potential advantages of *A. torulosa* include:

- Longer lived (> 15 yrs).
- Adapted to infertile soils (more drought tolerant).
- Less competition with agricultural crops (deeper rooted).
- Nutritious seed for human food (> amino acid content than *A. colei*).
- Seeds easier to harvest & process than *A. colei.*
- Seed can be stored for long periods.
- Higher & stable seed production than *A. colei.*
- Multi-purpose Agroforestry tree.
    1. Fuel wood products
    2. Construction timber
    3. Windbreaks
    4. Seed
- Improve soil fertility via N. fixation & mulch/improved organic matter.
- Reduce risk of famines.
- Foliage unattractive to livestock.
- Direct seeding.

Future directions: Research needs

The primary focus of Acacia research in the MIDP at Maradi over the next three years will continue to evaluate, select and breed *A. torulosa* provenances. Two types will be targeted: 1. Tall erect timber type. 2. Spreading high wood/ seed producer. Field experiments will establish both types in local Agroforestry systems.

The breeding system of *A. torulosa* although assumed to be outcrossing needs to be determined.
Seed needs to be analyzed for human and animal food potential.
Methods for clonal propagation need to be identified.
Direct seeding trials have been successful, but need to be refined to ensure rapid, reliable and cost effective propagation in the field.

Re-evaluation of a broader genetic base of other deeper rooting Acacia species such as *A. tumida* and *A. elachantha* and the selection of widely adapted, superior seed/wood producers of *A. colei* lines should be carried out.

The performance of Australian Acacias within the broader Sahelian Eco-farm Agroforestry systems research with pilot sites across Niger need to be monitored.
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Proposed Regional Collaborative program

The case for establishing a long-term program for the domestication of Australian Acacias for the Sahelian zone of West Africa is stronger than ever. This program should be directed and co-ordinated by ICRAF with support from CGIAR and/or ACIAR. This program should embrace the major agro-climatic zones in the main West African countries (Mali, Burkina Faso, Senegal, Niger) with arid and semi-arid tropical zones. Major components of this program should include:

1. Identify agro-climatic zones with potential.
2. Provenance trials to identify adapted multi-purpose trees.
3. Selection and breeding for key selection criteria for agro-climatic zones.
4. Determine optimal management practices, planting methods, spacing, planting systems (Plantation, field borders, Agroforestry systems) in participation with the target communities.
5. Cost/benefit analysis for Agroforestry systems based on Acacias versus traditional and alternative systems
6. Funding for this program should come from recognized international sources to ensure long term funding and the viability of the program.

Once this program has been established key partners such as National agricultural research agencies and Non-Government Organizations involved in rural development (e.g. SIM, World Vision, Care etc) could be involved with local target communities to ensure potential impacts are realized.

A potential model for this program (5 yrs) could include:

1. Program leader (ICRAF)
2. Key Collaborator in each country
3. Regional field trials in agro-climatic zones
4. Annual workshops (2-3 days) for result sharing/discussion and direction setting. Rotated to different countries with field visits.
5. Invited participant to include key technical advisors from CSIRO (ATSC).

An important starting point for this program should include a through examination and study of the factors that have either promoted or hindered the planting and uptake of Australian acacias for human food and other uses in the Maradi area of Niger.

A training and information workshop could be conducted at Maradi so that MIDP technicians with input from INRAN can share their extensive knowledge and experience (>10 yrs) with Australian Acacias.

Conclusion

Australian Acacias should be evaluated widely in the agro-climatic zones of the Sahel. Along with the promotion of more widely known species such as *A. colei*, ongoing evaluation and domestication of other promising species (e.g. *A. torulosa*) for use in Agroforestry systems should be a future priority. Whilst the past emphasis has been on developing new Human foods, a broader multi-purpose use for these Acacias should be encouraged. Local communities can decide what is the most suitable use for these species for their needs.

If progress is going be made and poor communities impacted across the Sahel, then a well organized, long-term collaborative program for the domestication and promotion of these Acacias should be established with sustainable funding from international sources.

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