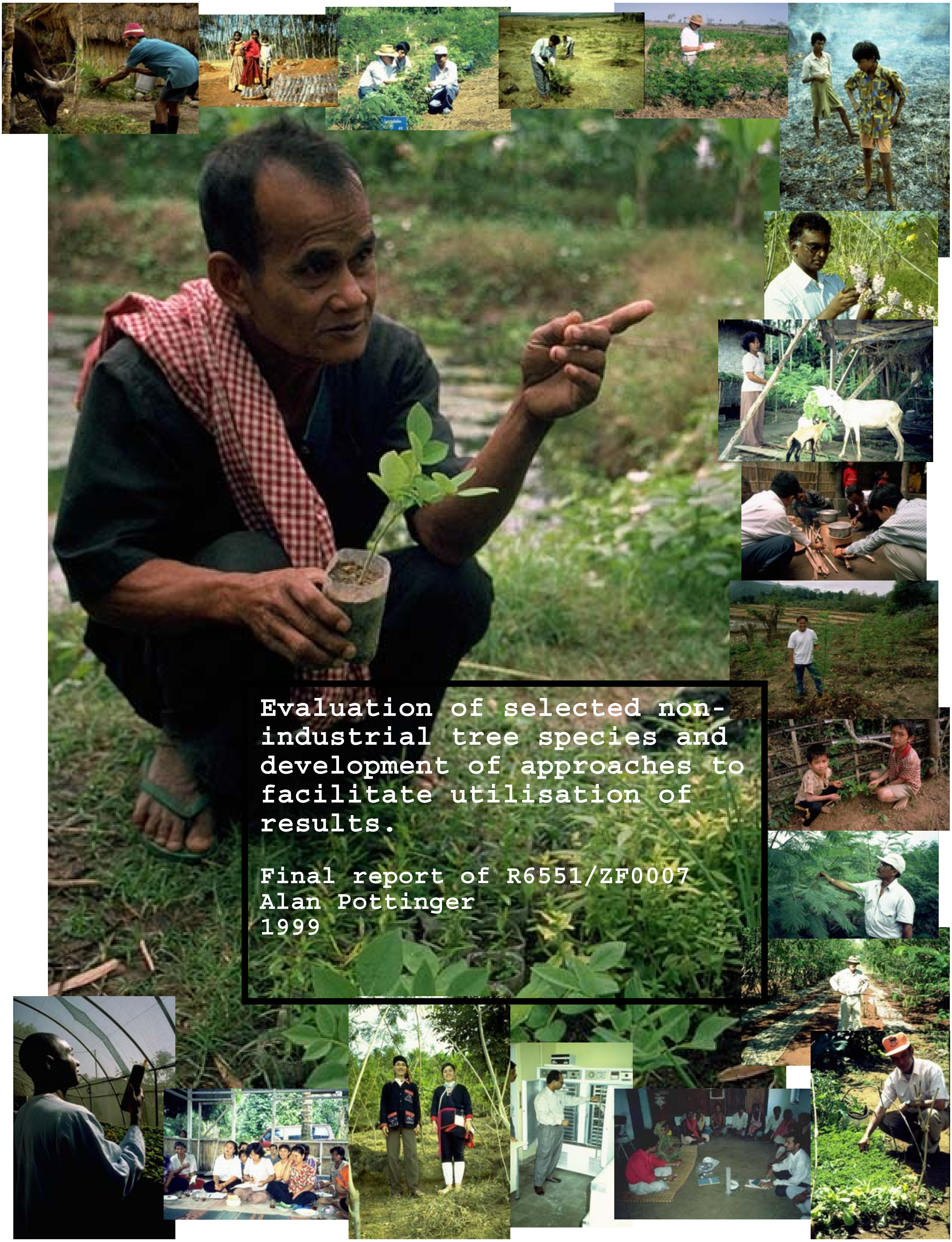

Evaluation of selected non-industrial tree species and development of approaches to facilitate utilisation of results.

Final report of R6551/ZF0007

Alan Pottinger

1999

Contents

Executive summary

The project was designed to investigate improvements to the current widespread utilisation of sub-optimal germplasm in agroforestry programmes, the poor uptake of results from agroforestry tree evaluation programmes, and the lack of availability of seed of superior agroforestry tree provenances.

The research activities included investigating improvements to network management, investigation of uptake pathways for research results and development of guidelines for improvements to seed orchard design.

The project found that:

- Network management can be improved by devolving responsibility with collaborators to a regional level.
- Uptake pathways for agroforestry tree domestication programmes can be established and impact can be demonstrated.
- Genetic structure of the seed producing population and behaviour of pollinating agents needs to be considered in seed orchard design.

In addition to the practical measures required to implement these results it was suggested that:

- A strategy for agroforestry tree domestication should be compiled by FRP.
- Selection of partners to assist in development of uptake pathways should be a priority exercise in agroforestry tree domestication activities.
- Impact assessment must be considered and incorporated into tree domestication projects.

Acknowledgements

The progress made in R6551 has been made possible by the partnerships that I have made with several scientists. In particular I would like to thank the following for sharing with me their enthusiasm and experience: Joshua Daniel (BAIF), Peter Horne and Werner Stur (FSP) and Asim Biswal (ISPO). The continuing contribution to ideas on tree domestication by Tony Simons (ICRAF) was also greatly appreciated. At home, I'd like to thank Jo Chamberlain and Phil Bacon who were always on hand to provide valuable inputs to the project.

List of acronyms

ACIAR	Australian Centre for International Agricultural Research
AusAID	Australian Agency for International Development
BAIF	Bharatiya Agro Industries Foundation
CEDAC	Centre d’Etude et de D■veloppement Agricole Cambodgien
CIAT	Centro Internacional de Agricultura Tropical
CFI	Commonwealth Forestry Institute
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DANIDA	Danish International Development Administration
DFID	Department for International Development
DPI	Department of Primary Industries
ET	Evergreen Trust
FAO	Food and Agriculture Organisation of the United Nations
FRP	Forestry Research Programme of DFID
FSP	Foragers for Smallholders Programme
GO	Governmental organisations
GRET	Groupe de Recherche et d’◷changes Technologiques
IFPRI	International Food Policy Research Institute
ICRAF	International Centre for Research in Agroforestry
ISPO	Indo-Swiss Project Orissa
NGO	Non-governmental organisation
ODA	Overseas Development Administration
OFI	Oxford Forestry Institute

A farmer feeds her sheep with newly-introduced Gliricidia sepium *in North Sumatra.* G. sepium *has been widely adopted amongst villages in several countries through collaboration with local scientists and NGOs.*

1 Background

1.1 SUMMARY OF PROJECT DETAILS

Project number: R6551/ZF0007

Project title:	Evaluation of selected non-industrial tree species and development of approaches to facilitate utilisation of results
Period of funding:	01/05/96 – 31/05/99
Total cost:	£365 958
Production system:	Forest/Agriculture Interface (Also applicable to: Semi-arid System and Hillside System)
Production system purpose:	Forest/Agriculture Interface – 1.2 (Also applicable to Semi-arid System – 1.2, Hillside System – 1.1 & 3.1)

Commodity base:	Tree fodder, fuelwood and poles
Beneficiaries:	Small-holder farmers, resource-poor farmers, hill farmers
Target institutions:	Forestry & Agriculture Research Institutions, ICRAF, NGOs
Geographic focus:	India, Brazil, Bolivia, Indonesia, Nigeria, Cameroon, Kenya, Honduras, Mexico, Malawi, Zimbabwe, Sri Lanka
Project Leader:	Alan Pottinger, Oxford Forestry Institute
Principal collaborators:	- International Centre for Research in Agroforestry – ICRAF (Nairobi, Kenya) - Centro Internacional Agricultura Tropical – CIAT (Cali, Colombia) - BAIF Development Foundation (Pune, India)

1.2 IDENTIFICATION OF PROBLEMS AT WHICH THE PROJECT WAS AIMED

Increasing human populations and escalating pressures on natural resources have been the driving force behind agricultural research in the developing world. Until fairly recently trees were not seen as playing a significant part in this process. However, an increased focus of forestry donors towards poverty alleviation has recently sought to recognise the valuable role played by trees in many agricultural systems. Little formal research had been carried out on 'agroforestry' until the 1970's when donors began to consider the potential for using trees on farms. A multitude of species was identified as playing a potential role in improving agricultural productivity, but many were highlighted for their physiological characteristics rather than any proven value in established agroforestry system.

Tree management forms an integral component of many tropical agricultural systems, ranging in scope from extensive silvopastoral systems to intensively managed fodder banks. For a variety of reasons a small number of mainly exotic species have dominated tree planting activities in the agroforestry sector with information on their performance creating an ever-increasing demand for seed. Links between tree breeders and small farmers have, however, traditionally been weak with the results that single *ad hoc* introductions have often formed the basis of the subsequent spread of a species throughout a country (Hughes, 1993). In many cases this has resulted in problems including susceptibility to pest attack and a lack of tolerance to a wide range of ecological conditions. In addition, experience from programmes designed to evaluate genetic diversity in tree species has shown that early introductions are almost always inferior in terms of performance to other sources of seed from within the native range of the species in question (Birks and Barnes, 1990; Pottinger, 1992).

DFID has responded to the potential to improve farmer's overall productivity through the use of trees on farms by supporting a range of collection and evaluation activities with agroforestry tree species. The current focus is on species in four genera; *Gliricidia*, *Leucaena*, *Calliandra* and *Acacia*. This project is concerned with the first three and each programme is at a different stage of domestication. (DFID-funded work with African Acacias has been undertaken through a series of projects over the past 10 years. Current studies include R6550 Genetic evaluation of African Acacia species and R7275 African Acacias – Monographs and Manuals) Superior seed sources have been identified for *Gliricidia sepium*, while a network of over 30 evaluation trials has been established with *Calliandra calothyrsus* since 1993 (Pottinger, 1996a). The evaluation trial network of the International *Leucaena* Research and Development Network LEUCNET is currently being established and managed with FRP support (Pottinger, 1996b).

Identification of superior seed sources and promotion of results to end users requires significant quantities of seed to be produced locally in order to satisfy subsequent demand. FRP has supported establishment of seed orchards of *G. sepium* in six countries but these have used bulk collections planted in a simple design (Simons and Dunsdon, 1992). There is currently a lack of information on design of such orchards to assist in both increased seed production and improvement of the genetic quality of the seed produced.

The fact that most planting of non-industrial tree species is currently carried out with seed of either known relatively poor performance or undocumented origin bears testimony to the lack of understanding acknowledged by DFID and other major donors agencies of how to improve uptake of results from evaluation activities. Recognition of the need to investigate this subject led FRP to support a pilot initiative with CIAT in Southeast Asia, managed under R5654 (Pottinger, 1996b), designed to look at uptake of results. However, results from R6054 (Germplasm exchange and use of multipurpose trees in small farm communities) suggest that the means of uptake of results from evaluation activities is likely to vary greatly between countries (Cromwell et al, 1995).

1.3 DESCRIPTION OF RESEARCHABLE CONSTRAINTS

The overall objective of the project was to assist the process of delivering research results from FRP-funded agroforestry tree evaluation activities to poor farmers. The approach to addressing this objective was to identify researchable constraints to the process and focussing effort on improving their effectiveness. Three researchable constraints were identified and are described below.

(1) *Current widespread utilisation of sub-optimal germplasm.* Current and past networks coordinated by OFI have indicated that initial introductions of subsequently popular agroforestry tree species do not provide optimal performance in small farming systems in terms of wood or leaf yield, or resistance to insect attack. This feature of land race material is recognised widely among researchers and tree breeders in both tropical and temperate regions and results from OFI networks have resulted in high demand for seed of hitherto unused provenaces. The most efficient manner in which to conduct evaluation activities with new germplasm is through carefully managed networks as has been demonstrated by commercial cooperative tree breeding programmes in North America and Europe, and major aid donors n the tropics, such as DFID, FAO, DANIDA and ACIAR.

(2) *Poor uptake of results from agroforestry tree evaluation programmes.* Although significant amounts of funding have been directed towards evaluation activities involving agroforestry trees many major donors are aware that there has been little evidence of uptake of results by tree growers. Both ICRAF and CIAT have identified this as a constraint to increased productivity on small farms.

(3) *Lack of availability of seed of superior agroforestry tree provenaces.* Agroforestry tree evaluation activities in the past have tended to finish with the identification of superior seed sources. This has resulted in demand for seed of those sources far exceeding supply from either the native range or seed banks (Dawson and Were, 1997). This situation is hampered further by a lack of seed collection by seed banks in the native range of sources of species that had no obvious value prior to the evaluation programme. Communication received at the Oxford Forestry Institute (OFI) revealed the desire of many state-funded forestry organisations as well as NGOs to produce agroforestry tree seed for distribution to farmers in order to overcome this problem.

1.4 POTENTIAL BENEFICIARIES

Potential beneficiaries from the project and the potential benefit to each group from involvement are summarised in Table 1.

1.5 IDENTIFICATION OF PROJECT DEMAND

Demand for the research project was identified through the Project Manager's extensive involvement in OFI evaluation networks. Discussion and correspondence with collaborators and FRP over several years identified the researchable constraints and the project was linked closely with several FRP-funded projects

Table 1. Potential beneficiaries from R6551

Potential beneficiaries	Potential benefit
Donor agencies (particularly DFID, ICRAF and CIAT)	• Improved outputs from evaluation networks on *Gliricidia*, *Calliandra* and *Leucaena*. • Guidance on improvements to research impact • Advice on improved seed production for agroforestry tree species
NGOs (particularly BAIF)	• Scientific, technical and financial support for agroforestry tree evaluation and uptake activities. • Improved access to scientific information and potential collaborators.
Small farmers	• Access to agroforestry tree germplasm of known high quality.

concerned with exploration, collection and evaluation of agroforestry tree germplasm, management of evaluation networks and uptake of results; namely

R4285 Exploration and collection of *Calliandra calothyrsus*
R4524 Intensive study of the *Leucaena* genetic resource in Mexico and Central America

R4525 Evaluation of the potential for genetic improvement of *Gliricidia sepium*
R4584 Development of seed distribution and trial management procedures in tree improvement projects
R4856 Genetic improvement of non-industrial trees with particular reference to *Gliricidia sepium* R5401 Seed production and experimental efficiency in a seedling see orchard of *Gliricidia sepium*
R5654 Investigation of approaches to improve effectiveness of transfer of results from OFI tree improvement programmes to the field
R5728 Genetic improvement of *Calliandra calothyrsus*
R6054 Germplasm exchange and use of multipurpose trees in small farm communities

Establishment of seed orchards for local use is a cornerstone of agroforestry tree domestication. Here in Bali, an orchard of Gliricidia sepium *has been established in collaboration with the Forages for Smallholders Project for distribution of seed to local farmers.*

2 Project purpose

2.1 DETAILED SCIENTIFIC AND TECHNICAL OBJECTIVES

The detailed scientific and technical objectives relating to the researchable constraints are given below:

(1) *Current widespread utilisation of sub-optimal germplasm*

- To promote the availability of seed for evaluation as part of the OFI evaluation network programme.
- To support the efficient management of networks and individual evaluation trials.
- To establish a programme of regional management of the *Leucaena* network.
- To assist in the publication and promotion of results from networks in the form of newsletters, conference papers, journal articles and manuals where appropriate.

(2) *Poor uptake of results from agroforestry tree evaluation programmes*

- Investigation of the uptake of results from OFI networks through formal collaboration with the Forages for Smallholders Project (FSP), established by CIAT and ACIAR, and with the Bharatiya Agro Industries Foundation (BAIF).
- Investigation of the uptake of results from OFI networks through informal collaboration with network participants.

(3) *Lack of availability of seed of superior agroforestry tree provenances*

- Identification of genetic and management factors influencing production of seed in agroforestry tree seed orchards suitable for adoption by resource poor farmers.
- Production of seed orchard designs suitable for low cost seed production.

2.2 ADDRESSING THE RESEARCHABLE CONSTRAINTS

The project activities designed to address the researchable constraints listed in 1.3 are given in Table 2.

Table 2. Project activities

Researchable constraint	Means of addressing researchable constraint	Project activity
Current widespread utilisation of sub-optimal germplasm	Improvement of approaches to network management	• Identification of suitable sites and collaborators. • Coordination of Internet Discussion Groups on *Calliandra* and *Leucaena* • Production of newsletters on *Calliandra* and *Leucaena*. • Promotion of network activities and availability of seed at meetings, workshops and during visits to field experiments. • Provision of information to collaborators on issues relating to the establishment, management and assessment of their trials(s) through correspondence and visits. • Distribution of seed from OFI. • Establishment of Regional Management of *Leucaena* trials through provision of funds, germplasm and advice to two Regional Managers, in Colombia and Malawi, who will act as coordinators of LEUCNET trial activities in Central/South America and Africa respectively. • Collaboration with network participants to encourage publication of their results.
Poor uptake of results from agroforestry tree evaluation programmes	Investigation of uptake of results from agroforestry tree evaluation programmes	• Support for the Forages for Smallholders Project (FSP) with funds, germplasm and advice to encourage use of results from OFI networks (principally *Gliricidia*) with resource poor farmers throughout south-east Asia. • Collaboration with the BAIF Development Foundation in India to work with local NGOs in utilisation of tree legumes on farms. On-site training to be given to field personnel on seedling raising, establishment of trees and their maintenance. Cuttings and

Researchable constraint	Means of addressing researchable constraint	Project activity
		seed of superior provenaces of G. sepium to be supplied. • Information received from these collaborators to be used to improve uptake of results for researchers and development workers.
Lack of availability of seed of superior agroforestry tree provenaces	Research into seed orchard design	• Establishment of field trials to investigate management factors influencing production of seed from agroforestry tree seed orchards. • Development of seed orchard designs that can be adopted by resource poor farmers.

Women in Pulau Gambar, North Sumatra, meet with the Forages for Smallholders Programme to give feedback on the introduction of gliricidia on their farms.

3. Research activities

3.1 NETWORK MANAGEMENT

3.1.1 Background to tree legume networks

Introduction

Collaborative approaches to research have many advantages over isolated research projects. Principal amongst those is the ability to share resources and expertise. Foresters have traditionally recognised the value of working together in research programmes and were responsible for establishing one of the first international research organisations, the International Union of Forestry Research Organisations – IUFRO, in 1892.

Tropical forestry research was instigated largely to support colonial forestry services and was consequently geared towards managing and exploiting the industrial potential of tropical forests. However, a reduction in imperial influences coupled with many social and political changes resulted in a gradual shift in tropical forestry research over the past 20 years away from exploitation and towards greater social and environmental awareness of the value of trees.

DFID and genetic resource networks

DFID's involvement in genetic resource research was initiated in the early 1960s when the, then, ODA focussed its efforts in tree improvement towards the development of the plantation forestry base (B.C.F.C., 1962). Forestry research management at ODA over the following 20 years fostered the implementation of a string of projects designed to identify, explore and evaluate species and provenances of a small number of tropical pine species. Several global networks were established (Pottinger, 1993) comprising an exceptionally comprehensive set of provenances and provenance trials covering over 60 countries.

In the mid-1980s domestication activities with a small number of genera of tree legumes was initiated at OFI through ODA support (Pottinger, 1992). Following intensive exploration and collection activities, seed of species in the genera *Leucaena*, *Gliricidia* and *Calliandra* was subsequently distributed to collaborators using the same approach as had been employed with the earlier tropical pine programmes (Pottinger, 1996).

Evaluation of the agroforestry tree networks

The ultimate objective of agroforestry evaluation networks is to contribute to the increase in productivity of tree/crop based farming systems. Results from evaluation activities form part of the overall domestication process (Figure 1) but on their own are of limited value. Encouragement of uptake of results is essential if impacts from the research programmes are to be made.

Figure 1. Simplified steps in a tree domestication strategy.

- Choice of species
- Exploration & seed collection
- Taxonomic studies
- Seed distribution for evaluation in on-station trials
- Publication and dissemination of results from trials
- Establishment of on-farm trials
- Uptake of results by farmers
- Seed production

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uptake of results and 3.3 describes work carried out to improve seed production.

Network management

The achievements of the networks can be viewed from three perspectives; the donor, the research collaborators, and the broader development community.

The donor - DIFD

There is no doubt that the pan-tropical tree networks established by DFID have been the flagships of FRP-funded genetics work. They have given a high profile to DFID activities in many countries and generally created a good reputation for DFID support in forest genetics. However, the pre-eminent role that ODA and OFI enjoyed in global tropical forest genetics until the late 1980s has gone. A poor ability to show impact from domestication activities combined with the recent proliferation of forestry research organisations and the strengthening of others involved in germplasm evaluation has meant that DFID is now generally seen as only one of a range of organisations involved in this field. Furthermore, it could be argued that both DFID and OFI have been overtaken in the field of gene resource exploration, evaluation and utilisation by other organisations with a longer-term approach to supporting gene resource activities - most notably ACIAR and ICRAF.

One of the most significant achievements of the networks has been to highlight the research strategy required to adequately evaluate species for domestication. Although the approach adopted by OFI (and formerly the Commonwealth Forestry Institute – CFI) to the thorough exploration and subsequent evaluation of a range of species was grounded in basic genetic principles employed for many years in temperate tree improvement programmes it is fair to say that they brought to prominence in tropical programmes. This approach to tropical tree domestication remains the standard to which many organisations refer.

The exceptionally high level of support provided by ODA/DFID to the early stages of tree domestication provided a remarkable foundation of knowledge and germplasm for later use. Without such a commitment it would have been impossible to undertake the subsequent evaluation programme. The ODA/DFID-funded domestication programmes have helped to highlight the necessity of research to support tree-planting activities.

The continued shortage of organisations able to provide the financial support necessary to undertake comprehensive collection and evaluation programmes has meant that OFI is still seen as a principal source of seed of high performance and documented provenance. However, with increased support for local seed production and the current lack of interest from DFID towards new tree domestication activities the role of UK-based organisations in this area is likely to diminish rapidly.

Research collaborators

Genetic improvement of trees is often seen as an esoteric issue that is rarely taught to those working in agroforestry development. Difficulties in conceptualising the issue of provenance variation are frequently compounded by scientific isolation for smaller research organisations with the results that tree improvement and domestication programmes are frequently flawed or non-existent. One of the most important achievements of the DFID-supported networks and their associated activities has been provision of information on tree improvement strategies. Although this has generally been in an informal and unstructured manner (often through visits or publication of results) it has provided an invaluable resource to many projects involved in selection and utilisation of tree species and provenances.

In addition, the very nature of collaboration has enabled many researchers to enter into multilateral communication within a research network for the first time. LEUCNET News (Appendix 12) has perhaps been the best example of an easy and effective means for researchers to enter into a network's activities through the rapid publication of views and results to a wide peer group.

Another outcome of the OFI/DFID networks is that seed has been made available to collaborators that would otherwise have been unavailable to them. Producing a collection of well documented seed from hitherto unsampled populations is only possible through the efforts of well-endowed organisations that have the ability to work in several countries. There are few such organisations and in the public sector and ODA/DFID, along with DANIDA and CSIRO, has led the way for forest tree species. The provision of seed for evaluation is an integral step in any domestication programme and has provided the potential for researchers to develop valuable genetic resources locally.

Development community

A network that serves only its members will have limited effects. It has always been the intention of OFI/DFID networks to support the uptake of results by organisations and individuals that did not receive seed. Indeed, one of the objectives of across-site evaluation and assessment of provenance stability in field trials is to provide information on seed source selection to the broad research and development community. Such information has always been made freely available wherever possible and produced in a variety of forms. Recent developments in video (Pottinger, 1999) and Internet storage of newsletters (LEUCNET News) and databases (Bray et al, 1998) provide examples of the potential to explore non-traditional means of dissemination of project outputs. Promotion of networks and their outputs is an on-going activity and journal articles are joined by conference papers and general talks as means of broadening the involvement of researchers and development workers. It is noteworthy that all of the collaborative agreements for support to research activities discussed in section 3.2 (with the exception of CEDAC) were made following discussions at workshops.

How important are networks for research?

No impact assessment protocol was developed for any of the germplasm evaluation networks supported by ODA/DFID and as such it is impossible to quantify their importance. This project has taken the first steps towards investigating impact with the agroforestry networks and has suggested an impact assessment protocol. However, another way of addressing this question is to ask what would have happened without the research networks. To some extent this can be answered by looking at domestication activities supported by other public sector organisations. Within agroforestry the most significant widespread domestication programmes have been developed by ICRAF and most recently SAFORGEN/IPGRI. A review of their strategies reveals three interesting points. Firstly, the ICRAF strategy is broadly similar to, although more advanced than, that employed by OFI - undoubtedly partly due to the overlapping influence of Tony Simons[1] at both OFI and ICRAF. Secondly, the SAFROGEN/IPGRI approach is strongly influenced by ICRAF's

[1] Dr Tony Simons, Head – Tree Domestication, ICRAF, United Nations Avenue, PO Box 30677, Nairobi, Kenya.

experiences (Eyog-Matig, pers comm.[2]). And, thirdly, both ICRAF and SAFORGEN/IPGRI put a heavy emphasis on species priority setting exercises (Franzel et al, 1996; ICRAF, 1997; Maghembe et al, 1998), something that was omitted completely from ODA's approach. It is therefore highly probable that the ODA/DFID-funded approach to domestication developed at OFI was an influence in the development of other significant domestication programmes. In addition, in spite of the shortcomings of the absence of a demand-driven prioritisation process in the selection of species for domestication the selection process was rigorous enough to identify species that are of apparent widespread value. As such, the exploration, collection and evaluation programmes supported by ODA/DFID provided a unique resource from which to form the basis of domestication programmes of importance to many organisations. It is highly unlikely that had ODA/DFID not supported this work that any other organisation would have initiated such time consuming and scientifically rigorous projects with *Leucaena*, *Gliricidia* and *Calliandra*. This is perhaps illustrated best by considering the establishment of the International *Leucaena* Research and Development Programme, LEUCNET. Its overall objective is to carry out research on the genus *Leucaena* for the benefit of poor farmers. The major partners were initially the University of Queensland (UQ), the Australian Centre for International Agricultural Research (ACIAR) and the University of Hawaii both of whom had significant collections of *Leucaena* species. However, it was only through collaboration with OFI that LEUCNET was able to access seed of the most complete collection of *Leucaena* seed in existence, complied by Colin Hughes at OFI with ODA support. Without the ODA/DFID/OFI seed collection the evaluation programme of LEUCNET would have been compromised so severely that it would have been impossible to draw any conclusions regarding the potential of species within the genus.

Management structure of the networks

The term "network" is in many ways a misnomer. Most networks operate with one central co-ordinating body (which usually supplies funding for co-ordination and carrying out preparatory work) and a group of organisations that collaborate with it rather than with each other. This has always been the case with OFI networks and due to its apparent success with the tropical pine networks this approach was adopted for the tree legume networks. However, the success of this management structure is largely dependent upon the resources available to the collaborating organisations. If they are well supported financially and are staffed with motivated researchers who have the resources to implement the results of the evaluation trials then results are generally taken up efficiently and the network appears to operate efficiently. This is often the case when research units within organisations dealing with industrial species participate in networks. If, however, financial and human resources are scarce it is much more difficult to carry out research and trials often fail before results are produced. This situation is more typical of forest departments and NGOs dealing with agroforestry species. Many trials fail to get established due to problems encountered with seed handling, nursery operations and the early stages of trial establishment (Pottinger, 1996). The apparent success of the tropical pine networks meant that ODA/DFID did not supply funds for collaborators to establish and manage trials. However, a gradual recognition of the shortcomings of such an approach with the tree legume networks led to the development of the concept of funding Regional Managers (See 3.1.3.3).

[2] Dr Oscar Eyog Matig, Regional Coordinator of SAFORGEN, IPGRI, c/o IITA, 08 B.P. 0932, Cotonou, B■nin.

3.1.2 Summary of quantitative information of seed distribution

Seed distribution activities are summarised in Table 3 and Figures 2 and 3.

Table 3. Summary of seed distribution activities relating to tree domestication activities

Network	Amount of seed collected during project (kg)	Amount of seed distributed (kg)	Current seed stocks (kg)	Number of seed orders sent during project	Number of trials established during project*	Total number of trials in network*
Calliandra	10	15	11	30	7	42
Gliricidia	40	45	10	15	0	**
Leucaena	2	12	160	15	22	45

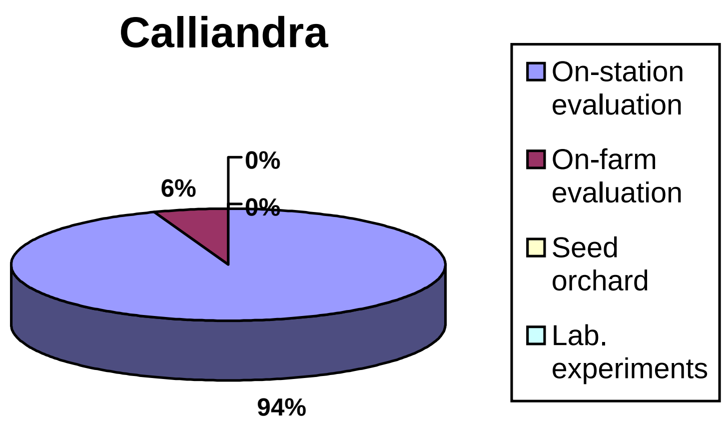
* Trials established on-station
** Not relevant as network was been assessed prior to R6551

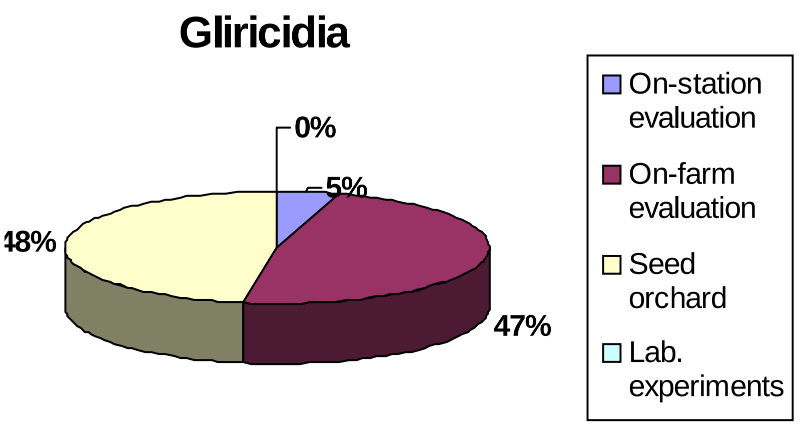
Discussion of seed distribution activities for each network is given in sections 3.1.3.1 to 3.1.3.3.

Future of OFI seed stocks

FRP's continually reducing involvement in seed collection and distribution activities has called into question the cost-effectiveness of maintaining a large store of seed to support such activities. An issues and options paper on the future of the seed store is attached as Appendix 6.

Figure 2 Seed use profile for Calliandra, Gliricidia and Leucaena (based on seed orders)





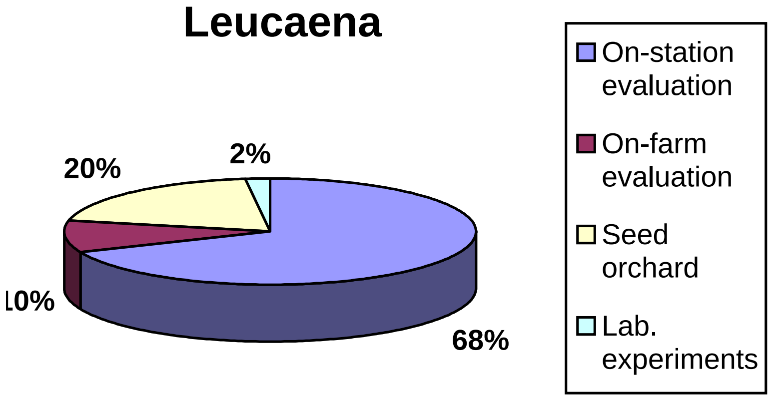
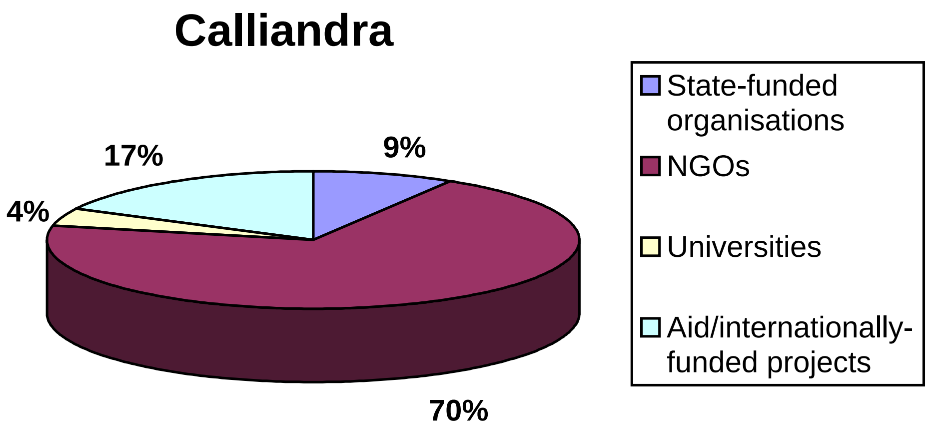
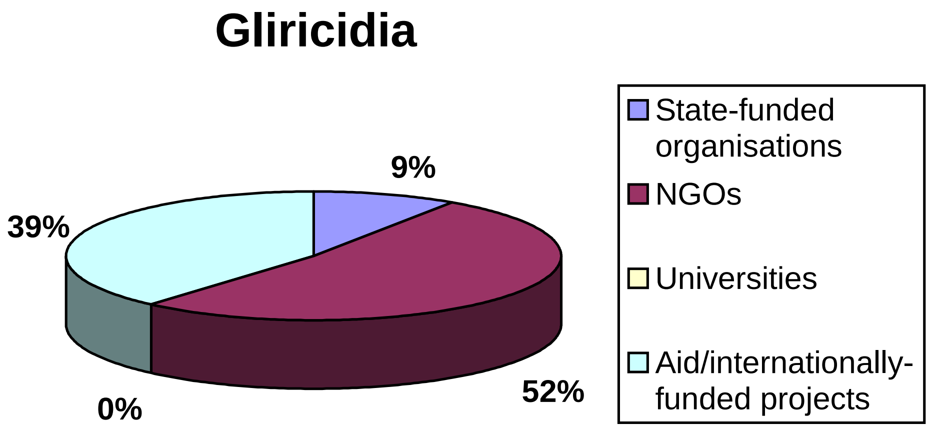
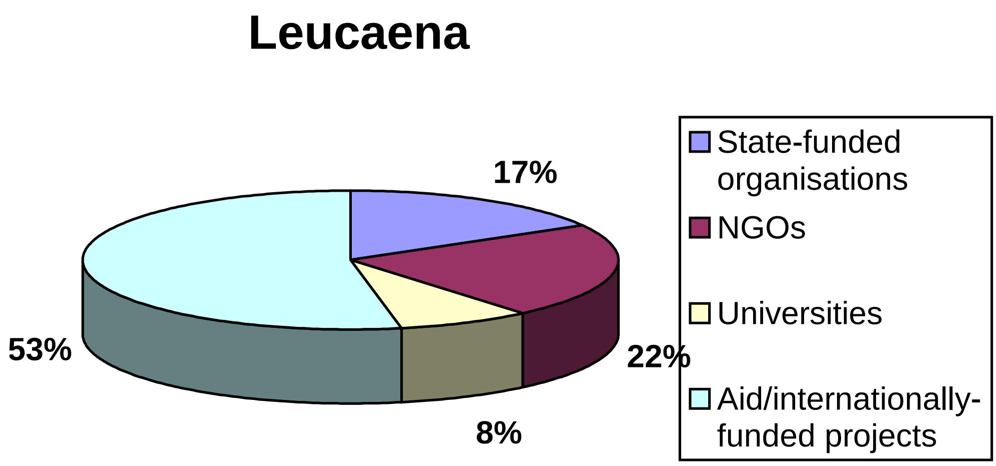


Figure 3. Seed recipient profile for *Calliandra*, *Gliricidia* and *Leucaena* (based on number of seed orders)







3.1.3 Network activities

3.1.3.1 Gliricida

Background

Gliricidia sepium was selected by ODA as a focus for exploration and seed collection in the mid-1980s. It was subsequently taken through the initial steps in the domestication process (Figure 4) by several FRP-funded projects (R4525 - Evaluation of the potential for genetic improvement of *Gliricidia sepium,* R4856 - Genetic improvement of non-industrial trees with particular reference to *Gliricidia sepium,* R5401 - Seed production and experimental efficiency in a seedling see orchard of *Gliricidia sepium*). A comprehensive background to the ecology of the species, its uses and pattern of genetic variation can be found in Stewart *et al* (1996).

Figure 4. Stages in the domestication process showing the current stage of involvement with *Gliricidia sepium* by FRP

- Choice of species
- Exploration, seed collection & taxonomic studies
- Seed distribution for evaluation in on-station trials
- Publication and dissemination of results from trials
- Establishment of on-farm trials
- Uptake of results by farmers
- Seed production

(Steps accomplished and currently being undertaken illustrated in green and red respectively)

Twenty-eight provenances were collected and seed for over 160 trials was sent to 55 countries (Pottinger, 1992). Results from analysis from 23 trials indicated the superior performance of the Retalhuleu provenance from Guatemala, followed by Monterrico also from Guatemala and Belen Rivas from Nicaragua (Dunsdon and Simons, 1996).

Following publication of results from the evaluation network a small number of seed orchards were established on an *ad hoc* basis in Guatemala, Eritrea, Malawi and Indonesia (Pottinger, 1996). However, neither ODA nor OFI adopted a formal approach towards either the establishment of seed orchards or the encouragement of uptake of results from the research projects.

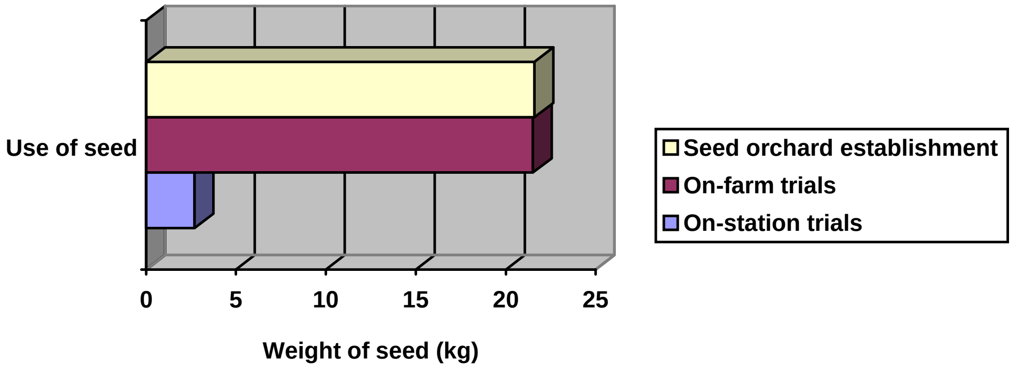
Current stage in the domestication process

The on-station trials established by the gliricidia network have generally served their purpose and provided results for both local and international use. Current emphasis with gliricidia is towards encouraging uptake of results from the network (see 3.2). This section deals with the seed distribution activities within the domestication programme.

Activities

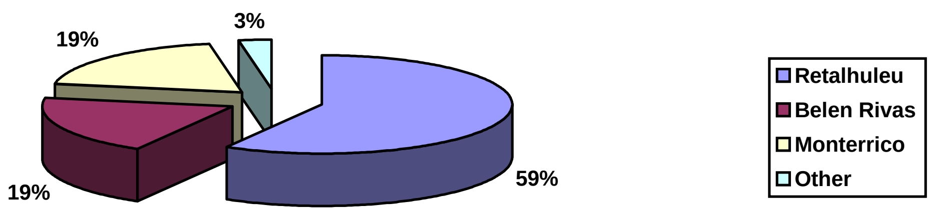
Seed distribution
Forty-five kgs of seed were distributed from the OFI seed store at Alice Holt during the period of the project (Figure 5). Most went to support the initiatives designed to support uptake of results by farmers.

Figure 5. Use of seed of *Gliricidia sepium* distributed from OFI 1996-99



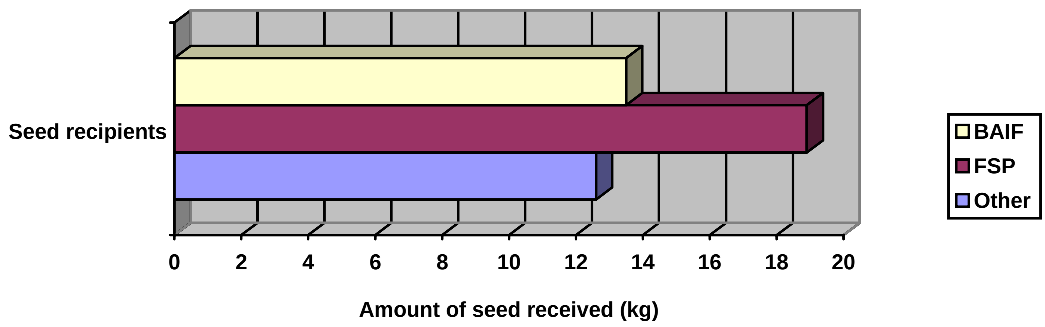
Following publication of the results from the across-site analysis of the provenance trials only the most promising provenances were distributed for establishment of the on-farm trials and seed orchards. Although the provenance Retalhuleu was clearly the best overall for both leaf and wood production when considered across all experiments (Dunsdon and Simons, 1996) this was not the only provenance distributed for adoption by farmers or the establishment of seed orchards within R6551 (Figure 5). It was considered that the promising results obtained from the provenances Belen Rivas and Monterrico from the on-station experiments should be investigated further in the on-farm evaluation process. In addition, the need to maintain a broad genetic base to guard against potential problems of pest attack and narrow site adaptability has always been a cornerstone to the OFI approach to tree domestication. It was therefore felt that distribution of more than one provenance would not only provide more information of on-farm performance but would also contribute to a reduction in risk encountered by farmers in food production (Figure 6).

Figure 6. Provenances of *Gliricidia sepium* distributed from OFI 1996-99



Recipients of seed were mainly those involved in the uptake study described in 3.2 (Figure 7).

Figure 7. Recipients of seed of *Gliricidia sepium* 1996-99



Video distribution
Distribution of the OFI-produced video *Gliricidia: seeds of change* continued with a further 25 copies being sent out in addition to the 174 distributed by R5654 (Pottinger, 1996).

Discussion

Seed distribution activities have mainly supported the uptake study described in 3.2. Seed was not advertised widely for distribution yet even amongst the small number of clients who received seed demand at times outstripped supply. New collections were made and alternative seed sources were investigated to support the NGOs involved in the uptake study. There should be no doubt that demand for seed of gliricidia is high and that uptake of results from DFID-funded domestication work with gliricidia could be greater if more projects were involved in the programme.

3.1.3.2 Calliandra

Background

During the 1980's researchers at OFI became increasingly aware of international interest in the nitrogen-fixing woody legume *Calliandra calothyrsus*. While the widespread use of the species in Indonesia had been recognised for some time requests for research quantities of seed from OFI's seed bank from other parts of the world became more frequent. This, coupled with increasing reference to *C. calothyrsus* in research papers and reports led OFI to initiate a research programme to investigate the full breadth of genetic variation in the species and its close relatives and their potential for domestication (Pottinger, 1996a).

Herbarium samples provided the opportunity for detailed study of the taxonomy of the Series and seed was sent to the UK for temporary cold storage prior to distribution for international evaluation. The availability of small quantities of seed for research purposes was advertised through NFTA Research Reports (Macqueen, 1991), and, in addition, all researchers who had expressed an interest in calliandra were contacted directly with an invitation to join the network.

Stage in the domestication process

Trial results have been assembled and analysed and superior provenances have been identified (see below). Results are currently in press (Pottinger and Dunsdon, in press) and will provide researchers and development workers with valuable information on the provenances that should form the basis of any calliandra adoption programme (Figure 8).

Figure 8. Stages in the domestication process showing the current stage of involvement with *Calliandra calothyrsus* by FRP

- Choice of species
- Exploration, seed collection & taxonomic studies
- Seed distribution for evaluation in on-station trials
- Publication and dissemination of results from trials
- Establishment of on-farm trials
- Uptake of results by farmers
- Seed production

(Steps accomplished and currently being undertaken illustrated in green and red respectively. Black indicates no significant current activity).

Activities

Seed distribution
Fifteen kgs of seed were distributed from the OFI seed store at Alice Holt during the period of the project. Recipients of seed were mainly those involved in the establishment of experimental trials (Figures 9 and 10).

Figure 9. Use of seed of *Calliandra calothyrsus* distributed from OFI 1996-99

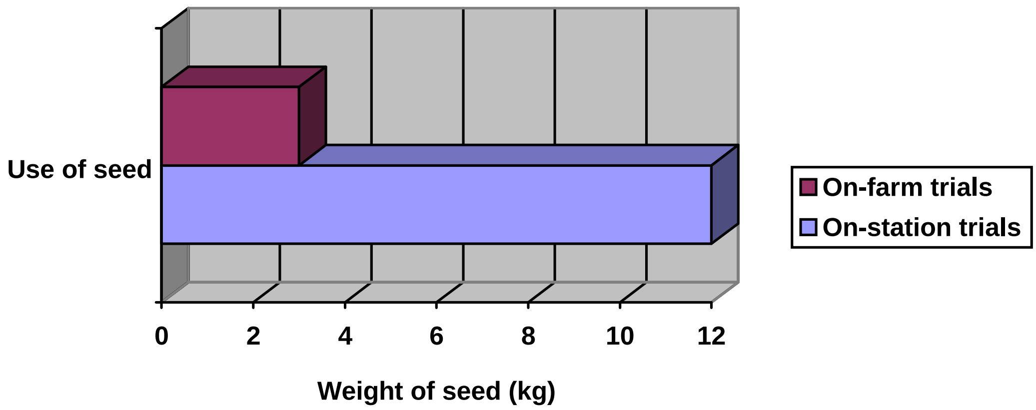
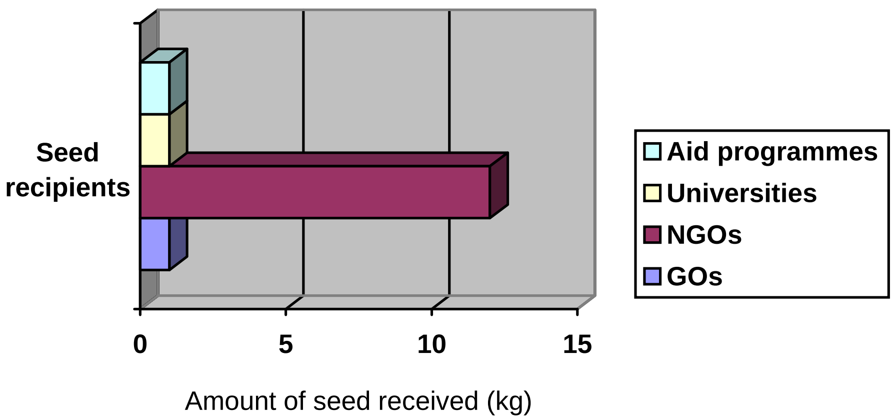


Figure 10. Recipients of seed of *Calliandra calothyrsus* 1996-99

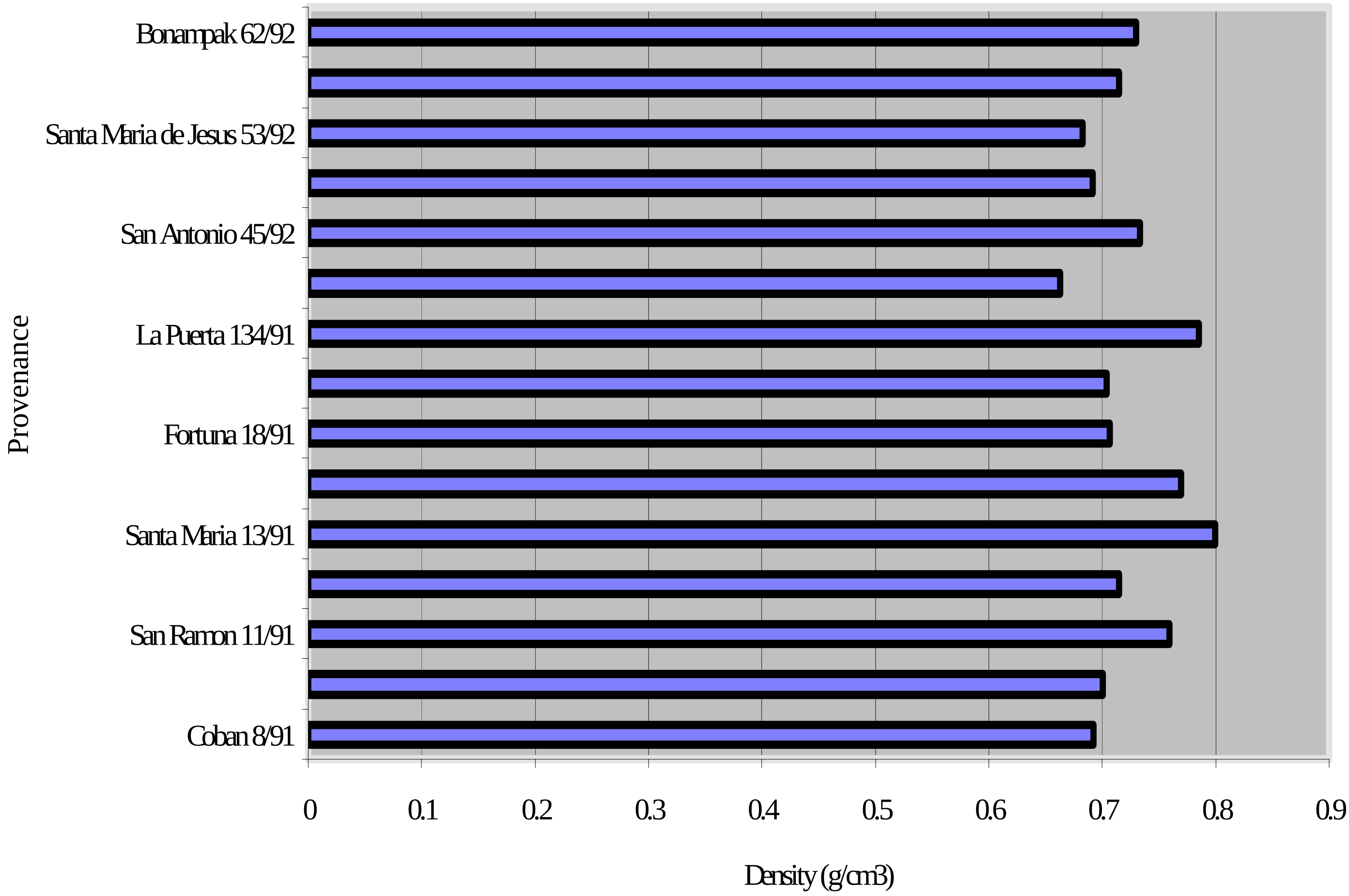


Thirty-two provenances were distributed for evaluation in relatively even quantities. It is likely that the publication of results from the across-site analysis (Pottinger and Dunsdon, in press) will lead to a demand for only three or four provenances.

Video distribution
Distribution of the OFI-produced video *Calliandra: the next generation* continued with a further 44 copies being sent out in addition to the 143 distributed by R5654 (Pottinger, 1996).

Wood density analysis
Although the principal use of calliandra is for animal fodder its wood is also valued by farmers as a useful source of fuel. In a study to investigate the variation in wood density amongst provenances of *C. calothyrsus* Gourlay (unpubl. data[1]) measured wood from nine month old samples of the species. The younger branches of trees are frequently harvested for firewood rather then the main stem of the tree so this age was considered particularly relevant. Wood from 15 provenances was supplied by the IRA/ICRAF Project in Cameroon. He found significant variation in density ($P<0.001$) between the provenances ranging from 0.66 g/cm^3 (Madiun) to 0.80 g/cm^3 (Santa Maria) (Figure 11).

Figure 11. Wood density in provenances of *Calliandra calothyrsus*



These figures are slightly higher than those recorded by the National Academy of Sciences where they found that C. calothyrsus ranged between 0.51 and 0.78 g/cm^3 (N.A.S., 1980) but nonetheless confirm the quality of the wood for fuel.

[1] I.D. Gourlay, Oxford Forestry Institute, South Parks Road, Oxford, UK

Wood fibre length analysis

Results of Final Honours Project in Biological Sciences completed at the University of Oxford by W.Wong\supervised by A.J. Pottinger (Wong, 1998).

Samples of wood taken from 15 provenances of *C. calothyrsus* grown at Yauonde, Cameroon, were analysed for fibre length.

Significant differences were found in wood fibre length between provenances and also between replicated blocks. The variation found between the reps is likely to be an indication of the environmental factors that influence the development of the trees. It also highlights the differential effects that the environment can have on trees grown from different provenances.

Given that, in general, the degree of genetic control over wood characteristics is high and the necessity for adaptive variation low, the results show an unexpectedly high level of significant variation in fibre length between provenances.

Although the variation in fibre length found between provenances was significant, it should be noted that the absolute differences found were small (in the order of ±).08mm difference between the means of the provenances). It is therefore likely that any selection for the improvement of fibre length will be limited.

The young age of the samples used in this analysis should be noted when interpreting the results from this study and further samples from older trees would be needed to draw firmer conclusions.

Trial evaluation (adapted from Pottinger and Dunsdon, in press)

<u>*Background*</u>

For *Calliandra calothyrsus*, along with many other agroforestry tree species, the initial interest in the performance of the species developed from records of the growth of a very limited selection of the genetic diversity contained within the species (Pottinger, 1996). In fact, the somewhat unusual history *of C. calothyrsus* as an exotic, where it is seldom used in its native range and planted widely in only one country, Indonesia, meant that until recently almost all seed available to researchers and those interested in planting programmes came from one source in Indonesian. This "land race" was itself derived from seed originating from one small area of Guatemala (Chamberlain, in press).

The OFI research programme mentioned above comprised an intensive investigation was undertaken of the genetic resources *of C. calothyrsus* throughout its native range. This involved mapping the complete distribution of the species including previously unrecorded populations, establishment of provenance boundaries, collection of seed from throughout the ecological amplitude of the native range and a detailed review and re-classification of the taxonomy within the series Racemosae (Macqueen 1992). Fifty provenances were recorded and over 50 kgs of seed were eventually collected from 8 countries.

Within each provenance seed was collected from a minimum of 25 trees spaced at least 50m apart with no phenotypic selection criteria employed in order to provide as broad an indication as possible of the genetic variation present (Macqueen 1993). Most seed was bulked following collection but in a few cases where significant amounts of seed were available from a range of trees individual collections were kept separate to accommodate the potential of carrying out family selection for later breeding efforts.

<u>*The International Calliandra Provenance Trial Network*</u>

Seed was sent initially to the UK for temporary storage from where it was subsequently distributed to 48 organisations in 39 countries for the establishment of field trials to investigate the performance of the provenances. Two experimental designs were proposed to evaluate the performance of different provenances when grown principally for leaf production (Figure 12) or fuelwood (Figure 13). In order to accommodate the many varied planting designs used on small farms, some degree of flexibility was permitted in spacing and cutting regimes. Practical limitations to experimental management meant that only a proportion of the 50 provenances collected were sent to each collaborator. However, poor germination was encountered at many sites, which resulted in an unequal provenance representation of provenances across trials.

Figure 12. <u>Trial design to evaluate potential of *C. calothyrsus* for leaf production (from Macqueen, 1993).</u>

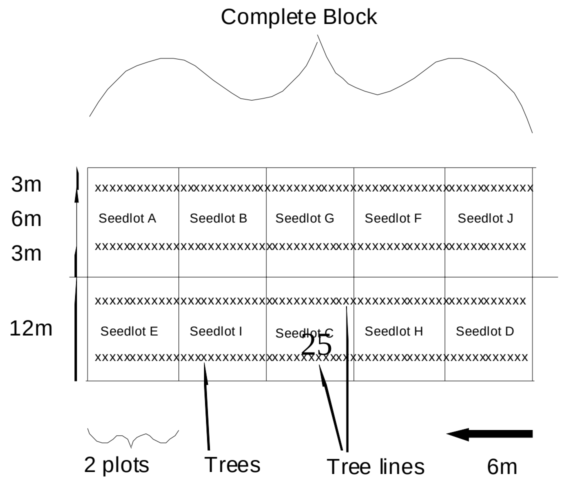
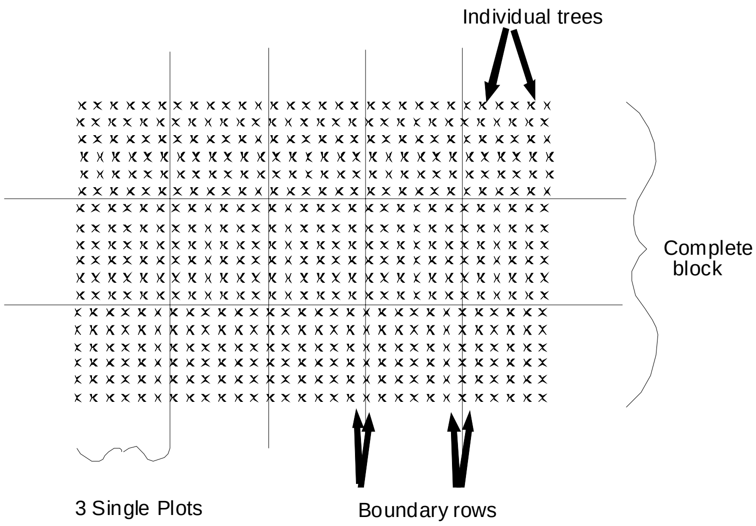


Figure 13. Trial design to evaluate potential of *C. calothyrsus* for fuelwood production (from Macqueen, 1993).



Information provided by collaborators

The results from the trials from which data were received formed the basis of the evaluation of *Calliandra* performance. This evaluation was restricted to 37 provenances of *C. calothyrsus*. Table 3 gives a list of the provenances represented in one or more of the trials evaluated. Altogether, data from 21 trials were included in the analysis; a full list of these trials is given in Table 4. Provenance representation was very unequal, with none of the provenances planted on all the sites, and several provenances represented in just one trial.

Whilst the measurement of height, in terms of the length of the longest stem, was almost universally standardised, the measurement of wood production and leaf production varied considerably. This variation is reflected in the trials within this analysis. Results are sometimes given on the basis of a one-off cutting, with figures given either for dry matter or fresh matter on an individual tree basis; alternatively, figures from a series of cuttings of a line of plants are combined to give a tonnes/hectare production total of either fresh or dry matter; or there are numerous other ways of assessing and expressing production.

Table 3. Provenances of *Calliandra calothyrsus* included in the trials analysed.

OFI no.	Provenance	Country	Altitude (m)	Rainfall (mm)
21/91, 48/92	Georgesville	Belize	350	1539
46/92	Gracie Rock	Belize	90	2313
22/91, 45/92	Santa Cruz	Belize	150	3068
59/93	Agua Zarcas	Costa Rica	200	2770
18/91, 56/93, 108/94	Fortuna	Costa Rica	85	4718
53/93	Los Chiles	Costa Rica	60	1944
57/93	San Isidro del General	Costa Rica	700	2951
60/93	San Miguel	Costa Rica	1300	1867
19/91	Santa Maria	Costa Rica	825	3222
20/91, 54/93	Turrialba	Costa Rica	800	2363
55/93	Upala	Costa Rica	100	2589
16/91, 47/92	Alotenango	Guatemala	1100	1203
51/92, 35/93	Barillas	Guatemala	1320	5829
8/91	Coban	Guatemala	1300	2517
10/91	Flores	Guatemala	220	1994
9/91, 51/92, 153/92, 34/93	Patulul	Guatemala	330	3185
53/92, 33/93	Santa Maria de Jesus	Guatemala	1500	4236
14/91	Cofradia	Honduras	300	1091
48/93	Gualaco	Honduras	610	905
12/91, 17/91, 73/92, 15/96	La Ceiba	Honduras	80	2884
46/93	Lago Yojoa	Honduras	550	2596
23/91, 75/93	Las Flores	Honduras	1076	1688
47/93	San Esteban	Honduras	420	3318
13/91	Santa Maria	Honduras	500	1145
15/91, 49/93	Trujillo	Honduras	50	2715
148/91	Bandung	Indonesia	715	1949
147/91	Maduin	Indonesia	800	1884
60/92	Apic Apac	Mexico	860	898
61/92, 31/93	Bombana	Mexico	950	1256
62/92	Bonampak	Mexico	400	2156
49/92, 37/93	Chilon	Mexico	769	1515
40/92	Ixtapa	Mexico	1100	1701
36/93	Ococingo	Mexico	900-1500	1804
44/92	Plan del Rio	Mexico	240	1957
50/92	Union Juarez	Mexico	930	3786
134/91, 109/94	La Puerta	Nicaragua	600	1889
11/91, 110/94	San Ramon	Nicaragua	850	1394
62/93	Boquete	Panama	1200	3735
63/93	Cangandi	Panama	10	3036

Table 4. Trial details and site descriptions of *Calliandra calothrysus* provenance trials.

Country	Trial Code	Collaborating Organisation	Site Location	Site Details		
				Altitude	Rainfall	Soil pH
Australia	Landsdowne, AUS					
Australia	Utchee Creek, AUS					
Cameroon	Minkoameyos, CMR	IRA/ICRAF Agroforestry Programme	351´N, 1126´E	813m	1692mm	6
Cameroon	Nkoemvone, CMR	IRA/ICRAF Agroforestry Programme	242´N, 1221´E	630m	1820mm	4.5
Cameroon	Yaounde, CMR	IRA/ICRAF Agroforestry Programme	351´N, 1126´E	813m	1692mm	6
Colombia	Santander de Quilichao, COL	Centro de Investigacion Agricola Tropical				
Ethiopia	Bako, ETH	Institute of Agricultural Research				
Fiji	Nadruloulou, FIJ	Fiji-German Forestry Project				
Jamaica	JAM	University of West Indies				
Kenya	Embu, KEN	ICRAF				
Madagascar	MDG	National Seed Bank				
Mexico	Yapacani, MEX	Centro de Investigacion Agricola Tropical			1800mm	5.7
New Caledonia	Port Laguerre, NCA	CIRAD Forêt				
Philippines	Los Banos, PHL	Ecosystems Research & Development Bureau				
Sri Lanka	Doragala, SRL	GTZ				
Sri Lanka	Pallekelle, SRL	GTZ				
Tanzania	SUA farm, TAN	Sokoine University of Agriculture				
Tanzania	Gairo, TAN	Sokoine University of Agriculture				
Uganda	Kifu, UGA	ICRAF				
Zambia	Misamfu, ZAM	ICRAF				
Zimbabwe	Domboshawa, ZIM	ICRAF				

Table 5. Summary of results for *Calliandra calothrysus* trial series: stem length (m).

Site \ Trial	Minkoameyos, CMR	Nkoemvone, CMR	Yaounde, CMR	S de Quilichao, COL	JAM	MDG	Yapacani, MEX	Port Laguerre, NCA	Kifu, UGA
Provenance — Site mean	3.55	3.66	5.13	2.03	2.07	0.74	2.82	2.15	5.76
Std. dev.	-	-	-	*0.39*	*0.48*	-	*0.75*	-	*0.88*
Georgesville				2.24		0.98	3.32		6.29
Gracie Rock								2.64	
Santa Cruz	3.08	2.73	5.27						
Agua Zarcas				2.14					
Fortuna	3.59	4.52	4.54	1.86		0.75		2.38	6.05
San Miguel							2.51		
Santa Maria (CR)				2.18					
Turrialba	3.54	3.14	5.27				2.89	1.96	
Upala				2.00					
Barillas	3.72	3.80	5.75			0.69	2.98		
Coban	3.87	4.05	5.50				2.68		5.80
Flores	4.35	4.26	5.50	2.16	2.18	0.69	3.04	2.58	6.16
Patulul				2.20	2.54	0.65	3.24		
Santa Maria de Jesus	3.15	3.61	4.88	2.17	2.31	0.78	2.60	2.05	5.39
Gualaco								2.19	
La Ceiba	2.71	2.96	4.24	1.43	1.46	0.70	2.44	1.86	4.70
Lago Yojoa					1.83				
Las Flores							2.22		
San Esteban								1.82	5.14
Santa Maria (H)	3.14	3.28	4.82						
Trujillo			4.62		1.84				
Maduin	3.39	3.82	5.43	1.96		0.65		2.14	6.30
Apic Apac									
Bombana	3.92	4.21	5.01				3.12	2.67	6.42
Bonampak	4.15	3.85	5.80		2.34	0.74	3.18		
Chilon				2.05			2.62		
Ixtapa								1.39	
La Puerta	3.45	3.34	5.13			0.77		2.17	
San Ramon	3.64	3.70	5.17	2.02		0.79	2.77	2.04	5.02
Boquete				2.00					

Table 6. Summary of results for *Calliandra calothrysus* trial series: wood production.

Trial Site / Provenance	Landsdowne, AUS	Utchee Creek, AUS	Yaounde, CMR	Bako, ETH	Nadruloulou, FIJ	JAM	Embu, KEN	Los Banos, PHL	Doragala, SRL	Pallekelle, SRL	SUA farm, TAN	Gairo, TAN	Kifu, UGA	Misamfu, ZAM
Site mean *Std. dev.*	4.07 *0.98*	1.55 *0.51*	29.5 -	0.89 *0.42*	2.43 -	33.3 *22.2*	3.31 -	0.82 *0.82*	1.75 -	1.25 -	7.35 -	9.43 -	28.5 *12.5*	2.18 -
Georgesville	5.68	1.55						0.73	1.84	1.05			24.6	
Gracie Rock				1.09	3.61									2.24
Santa Cruz			29.1								8.13			
Agua Zarcas				0.79										
Fortuna	3.38	1.37	31.2		2.79		3.04		2.06	1.03	6.51	14.73	23.2	
Los Chiles								0.85						
San Miguel											4.99	12.77		3.04
Turrialba	3.89	1.27	31.9	0.88					1.80	1.21				
Alotenango											7.15	10.50		
Barillas	3.74	1.74	33.9		2.56			0.93	1.59	1.49				2.23
Coban	4.13	1.34	23.1	0.87			3.06		1.53	1.21			27.5	
Flores	4.59	1.73	32.5	0.74	1.77	43.1	2.44		1.28	1.30	9.72		32.8	1.70
Patulul	5.17	1.49				57.8			1.68	1.16	3.90			
Santa Maria de Jesus	4.13	2.03	21.7	0.97	1.21	37.6	4.44		1.63	1.24	5.60		24.8	1.68
Cofradia												9.16		0.94
La Ceiba	4.21	1.26	19.7	0.73	3.65	27.0	2.66		1.66		6.86		22.8	1.49
Lago Yojoa						10.9								
Las Flores	2.99	0.89												
San Esteban									1.64	1.29			28.0	
Santa Maria (H)	3.30	1.49	25.1											
Trujillo			21.7			35.9								
Bandung											8.74	11.67		3.59
Maduin	3.77	2.21	35.3		1.40		3.68		1.88	1.28			34.8	1.32
Apic Apac												6.37		
Bombana			32.5	0.75	2.09				1.94	1.16	7.96	5.99	27.5	3.19
Bonampak			31.9			35.4								
Ixtapa	2.87	1.09		0.92							4.86			2.49
Ococingo								1.01						
Plan del Rio	3.71	1.03							2.51	1.53	7.83	7.81		1.70
Union Juarez	4.65	1.51							1.24	1.55	9.03			3.32
La Puerta	4.99	2.35	33.9											1.55
San Ramon	4.03	1.96	39.3	1.15	2.89		3.88	0.59	2.02	1.06	11.67	5.83	32.2	2.19
Cangandi					2.33									

Table 7. Summary of results for *Calliandra calothrysus* trial series: leaf production.

Trial Site / Provenance	Landsdowne, AUS	Utchee Creek, AUS	Minkoameyos, CMR	Nkoemvone, CMR	Yaounde, CMR	Bako, ETH	Nadruloulou, FIJ	JAM	Embu, KEN	Los Banos, PHL	Doragala, SRL	Pallekelle, SRL	SUA farm, TAN	Gairo, TAN	Kifu, UGA	Misamfu, ZAM	Domboshawa, ZIM
Site mean	3.96	2.35	1.62	1.29	5.19	2.01	1.33	52.5	5.85	0.57	2.68	2.68	3.52	4.39	8.20	0.64	3.28
Std. dev.	*0.86*	*0.67*	-	-	-	*0.31*	-	*34.2*	-	*0.42*	-	-	-	-	*4.46*	-	-
Georgesville	4.92	2.58								0.50	2.85	2.39			6.54		
Gracie Rock						2.20	1.69									0.56	
Santa Cruz			1.62	0.77	5.15								3.91				2.70
Agua Zarcas						1.81											
Fortuna	3.01	1.84	1.61	1.88	4.75		1.29		5.49		2.94	2.31	3.10	6.52	6.33		3.70
Los Chiles										0.65							
San Isidro del General																	3.70
San Miguel													2.19	5.89		0.75	
Turrialba	3.19	1.80	1.95	1.11	5.15	2.18					2.80	2.63					
Alotenango													3.35	4.91			
Barillas	3.65	2.32	1.50	1.16	5.56		1.44			0.64	2.48	2.87				0.63	
Coban	3.68	1.76	1.59	1.59	3.93	1.81			5.53		2.36	2.71			7.24		
Flores	4.94	2.41	1.85	1.41	5.49	1.66	1.07	63.1	4.69		2.08	2.57	4.57		7.40	0.47	4.30
Patulul	4.67	2.36						57.8			2.57	2.35	1.85				3.80
Santa Maria de Jesus	3.65	3.11	1.40	1.20	3.93	2.20	0.94	74.8	7.13		2.93	2.82	2.93		7.03	0.70	3.10
Cofradia														4.49		0.53	
La Ceiba	3.88	1.95	1.32	1.57	3.86	1.65	1.97	46.7	4.36		2.43		3.10		7.30	0.33	2.30
Lago Yojoa								18.0									
Las Flores	4.06	1.95															3.20
San Esteban											2.66	2.63			10.8		
Santa Maria (H)	3.49	2.55	1.20	1.06	6.24												
Trujillo					3.19			57.9									
Bandung													4.27	5.18		0.71	
Maduin	3.67	3.06	1.91	1.15	5.76				5.77		2.70	2.84			7.90	0.69	2.70
Apic Apac														2.91			
Bombana			1.49	1.15	5.42	1.71	1.14				2.81	2.56	3.98		6.93	0.74	2.90
Bonampak			1.54	1.40	4.95			47.2									3.40
Ixtapa	3.39	1.87				2.21							2.44			0.63	
Ococingo										0.52							
Plan del Rio	4.08	1.97									3.52	3.02	3.76	4.03		0.57	
Union Juarez	4.26	2.43									2.20	3.34	4.44			0.61	
La Puerta	4.51	3.43	1.85	1.12	7.53											0.82	
San Ramon	4.18	2.64	1.89	1.51	6.92	2.66	2.08		7.96	0.55	2.94	2.46	5.40	2.80	12.5	0.88	3.50
Cangandi							0.91										

Table 8. Summary of analyses of variance for *Calliandra calothyrsus* provenance trials.

Trial Site	Significance levels of differences between provenances		
	Height	Wood production	Leaf production
Landsdowne, AUS		< 0.001	< 0.001
Utchee Creek, AUS		< 0.001	< 0.001
S de Quilchao, COL	< 0.001		
JAM	< 0.001	< 0.001	0.001
Yapacani, MEX	< 0.001		
Los Banos, PHL		0.002	0.108
SUA farm, TAN		0.012	0.025
Gairo, TAN		0.201	0.217
Kifu, UGA	< 0.001	< 0.001	< 0.001

Evaluation methodology

Since stem length was the only trait assessed in a standard manner, it was used as a basic indicator of growth although it is acknowledged that it is almost never a trait of any importance to growers of *C. calothyrsus*. For that reason it was not assessed in a majority of the trials included in this analysis. Wood production and leaf production, the traits of interest to most growers, were assessed on most sites. The assessment methods, however, differed widely and were not always stated with the results and meant that a combined analysis of all 21 trials was impossible. Direct comparisons across all sites for these traits are, therefore, very difficult to make and consequently conclusions are provided with caution.

To overcome the differences in assessment methodologies, a method of standardisation was needed in the expression of provenance performance on all the sites. The simplest such method is to use the site mean as a benchmark, and express provenance performance relative to this. The unequal representation of provenances in the trials, however, made this impossible, because each site mean would be biased by the set of provenances represented on that site. An alternative method is to use a control seedlot, or to form a benchmark using a subset of provenances. In this analysis, three provenances were represented on 19 sites, and the mean of these three provenances was used as the benchmark value on each site. Evaluation of provenance performance, relative to this benchmark was restricted to categorising performance into four classes: above all three provenances used in forming the benchmark; above the benchmark value; below the benchmark value; and below all three provenances. The frequency with which a provenance falls into each of these categories gives a robust guide to the stability of the provenance's performance across the sites, an important consideration when making recommendations about choosing provenances for a wide range of conditions.

Finally, since farmers are primarily interested simply in those provenances which produce the most wood or leaf material, a study was made of the frequency with which each provenance was one of the top three performing provenances on each site. Whilst this frequency is obviously affected by the number of sites the provenances are represented on and the number of provenances on each site, it gives a simple and quick guide to promising provenances.

Trial results

Stem length

Table 5 shows the mean stem length for each provenance at each site on which it was planted, with the overall site mean and pooled standard deviation (where known) given as a guide to variation within the site. Figure 14 shows the performance of the provenances in comparison to the benchmark, broken down into the four categories described above. The performances of the three provenances used to form the benchmark are shown relative to each other. Figure 15 shows the frequency with which each provenance was one of the top three performing provenances on a site.

Figure 14. Performance of *Calliandra calothyrsus* provenances relative to 'benchmark' - stem length

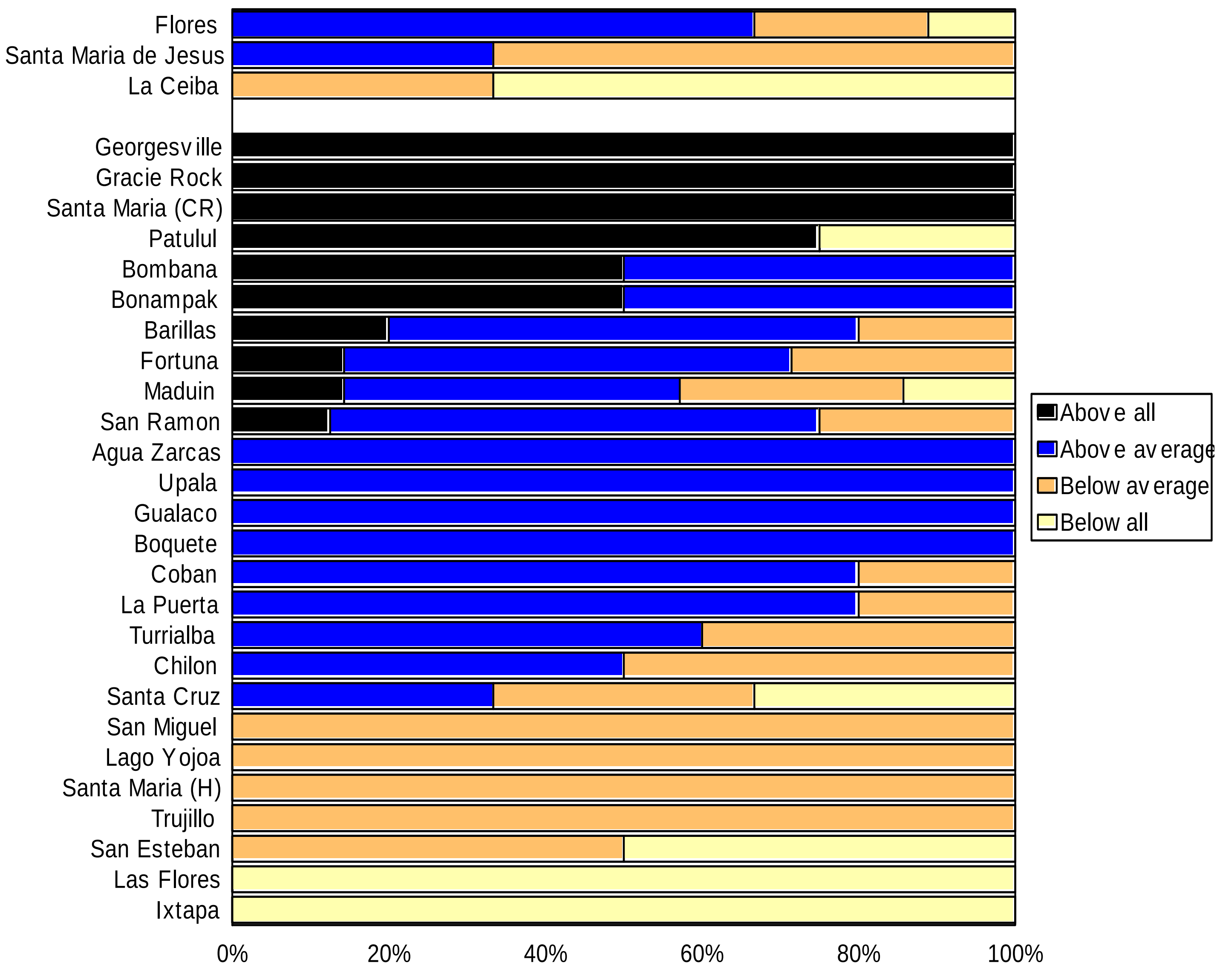
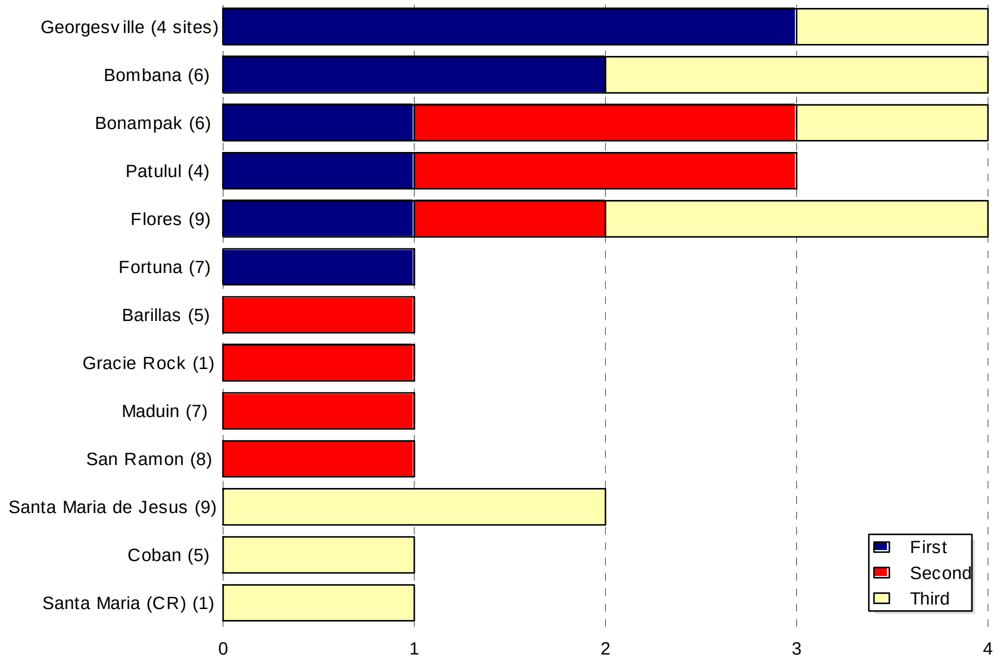


Figure 15. Top performing provenances of *Calliandra calothyrus* - stem length



From Figure 14 it can be seen that Flores provenance from Guatemala was generally the best of the three benchmark provenances, whilst La Ceiba from Honduras was almost always the worst of these three. Of the other provenances, it can be noted that Georgesville and Gracie Rock, both from Belize, and the Costa Rican Santa Maria provenance always outperformed all three of the benchmark provenances. This is more significant in the case of Georgesville, since it was represented on four sites whereas the other two provenances appeared on only one site. All the Guatemalan provenances had above-average stem length, an interesting result that corresponds with results found in a study of *Gliricidia sepium* provenances (Dunsdon & Simons, 1996). The Honduran provenances were all below average for this trait. Figure 15 shows Georgesville to be among the top three performing provenances on all four sites at which it was represented and the top performer on three of those sites.

Wood production

Table 6 shows the mean wood production for each provenance at each site on which it was planted. The figures shown are a mixture of fresh weights and dry weights, expressed on a kilograms/tree or tonnes/hectare basis. The overall site mean and pooled standard deviation are given where known. Figure 16 shows the wood production of each provenance relative to the benchmark, broken down into the four categories described earlier. The performances of the three provenances used to form the benchmark are shown relative to each other. Figure 17 shows the frequency with which each provenance was one of the top three performing provenances on a site.

Figure 16 clearly illustrates that there is much greater variation in provenance performance for wood production than for stem length. This is to be expected, and is in part due to the responses of the provenances to different management regimes and assessment methodologies. This greater variation in provenance performance means that the provenances that always had above-average wood production were those that were only represented on a small number of sites, Gracie Rock and Bandung being the only such provenances that were at more than one site. La Puerta, Georgesville, San Ramon and Barillas were all generally high wood producers. Once again the Guatemalan provenances generally performed well, as did the Nicaraguan provenances for wood production. It is also worth noting the above-average performance of the two Indonesian land-race seedlots. This is confirmed, in Figure 17, by the high frequency with which Maduin in particular was one of the top three performing provenances, bettered only by San Ramon.

Figure 16. Performance of *Calliandra calothyrsus* provenances relative to 'benchmark' - wood production

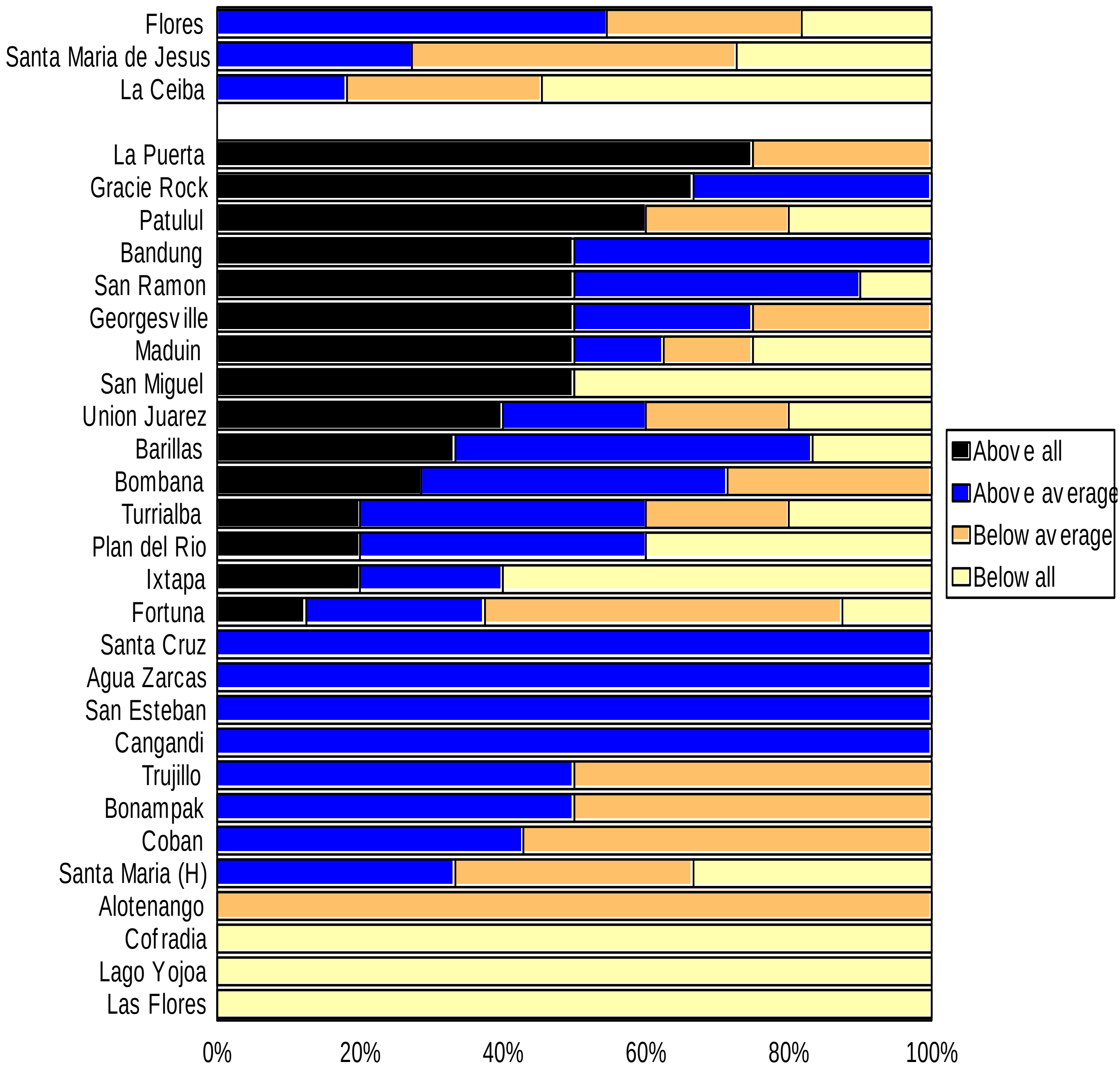
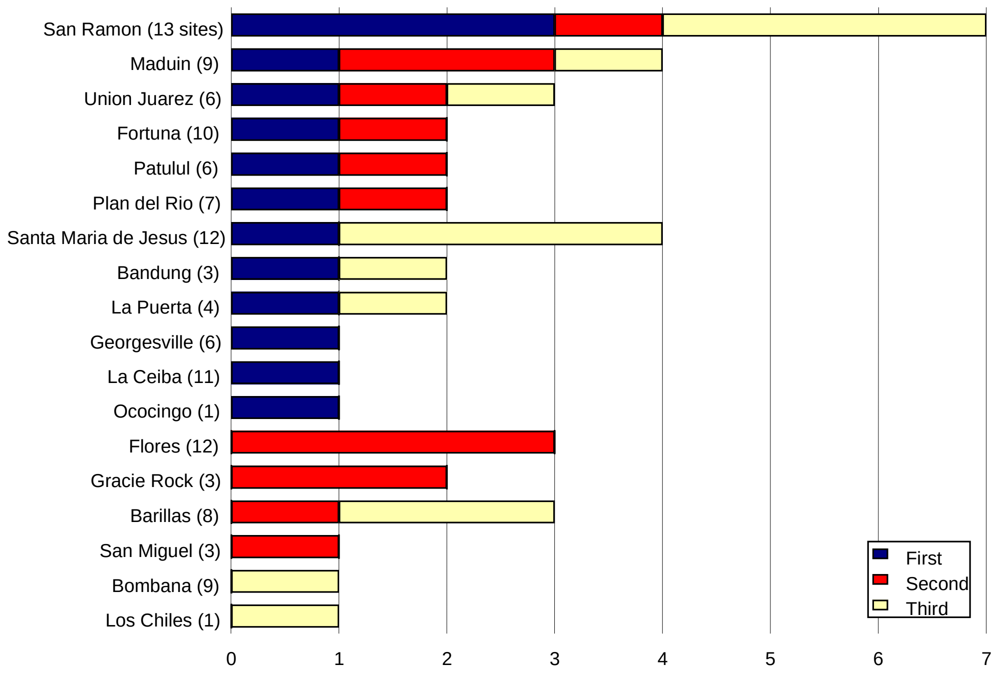


Figure 17. Top performing provenances of *Calliandra calothrysus* - wood production



Leaf production

Table 7 shows the mean leaf production for each provenance at each site on which it was planted. The figures shown are again a mixture of fresh weights and dry weights, expressed on a kilograms/tree or tonnes/hectare basis. The overall site mean and pooled standard deviation are given where known. Figure 18 shows the leaf production of each provenance relative to the benchmark, broken down into the four categories described earlier. The performances of the three provenances used to form the benchmark are shown relative to each other. Figure 19 shows the frequency with which each provenance was one of the top three performing provenances on a site.

It was expected that leaf production would show still greater variation in provenance performance than the other two traits, but this appears not to be the case. Comparing Figure 4a with Figure 3a shows that, on the contrary, there appears to be less variation in provenance performance for leaf production than for wood production. From Figure 4a, the performance of San Ramon is particularly notable. This provenance's performance was above average in terms of leaf production on every one of the 13 sites at which it was represented and outperformed all three of the benchmark provenances on 9 of those sites. Figure 4b confirms this, showing San Ramon to be the top performing provenance on 6 sites and one of the top three performers on 10 sites. With no below-average performances, San Ramon is clearly the "best-bet" provenance for leaf production. As with wood production, the two Indonesian land-race seedlots are generally above-average performers, and the Nicaraguan provenances are generally above average. The performance of the Guatemalan provenances is more mixed for this trait.

Figure 18. Performance of *Calliandra calothyrsus* provenances relative to 'benchmark' - leaf production

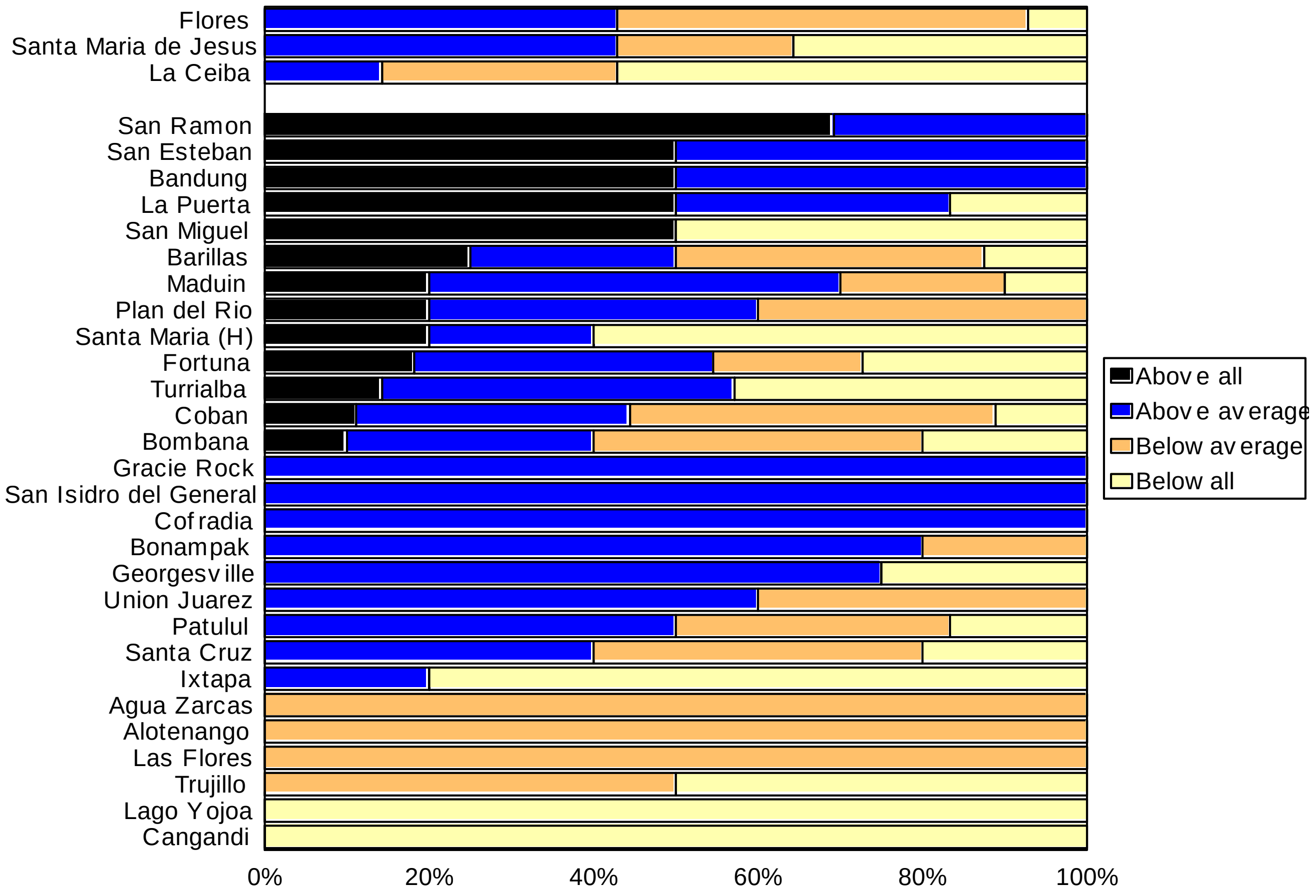
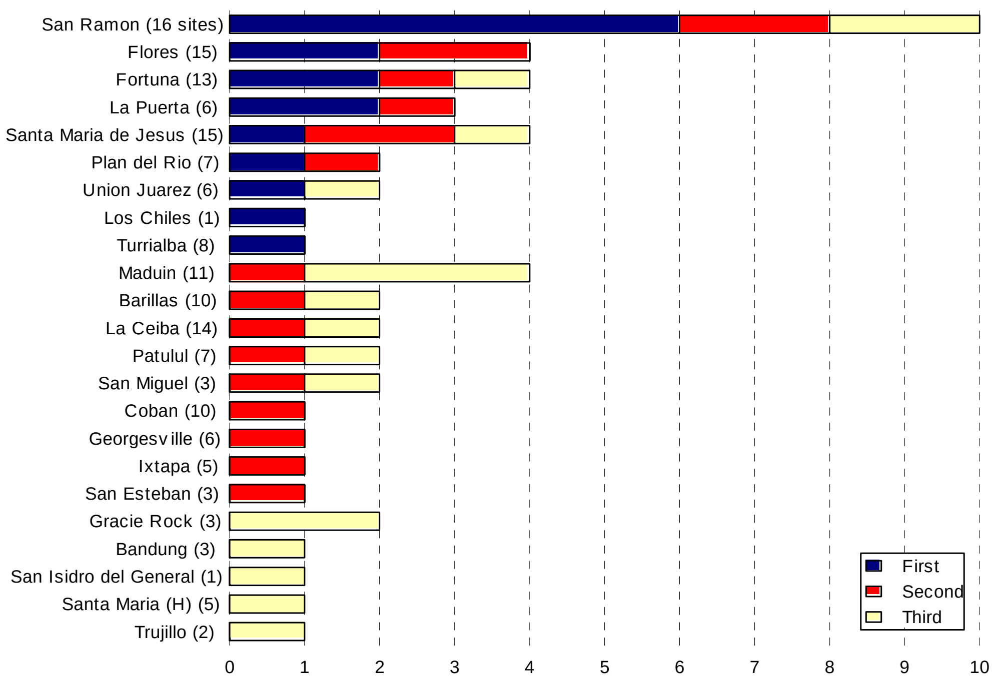


Figure 19. Top performing provenances of *Calliandra calothyrsus* - leaf production



Conclusions

Despite the incomplete nature of the data set that this analysis was based upon, and the resulting difficulty in making a direct across-sites comparison, there are a number of interesting and important conclusions that can be drawn.

- Since wood production and leaf production are the two traits for which *C. calothyrsus* is generally planted, there is clearly one provenance that appears to be the most promising. In terms of frequency of top performance, and stability of above-average performance, the Nicaraguan provenance of San Ramon emerges as superior, especially strongly so for leaf production. This provenance could thus be recommended as a "best bet" provenance for planting.

- The Indonesian land-race seedlots were shown to be amongst the better performers, both in terms of leaf production and particularly wood production. These are already more widely distributed and available than the more-recently collected OFI seed sources, and it would seem that, with the exception of San Ramon, the newer seed sources have little benefit to offer over the land-race material in terms of wood and leaf production.

An interesting result was noted in the stem length analysis. This trait is often used as a basic indicator of growth as it generally less affected by management techniques (measurement takes place before lopping begins). It is therefore noteworthy that the Guatemalan provenances of *C. calothyrsus* included in this trial were all amongst the top-performing provenances for this trait as results also showed in a similar study of the genetic variation of *G. sepium.*

Discussion

The performance of the calliandra network has varied overall. Seed distribution and trial establishment created a significant network of field experiments, and papers presented at the International *Calliandra* Workshop (Evans, 1996) indicated that seed from OFI was crucial to the establishment of collaborative research projects with the species. However, the subsequent difficulty in obtaining information from trial managers on the progress and outcome of their experiments not only caused a delay in production of results but also resulted in a sub-optimal number of trials contributing to the across-site analysis. The principal reason for this was a general low priority placed by most trial managers to supply results. If network management is to be undertaken with collaborators who have limited financial resources it is essential to provide funds to them for establishment and management of trials. Without such support the ability to carry out work and the incentive to produce results will be severely compromised.

Valuable results have been produced from the network in terms of identification of high performing provenances that will provide the essential basis for any continued efforts to promote the species for agroforestry. However, there is at present no commitment apparent from DFID to continue along the domestication pathway with calliandra. Unless support is provided to researchers and development workers involved directly with farmers the impact of the calliandra domestication programme funded by FRP will be severely limited.

3.1.3.3 Leucaena

Background

Funding from ODA for research into the tropical tree legume genus *Leucaena* started in 1984. Subsequent projects have investigated the genetic variation in its native range, the laboratory and in a range of field experiments.

Although *L. leucocephala* is the most widespread agroforestry tree significant limitations to its further use have become apparent, most notably severe attack by the sap-sucking aphid *Heteropsylla cubana*. Recent research efforts have focussed upon the need to expand the genetic base used by farmers by investigating currently under-utilised species and hybrids.

Collaboration between the Universities of Hawaii, Queensland and Oxford led to the creation of LEUCNET in 1995 with the aims to:

- Provide a cooperative network structure to more effectively integrate the efforts of the many individuals and groups around the world working on aspects of *Leucaena* R & D.
- Foster cooperative research projects within the LEUCNET framework that exploit the lesser known species and hybrids of *Leucaena*.
- Ensure more efficient use of decreasing resources for *Leucaena* improvement.
- Provide a structure for ensuring the flow of outputs from research projects to the end-user, the farmer.

Stage in the domestication process

Comprehensive new seed collections (comprising more than 1000 seedlots) including all taxa of *Leucaena* and bulk provenance and individual family collections were made prior to R6551 and the distribution of seed for the establishment of more than 100 trials in more than 30 countries within LEUCNET has now taken place. LEUCENT covers a wide range of activities and various organisations have developed their own approaches to domestication of some of the species. In general, however, the most advanced programmes have yet to deliver significant results to farmers (Figure 20).

Results have already been produced from some trials and are published frequently in LEUCNET News (Appendix 12).

Figure 20 <u>Stages in the domestication process showing the current stage of involvement with *Leucaena* species by FRP</u>

- Choice of species
- Exploration, seed collection & taxonomic studies
- Seed distribution for evaluation in on-station trials
- Publication and dissemination of results from trials
- Establishment of on-farm trials
- Uptake of results by farmers
- Seed production

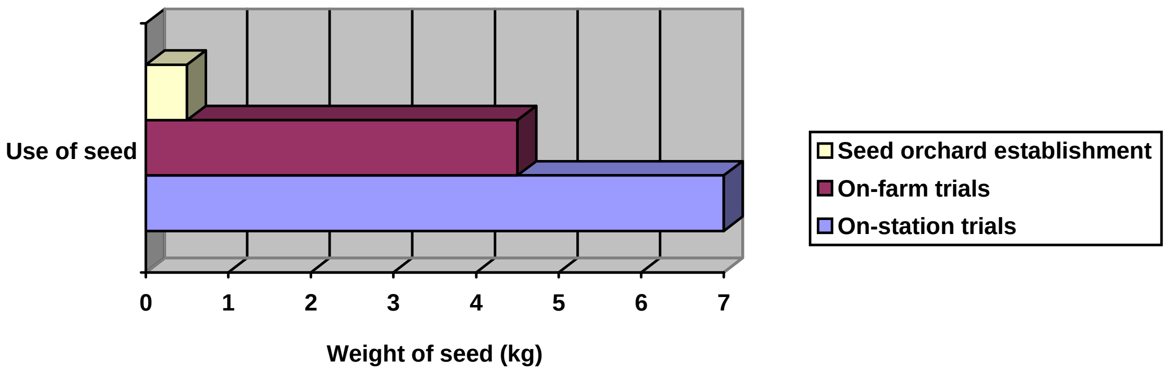
(Ste… …pectively. Steps in black indicate no significant current activity).

Activities

Seed distribution

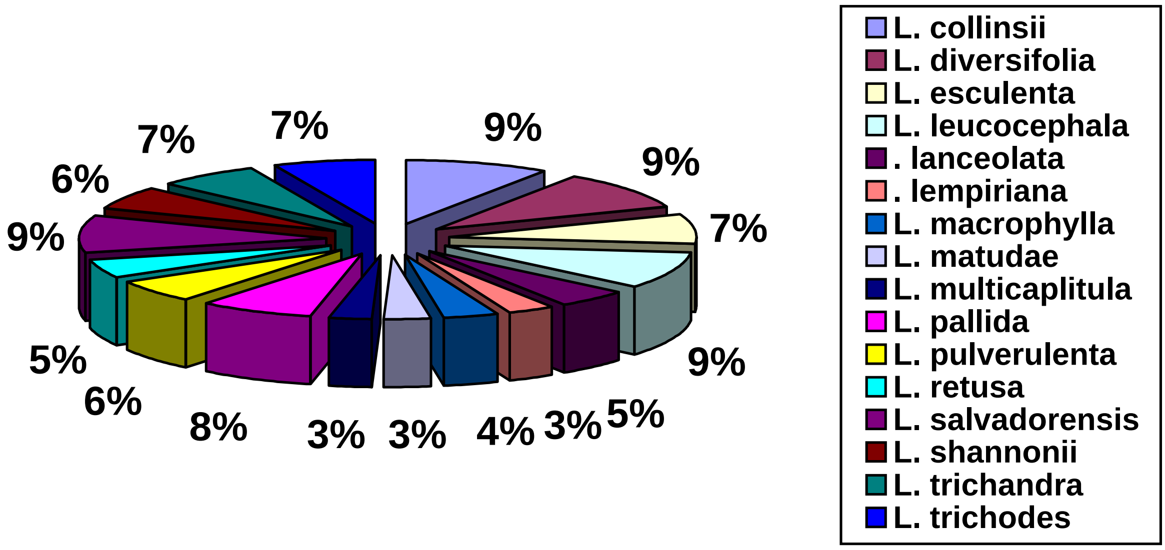
Twelve kgs of seed were distributed from the OFI seed store at Alice Holt during the period of the project mainly for the establishment of on-station trials (Figure 21).

Figure 21 Use of seed of *Leucaena* species distributed from OFI 1996-99



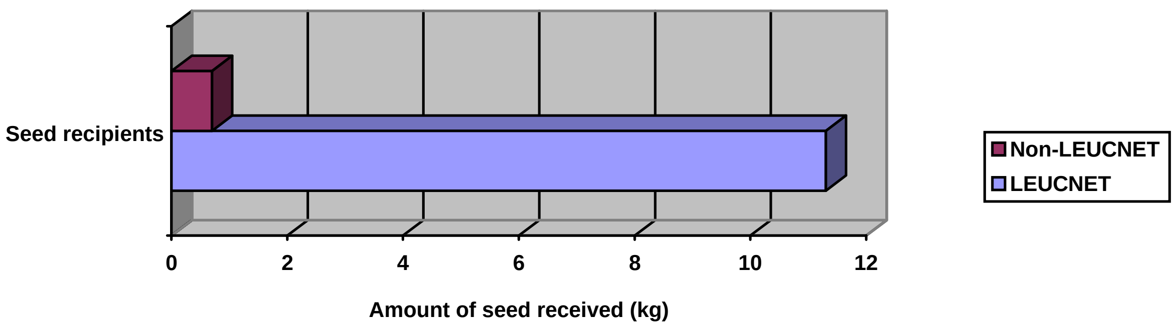
The large number of species distributed reflected that stage in the domestication process with *Leucaena* (Figure 22).

Figure 22 *Leucaena* species distributed from OFI 1996-99



Recipients of seed were mainly those involved in the LEUCENT evaluation study (Figure 23).

Figure 23. Recipients of seed of *Leucaena* species 1996-99



Video distribution

Distribution of the OFI-produced video *Leucaena; miracle tree or myth* continued with a further 108 copies being sent out in addition to the 143 distributed by R5654 (Pottinger, 1996).

LEUCNET News

Three issues of LEUCNET News were produced during the project containing articles and papers on research and development work being carried out with the genus *Leucaena*. During this period the mailing list of LEUCNET News grew from 376 to over 1300. It is interesting to note that this growth has occurred without any direct promotion from the coordinators (Max Shelton of UQ 1996-98 and myself 1998-99).

LEUCNET News' success is an example of a project output being demand led. Although readers are encouraged to contribute articles it is they and not the editors who determine the content. The continuing growth in its readership and the positive comments received regarding its value suggest that this is a very useful medium for promoting research results.

LEUCNET News is produced as hard copy and distributed by mail to over 60 countries. However, the expansion both in content of the newsletter and membership has resulted in a rapid increase in production costs. LEUCNET News is also available on a web site at http://users.ox.ac.uk/~dops0024/ where it has between 5 and 10 hits per week. All costs have been borne jointly by the University of Queensland (though ACIAR support) and FRP through this project. The completion of R6551 and the breakdown in collaboration between UQ and Oxford University has left the future of the newsletter in doubt. Discussions are currently underway between myself, FRP and ACIAR to determine the future of the newsletter. Options and issues are discussed below:

- Cessation of involvement by FRP

It was stated unofficially at the outset of LEUCNET that LEUCNET News would have a lifespan of a few years. It was considered that this would reflect available funding but also compliment the stage of development of the genus in the domestication process. It could be argued that now that much of the evaluation work has been completed there are fewer requirements for continuation of the newsletter. However, articles are still being sent to the editors on a range of issues that reflect the continued interest of collaborators including propagation, molecular genetic analysis and microsymbiont studies. The increasing membership would suggest that there is a greater demand than ever for the information and the format of presentation supplied by LEUCNET News.

The main incentive to FRP for stop funding LEUCNET News is the cost and the associated difficulty of finding a suitable editor. The last edition produced at OFI cost about £1 per copy to print and a further £0.75 to post and with the completion of this project there is no longer a researcher committed to editing future copies.

- Continuation of involvement by FRP

A continued involvement in LEUCNET News would maintain FRP's high profile in international Leucaena research and development. However, it would require a substantial investment of funds for each copy. The question of how long the newsletter should continue would need to be addressed.

In addition, the reluctance of researchers at the University of Queensland to collaborate on the newsletters' production has led to some difficulties in obtaining information from collaborators principally involved with ACIAR-sponsored activities. Any continuation of involvement would have to find a solution to this apparently intractable situation.

- Reduced involvement by FRP

The lack of a clear commitment by FRP towards research and development of the Leucaena genus coupled with the problems of cost and human resources required for continued involvement in

LEUCNET News suggests that FRP are not in a position to continue involvement with the newsletter for a substantial amount of time. However, given the undoubted benefits to FRP of association with LEUCNET News a compromise position is currently being discussed whereby FRP will support the publication of one more issue of LEUCNET News on the understanding that research at the University of Queensland collaborate in its production. Thereinafter the University of Queensland will have the opportunity to continue the newsletter if they wish. IT would appear that the most sensible approach to future issues would be to produce them only on the web site. This would require less time from the editors and would eliminate printing and postage costs.

Second LEUCNET workshop, Hanoi, 1998

At the inaugural LEUCNET workshop, held in Bogor in 1995, it was agreed that the collaborators would arrange to meet again to compare results from evaluation trials and discuss the future of research and development with *Leucaena*. FRP had made a significant financial contribution to the first meeting, supporting the participation of five participants and providing substantial support to production costs of the proceedings.

Given the prominent role of both FRP and OFI in LEUCNET it was with some surprise that the second meeting of LEUCNET was organised without any consultation with either. The breakdown in collaboration between OFI and the University of Queensland had (see Discussion) resulted in the latter institution finalising plans to hold the workshop in Hanoi without the possibility of input from FRP-funded researchers.

LEUCNET had been established by the three main organisations involved with Leucaena research and development, namely the universities of Oxford, Queensland and Hawaii. Dr Max Shelton of UQ and myself had subsequently run it. Organising a major workshop without the participation of one of the major partners was a clear indication of severity of the breakdown in collaboration between researchers in Queensland and Oxford. In practical terms these problems did not impact to a significant degree on either the workshop organisation or its running. Thirty-five papers were presented and a strong level of cooperation was fostered. However, the lack of input from FRP in the development and promotion of the workshop undoubtedly created an impression that the University of Queensland (supported through their ACIAR project) was running LEUCNET. Although there was little that could have been done to avoid this situation it is a timely reminder of the need to apply extreme caution when dealing with contentious issues with research partners.

Study of wood quality and yield in the genus *Leucaena*

Introduction

For many farmers the principal product of interest from agroforestry trees, including *L. leucocephala*, is fodder for ruminant livestock. Accordingly, greater research effort has been directed towards improving leaf yield and quality than towards wood production. In spite of this, wood produced on farms is an increasingly important output from many trees. However, there has been little attempt to quantify wood quality and, to a lesser extent, productivity in most agroforestry tree species.

The network of trials created by LEUCNET provided an opportunity to investigate wood production and quality in the genus *Leucaena*. Accordingly, an investigation was initiated in order to provide more information on which species were the best for wood quality and yield using several of the field trials.

The results of the study were presented at the second LEUCNET meeting (Pottinger et al, 1999) and are summarised below.

Discussion

The assessment of mean wood productivity revealed the good growth rate of *L. leucocephala,* but when viewed in conjunction with wood density results suggested that this species should not be favoured for wood production. In fact, few taxa provided evidence of both high density and good wood production (Figures 24 and 25). However, the results have highlighted two species that appear promising in terms of their ability to grow well and produce wood of high density, when compared with commonly grown agroforestry species. It is interesting to note that these two species, *L. salvadorensis* and *L. collinsii* ssp. *zacapana* are already valued highly by farmers in Central America and Mexico for the volume and quality of their wood products (Hughes, 1993; Hellin & Hughes, 1993). (It is, nevertheless, important to note that several LEUCNET trials in southeast Asia not included in this study reported relatively poor growth of *L. collinsii* ssp. *zacapana*).

While this study has provided an indication of Leucaena species that appear promising for wood production, evaluation of wood productivity from a wider range of trials is required before firm conclusions can be drawn. Future assessment of field trials within LEUCNET will assist scientists, rural development agencies, and ultimately farmers, to make better informed choices with species selection for tree planting on farms if wood production is the principal output.

Regional management of LEUCNET

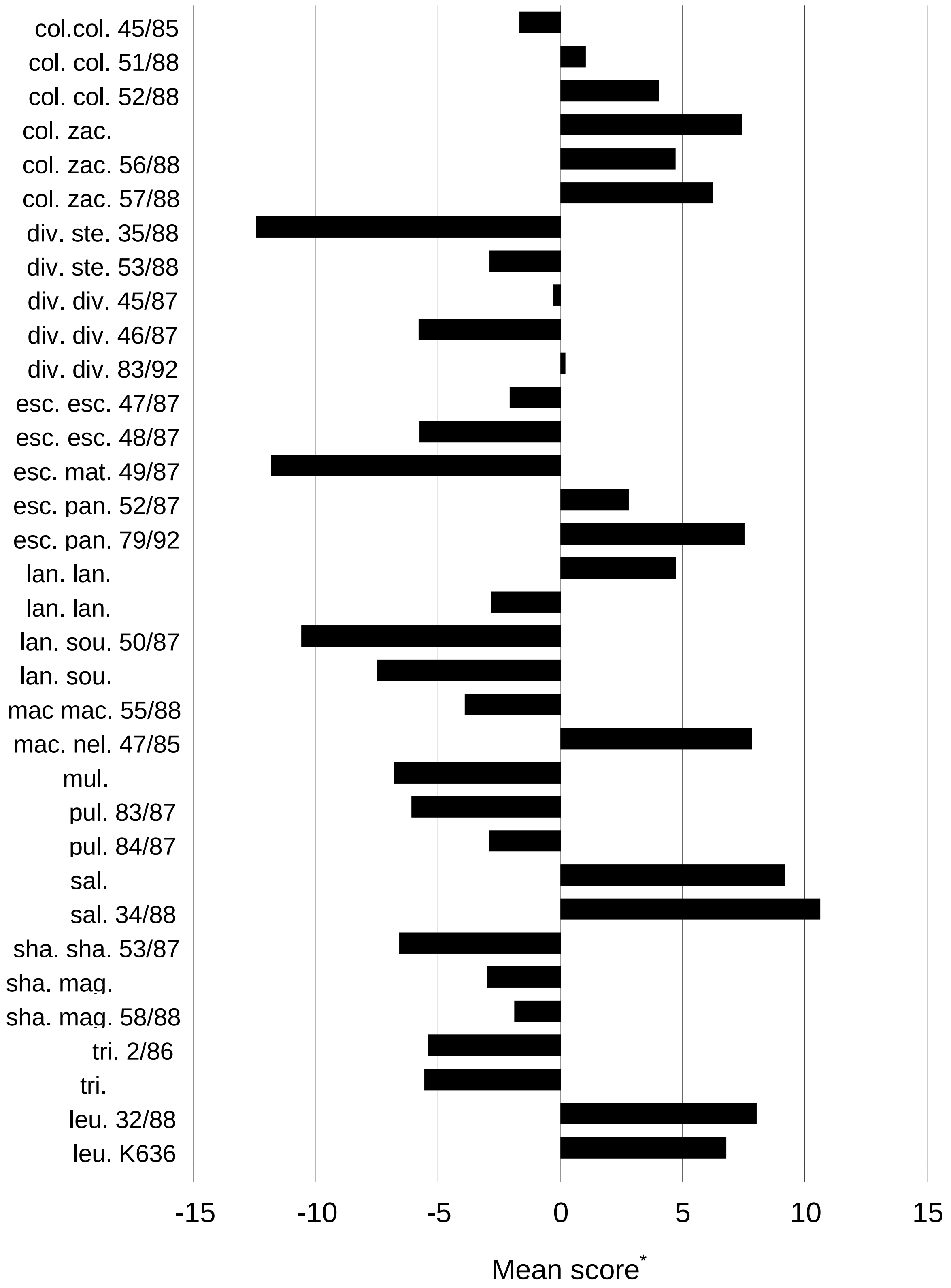
The shortcomings and inefficiencies of attempts to manage large evaluation networks centrally were highlighted by the author (Pottinger, 1996) and led to the willingness of FRP to consider supporting a different approach to network management. Two key regions where LEUCNET trials were either in existence or to be established shortly were selected and potential regional managers identified. The objective of the investigation was to find out if network efficiency increase when central management was devolved.

The Regional Managers identified were Dr Pedro Argel of CIAT and Dr Jumanne Maghembe of ICRAF and their institutions agreed that they would cover Central and South America, and Africa respectively. Simple contracts were formulated and signed to provide the Regional Manager a large degree of freedom to determine how to achieve the objective of improving the efficiency of field trials undertaken by OFI. The lack of prescription was deliberate, as a key part of this investigation was to find out if local views on trial management differed significantly from those that had been suggested previously by UK-based international trial managers.

Summaries of the outputs of each Regional Manager are presented Appendicies 8 and 9.

Figure 24. Mean wood density of 34 Leucaena accessions grown at three sites

Figure 25. Mean wood production score of 34 Leucaena acccessions grown at 11 sites



The World *Leucaena* Catalogue

Introduction

The compilation of a World *Leucaena* Catalogue was agreed to be a high priority at an International Workshop held in Bogor, Indonesia, in January 1994 (Shelton *et al.* 1995). Financial support for the compilation, production and distribution of the catalogue were provided through ACIAR Project No. 9433 and the UK Department for International Development through R6551. The authors were R.A. Bray[1], C.E. Hughes[2], J.L. Brewbaker[3], Jean Hanson[4], B.D. Thomas[5] and Amanda Ortiz[6]

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3: University of Hawaii at Manoa, Honolulu, Hawaii, U.S.A.
4: International Livestock Research Institute, PO Box 5689, Addis Ababa, Ethiopia
5: Australian Tropical Forages Genetic Resource Centre, CSIRO Tropical Agriculture, 306 Carmody Road, St Lucia, Queensland 4067, Australia
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Background/Objectives

Three major germplasm collections of *Leucaena* species have been assembled by CSIRO (Australia), the University of Hawaii (USA) and the Oxford Forestry Institute (UK). As well as these three major collections there are a number of national *Leucaena* germplasm collections, which have often been largely derived from the three major collections. The two most significant of these are held at CIAT (Colombia), and at ILRI (Ethiopia). Each of these collections has been assembled with distinct objectives, philosophies. All five collections maintain computerised databases, with their own individual numbering systems, but up until now there has been no single integrated cross-referenced database of these major collections. Because *Leucaena* germplasm has been widely and freely exchanged throughout the world, and also because of the non-standard recording of passport data, it has not been possible before now to compare the holdings in different collections, and thus to assess accurately the extent to which duplication between collections might have occurred, nor to determine readily the full range of collection sites that have been sampled.

The objectives in compiling the catalogue have been:

1. To provide an easy to use database of the main *ex situ* collections of *Leucaena* seed.
2. To collate, and standardise as far as possible, passport data from the various collections, and thus allow detailed study and/or comparison of the various accessions.
3. To standardise the species nomenclature across the various collections.

The extent of the various collections included in the Catalogue is indicated in Table 9.

The catalogue was originally supplied as an Excel (V5.0) spreadsheet to key collaborators in LEUCNET in 1998. Excel was chosen because the software is widely used, and provides good search facilities. Following comments and subsequent alterations ICRAF kindly agreed to adapt and host the Catalogue on their web site at http://icrafnt2/cfdocs/examples/treessd/LeuCat/main.HTM. This has meant that free access is ensured. ICRAF's generous support (for which no contribution was requested) is greatly appreciated and is typical of their approach to collaboration in to R6551.

Table 9. The number of entries of various *Leucaena* species in the catalogue, both originally and after assessing direct duplication.

Species	Subspecies/variety	No. of entries in catalogue	No. of entries after adjusting for duplication
collinsii	*collinsii*	24	17
	zacapana	31	29
confertiflora	*adenotheloidea*	7	7
	confertiflora	10	7
cuspidata		7	6
diversifolia		101	68
esculenta		67	61
greggii		42	39
involucrata		2	2
lanceolata	*(unassigned)*	8	8
	lanceolata	55	44
	sousae	22	15
lempirana		2	2
leucocephala	*(unassigned)*	435	414
	glabrata	201	150
	ixtahuacana	2	2
	leucocephala	523	473
macrophylla	*(unassigned)*	11	8
	macrophylla	34	24
	istmensis	11	8
magnifica		7	5
matudae		3	2
multicapitula		5	4
pallida		57	41
pueblana		3	3
pulverulenta		53	43
retusa		28	22
salvadorensis		15	10
shannonii		55	43
trichandra		112	97
trichodes		35	27
xmixtec		0	0
xspontanea		16	16?
"hybrid"		142	142?
?		34	32
Total		2160	1871

The full version of the text accompanying the World *Leucaena* Catalogue is in Appendix 10.

DISCUSSION

This section has dealt with two separate issues; the management of LEUCNET and the concept of regional management of a network. The outputs of each are discussed below.

LEUCNET

LEUCNET has been an extremely successful network. There are a large number of participants, a high level of interaction amongst collaborators and significant progress on the domestication of species in the genus *Leucaena* and their hybrids. The reasons for this success are due to:

- *A high demand for the research established at the outset*

LEUCNET was established from the joint interests of three organisations; the universities of Oxford, Queensland and Hawaii to implement further research with their substantial collections of germplasm. However, it is worth noting that as far as OFI was concerned, no indicators of demand for the research were required from potential end-users in order to receive funds from FRP.

- *The collaborative approach adopted*

These three organisations had researchers who were well known to each other and appeared to have the potential to work well together. In addition, each organisation had a wide group of collaborating organisations between which there was relatively little overlap.

- *Central support from well-funded research programmes*

The research programmes of OFI and UQ had guaranteed funding to carry out widespread evaluation of the genetic resource.

- *A strong genetic base of material*

Thorough the rigorous scientific approach to sampling the genetic base of the genus undertaken by Colin Hughes of OFI an exceptional range of germplasm was made available from which to conduct an evaluation programme. This provided the strongest possible base from which to conduct further domestication activities.

- *The publication of LEUCNET News*

This newsletter provided the perfect forum for a rapid means of distributing results from the network. In addition, it encompassed a range of approaches to presenting results; from formal scientific papers to research highlights.

While each of the issues above has contributed significantly to the overall success of the network the principal reason why LEUCNET has progressed more vigorously than any of the other domestication programmes in which FRP has been involved has undoubtedly been to the involvement of the ACIAR-funded programme 9433 *New Leucaenas for Southeast Asian, Pacific and Australian agriculture* managed from UQ.

ACIAR's research projects require a measurable beneficial impact to the Australian economy and this obligation has helped create a dynamic and progressive research programme. Frequent visits to researchers by key figures in the management of the project in Australia have created a more positive and collaborative approach to network-based research than any of the FRP-funded networks has achieved. They have encouraged and cajoled collaborators to produce results in a reasonably short time and have made significant progress in the overall domestication of the genus.

The approach of the ACIAR-funded project to domestication is, however, questionable. The links between on-station and on-farm evaluation are weak and their knowledge of seed production pathways is limited. Their somewhat cavalier approach was highlighted by their allegedly illegal procurement of plant variety rights for a "line" of *L. leucocephala* that precipitated the breakdown of relations with Oxford University. However, in spite of their shortcomings, it is the multi-faceted manner in which they approached the overall question of tree domestication that has enabled them to succeed in a manner than has not been possible with FRP's approach. ACIAR has looked more closely at the end uses of *Leucaena* before developing a research programme and guided much of their work towards improving animal production. A fundamental difference between their approach and that of FRP is that they recognised that the domestication of a tree species should be undertaken by those with a knowledge of it and an involvement in its end use. *Leucaena* species are used mainly for forage and as such UQ has used forage agronomists to manage their *Leucaena* research programmes. FRP, on the other hand, has not encouraged the involvement of forage specialist in an integrated manner in the domestication of *Leucaena* – a situation that is likely to be the result of an absence of an overall strategy for domestication of species in the genus. FRP has instead focused its evaluation programme on the concept of *Leucaena* as a tree rather than looking at what the tree is used for. As such their approach to domestication has followed the path of the tropical pine evaluation programme too closely and has subsequently suffered from a lack of consideration of how the results might be used.

FRP's involvement in the early stages of the domestication process has undoubtedly established the foundation for other organisations to benefit. While FRP's support for exploration, seed collection and evaluation has been laudable, their lack of long-term commitment to assisting in the uptake of results will mean that visible impact from their investment will be limited. In contrast, the continued interest of ACIAR in measuring the uptake of results from its research programmes (e.g. ACIAR Economic Assessment Series) means that impact of their work is likely to be greater than that which FRP is likely to record.

Where does LEUCNET go from here?

LEUCNET's future is uncertain. Although ACIAR is continuing to support evaluation and uptake work with *Leucaena* species and hybrids FRP has planned no further involvement. Some of LEUCNET's activities may continue, and there are many trials that will be evaluated without the need for external funding. However, DFID will not be able to measure the impact of their investment in *Leucaena* research and development unless they continue their involvement and devise projects specifically with measuring impact in mind.

With the planned end of LEUCNET News in 2000 and no central co-ordination offered by R6551 LEUCNET will cease to exist. This is not necessarily a problem as much of the need for an organised network was to support seed distribution and trial establishment. These functions have been fulfilled and it is now up to the researches working wit the species to determine how to continue the domestication process. The main problems with the termination of LEUCNET are:

- It is quite likely that development of the species will be limited without external inputs to provide more seed and assistance to uptake activities.
- DFID will not be able to encourage uptake and measure impact of its investment.

REGIONAL MANAGEMENT

Traditionally, ODA/DFID research projects have not provided funds for evaluation of genetic resources in field trials. This has been intentional and was based on the same approach as appeared successful with the previous CFI/OFI tropical pine networks. The recognition of the possible shortcomings of this approach and the subsequent provision of support to both ICRAF and CIAT within this project to manage regional networks of trials has provided encouraging results. The two organisations have taken markedly different approaches to the utilisation of funds but each has produced visible results in a range of activities. CIAT is at an earlier stage than ICRAF in the domestication of *Leucaena* and consequently focussed on trial establishment. Seventeen trials were established in nine countries and, in addition, field days were held. The trials were managed well and reports indicated that the networks were run more effectively than would have been possible purely from a UK base. ICRAF concentrated on the development of their existing results and investigated seed production and hybrids. Again, the level of contact that was maintained with scientists directly involved in the programme was far greater than would have been possible without their involvement.

The success of this approach was not a complete surprise but should go a long way to confirming the validity of providing support to regional managers in research networks. However, it is very important to recognise that this approach will only work if appropriate partners are selected. This is a time consuming process and a great deal of time and effort went into discussions with both ICRAF and CIAT regarding what both they and FRP wanted from the arrangement. If such activities are to take place in the future it is imperative that FRP invests appropriate funds in support of partner selection.

3.1.4 Discussion

The three networks studied are at very different stages of development. The gliricidia network has undergone evaluation and uptake of results is currently taking place, the *Calliandra* network has just produced results that can be used for the production of seed of the best performing provenances, and the *Leucaena* network covers almost the full range of stages from evaluation to uptake.

The future of each of the networks is unclear. If DFID is interested in showing meaningful impact from its research activities with agroforestry tree networks it must continue its input into the domestication programme. Without further involvement it will be impossible to measure the value of the substantial investment that DFID has already made in the process of tree domestication. In this regard it is interesting to note that a small number of organisations are taking results forward from FRP-funded research. However, with significant inputs required in the uptake process the initial role of FRP is overshadowed. For example, the research highlight provided below by ICRAF illustrates how calliandra development is occurring in the Embu region of Kenya with provenances initially collected by OFI. As domestication programmes take further steps forward it is not surprising that without their continuing involvement the initial input of DFID is overlooked, as is the case here.

As far as network management is concerned the project has provided strong indications that developing management responsibilities to regional managers can be a highly effective means of delivering results. The logic of encouraging a greater input for the researchers involved with the programme was not tempered by loss of control of the research programme. In fact the converse was true. Several new research ideas were suggested and completed by the regional managers that would not have taken place if the networks had been managed centrally from the UK.

Calliandra on the move!

On August 31-September 1, Kwesi Atta-Krah, Steve Franzel, and Frank Place accompanied Charles Wambugu, ICRAF dissemination staff member, to visit some of his field sites in the Central Highlands of Kenya, where he is helping farmer groups establish fodder tree nurseries. Other participants on the tour were from the International Livestock Research Centre, Nairobi, and two research centers of the Kenya Agricultural Research Institute (KARI): Embu and Maguga.

Since the early 1990s, The KARI-KEFRI-ICRAF National Agroforestry Research Project, based at KARI's Regional Research Centre, Embu, has been active in testing and disseminating *Calliandra calothyrsus* fodder trees around Embu. About 2,000 farmers have planted them. But the project lacked the staff and resources required to extend to other areas of the Kenyan highlands, where about 400,000 smallholder dairy farmers live. Farmers value the fodder trees as a supplement to their basal feeds and as a partial substitute for commercial dairy meal, which they find to be expensive and of unreliable quality. The trees are also useful for conserving the soil and for providing firewood. The planting of 500 fodder trees can increase household income by about USD 130 per cow or USD 220 per household.

In February, 1999, Charles was hired through a KARI-ICRAF-ILRI project of the. Systemwide Livestock Programme (SLP), a centre-wide initiative, to facilitate dissemination of fodder trees in central Kenya. Based at the KARI Regional Research Centre in Embu, his progress in the first 6 months of employment has been remarkable. Working with KARI researchers, Charles has assisted staff of the following organizations to train farmers: 3 departments of the Ministry of Agriculture, 2 provincial administrations, 1 international NGO, 2 local NGOs, 2 Church organizations, 10 community based organizations, and 117 farmer groups. In all cases, Charles works with farmers groups, ranging in size from 4 to 50 members. Most of the groups were pre-existing, dealing with activities such as dairy goats, handicrafts, water tanks, soil conservation, or tree nurseries. They include womens' group, mens' groups, youth groups, and mixed groups. Charles and his partners have facilitated the development of 160 nurseries involving over 2,037 farmers in 6 districts during the first six months of his employment. Roughly, about 800,000 calliandra seedlings have been raised, about 400 seedlings per participating farmer, and 20,000 mulberry cuttings distributed.

The degree of enthusiasm among farmers is impressive. In Kagarii Catchment, Nyeri District, Charles and Ministry of Agriculture staff initially assisted 5 farmer groups to establish 13 nurseries. These groups later recruited another 7 farmer groups in the village who then established 12 more nurseries to make a total of 25 nurseries in the area. The farmers hired a bus to take 35 of them to Embu for one day, where they visited the KARI research station, a farmer group nursery, and an individual farmer with mature Calliandra hedges.

ICRAF's interest in the project is not solely in extending the technology, we also want to conduct research on dissemination in order to improve dissemination efforts elsewhere. Using funds from the SLP and the Systemwide Program on Property Rights and Collective Action, Frank Place, Charles Wambugu, Steve Franzel and KARI researchers Festus Murithi and Paul Tuwei will assess factors affecting the performance of farmer groups involved in establishing nurseries and and planting and disseminating fodder trees. The project is thus off to an excellent start in contributing to three objectives which are part of ICRAF's mission: working with and building capacity among a range of partners, conducting cutting-edge research on development processes, and improving the well-being of smallholder farmers.

3.2 UPTAKE OF RESULTS FROM EVALUATION NETWORKS

3.2.1 Introduction

ODA's initial forest genetics research networks were established in the late 1960s and focussed on tropical pines native to Central America and Mexico. The provenance trials that were established throughout the tropics formed the backbone of what appeared to be a highly effective network. Several hundred trials were established (Pottinger, 1993) and results were produced by both the coordinating agency (CFI/OFI) and the collaborators themselves.

In the mid 1990s it became apparent that the assumption that agroforestry tree evaluation networks would operate successfully employing the same approach as had been used with tropical pines was incorrect largely for two reasons. Firstly, there was an initial lack of appreciation of the structure of genetic resource research networks, and secondly, the assumption that the tropical pine research networks delivered adequate results was unsubstantiated.

The structure of genetic resource research networks

The structure of a research network is determined to a large extent by the human and financial resources of the collaborators. A group of collaborators with access to land, manpower, scientific expertise and funds will be in a strong position to produce results. If, as was the case with many collaborators in the tropical pine network, those collaborators are also from the organisations that want to implement the work then the uptake pathway is straightforward and efficient. In other words the target group of collaborators was the same as the target group of beneficiaries of the research. The means to implement results were accessible to the same organisations that collaborated in the experiments. Conversely, in most agroforestry research networks the organisations carrying out the research are unlikely to be those implementing the results. In this case the target group of collaborators may be forest departments or NGOs whereas the target group of beneficiaries is poor farmers. In these situations uptake pathways are complicated and may involve many organisations.

The apparent success of the tropical pine research networks relied mainly on the ability of a relatively small number of collaborating organisations to implement the results. The high profile nature in which this was reported combined with the influential role within the tropical forestry scientific community of several of the key researchers involved in the programme served to obscure the many organisations that found themselves unable to utilise results. The reasons behind the problems of uptake of results remained unexamined partly because the lack of uptake went largely unnoticed and partly because uptake and impact of results were not principal objectives of the research projects.

Delivery of results from the tropical pine research networks

It is estimated that ODA spent over £8 million on research projects associated with the tropical pine research networks managed from OFI, during which it distributed over 20 million seeds (Henderson, 1999). Both ODA and the Oxford Forestry Institute undoubtedly benefited greatly from the collaborative partnerships formed through the establishment of the networks. The much-vaunted exploration and evaluation programmes that underpinned the evaluation networks when combined with the efficient management of the trials created a high profile for both ODA and OFI activities in tree improvement. However, assessing the scientific and developmental value of the work proved difficult. The short-tem project structure, lack of post-project evaluation and dissociation between ODA research projects and final users of results combined to make a meaningful estimate of the subsequent value of either the economic or social outcomes of the work impossible (Henderson, 1999). The continued lack of a tree domestication strategy within FRP meant that no plans for assessing uptake of results were adopted into the agroforestry research programmes supported by DFID when they were initiated.

With increasing pressures to show the impact of FRP research it was decided to investigate the uptake of results from the tree legume evaluation programmes within R6551.

Methodology

The investigation of uptake pathways requires an identification of end users. Although there was a previously implied assumption that FRP had knowledge of who user groups were and what their needs were likely to be this was incorrect. FRP had not worked closely with user groups in tree domestication programmes.

An approach was therefore required in order to identify and contact potential end users. Forming direct contact with farmers would be likely to require a substantial input of funds over a significant period of time and was therefore considered not possible within the project. Forming indirect contact with farmers through the use of partner agencies suggested a much more efficient use of existing expertise amongst NGOs and government-funded extension agencies and was therefore selected for implementation. The next stage was to identify suitable partners to assist in the process.

A small number of key collaborators who had worked successfully with FRP on domestication-related projects were identified as potential collaborators to assist in the clarification of impact pathways. The criteria for selection were as follows:

- Collaborative experience with OFI (both scientific and financial)
- Interest in adoption of tree legumes with farmers
- Capacity to promote tree legumes with farmers.

The final list included the following:

- BAIF Development Foundation (India)
- Forages for Smallholders Programme (Indonesia, Laos, Philippines and Vietnam).
- Indo-Swiss Project (India)

To which was added later:

- Evergreen Trust (UK/Tanzania)
- CEDAC (Cambodia).

Measuring impact

In order to evaluate the success of the partnerships adopted with in each of the case studies it is necessary to employ some means of assessing the impact of the activities carried out. In measuring impact we are trying to evaluate what has happened as a consequence of research that would not have happened without the involvement of FRP-funded research. As such certain assessment criteria need to be adopted. In the past there has been no realistic assessment of impact in the ODA/DFID projects involved with tree domestication activities and therefore no standardised means of approaching impact assessment. A simple model for impact assessment was established for this study based on performance measurement indicators (N.R.C., 1995) (Table 10).

Table 10. Network evaluation model

Objectives	Resources	Activities	Collaborators	Outputs	Outcomes	Immediate impacts	Long-term impacts
Planning process - Problem identification - Client identification Framework for deciding on outputs	Funds available - Source - Use Expertise - Internal - External	Processes involved in pursuit of objectives Monitoring - Feedback mechanisms	Clients listed	Quantitative, e.g. number of seedlings Qualitative - Client satisfaction - Donor satisfaction Knowledge	How are the research findings being used?	Feedback from clients Market indicators (quantitative gains from research activities)	Feedback from - Clients - Managers - Donors Market indicators (quantitative gains from research activities))

Past approaches to development of domestication programmes

The choice of species for inclusion in FRP-funded domestication activities has been a prime example of research priorities being established by researchers with little quantifiable reference to end users as defined by donor policy. The focus on pines from the 60's through to the mid 80's could be accounted for by the pervading assumption at the time that strengthening the industrial forestry sector delivered the type of "development" desired by the donor. However, the in-house selection of species priorities in the mid- to late-80's that subsequently accounted for several million pounds of development aid funds was not only an example of poor awareness by ODA of user needs but showed a lamentable lack of employment of basic scientific methodology. The outcome of this approach with its focus upon a small group of exotic species that provided either wood or fodder has subsequently been shown to be not only simplistic in its approach but also largely incorrect in assessing real needs of farmers. Species prioritisation activities carried out by other agencies that have involved farmers have generally identified income-earning trees as priorities (Eyog Matig pers. comm.[1]; Franzel, et al, 1995; ICRAF, 1997; Powell pers. comm.[2]; Raintree and Taylor, 1992).

The comprehensive exploration and collection activities that followed were justified by the assumption that on-station evaluation would eventually be followed by seed distribution programmes designed at supporting research initiatives throughout the tropics. Although these programmes took place and for many years were widely seen as being the standard against which other evaluation programmes were compared there was never any meaningful measure of impact beyond numbers of trials and countries involved in the programmes (Pottinger, 1993). In project preparation documents justification was based on an assumption that research centres would take results forward yet with no examples of how this would be carried out. There was undoubtedly an attitude within the community of donors and scientists involved in tree domestication work based at OFI that impact would take care of itself. Although it is easy to reflect that this view was naïve it is important to remember that many researchers involved in the domestication process (including the donors) came from an industrial forestry background where the uptake pathways are much simpler. Often the researcher and grower are part of the same organisation, something that is rarely if ever the case with farm forestry where links between researchers and growers are often weak or non-existent. Poor integration of social scientific thinking in forestry into the FRP-funded domestication programmes at OFI meant that significant amounts of funds were directed towards programmes that had no clearly defined end point. Users were seen as a distant group with whom there was no contact, and no discernible means of reaching them.

The outcome of this situation was that impact was considered almost as an afterthought. Retrospective means of ensuring impact were hastily brought into existing projects although little thought was given regarding what was meant by impact and how it should be measured. However, recent interest and pressure to develop means of addressing the previous lack of measurable impact have resulted in a more rigorous project application procedure with clearly identified requests to identify and measure uptake and impact of results.

The following sections deal with a series of case studies to investigate the manner in which research results can pass from researcher to end user. In each case the implementing agency was encouraged to develop plans based on its own experience for implementing uptake of results from domestication activities. The intention of this approach was to increase the input of “local” scientists in project planning and to compare approaches amongst the partners.

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[1] Dr Oscar Eyog Matig, Regional Coordinator of SAFORGEN, IPGRI, c/o IITA, 08 B.P. 0932, Cotonou, B■nin.
[2] Mark Powell, Senior Scientist, Winrock International, Morrilton, Arkansas, U.S.A.

3.2.2 Case studies

3.2.2.1 BAIF

The BAIF Development Research Foundation was established in 1967 by Manibhai Desai, a disciple of Mahatma Ghandi, as a means of promoting agricultural development throughout India. BAIF's mission is to create opportunities of gainful self-employment for rural families through development of degraded natural resources, ensuring a sustainable livelihood, while at the same time enriching the environment. Initial activities focussed on improving milk production through cattle breeding but this soon grew into a multidisciplinary approach to rural development encompassing health, literacy, empowerment of women and improvements in local leadership as well as a range of activities aimed at improving agricultural productivity.

BAIF now works in seven states (Uttar Pradesh, Rajasthan, Mahrashtra, Gujarat, Karnataka, Madhya Pradesh and Andhra Pradesh) and is committed to a major programme of promoting tree-based farming systems, principally through their Tribal Rehabilitation Programme. Participatory approaches to selection of problems and interventions are central to BAIF's operational philosophy. This approach is borne out in the management structure of the organisation where programmes have been decentralised and managed at state level by autonomous institutions.

Seed production of Gliricidia sepium *at BAIF's main research station provides seed for their uptake activities with farmers.*

As a charity, BAIF is dependent upon outside funding and has developed a broad portfolio of projects supported by IDRC, DANIDA, Winrock International, FAO and the Ford Foundation. OFI began collaborating with BAIF in the mid 1980s when a trial of hardwood species native to the dry zone of Central America was established in Maharashtra under ODA research scheme R4179, Multipurpose tree evaluation - initial phase, and subsequently developed further under R4454, Evaluation of Central American multipurpose hardwood tree species for dry zones. Gliricidia was the subject of collaboration in R4525, Evaluation of the potential for genetic improvement of *Gliricidia sepium*, and R4856, Genetic improvement of non-industrial trees with particular reference to *Gliricidia sepium*. Close contact has been maintained with BAIF's throughout these projects but also though personal contacts with their President, Dr Narayan Hegde, and their Senior Scientific Director, Dr Joshua Daniel.

BAIF considers that India is in the midst of a growing number of development programmes in which tree planting is a key component, and has highlighted the acute shortfall in provision of high quality seed and seedlings for use in such programmes. The State sector does not involve itself in seed production of agroforestry species to any significant degree, and no organised tree seed production system has become established amongst NGOs. The result has been either dependence upon local seed collections, usually of poor quality stock, or purchase of seed from suppliers who are themselves dependent upon stock of unreliable and sub-optimal origin.

As the country's largest NGO in rural development, and with good international contacts in agroforestry research, BAIF appeared perfectly placed to link the outputs of scientific research with farmer's needs. Using their experience in promoting the use of *Leucaena leucocephala* throughout India, Dr Daniel and I proposed two projects to promote the uptake of results from FRP-funded activities with gliricidia. The first was to establish seed production areas of key agroforestry species used by farmers, and the second to develop pathways to encourage use of gliricidia. The progress of each project is described below.

Seed production of several species of interest to farmers has enabled BIAF to become India's leading NGO in agroforestry tree development.

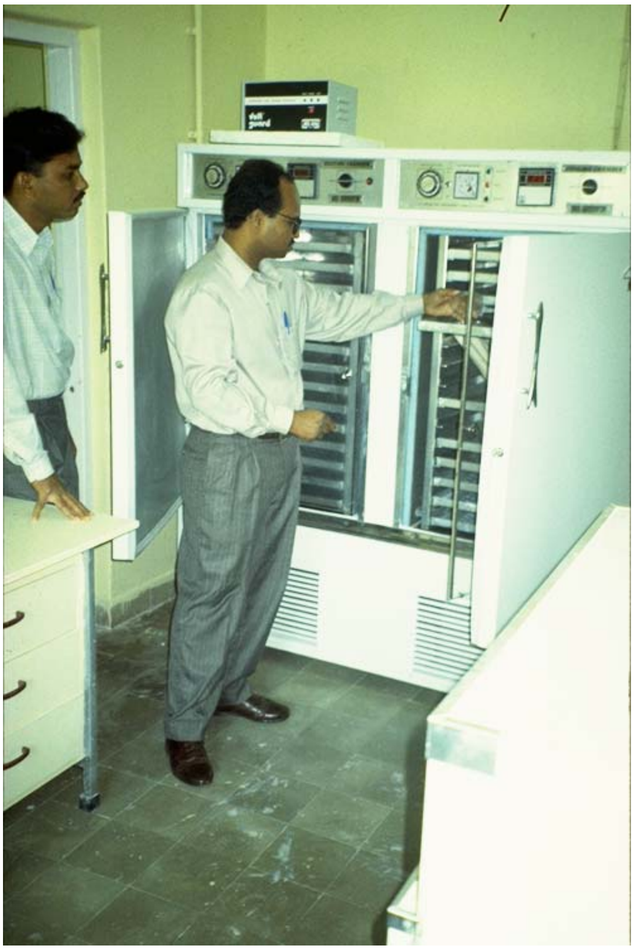
A. Establishment of seed orchards a and laboratory for tree seed production

Objectives
The specific objectives of the project were to establish seed orchards of 10 species for use in agroforestry and establish a laboratory for seed processing and storage. The species for seed production were based on preferences stated by farmers to BAIF for use on small farms.

Results
A seed production area was proposed at the Central Research Station (CRS), Urulikanchan, Maharashtra, covering 20 ha and comprising the following 10 species;

- *Acacia mangium*
- *Acacia nilotica* var *cupressiformis*
- *Azadirachta indica*
- *Ciba pentranda*
- *Dalbergia sissoo*
- *Faidherbia albida*
- *Gliricidia sepium*
- *Gmelina arborea*
- *Grevillea robusta*
- *Leucaena leucocephala* (K636)

The area devoted to each species was determined by demand for seed experienced by BAIF. Accordingly, 3 ha each was established for *G. sepium* provenances Retalhuleu and *L.*



Seed processing and storage facilities have been established through FRP support. This has enabled BAIF to plan its extension activities better than previously and work with a greater number of farmers.

leucocephala K636. Smaller areas were also planned for the second and third best performing provenances from the results of the OFI across-site analysis (Stewart et al, 1996). Seeds of *G. sepium*, *C. calothyrsus* and *L. leucocephala* were provided by OFI. All other seed came from either the Australian Tree Seed Centre or India sources (Daniel, 1998).

Village tree nurseries are a key factor in the supply of improved germplasm. BAIF supports nurseries in several villages.

Growth of *G. sepium* has been excellent but seed yields have been low due to an aphid attack. Although the orchards are only 18 months old seed production from all other species is encouraging.

Seed laboratory: Existing buildings at CRS were modified and seed collecting, storage and testing equipment purchased.

B. Utilisation of superior provenances of *Gliricidia sepium*

Objectives

In order to promote the uptake of results from the gliricidia domestication programme in India the above project was developed with the following objectives:

- To establish multiplication stands of superior gliricidia provenances.
- To conduct field days for farmers to disseminate information on Gliricidia production and use.
- To distribute planting material of superior gliricidia as seed or cuttings.
- To compare the growth of the introduced provenances of gliricidia with local ones in on-farm experiments.

Project sites were selected at Vansda in Gujarat, and Tiptur and Mundgod in Karnataka. Gliricidia seedlings were given to participating farmers for planting as single bund rows. Gliricidia was already known to farmers in both project areas and usually planted on farms that are not more than 2 ha in size. It is readily eaten by far animals in Karnataka but not in Gujarat.

Seed stands of gliricidia were established at the BAIF Karnataka campus in 1997 in addition to the main orchards at the CRS.

Results
BAIF has distributed over 4000 trees to farmers in addition to advice on propagation by seed and cuttings. Gliricida planting has increased in each of the target areas with farmers continually requesting seedlings from BAIF. Farmers usually plant between 50 and 200 trees on farms and each tree produces between 1 and 2kgs (fresh weight) of leaves annually from the second year onwards. Trees are generally kept small to reduce competition with adjacent crops. However, some wood harvesting is possible with some farmers recording annual harvest in excess of 50 kgs. The quality of the young wood is generally poor but it is estimate d that this amount will be enough to meet the energy needs of a farmer's household for between 10 and 15 days (Daniel pers comm.).

Leaves are mainly used as green manure in to add to other sources of organic material such as farmyard manure. Although the leaves contain nitrogen BAIF consider that the improvement to soil structure that results from applications of the green manure to be equally important.

Field says were organised in 1997 and 1998 to promote the use of gliricidia among farmers in neighbouring areas. The field day programmes consisted of a tour of the farm where both Retalhuleu provenance and the local provenance of gliricidia were being grown to allow for a comparison. Cultivation and management were discussed and guidelines provided in the form of a leaflet produced in three local languages Marathi, Kannada and Gujarati (Appendix 4). In addition to the information provided the leaflets also contained the lyrics to two songs specially commissioned for the project highlighting the benefits of the tree (Box 2). Seeds and trees were also distributed during the farmer's field days. These activities are featured in a video "Gliricidia: a story of tree domestication" (Pottinger, 1999c) (see pages 65-67).

Assessment of growth performance is planned to take place as a joint exercise between BAIF staff and local farmers so that perceptions of the tree's performance on farms can be recorded rather than simple quantitative measures of growth.

Discussion

There is no doubt that there is a genuinely strong demand for gliricidia from farmers working with BAIF. (See Box 1) A consultative approach between the NGO and farmers has enabled priority species to be identified and subsequently developed. BAIF has been able to use its substantial experience with agricultural extension to promote gliricidia using a tried and tested approach. BAIF's commitment and ability to produce the planned results has been excellent and the results produced from FRP's substantial investment in gliricidia domestication have been efficiently promoted.

However, the more important issue is whether BAIF have conducted the promotion and uptake of the species more effectively than could have been achieved by an FRP project manager. Clearly, without an adequate control it is not possible to provide a conclusive answer but it is difficult to envisage how more direct management by an FRP project manager could have produced more effective uptake of results. BAIF are in constant contact with farmers and appreciate their needs. Field days maintain a good collaboration between scientists, extension workers and farmers in a manner that would not be possible if the process was controlled more centrally.

In India, NGOs and research organisations abound and it is essential to have good contacts and experience in the country before attempting any uptake exercises. Any project attempting to promote results form the gliricidia research funded by FRP would have to work though some form of intermediate agency to deliver results. BAIF provided a strong combination of an extensive network of collaborators, significant experience in the filed of agricultural extension, and an excellent record of financial management in collaboration with OFI. This combination meant that they were the obvious choice to conduct such an exercise. However, without the experience of collaboration with them it would have been very difficult to produce such effective results.

Box 1 Some comments from farmers working with BAIF

Basavaraju **“ I know gliricidia from the time I was a boy. But the seedlings of the new variety of gliricidia give by BAIF is growing faster. ”**

Shankarnarayana **“ This tree is commonly known as ‘manure tree’. Only now I understand why it is called that. ”**

Jamsu Kunchia **“ I plant local trees for the next generation and trees like gliricidia for my use because I can harvest them so soon. ”**

Jagal Chilu **“ Any time I find it taking up too much land I cut it, and then it grows again. ”**

Box 2 Songs commissioned from BAIF to encourage uptake of gliricidia

The Gliricidia tree

"Let's leave the orchard, dear
There they hold a forest fair"

"Why so haste y fair queen?"
"To see the garden ever green"

Where's the spot, you speak indeed?
Hear, oh dear, mind! Take heed.

Medium shaped and leafy green
Bundles of flowers blush unseen

Its foliage falls upon the field
Nutrient rich, it assures a high yield.

Known to be a friend of the farmer
It gives him fuel, fence and fodder

Across the slope they grow in a file
And help to serve the surface soil

The name of gliricidia tells its story
It kills the rats and stops your worry

Grow gliricidia on your field
To fight any trouble, here's a shield

Grow gliricidia to meet your needs
Use the cuttings or wholesome seeds

Here's a green friend from the West
Among the trees, it's one of the best

Song in Marathi by G.T. Mahajan

Gliricidia: the manure tree

When there was uncertainty
You came to the rescue
As a provider of all
You are the tallest
In your category
Gliricidia

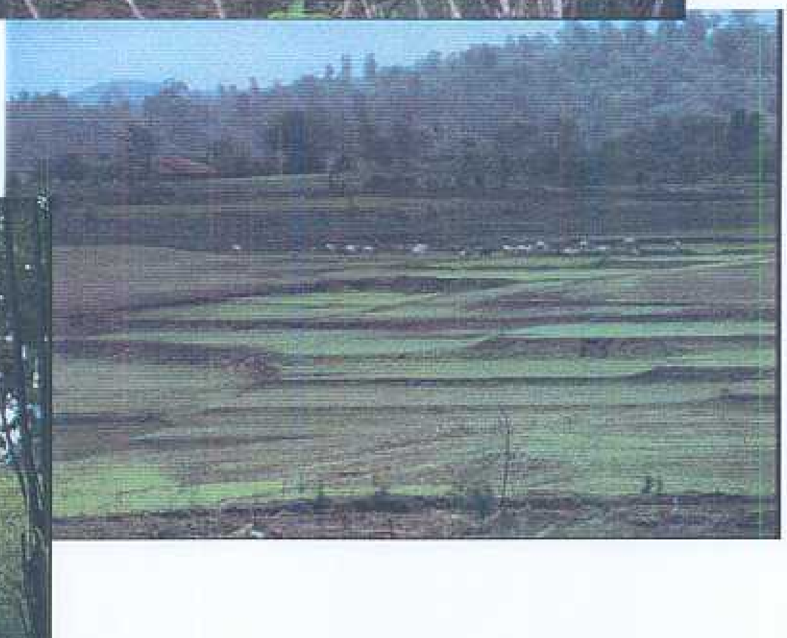
Even as our soil loses its life
Due to the overuse of chemical
fertilisers
You are a ray of hope
Providing vital ingredients and
Making our land fertile again
Gliricidia

When nature turns against us
With unpredictable droughts and
floods
You never forget to feed
With leaves free of pests and
Flowers that attract honeybees
Gliricidia

Born somewhere
But growing here like our own
daughter
Guarding our farms as a live fence
Helping us in natural agriculture
You truly are the manure tree
Gliricidia

Song in Kannada by I.I. Hugar

Scenes from the making of
"Gliricidia: a story of tree
domestication"



3.2.2.2 Forages for Smallholders Project (FSP)

Peter Horne (Senior Scientist, FSP)

"How much seed did we get from the gliricidia orchard near Ban Ma Thuot?"

Truong Tan Khanh (Vietnamese farmer working with FSP)

"About 500g"

Peter

"What happened? There was supposed to be much more than that!"

Khanh

"Well, when the local farmers saw how fast the trees were growing they took all the seed away to plant on their own farms."

Box 3. NGO feedback on the popularity of gliricidia in Vietnam.

Introduction

The Forages for Smallholders Project (FSP) is a 5 year (1995-99) Southeast Asian regional project funded by AusAID and managed by CIAT in collaboration with CSIRO. Its focus is to develop forage technologies, in partnership with smallholder farmers in upland areas, where forages are needed for livestock feeding and resource management (including erosion control, soil fertility improvement, weed control and reducing labour requirements). Although such participatory approaches to technology development are becoming widely used in rural development, they are new to forage technology development in Southeast Asia. With the assistance of the Participatory Research Project at CIAT, the FSP introduced farmer participatory research methods in the region in 1995 and has subsequently tested, modified and implemented them (Cheng and Horne, 1997; Stur and Horne, 1998). Often farmers want multiple benefits rather than a solution to a single problem. They modify the way they plant and use forages and the results of their innovations are shared with other farmers and across the region through a regional network. Their interest in experimenting with tree legumes combined with their experience in promoting forages over a wide region suggested they would be good partners to promote research results with gliricidia.

The FSP is a network of smallholder farmers, development workers and researchers. It is coordinated by national organizations in Indonesia, Laos, Malaysia, Philippines, Thailand, Vietnam and southern China. In partnership with the national coordinating agencies, FSP staff identified sites in Indonesia, Laos, Philippines and Vietnam where collaborators were willing to work with farmers in developing new technologies. These development workers were employed either by local government agencies or community development projects (both GOs and NGOs). Research sites were selected to cover a wide range of environments and farming systems commonly found in upland Southeast Asia.

Before starting to evaluate forages with farmers, the FSP conducted regional forage evaluation trials. These were sometimes conducted in research stations, sometimes on farmer's fields and were usually controlled by researchers. The information from these evaluations, together with local information, formed the range of forages that could be offered to farmers for evaluation. In some cases tree forage was not identified as a requirement and was therefore not included in this study. Regional and on-farm evaluations were supported by two sites in the Philippines and Laos that produced seed and vegetative material of a range of mainly herbaceous forages, but included gliricidia.

On-farm evaluation is an integral part of finding out the demands of farmers.

The specific objectives of providing financial support to FSP were:

- To integrate OFI tree legume germplasm, particularly *Gliricidia sepium*, into smallholder farming systems,
- To gain an understanding of the mechanisms of adoption, and
- To develop seed supply systems of successful provenances.

Establishment of local seed orchards, as here in Laos, enables easy access by farmers to improved seed.

Summary of outputs

FSP activities

Establishment of seed production areas
Several small seed orchards of *Gliricidia sepium* were established in Vietnam, Lao PDR, and Indonesia in 1997 (Table 11). The first 10kg of seed of Retalhuleu have recently been harvested from the seed orchard in Daklak, Vietnam. This seed will be used for distribution to farmers under the FSP programme.

Seed harvests in other areas were disappointing; the reason was unseasonable rainfall during the dry season in many parts of Southeast Asia that coincided with peak flowering. This was particularly pronounced in eastern Indonesia that usually has a long severe dry season

In 1998, a new seed orchard of *Gliricidia sepium* provenance Retalhuleu was established at ILIARC Agricultural Station in Sual, Pangasinan, Philippines (Table 11).

Table 11 Seed orchards established

SPECIES	NUMBER OF TREES	LOCATION	PLANTED	STATUS
Gliricidia sepium Retalhuleu	500	Buon Don, Daklak, Vietnam	1996	productive (10 kg harvested in early 1999)
	80	DLF Livestock Station Nam Suang, Lao PDR	1996	not yet productive
	100	BPT-HMT Forage Seed Production Centre Serading, Sumbawa, Indonesia.	1996	small amount of seed harvested in 1997/98 (<1kg); rain in 1998/99
	350	BPT-HMT Forage Seed Production Centre Kabaru, Sumba, Indonesia	1997	not yet productive
	300	ILIARC Livestock Station, Sual, Pangasinan, Philippines	1998	not yet productive
Gliricidia sepium Monterrico	500	Thu Duc, Ho Chi Minh City, Vietnam	1996	not yet productive
	80	DLF Livestock Station Nam Suang, Lao PDR	1996	not yet productive
Leucaena leucocephala K636	200	BPT-HMT Forage Seed Production Centre Kabaru, Sumba, Indonesia	1997	productive (30 kg harvested in early 1999)

All seed orchards are well established with tree height ranging from 2 – 5 m. Good seed harvests are expected in 1999/2000.

In Laos, multiplication orchards of gliricidia provenances Retalhuleu and Belen Rivas have been established in 8 villages in Luang Phabang and Xieng Khouang provinces. Each of these orchards consists of 500-600 trees that can be used for seed production or as a source of vegetative planting material for farmers in the area.

Identification of three target areas and collaborators
Seed of gliricidia and other tree legumes were offered to farmers at all FSP sites, since our national partners felt that gliricidia may be useful for farmers in a wide range of farming systems (Table 12). Interest by farmers varied among sites; in 1998/99 more seed was made available at sites where farmer demand was greatest.

Planting of trees on farms
In 1998 the number of farmers evaluating and adopting gliricidia and other tree legumes has increase to more than 300 farmers (Table 2). The greatest increase occurred in Makroman and Marenu in Indonesia, and Luang Phabang and Xieng Khouang in Laos. The rate of adoption is expected to increase in 1999.

The impact of FRP's support for agroforestry tree domestication can be seen by farmers using improved provenances. Here in Indonesia cows are fed provenances of Calliandra calothyrsus *that have only become available following the OFI field trial network.*

Adoption of tree legumes is a slow process. To some extent this is simply a function of the relatively long period (1-2 years) from planting to first use as feed. Other forages, such as grasses and herbaceous legumes, can be used within 2-3 months. In areas where tree legumes had not previously been used, farmers sometimes have heard or experienced negative factors about tree legumes that limit their willingness to try them. An example is Makroman, Indonesia where farmers consistently reported that their animals (including goats) do not like gliricidia and that it cannot be fed in large amounts. In 1997, a few farmers planted new provenances of gliricidia and participated in a goat dispersal scheme by the local Livestock Services. The goats relished gliricidia and this information has spread to other farmers who have started to plant large areas of gliricidia in 1998.

Large-scale expansion of gliricidia can only occur when there is sufficient vegetative planting material available in the area. Establishing tree legumes from seedlings is much slower and is fraught with problems unless it is in an area where there are no free-grazing animals such as in intensive agricultural systems. It is expected that vegetative planting material for expansion will be available in all areas in 1999. This should increase the rate of expansion within farms and facilitate the spread to new farms.

The availability of large amounts of seed from local seed orchards will also help to speed up the introduction of gliricidia to new areas.

Seed production by farmers often relies heavily on the initiative of the farmers concerned. The farmer pictured assists the Forages for Smallholders Programme in return for a small amount of pay and access to seed of selected provenances of Gliricidia sepium *and* Calliandra calothyrsus*. He then sells seedlings to his neighbours.*

Uptake of results from tree domestication programmes frequently relies on initiatives like this. Such effective means of promoting information and seed only occurs where projects have time and resources to identify key individuals in the community who can assist in the uptake process.

Feedback from farmers

The perceived palatability of tree leaves and good growth are probably the most important factors determining the interest of farmers to try out new tree legume species. In areas where gliricidia is fed to sheep and goats, gliricidia tends to be more readily adopted than in areas where the forage is fed to cattle or buffaloes, simply because sheep and goats eat it more readily. In all areas gliricidia is eaten by cattle but, unless used to the species, they initially tend to be more reluctant than sheep and goats.

Feed back from farmers is still limited since, in many cases, the trees are still small or farmers have only been feeding the tree legumes for a relatively short period. Sam Fujisaka conducted a more detailed survey eliciting reasons for adopting (or not adopting) tree legumes from farmers (Appendix 5). Frequently farmers at FSP sites have mentioned that gliricidia has good growth, it is liked by sheep and goats, it increases animal growth and milk production, it is easy to establish from cuttings but it is frequently infested by pests and it needs to be mixed with other feed.

More details on adoption of tree legumes and farmers comments on tree legumes will be collated as part of ‘Adoption Tree’ survey which is currently being conducted at all FSP sites. The results of the survey will be presented at the Workshop ‘Working with farmers: the key to adoption of forage technologies' which will be held in Cagayan de Oro, Philippines from 12-15 October 1999.

Collaboration with government agencies
Involving appropriate government agencies fully in the project is essential. The FSP has formed effective partnerships with government agencies and the local partners recognize that tree legumes are important, particularly in resource-poor upland farming systems. Local extension agencies are fully involved in the project and, in most cases, carry out the on-farm activities. This will be continued.

Adoption of forages
A study was commissioned to investigate factors influencing uptake and adoption of forages in Southeast Asia. Fieldwork was conducted to examine under what conditions have farmers adopted and incorporated trees in their mixed systems. Three sites in Bali, Indonesia, were included to understand systems in which farmers have incorporated many trees and some grasses in their traditional intensive systems. Three FSP project sites--one each in Vietnam, Sumatra (Indonesia), and northern Mindanao

On-station field trials form the backbone of a domestication programme. Peter Horne from FSP discusses results from a Leucaena trial with an extension worker and a farmer in central Vietnam.

(Philippines)--were visited to examine the actual or potential adoption of introduced forages, including trees, in what are more extensive land use systems. Ethnographic and participatory evaluation procedures were used to understand mixed agricultural systems, farmers' animal feeding systems, and farmers' perceptions regarding the forages utilized. The full report can be found in Appendix 5. The most important outcomes of the study were:

- Analysis of traditional systems in Bali suggested that farmers were likely to grow trees for fodder if agriculture was intensive; cattle were penned and fed by cut-and-carry; agroforestry was an integral part of local systems; shade-intolerant annual crops were not relied upon as the major agricultural output; and trees were superior to other sources in providing fodder in the dry season
- Farmers perceived legume tree fodders positively in terms of animal health and weight gain; but were less happy about competition with crops, the (perceived) need to mix tree fodder with other sources, insect pests, and slow regrowth.
- Farmers did not appear to consider the difficulty of tree establishment as a constraint to adoption.

Conclusions regarding adoption of tree legumes in Southeast Asia

The rate of adoption of tree legumes has accelerated at sites where farmers are experiencing the benefits of tree legumes, and this trend is expected to continue. In most cases the entry point for tree legumes has been as animal feed, and good growth of trees and 'palatability' of leaves tend to be important initial factors determining the interest of farmers. Another important determinant is prior experience by the farmers. If these are positive then farmers are quickly interested in trying out new germplasm. If prior experiences have been negative then there is little interest in testing new material.

Conclusions regarding collaboration with FSP

The collaboration with FSP has generally been very successful. Seed and trees have been made available to farmers in a highly participatory programme and seed orchards have been established to ensure the continued uptake and impact of research results (Boxes 3 & 4). Having visited many of the sites and discussed their work with most collaborators in the programmes it was evident that an extremely efficient research network had been created covering many collaborators throughout the four countries in the study. Enthusiasm from participants and subsequent uptake of results was high and reflected the continued input from the two programme managers, Peter Horn and Werner Stur. Local and regional workshops were held on an annual basis which definitely contributed to a perception of "ownership" of the results by participants.

The socio-economic study was much less thorough than was anticipated and consequently disappointing in its outcomes. However, useful conclusions were drawn regarding the good potential for further uptake of results from FRP-funded tree legume research.

FSP put great emphasis on working in partnership with national governments and NGOs to achieve impact but they make clear that to gain such benefits requires commitment and time. These two factors are often impossible to achieve with FRP's short-term approach to funding. If this situation is to continue it emphasises the opportunities and responsibilities of DFID bi-lateral programmes to become more involved in uptake of research results.

A summary of the association between R6551 with FSP was selected as the FRP entry in the inaugural DFID-funded RNRKS Award Scheme. See Appendix 13.

Box 4 Perception of the uptake project by FSP

"We work with many smallholder farmers who rely almost totally on livestock to provide livelihood security for their families. In many areas, especially in Indochina, these farmer are battling with inadequate feed supplies during the dry season, but commonly their problem is not a lack of feed but the feed availability is of very poor quality (such as rice straw). One of the very few ways of overcoming this problem is

Table 12. <u>Farmer evaluation of tree legumes</u>

Site	Predominant agro-ecosystem	Livestock	No. of farmers involved		Comments
			1997/98	1998/99	
Indonesia					
Sepaku II, East Kalimantan	grasslands extensive upland	cattle	5	>20	gliricidia for live fences and supplementary feed for cattle; expanded to new villages
Makroman, East Kalimantan	upland agriculture	cattle goats	5	>30	gliricidia for feeding to goats; expanded to new villages
Gorontalo, North Sulawesi	coconut plantations extensive upland	cattle buffaloes	1 farmer group	no expansion	gliricidia and other tree legumes are being evaluated in a communal nursery
Marenu, North Sumatra	extensive upland	sheep	10	>50	gliricidia as feed for sheep; major expansion to neighboring farmers in same area
Pulau Gambar, North Sumatra	rainfed lowland	sheep	15	no expansion	women's cooperative using gliricidia for feeding to sheep
Saree, Aceh	grasslands	cattle	1 farmer group	no expansion	gliricidia (>300 trees) for use as supplementary feed for grazing cattle and as live fences
Laos					
Luang Phabang	extensive upland slash and burn	cattle	6	>50	gliricidia and leucaena as fencelines around their fallow upland rice fields, feed for cattle.
Xieng Khouang	slash and burn	cattle	3	>50	calliandra around fallow fields, feed for cattle.
Philippines					
Cagayan de Oro, Mindanao	extensive upland	cattle buffaloes	1 farmer group	>20	gliricidia and other tree legumes as feed for cattle
M'lang and Carmen, North	extensive upland	beef cattle	2 farmer	no	gliricidia and other tree legumes for cattle; no expansion

Site	Predominant agro-ecosystem	Livestock	No. of farmers involved		Comments
Cotabato	rainfed lowland	buffaloes	groups	expansion	in 1998
Guba, Cebu	intensive upland	cattle	3	>10	leucaena, gliricidia and calliandra grown on terraces, for cattle feed and seed production; expansion to new areas
Malitbog, Bukidnon	extensive upland	cattle	5	>20	gliricidia provenances and other tree legumes for use as cattle feed, live fences and fire wood
Matalom, Leyte	upland agriculture	cattle	5	no major expansion	gliricidia and other tree legumes for use as cattle feed and live fences
Vietnam					
Xuan Loc, Hue	upland agriculture	Cattle	8	no major expansion	gliricidia, calliandra and leucaena in fencelines around their homegardens
	slash and burn				
	rainfed lowland				
Daklak	grasslands	Cattle	3	>10	gliricidia for seed production and vegetative cuttings
Quang Ninh	upland agriculture	Cattle	18	no further expansion	gliricidia as fencelines
Vietnam-Swedish Project (northern provinces)	upland agriculture	Buffalo, cattle	50	no further expansion	calliandra, gliricidia and leucaena as fencelines or in backyards; initially farmers were given seed which resulted in poor establishment

3.2.2.3 Indo Swiss Project Orissa

Introduction

The Indo-Swiss Project Orissa (ISPO) is a formal association between the government of Switzerland and the regional government of the Indian state of Orissa. The overall goal of the collaboration is to contribute towards improved productivity of the farm households of Orissa with emphasis on viable smallholder livestock and dairy production. The focus of work has been in establishing methods of sustainable land use with poor farmers, particularly Tribals.

ISPO works with some of the poorest people in India, the Tribals.

The senior researcher in the Co-operative Dairy Development programme, Dr Asim Biswal, suggested the inclusion of fodder trees in the programme following attendance at a workshop where I presented findings of FRP-funded research with tree legumes. He considered the main potential of fodder trees to be substitution of purchased cattle feed and poor quality rice residues.

Collaboration with ISPO appeared attractive for the following reasons:

- The project was interested to incorporate fodder trees into agricultural systems in which trees were not a feature.
- The target group were amongst the poorest and most vulnerable in India, the Tribals.
- ISPO is a well endowed project and did not request any financial support.
- ISPO had significant experience with adoption of agricultural practices, particularly herbaceous fodder. So, uptake pathways for research results already existed.

Seed for on-station and on-farm evaluation of *G. sepium*, *C. calothyrsus* and several *Leucaena* species were supplied along with advice on trial design.

The following experimental sites were selected:
- Demonstration farm in Saru village, Ganjam district (10 farmers)
- 2 villages in plains of Ganjam district (30 farmers)
- 2 villages in tribal area of Gajapati district (6 farmers)

Evaluation of survival and growth was undertaken by villagers under the guidance of project staff.

Farmer perception of the experimental evaluation of fodder trees

Before the study began the farmers were asked whether they would be interested in taking part in evaluation of fodder trees. They responded

- Is it possible for us to plant trees in our field bunds?
- Will these leaves of new plants be relished by our cattle?
- By feeding these leaves will there be an increase in the health of our animals?
- What kind of fertiliser or pesticides are required?
- Do we have to spend extra labour for cultivation?
- Can these seeds grow in our soil?

Project staff put great emphasis on discussing the concept of trees on farms with farmers prior to discussing whether any experimentation should take place. Farmers were given every opportunity to express their views and provided valuable comments regarding trial design and situation.

Farmers and ISPO staff discuss their objectives.

After the trials were established the farmers were asked why they had wanted to become part of the experiment. Responses included:

- We will now see and have in our village some different trees used in other parts of the world.
- To test whether these plants can grow in our soil.
- This trial is being conducted to increase fodder availability at a low cost.
- Through these fodder trees there is a chance that there will be an increase in the fat and protein in the milk.
- Tree trial plots are for benefit to us as we are seeing in our gochar land (community plot)

The idea of using community land in each of the villages was fundamental to the concept of participation. It was considered important that none of the farmers felt excluded. Around 40 per cent of the villagers visited the plots.

Collaboration with the Tribals was more difficult that with farmers on the plains due to their isolated locations. Simpler evaluations were attempted and small seed production areas established.

Results

Although enthusiasm for participation in the programmes was high amongst farmers difficulties were encountered at the establishment phase. Poor germination and low survival were compounded by a lack of familiarity with trial design by ISPO's scientific advisor. Consequently two trials needed to be replanted and several others yielded little in the way of growth data. However, the major objective of the experiment was to test the ability of ISPO to assist uptake of results from tree domestication activities. The project was successful in eliciting a high level of interest and participation evident in the villages involved. Comments from farmers were encouraging and indicate the potential of further development of the use of fodder trees (see Box 5).

Uptake of results was not high in this particular example but the pathways were evident. Furthermore, ISPO and similar projects have the ability and contacts to reach towards some of the very poorest sectors of the community, in this case Tribals in some of the most inaccessible parts of Orissa. If DFID is committed to poverty elimination it is essential that contacts with organisations such as ISPO are maintained.

Box 5. ISPO farmers comment on participation in tree fodder adoption programme

"My cow started looking good when I started feeding tree leaves. Earlier my cow was leaving some feed every day but after I started mixing Leucaena leaves in to those normal feed such as Kunda, straw or even mixing with water, my cow is consuming every thing without any left over. I also marked some increase in milk yield ".

But some times I face time constraint to bring leaves every day and to mix it with other feed in the feeding trough as I have to collect myself every day and to get leaves through out the year is also some times not possible.

Feeding leaves every day is good. But occasional feeding is not good as cow refuse the other feed on the day when leaves are not there. But if feeding is possible every day then cows look silk/shining and milk yield also increases. who makes his living out of milk money can make good money if he feeds leaves to his animals."

3.2.2.4 Evergreen Trust

Project purpose

The Evergreen Trust (ET) is a UK-based NGO working in sub-Saharan Africa on projects related to increasing agricultural productivity on small farms. ET's projects range from encouraging tree planting on farms to creation of profitable small agroforestry enterprises. They have collaborated with OFI since 1995 on the establishment, management and assessment of trials investigating the productivity of tree legumes on the island of Pemba, Tanzania. The ET programme on Pemba combines a number of projects designed to identify the needs of small-scale farmers and address the potential for assistance in terms of training, provision of seed and trees, and development of agroforestry systems and cashcrops.

The provision of good quality tree seed and seedlings has been identified as a major constraint to small-scale farmer's attempts on Pemba to improve farm productivity and diversify of crop production. Both ET and the small-scale farmers are aware that there is a great potential for many other fodder, fruit, timber and cashcrop species. In order to address the problem ET developed a programme with assistance from R6551 designed to establish seed production areas to benefit small-scale farmers. This is part of a wider programme supported by ET to encourage small-scale farmers to set up their own small-scale nurseries throughout villages on Pemba. It is planned that within three years the orchard and nurseries will be self-sustaining and need no further input from ET.

Project aim

Seed orchards of 11 species will be established in three ET locations, to provide seeds for 360 small-scale farmers setting up small-scale nurseries in villages across Pemba between 1999 and 2001.

Village tree nurseries provide the most efficient means of providing trees to Pemba's farmers.

Project activities supported by R6551

- Establishment of seed orchard of *G. sepium*

Although a shortage of animal fodder is not a major limitation to farm productivity there is nonetheless a desire to introduce fodder trees into local farming systems. *G. sepium* grows well on Pemba and is widely used for fodder and light construction (due to its termite resistance). Two seed orchards are planned for establishment in late 1999.

- Training

Training courses will be run with small-scale farmers covering; seed handling, storage, scarification, and sowing; grafting techniques; nursery hygiene; plant handling and potting.

Results

Seed orchard establishment has started at two sites for the production of seed of gliricidia, Retalhuleu provenance. Seed production will commence in 2000.

3.2.2.5 Centre d’Etude et de D■veloppement Agricole Cambodgien (CEDAC)

Introduction

Cambodia’s national economy, which is mainly based on the primary sector, has struggled to recover from the major disruption to food production suffered since the start of the civil war in 1970. Following the transformation process and the relatively stable political conditions since the early 1990s the economy has slightly recovered but Cambodia still ranks 153 out of 174 on the UN Human Development Index. Agriculture and its related sectors produce around 45 per cent of GDP and employs around 80 per cent of the active population (Koma, 1997; Turton, 1999).

The role of the public sector in agricultural productivity is limited due to a lack of funding and an inefficient system of distribution of funds. The activities of the agricultural sector in terms of innovation and development are heavily dependent upon support supplied by international organisations to Cambodian NGOs (Koma, 1997).

The sustainable agriculture movement in Cambodia is in its early stages and has been initiated and promoted largely by NGOs. One such organisation, the Centre d’Etude et de D■veloppement Agricole Cambodgien (CEDAC), has managed several on-farm evaluation trials of gliricidia supplied by OFI since 1997. CEDAC was established by a group of

CEDAC have promoted Gliricidia sepium for use on small farms without any financial support from FRP.

Cambodian farmers and university agricultural lecturers in 1997 through support of the French NGO Groupe de Recherche et d'Échanges Technologiques (GRET). CEDAC works closely with farmers and students to both improve knowledge of agricultural production systems and implement programmes designed at agricultural development. During the early part of 1998 they integrated gliricidia into their agricultural outreach programme without any assistance from either FRP or OFI. The enthusiasm and quality of their on-farm work combined with the contacts, both national and international, suggested that they might be worth including as a case study for R6551.

Although Cambodia is not a target country for FRP and CEDAC was not a planned partner for R6551, the opportunity for a potentially low-cost study of uptake pathways with some of the poorest farmers encountered in the project appeared to justify a visit while I was in the region working with FSP.

Discussions with CEDAC staff and visits to field sites indicated a well-established network of farmers groups in regions surrounding Phnom Penh and a strong commitment to work with the government to improve agricultural productivity. CEDAC had already initiated a programme to increase the use of tree legumes to provide improved fodder quality for poor farmers and had already started a project to develop local nurseries for the production of gliricidia seedling for distribution to farmers.

Obtaining fuelwood is a major problem for farmers in Cambodia due to low forest cover and a rapidly increasing population. Gliricidia sepium is considered a valuable source of fuel.

Discussions were held to develop the work plan to increase the dissemination of trees and a programme was initiated in early 1999 with financial support from R6551. The project, entitled *Farming systems development in the rainfed lowlands from 1999 to 2002*, will work in three areas (Prey Veng, Kampong Cham and Angsnouri District, Kandal) with following goals:

- To improve the understanding of agricultural research and extension services in each of the study areas.
- To improve the capacity of small farmers in developing and organising the dissemination of agricultural innovations.
- To mobilise villagers in 20 target villages to plant trees in a "re-greening" initiative.

Three kgs of gliricidia (provenaces Retalhuleu, Belen Rivas and Monterrico) have been received by CEDAC. Over 500 seedlings have been distributed from CEDAC's two nurseries and small quantities of seed (50-100 gms) have been distributed to 14 village farmers' groups via the participation of 5 NGOs for integration into their local nurseries.

The following brief report of activities was received in May 1999.

Mkak Commune: two tree nurseries established and five families involved in planting gliricidia. Seedlings given to other villagers. Objective in remainder of 1999 is to expand to the involvement of 15 households in two villages plus one school.

Srey Santhor District: Three families involved in project – due to expand to 30 in three villages by the end of the year. Gliricidia also due to be planted along village road, on school campus and pagoda campus.

Baphnom District: 30 families participating and 8 nurseries planned by the end of the year.

At present CEDAC is supplying the seed sent from OFI to the organisations listed in Table 13.

Table 13 Organisations receiving seed of glricidia from CEDAC

Name	Name of Organization	Growing place
Tuy Sam Ram	CRS	CRS Svay Rieng
Pou Sovan	24HTV	24HTV Kandal
Tat Sok	CEDAC	Srey Santhor
Or Thy	CEDAC	Srey Santhor
Pen Chantha	UNACAS	UNACAS Angsnoul
Sim Ry	GTZ/PDP	Santouk, Kg.Thom
Keo Kim neth	GTZ/PDP	Staoung, Kg.Thom
Lang Seng Horng	CEDAC	Saang, Kandal
Pel Sokha	CEDAC	Kampong Cham
Men Prach Vuthy	PARTAGE	Kg.Speu,Kandal
Sam Vitou	CEDAC	Mkak, Kandal
Lang Seng Horng	CEDAC	Dangkor, Phnom Penh
Tuy Sam ram	CRS	CRS Svay Rieng
Pou Sovan	24HTV	24HTV Kandal

Discussion

CEDAC was selected for involvement in R6551 due to the initiative already shown by staff with regard to integration of tree legumes into their agricultural development programmes and the direct involvement that they have with poor farmers. Although the programme of work developed between R6551 and CEDAC is in its early stages they have already indicated how effectively they can work with the ultimate beneficiaries of tree domestication programmes.

No further funds are due to be supplied by FRP but monitoring of progress will continue and informal support will be provided.

3.2.3 Discussion

The relatively late recognition of the need to investigate impact pathways for tree domestication projects is largely the result of the previous misconception of the success of the tropical pine networks. The assumption that results would be taken-up without the need for direct involvement by ODA had its roots in the perception of a relatively streamlined implementation of research results by forestry plantation companies. While the ODA-funded tropical pine work was undoubtedly of the highest quality in terms of methodology, implementation and production of scientific results, the subsequent inability to show outputs with tangible developmental impact meant that any programme following the same approach would struggle to do better. It is worth pointing out that the recent support for initiatives investigating linkages between forestry researchers and end-users of results has been a reaction to a lack of evidence of impact of research rather than a planned part of a research strategy.

In hindsight it is easy to see the approach to tropical pine domestication as an example of a methodology driving a research programme rather than an identified demand for a research output. One of the results of pursing such an approach was that impacts were not seen as important until relatively late in the day. Whatever the reasons for pursuing the research strategy of ODA towards tree domestication it resulted in a marked lack of appreciation of the problems of uptake of results from research with agroforestry species when exploration programmes were initiated. No realistic outcomes for rural development were required at the outset and there was little necessity demanded by ODA for researchers to present evidence to suggest that these genera were any more important than other potential agroforestry tree species. ODA's lack of strategic planning in prioritising tree species for research was an example of the complete absence of a domestication strategy for tree species. Furthermore, in spite of the large amounts of ODA and DFID funding that tree domestication activities had absorbed no provision was made for the medium- to long-term nature of tree domestication research. This has resulted in the adoption of a piecemeal approach to tree domestication with no commitment at any stage from ODA or DFID to provision of funds for the next step. The enforced short-term objectives that have governed each 3-year research project have meant that the ultimate beneficiaries of the research programme, poor farmers, have until recently been given a low priority.

Medium- and long-term research activities inevitably suffer from short-term approaches to research funding. Tropical tree domestication programmes are an example of an activity that needs to be planned over at least a ten-year period. While it is acknowledged that the short-term nature of research funding is unlikely to alter significantly in the near future there is scope for FRP to devise research strategies for certain activities while accepting that they cannot be encompassed within a three-year period. This would not necessarily commit future research funds but would provide a framework from within which it would be possible to see the stage of current research. If such a strategy had been implemented with the agroforestry domestication programmes then clear performance indicators could have been adopted by which to evaluate the programme at various stages. At present no such strategy exists for any of the tree species involved in FRP-funded domestication activities. If this situation persists then little evidence of either uptake or impact will be possible from the substantial investment made by FRP in the domestication of *Calliandra calothyrsus* or species in the genus *Leucaena*.

Realistic evaluation criteria must be set in order to judge the success of a project. Suggested evaluation criteria such as 'number of farmers involved' and number of trees produced' are indicators that are easy to quantify but in themselves do not necessarily indicate uptake.

Conversely, estimating the financial benefit to individual families through the use of tree legumes is virtually impossible due to the complex nature of identifying the true impact of the research. Guidance is required for researchers to determine and measure meaningful impact from their work. Without knowing what benefits DFID is interested in it is impossible to know if the marginal increase in their attainment is worth the extra investment of funds.

It could be argued that research designed to assist poor farmers takes place within a complex environment that is difficult to define and that, consequently, exact definition of outputs is inappropriate. This is true to a certain extent but a development agency has to combine the investigative element of research with a targeted outcome of research activities. The inherent difficulties in finding the causal agents of change within a complex research and development environment should not deter the establishment of clear criteria of impact. DFID must be more precise on what these are, as at present the domestication research networks have had no guidance on where their emphasis should lie. Multiple impact pathways may be time-consuming and difficult to implement but are likely to be an effective means of delivering meaningful impact in the long term.

Another area where guidance is required is in the spatial and temporal aspects of measuring impact. To what degree does DFID want immediate impact, and what trade-offs are allowable? How localised should results be? How involved does DFID want to be in the uptake process? i.e. what emphasis does it place on being the implementing agency, or even seeing the results implemented within the lifetime of the project?

The investigation of the uptake of results from domestication activities in this study was intended to provide two outputs:

- To promote uptake of results
- To investigate uptake pathways

Each of the case studies adequately demonstrates that uptake of results has occurred. Results, in the form of improved germplasm and information, have been adopted by project partners and passed to farmers. The amount of uptake of results varied amongst the organisations in the case study, and it is generally too early to measure the degree of impact from the utilisation of results. However, the important points to note are:

1. Uptake occurred
2. This took place with minimal direct intervention from FRP.
3. It would not have taken place without intervention from FRP.

Provision of seed, genetic information, general guidance and monitoring were the main inputs from R6551 but the actual uptake process was managed by the partner organisation. A review of two of the case studies in R6551 (BAIF and ISPO) undertaken by the University of Reading (Norrish et al, 1999) suggested that while project partners appreciated the freedom to develop uptake programmes the process could have been improved through more direct intervention by R6551. This comment correctly identified a shortcoming in the approach adopted but one that was enforced by the lack of possibility for direct contact with the principal collaborators due to pverall project commitments. However, it illustrated an important point in that for some partners a greater degree of interaction is required to push the programme forward than with others. Emphasis is required at the project planing stage to determine accurately the needs of any partners carrying out uptake activities.

Regardless of the degree of uptake, it is important to recognise that without FRP intervention no uptake of FRP-funded results would have taken place in any of the case study projects (with the possible exception of CEDAC). FRP must therefore recognise that if the uptake of results from tree domestication activities is an objective then a commitment has to be made to supporting uptake initiatives. Results will not be taken up without FRP's involvement. To illustrate: all of the NGOs studied approached me directly to assist them with developing approaches to utilising the results from previous FRP-funded research for the benefit of poor farmers. Their objective, in each case, was to obtain germplasm of the highest quality and to establish new programmes for fodder tree adoption. Without FRP-funded intervention at this stage it would not have been possible for the collaborators to access results in the form of improved germplasm, which would have resulted in an absence of impact from the FRP-funded domestication research activities.

The initial stages of progression beyond on-station experimentation are usually the weakest links in the domestication process. Omission of scientific and management input at this crucial stage frequently results in sub-optimal germplasm being adopted in agroforestry programmes after which there is less opportunity for meaningful interventions with germplasm (Cromwell et al, 1996). This study has indicated that once programmes involved in the uptake of results have access to seed of improved provenances, and an adequate understanding of how it should be used, they are capable of promoting the results with farmers. These results indicate that it is not necessary for continued major scientific or financial input into the latter stages of domestication in order for the programmes to show impacts with farmers.

These results also show that choice of suitable partners to implement the uptake of results from evaluation studies is a crucial issue. If FRP is interested in supporting the uptake of research results from such programmes pre-project workshops could compliment personal knowledge of individuals and organisation in selecting the best partners. In this regard, it would appear to make sense for bilateral programmes to take a more significant role in promoting the uptake of research results. They are in a strong position to identify needs and collaborators and should be able to provide FRP with valuable indicators to research priorities. It is worth noting that the collaboration between BAIF and OFI has taken place without any input from or communication with DFID India.

The approach adopted in this study was to select a range of collaborating organisations and "plug in" to their activities. It could be argued that a more prescriptive approach should have been adopted that would have allowed direct comparisons between organisations. However, the very reason for instigating this activity was due to an acknowledgement by FRP that they had little knowledge of how uptake of results occurred. As such it was decided that the most appropriate means of investigating this process was to take an active role in developing programmes for the use of tree legumes but to allow the implementing organisations to take a lead in the manner in which the programmes were implemented, based on their own experiences.

It was hoped that general indicators of success and failure would become evident by employing a standard means of evaluating projects. However, it was accepted at the outset that this would be unlikely to produce precise guidelines for future uptake progress that would cover all circumstances. The evaluation protocol developed to evaluate project success was designed to cover not only the impacts of the work but also how the project had approached the whole issue of using trees in farming systems. This approach was adopted because it was recognised that it was necessary to understand the demand for results in order to develop means of developing protocols for encouraging uptake of results.

Each of the organisations selected for inclusion in this study implemented the results from FRP domestication studies. Success varied between projects as the subjective ranking in Table 14 indicates. The most successful project at producing impact was the FSP. Its success was due mainly to the high level of resources available (financial, scientific and extension) and the tremendous organisation of the project. The experience of the coordinators in agricultural extension activities in the region, their willingness to adapt this knowledge to work with trees and the extensive range of collaborators amassed by FSP meant that it was a rapid and effective means of channelling results to farmers.

The BAIF Development Foundation had many features in common with FSP, namely good scientists, collaborators and extensive experience in agricultural development. However, their project was not as well financed with the result that collaborative activities such as workshops and visits by project staff were less frequent than was possible with FSP. Although BAIF provided an excellent means of stimulating uptake of results from the gliricidia domestication programme is worthwhile noting that limited finances have been reflected in the implementation of a smaller programme than their organisation could handle.

The Cambodian NGO CEDAC provided perhaps the most valuable result from the study. While the success of FSP and BAIF could have been predicted to some extent due to their previous results, CEDAC were an unknown quantity. Their inclusion provided an opportunity to see if it was possible for a small, poorly-resourced organisation to take forward results without a continuous external input. The deep level of commitment of CEDAC staff towards rural development combined with the excellent organisation provided by their principal scientist, Dr Yiang Sang Koma, has created a programme that reaches directly to a large number of farmers. With virtually no financial resources available they had managed to supply seedlings of gliricidia to local farmers groups and they were committed to its promotion regardless of further financial input. For a small level of funding (£5000) they will be able to establish nurseries and hence seedlings of the best performing provenances of gliricidia in villages across about one-third of Cambodia. CEDAC illustrates the potential for a small NGO to provide effective uptake of results with relatively little input of funding.

Some of the tribal groups in Orissa are isolated and amongst the poorest in India. ISPO's interest in working with them made their inclusion in the study particularly interesting given DFID's poverty elimination focus. It is difficult to evaluate the success of their ability to provide an impact pathway for domestication results because the project was hampered by a poor understanding of nursery techniques for trees amongst project staff and the difficulties in reaching some of the isolated project sites. In spite of the limited results obtained during the study period ISPO provided a strong indication that the poorest of farmers can have access to results from tree domestication activities as long as appropriate partners are selected for collaboration.

The Evergreen Trust provided another example of a small NGO creating a strong framework into which results can be fed. Their successes will always be on a small scale as they have few resources to call upon but their enthusiasm to be part of a scientific network meant that impact pathways were being created with only a small amount of effort from R6551. The experience of working with the Evergreen Trust confirmed the findings from collaboration with CEDAC that even in areas where scientific capability is limiting it is possible to feed results to farmers through collaboration with local NGOs.

Table 14. Summary of performance of collaborators in case studies

Collaborator characterisation	Objectives	Resources	Activities	Collaborators	Outputs	Outcomes	Immediate impacts	Ranking	Long-term impacts
Country NGO/GO Size History of collaboration with FRP	Planning process - Problem identification - Client identification Framework for deciding on outputs	Funds available - Source - Use Expertise - Internal - External	Processes involved in pursuit of objectives Monitoring - Feedback mechanisms	Clients listed	Quantitative, e.g. number of seedlings Qualitative - Client satisfaction - Donor satisfaction Knowledge	How are the research findings being used?	Feedback from clients Market indicators (quantitative gains from research activities)	Subjective ranking based on impact from results of FRP-funded domestication activities on farmers.	Feedback from - Clients - Managers - Donors Market indicators (quantitative gains from research activities)
BAIF India NGO Major national operating in 7 states Several evaluation projects over 10 years	Highly consultative process of identification of farmer's needs and deciding on outputs.	Significant level of multi-donor support for agricultural productivity. High level of local scientific expertise available. High level of local extension expertise available.	Close interaction with farmers in distribution of germplasm, establishment of seed orchards and training. High priority given to monitoring project progress. Anticipated low priority given to evaluation.	Poor farmers	Large numbers of seedlings produced. Seed orchards established. Good feedback from farmers.	Farmers have direct access to FRP/OFI research results. Rapid uptake being implemented on a large scale.	Excellent feedback from farmers. Quantitative gains not yet available but likely to be produced within 12 months.	2nd=	Too early to assess.
FSP Laos, Indonesia, Philippines and Vietnam NGO Major international working in close collaboration with GOs Collaboration with individual scientists in evaluation activities.	Highly consultative process of identification of farmer's needs and deciding on outputs.	Significant level of multi-donor support for agricultural productivity. High level of international scientific expertise available. High level of local and international extension expertise available.	Close interaction with farmers in distribution of germplasm, establishment of seed orchards and training. High priority given to monitoring project progress. High priority given to evaluation.	Poor farmers and government agencies.	Large numbers of seedlings produced. Seed orchards established. Good feedback from farmers. Better understanding of uptake process.	Farmers have direct access to FRP/OFI research results. Rapid uptake being implemented on a large scale.	Excellent feedback from farmers. Quantitative gains not yet available but likely to be produced within 12 months.	1st	Too early to assess.

Collaborator characterisation	Objectives	Resources	Activities	Collaborators	Outputs	Outcomes	Immediate impacts	Ranking	Long-term impacts
Country NGO/GO Size History of collaboration with FRP	Planning process - Problem identification - Client identification Framework for deciding on outputs	Funds available - Source - Use Expertise - Internal - External	Processes involved in pursuit of objectives Monitoring - Feedback mechanisms	Clients listed	Quantitative, e.g. number of seedlings Qualitative - Client satisfaction - Donor satisfaction Knowledge	How are the research findings being used?	Feedback from clients Market indicators (quantitative gains from research activities)	Subjective ranking based on impact from results of FRP-funded domestication activities on farmers.	Feedback from - Clients - Managers - Donors Market indicators (quantitative gains from research activities)
<u>ISPO</u> India NGO Major NGO within Orissa working in close collaboration with GOs. Collaboration with lead scientist in training course.	Highly consultative process of identification of farmer's needs and deciding on outputs.	Significant level of single-donor support for agricultural productivity. Moderate level of local scientific expertise available. High level of local extension expertise available.	Close interaction with farmers in distribution of germplasm, establishment of seed orchards and training. Medium priority given to monitoring project progress. Anticipated low priority given to evaluation.	Poor farmers and government agencies.	Trials established. High level of awareness of trees on farms generated. Good feedback from farmers.	Farmers have direct access to FRP/OFI research results. Slow uptake being implemented on a small scale.	Good feedback from farmers. Quantitative gains not yet available but likely to be produced within next 24 months.	4^{th}=	Too early to assess.
<u>Evergreen Trust</u> Tanzania NGO Small organisation working in one region of the country. Previous management of OFI trial.	Highly consultative process of identification of farmer's needs and deciding on outputs.	Low level of charitable support for improving agricultural productivity. Moderate to low level of local and international scientific expertise available. Moderate level of local extension skills available.	Close interaction with farmers in distribution of germplasm, establishment of seed orchards and training. High priority given to monitoring project progress. Anticipated low priority given to evaluation.	Poor farmers	Large numbers of seedlings produced. Seed orchards established. Good feedback from farmers.	Farmers have direct access to FRP/OFI research results. Rapid uptake being implemented on a small scale.	Good feedback from farmers. Quantitative gains not yet available but likely to be produced within 24 months.	4^{th}=	Too early to assess.

Collaborator characterisation	Objectives	Resources	Activities	Collaborators	Outputs	Outcomes	Immediate impacts	Ranking	Long-term impacts
Country NGO/GO Size History of collaboration with FRP	Planning process - Problem identification - Client identification Framework for deciding on outputs	Funds available - Source - Use Expertise - Internal - External	Processes involved in pursuit of objectives Monitoring - Feedback mechanisms	Clients listed	Quantitative, e.g. number of seedlings Qualitative - Client satisfaction - Donor satisfaction Knowledge	How are the research findings being used?	Feedback from clients Market indicators (quantitative gains from research activities)	Subjective ranking based on impact from results of FRP-funded domestication activities on farmers.	Feedback from - Clients - Managers - Donors Market indicators (quantitative gains from research activities)
<u>CEDAC</u> Cambodia NGO Moderate-sized organisation working in one-third of country. Pervious management of OFI trial.	Highly consultative process of identification of farmer's needs and deciding on outputs.	Single-donor support to agricultural productivity. Moderate level of local scientific expertise available. High level of local extension expertise available.	Close interaction with farmers in distribution of germplasm, establishment of seed orchards and training. High priority given to monitoring project progress. Anticipated high priority given to evaluation.	Poor farmers	Large numbers of seedlings produced. Seed orchards established. Good feedback from farmers.	Farmers have direct access to FRP/OFI research results. Rapid uptake being implemented.	Excellent feedback from farmers. Quantitative gains not yet available but likely to be produced within 12 months.	2nd=	Too early to assess.

3.3 SEED ORCHARD RESEARCH

3.3.1 Introduction

Delivering results from domestication activities to farmers involves more than just providing an initial packet of seed. Any impact will be short-lived without providing farmers with access to further supplies. Sustainable solutions to seed supply involve local seed production initiatives rather than being tied to purchasing seed from development programmes. However, the fairly new adoption of many tree species and their relatively intensive cultivation has created a demand for seed of agroforestry trees which in many cases far exceeds current supply (Simons et al, 1994). Furthermore, current seed collection activities to provide for the commercial sector generally involve extensive collection from wild trees of undocumented provenance. If selected provenances are to be promoted it is essential that simple, low cost approaches to seed production are developed.

R6551 undertook two specific studies to investigate seed production of *C. calothyrsus* and three *Leucaena* species; *L. diversifolia, L. trichandra* and *L. pallida*. Each is described below.

3.3.2 Study of pollinators of *calliandra*

Background

In 1993 the tropical pasture seed production team based at Walkamin Research Station in north Queensland, Australia, was asked to produce substantial amounts of seed of the Indonesian land race of *Calliandra calothyrsus* to support a programme of fodder plant evaluation R & D coordinated by CSIRO Townsville and supported by MRC (Australian Meat Research Corporation). At the time imported seed was scarce and both supply and quality of imported seed was unreliable. There was little knowledge or experience of calliandra seed production in Australia, so it was necessary to develop a seed production system as well as to produce the seed.

Areas were established in early 1994 at two sites within the range of environments thought likely to be suitable for seed production. Management methods chosen through application of established seed production principles were applied. The methods were modified progressively as experience grew. The Walkamin site proved particularly suitable for seed production, and by late 1997 the project had served its purpose - the requirement for seed was satisfied, and a production system had been developed.

A visit to the Walkamin Research Station in 1996 revealed a seed orchard of *C. calothyrsus* producing significant quantities of seed. The orchard manager, Dr John Hopkinson, had thinned the orchard systematically and found that seed production had increased with increasing spacing between lines, up to a maximum of 8m between rows. Although such a spacing appeared to suggest that bats were pollinating the trees (Chamberlain, **) Dr Hopkinson was convinced that no bats were involved. The possibility that a major pollinating agent other than bats could be involved in seed production of calliandra had significant implications to the approach to domestication of calliandra being adopted by OFI. With a booklet on seed production in calliandra due to be funded by FRP (Chamberlain, in press) it became imperative to investigate both the pollinating agents involved and the seed production system employed at Walkamin.

A project was designed to answer the following questions:

- What pollinating agents are present and how effective are they?
- How have management procedures influenced seed production?

The report of the study can be found in Appendix 11. A summary of relevant points is included below.

Evaluation of the pollination biology and fecundity of *Calliandra calothyrsus* at Walkamin, North Queensland, Australia (Summary)

By Merran L . Matthews[1] and John M. Hopkinson[2]

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[2]Queensland Department of Primary Industries, Walkamin Research Station, Walkamin Qld 4872, Australia

Summary of methods and results

In order to estimate components of potential seed yield and sources of loss, records of inflorescence numbers, pod numbers, seeds per pod, and level of andromonoecy were made on randomly selected individual trees. On others, the diurnal course of stigma receptivity was reconstructed through use of the Nile Blue test. A series of pollinator exclusion experiments, both long- and short-term, was conducted, with inflorescences enclosed in cages or pollen proof bags, to allow inferences to be drawn on the nature, activity and effectiveness of pollination agents. These were considered along with observations of the occurrence and behaviour of prospective pollinators to judge the likely contribution of different agents to cross-pollination.

Great variation was recorded, both from tree to tree and between plot-edge and inner trees, in inflorescence and pod numbers per tree, with edge trees having by far the greater average numbers of both. Seed numbers per pod, estimated ovules per pod, and seed set per 100 ovules, were much less variable. Seed numbers per tree thus varied largely with the variation in inflorescence and pod numbers, and averaged 38191 and 7143 per tree respectively for edge and inner trees (equivalent to about 1.71 and 0.32 kg of seed per tree). The plantation as a whole was estimated to have produced 223 kg/ha of seed in the season.

Andromonoecy occurred, varied greatly and largely inexplicably within and between trees and positions in canopy, but overall was not frequent enough (overall average 6 % of observed flowers) to influence seed production materially.

The dominant variable with respect to pollination was the proportion of flowers that set pods rather than the proportion of ovules within an ovary that was fertilised. For example, for edge and inner trees respectively the seed:ovule ratios were 1:1.7 and 1:1.5 while the pod:ovary ratios was 1:50 and 1:25. Stigma receptivity had a marked diurnal rhythm with a peak at about 2000 hours and diminishing receptivity after dawn. Interpretation of exclusion experiments showed that a significant amount of self-pollination occurred, that pollinators were required to increase pod set and that although insects increased pollination minimally, larger agents did so appreciably. Examination of pollen balls from traps in an adjacent hive entrance confirmed that bees played a negligible part in pollination. Observations showed that Spectacled Flying Foxes (*Pteropus conspicillatus*) were certainly responsible for mass pollen transfer. This, considered with the rhythms of stigma receptivity, left them as prime candidates for the role of most important pollinator. Morning-active flower-feeding birds, notably friar birds and other honeyeaters, could not be eliminated as pollinators, but timing with relation to stigma receptivity, and obvious avoidance of anthers suggests a less important role.

Comparison with published records of seed production of *Calliandra* elsewhere, though difficult because of differences in properties measured, suggests that production from trees at Walkamin was generally better than the best documented in other countries, though not greatly so, and not for any single overriding reason. The high potential seed production at Walkamin is attributable partly to the plantation being in an environment conducive to vigorous reproductive activity of tropical legumes generally, partly to its deliberate management *as a seed crop*, and partly to the timely presence of abundant pollinators in the form of flying foxes. The realisation of that potential in terms of seed recovered is then a matter of harvest method, the preferred one of sweeping fallen seed from hessian spread beneath the trees being highly efficient compared with the usual hand-picking.

Summary of discussion

This study was initially intended to explain the cause(s) of what appeared to be an unusually high yield of *Calliandra calothyrsus* seed in a population growing as an exotic at Walkamin, north Queensland, Australia. The approach was to quantify the reproductive output of the population to determine where differences in seed production lay, and to determine the vector(s) responsible for pollination. Results have since shown that the Walkamin population may not differ significantly from other carefully monitored populations in any one aspect of its reproductive biology. Despite this, the exercise raised some interesting findings which point to ways of improving production, shed light on other aspects of *Calliandra* biology, and suggest routes by which failure of seed production, seemingly frequent though seldom documented, might be addressed.

Edge effects

One of the most striking results of the study was the effect of tree position on relative tree reproductive success; trees located at row ends significantly more successful. This was reflected in production of greater numbers of flowers, inflorescences and pods compared to those located within the plot. Edge trees were free standing on three sides, the fourth side abutting the next tree within the row. In contrast, inner trees were in close contact with each other, not only with their immediate neighbours, but also with trees of adjacent rows, often their canopies overlapping. Competition, either for light, water or soil nutrients, is the most likely explanation for these differences, as the management practices were the same for all trees. Progressive thinning over the last four years has resulted in the current spacing of 2m gaps between trees within a row, and 8m gaps between rows. The results from this study indicate these spacings are too close to promote maximum seed production and that further separation of individual trees is required. The ultimate aim would be to make trees within a row behave like edge trees, a change that would probably substantially increase productivity per tree and per unit area. If, for example, a spacing between trees within rows of 4 m achieved this objective, then seed production would be raised from the present value of about 200 kg/ha to something over 500.

Pod set

Of all the variables recorded in the analysis of reproductive success, the one most striking when one looks for ways of increasing seed numbers per tree is the very low rate of pod set (the number of pods produced expressed as a percentage of the number of ovaries). Relatively small absolute gains over the measured values of 4.2% and 2.0% for edge and inner trees respectively could obviously translate into considerable increases in seed production. The edge effect shows that pod set is under the influence of factors sensitive to spacing as well as of the more direct pollination variables, and other variation suggests other undefined environmental or genetic influences. It is possible, of course, that the branch's capability to supply assimilate or redistribute mineral nutrients limits the number of pods that can successfully form. Damage to flowers and/or ovaries may also be a factor reducing set. Flying foxes may exact a price for pollination in the form of damage – certainly the appearance of an inflorescence that has been visited by a flying fox, suggests it. Birds of at least one species – the paleheaded rosella – have been observed to graze on flowers. The debris of blown and aborted flowers that hangs from inflorescences is normally infested with the larvae of lepidopterous insects that may feed on living as well as dead flowers. Fungal flower blights such as Botrytis and Anthracnose are commonplace and highly destructive on flowers of trees of several other exotic species in districts where *Calliandra* is grown. There is clearly scope for investigation of factors other than pollination that lead to success or failure of pod set.

Seed numbers per pod

Seed number per pod was the only variable for which there was little or no variation between trees or treatments. It seemed that the critical factor in successful pollination were the events leading to pollen and stigma contact, and that once a polyad reached the stigmatic cup, the resultant seed number was fairly constant. Thus seed number per pod provided the least useful information of differences within the population, pod number being a much more informative measure.

Genetic variation

Significant variation between trees was recorded for all variables measured except seed numbers per pod. Although it is outside the scope of this exercise to try to discriminate between genetic and environmental effects, it is impossible not to form the opinion that there was considerable genetic variation within the population of trees in the plantation, and that it extended to details of fecundity. Apparent genetic variation had been noticed in past seasons in properties such as flowering time, flowering intensity (subjectively observed), pod shape, size and colour, etc. It is germane to record this in view of the doubts that have been expressed (Joanne Chamberlain[2], pers. comm.) about the narrow genetic base of the Indonesian land race from which the material was derived. It is also worthy of note in the same context that both we (at Kairi) and Brian Palmer[3] (at Lansdown) have encountered occasional plants of a white-flowered contaminant not *C. calothyrsus*, presumably introduced with the seed. This raises possibilities of contamination and cross-pollination with other introductions in the nurseries in Indonesia where the original seed was collected.

Comparison with reproductive success in other documented populations

The reproductive success of edge and inner trees is compared with that of *C. calothyrsus* recorded in three other countries where it is grown in Table 15. The comparison has led us to the conclusion that, with the exception of some aspects of edge trees, such as inflorescence number, the reproductive success of *C. calothyrsus* at Walkamin overall was slightly higher, but not greatly so, than plantations elsewhere. For example, the number of floral buds per node and number of nodes per inflorescence were comparable to those reported in Kenya (Boland and Owour, 1996), and when comparing inner trees with other populations there was no difference between total number of inflorescences per tree. There is a risk, of course, that comparison with published records of carefully managed trees distorts the general picture that comes from anecdotal evidence of frequent but unrecorded failure of seed production.

Andromonoecy

One aspect thought to contribute to the low seed yield observed in *C. calothyrsus* populations in areas such as Kenya (Boland and Owour, 1996) and Honduras (Chamberlain, in press), is a syndrome called andromonoecy. This syndrome is represented by inflorescences with a high proportion of staminate (male only) flowers. At Walkamin, andromonoecy represented only a slight reduction in the overall number of ovaries present in the population, the mean proportion of staminate flowers and buds being 0.06. A similar value (0.045) was recorded by Chamberlain (in press) in 1994 for unpollinated flowers in Honduras. However, other values of andromonoecy reported in Chamberlain's paper were much higher. For example, the proportion of staminate flowers for unpollinated flowers in 1995 was 0.118 and for buds it was 0.194. Both values at least double those reported at Walkamin. Andromonoecy was also reported in Kenya, though no mean values were given, which made comparison difficult (Boland and Owour, 1996). These authors inferred that the degree of andromonoecy was significant, suggesting that although their range included values of 0.02 staminate flowers per inflorescence, values were generally higher (up to 0.7). In comparison, at Walkamin, high values (>0.1) were the exception, rather than the rule.

In addition, Chamberlain (in press) reported that as the maternal investment increased, so did the proportion of staminate flowers towards the distal end of the inflorescence. No such relationship was apparent at Walkamin, though controlled manipulation of maternal investment had not been attempted. There was, however, a significant interaction between the proportion of staminate flowers, the location of the tree (edge vs. inner), and the position of the inflorescence in the canopy (lower vs. upper) at Walkamin. This interaction was the inverse between edge and inner trees, a greater degree of andromonoecy recorded in the lower canopy of edge trees, while a higher degree recorded in the upper canopy of inner trees. Light may be responsible for these differences, particularly for inner trees, which were heavily shaded by neighbours, all except the upper canopy. This result was the opposite of what had previously been thought; Bertin (1982) suggested that greater light allowed inflorescences to produced more hermaphrodite flowers, and thus more fruit set. Instead at Walkamin, inner trees produced more staminate flowers in the upper canopy where light was greatest. There may be another explanation. Pods are mainly concentrated in the upper canopy of inner trees, and if the same relationship exists at Walkamin as was reported by Chamberlain (in press) for plants in Honduras, increased maternal investment i.e. pod production, increased the proportion of staminate flowers produced. However, this can only serve as speculation, as again structured manipulation of maternal investment was not attempted at Walkamin.

Also, if increased maternal investment increases the degree of andromonoecy (Chamberlain, in press), then the low overall proportion of staminate flowers recorded at Walkamin may be directly related to the fact that the population is managed like a seed crop, in which irrigation and fertiliser possibly counteract the affect of limited resources.

Table 15: Summary table comparing floral, fructal and breeding system characteristics reported for *C. calothyrsus* growing in different countries

Measurement	Walkamin Edge trees	Walkamin Inner trees	Sri Lanka (Rajaselvam *et al* 1996)	Kenya (Boland & Owour 1996)	Honduras (Chamberlain, in press)
Floral characteristics					
Floral buds/node	23.5	23.2	-	24 (18.29)	-
Nodes/inflorescence	22.7	20.0	-	13-19	-
Floral buds/inflorescence	524.5	463.7	-	304 (123-516)	-
Inflorescences/tree	303.4	157.4	-	128	-
Ovules per ovary	8.8	8.8	-	12	-
Polyads/flower	-	-	-	296	-
Ovule:pollen	-	-	-	1:25	-
Prop. staminate flowers and buds/inflorescence	0.06	0.05	-	0.05-0.5 (b/w trees) 0.02-0.7 (b/w inflor.)	0.143 (node 1) 0.566 (node 14)
Prop. staminate flowers/ inflorescences (unpollinated)	-	-	-	-	0.045 (1994) 0.118 (1995)
Prop. staminate flowers/inflorescences (pollinated)	-	-	-	-	0.153 (1994) 0.277 (1995)
Prop. staminate buds/inflorescence (unpollinated)	-	-	-	-	0.194 (1995)
Prop. staminate buds/inflorescence (pollinated)	-	-	-	-	0.387 (1995)
Fructal characteristics (natural poll'n)					
% fruit set (ovaries to pods)	4.2 %	2.03 %		2.05 %	7.54 %
Pods/inflorescence	21	9	-	23	4.66
Seeds/100 pods	601	507	453-617	-	-
Aborted seeds/100 pods	255	369	50-142	-	-
Pods/tree	6354.6	1409.8	-	-	-
Breeding system					
% pod set/inflorescence: self pollination	-	-	2.6 %	11 and 12.9% (2 expts)	-
% pod set/inflorescence: cross pollination	-	-	33.3%	7.2 and 30.7 (2 expts)	-
Seed/pod: self pollination	5.77	-	0.7	-	-
Seed/pod: cross pollination	-	-	8.4	-	-

Pollination

The vectors responsible for pollination at Walkamin were determined in two ways – by observation of floral visitors, and by the systematic exclusion of these visitors. Before they could be assessed, it was critical that the diurnal rhythm of stigma receptivity be confirmed. For example, other studies have found peak receptivity to occur between early evening and early morning (Rajaselvam *et al*, 1996; Boland and Owour, 1996). In this study a Nile Blue test for lipids confirmed receptivity during the night, though no statistically significant peak of receptivity was recorded, and there were no significant differences between times. Instead there was a lot of variation in staining between stigmas at a given time due to stigmas being of different ages. This range of stigmatic age was believed to be the result of the experimental procedure, where, although all open flowers were removed prior to experimentation, additional flowers continued to open during the night resulting in samples of mixed stigmatic age. This occurrence would have implications on pollination, as a small proportion of stigmas would have been at peak receptivity when day pollinators arrived. However overall receptivity was greatest at night, confirming the importance of nocturnal pollinators to the pollination of *C. calothyrsus.*

In calliandra's native range in Honduras, nectivorous bats were found to be the main pollinators of *C. calothyrsus*. In particular, bats of the genus *Glossophaga* (Glossophaginae) visited repeatedly (79.6% of all observations), while other insectivorous bats and hawkmoths visited to a lesser degree (Chamberlain and Rajaselvam, 1996). Also, in Sri Lanka where *C. calothyrsus* is planted as an exotic, bats were reported to be important pollinators. Exclusion experiments showed two species of bat, including the Sri Lankan dog-faced bat and a species of Sri Lankan fruit bat visited the *Calliandra* population (Rajaselvam *et al*, 1996).

Bats were also found to be the primary pollinators of *C. calothyrsus* at Walkamin. Specifically, the Spectacled Flying Fox (*Pteropus conspicillatus*), known to roost in a small patch of rainforest 10 km south of Walkamin was frequently observed visiting the plot. This species is primarily a fruit eater, though the nectar source represented by the plantation of *Calliandra* at Walkamin appeared to be sufficient for repeated visitation by this species during the peak flowering period. Their numbers and behaviour whilst in the plantation were such that effective cross-pollination would have been achieved. For example their habit of progressively moving over the tree and consuming nectar, which transferred pollen onto its face and chest would have promoted self pollination, and their movement from tree to tree, would have effected pollination between trees. Observations of the tame flying fox confirmed this behaviour, the tame animal accumulating much pollen on its face and body in such a way that guaranteed contact between pollen and stigmas of subsequent flowers visited. We were unable to catch specimens of the Northern Blossom Bat, though its presence at Walkamin was confirmed by Clague[1] (pers. comm.), and knowledge of its numbers and behaviour would suggest that it is a potential, but not significant pollinator of *Calliandra.*

The presence of birds on *Calliandra* inflorescences has not been reported before. For example, in Sri Lanka, although pollinator observations were carried out over a 24 hour period, birds were not observed (Rajaselvam *et al,* 1996), and in Honduras, as mist netting was confined to the evening no birds were captured (Chamberlain and Rajaselvam, 1996). This was not the case at Walkamin, many different birds observed to frequent and work the flowers. However, their contribution to pod set at Walkamin was thought to be minimal as suggested by their feeding behaviour, which tended to avoid contact with anthers, and the fact that plants were not at peak stigma receptivity when birds were present. Even so, they should not be overlooked as potential pollinators, as they worked the flowers in the early morning, a time when some stigmas were still receptive.

In addition, the observed behaviour of insects on *Calliandra* flowers did not appear to facilitate pollination when combined with the floral structure, the anthers and stigma being a long way from the nectary. The lack of involvement by insects has also been reported by Rajaselvam *et al* (1996). Bees observed on inflorescences tended to rob flowers of nectar, rather than transfer pollen, and the low frequency of *Calliandra* pollen observed in pollen balls confirmed that bees did not contribute to overall pollination.

The exclusion experiments were designed to systematically exclude pollinator groups, the short term experiment serving to separate night and day pollinators, and bags and cages used to separate pollinator types, bird/bat or insect. In both experiments the control (continuously uncovered) produced the greatest number of pods, confirming that pollinators were necessary to increase pod set at Walkamin. Complete exclusion of birds and bats was not achieved by the cage design owing to its size and weight, which caused the inflorescence to droop, and in some cases, allowed anthers and stigmas to protrude from the cage. In addition, because of the agile nature of bats at Walkamin, and the length of their tongue, it is thought that bats would have had access the flowers regardless (Clague[1], pers. comm.). Despite this, some surprising results were obtained from the exclusion experiments, the least of which was the high pod production due to self-pollination recorded for inflorescences covered with bags (complete pollinator exclusion). Although the percentage fruit set after self-pollination could not be determined as the original number of flowers present was unknown, pod set after enclosure for one month produced almost 20 pods per inflorescence. This value was comparable to average pod set after natural pollination (this study, whole tree counts), and was greater than that reported for natural pollination elsewhere (Chamberlain, in press). Thus when data are interpreted from the exclusion experiments the occurrence of self-pollination must be considered.

There was no difference in pod set between inflorescences enclosed within a cage or bag overnight, which suggested that nocturnal insects with access to caged inflorescences contributed very little to overall pod set (nocturnal insects are relatively scarce in north Queensland at the time of flowering of *Calliandra*, as it is both dry season and "winter"). This has similarly been shown in Sri Lanka, very little seed set (0.98%) recorded after enclosure within cages (Rajaselvam *et al,* 1996). In contrast, significant differences were recorded in pod set between inflorescences covered during the day; those enclosed within a bag producing significantly more pods than caged inflorescences. The exposure of inflorescences to nocturnal pollinators when stigmas were receptive would have promoted pod set, and the subsequent enclosure during the day would have caused different affects. For example, it is hypothesised that within the bag humidity was high and reproductive parts were in close contact, thus promoting self-pollination to a greater degree than inside the cage, which was much more open. In fact humidity has been shown to promote pollination in other species. These results are further supported by pod set after continuous cover in both short- and long-term experiments. These treatments recorded highest pod set in uncovered inflorescences, then bagged, and caged had the least number of pods. The difference in pod set of bagged-day, versus during the night, may reflect a difference due to a double promotion of pollination – firstly by exposure to pollinators at night when the stigmas are receptive, and secondly as a result of the conducive environment for self-pollination provided by the bag.

Although detailed conclusions cannot be drawn, three general conclusions can; that pollinators appear to promote pod set, that a reasonable degree of self-pollination is possible, and that pod set is greatest when inflorescences are exposed at night when receptivity is highest.

Similar to studies in Kenya (Boland and Owour, 1996), sporadic pod set was observed on floral spikes at Walkamin, small regions bristling with pods, while others lacked pods completely.

Sporadic pollinator visitation was suggested as the cause of this pattern in Kenya (Boland and Owour, 1996), and is the favored explanation at Walkamin. Specifically, flying foxes were observed in reasonable numbers on some nights, and completely absent, or reduced, on others. This behaviour combined with the possibility that not all trees within the population were visited on a given night may cause this pattern of pod set.

Sporadic pod set was also observed in the long- and short-term exclusion experiments. Initially there was some concern that the duration of the short-term experiment was insufficient to ensure pollinator visitation to all experimental trees. However, results showed that all trees were visited, but to different degrees, significant differences recorded in pod set between trees and between inflorescences of an individual tree. One cannot rule out the possibility that other factors influenced pod set, but as some inflorescences within a tree had high pod set, while others from the same tree had low, or no pod set, it appeared that visitation may have been the limiting factor. Variation in pod set was less for the long-term experiment, all trees and inflorescences having reasonable numbers of pods suggesting that all trees were visited.

Overall it appears that suitable cross-pollinators are present in the form of the Spectacled Flying Fox at Walkamin. These animals are not present continuously throughout the flowering season, most likely other food sources, such as ripening fruit taking precedence. The species is also believed to be nomadic, favouring the coast in cold weather. The winter of 1998 was unusually warm on the Atherton Tableland, and perhaps for this reason their absence, at least from daytime roosts in the nearby Tolga Scrub, was of no more than a week's duration. An apparent contributor to overall pod set was the potential of trees to self-pollinate, a factor which was likely to have been promoted by flying fox visitation. The population displayed a similar reproductive pattern to populations reported elsewhere, stigma receptivity commencing in the evening and continuing until the morning. Continued but reduced receptivity during the day is likely to be due to the progressive opening of flowers during the night. This elongated period of receptivity potentially contributed to overall seed set, due to the presence of nectar feeding birds, which may affect pollination. The overall reproductive output of the Walkamin population appeared to be slightly greater than others reported elsewhere, though comparison was made difficult by a lack of consistency in the expression of the variables measured.

Conclusion

While the previous success of seed production at Walkamin was repeated and confirmed in detail, and while it is certainly more successful than that reported informally from many sites round the world, the record from three other carefully monitored sites suggests that the same order of production is achieved elsewhere. Whether or not the same order of recovery of seed is also obtained is not recorded, but it is relevant to point out that the success of *Calliandra* seed production at Walkamin has been attributable at least as much to efficient recovery as to production.

It became clear that Walkamin's yields, however good in relative terms, could be considerably increased with further attention to tree spacing, and that overcrowding was a major factor in limiting production. Inflorescence populations and pod set appeared to be critical variables. Andromonoecy was not a serious limitation to productivity.

We believe that the basis of success of success at Walkamin has been, first, the use of a climate suitable for a wide range of legume seed production; second, the application of management practices not greatly different from those used with herbaceous legumes, and particularly the manipulation of the timing of flowering through pruning so that it occurs at a favourable time for both effective seed set and reliable seed ripening; and, third, the use of efficient seed recovery methods replacing the usually inefficient hand-picking. The first two, however, only put in place a dense, vigorous population of inflorescences, and while the circumstances may enhance pollination, they do not on their own allow it to occur at a sufficient frequency to realise a heavy seed crop. This is the task of the pollinators, without which it seems that only limited success would be possible, and it is the flying foxes that seem to be most important in this role.

What lessons are there to learn from this exercise for people faced with failure of much-needed seed production in other parts of the world? Our experience of weak flowering at nearby Kairi and of legume seed production generally, makes us emphasise the choice wherever possible of a suitable climate, particularly with a reliable dry season. We further obviously attach importance to management, with emphasis on tree spacing as well as pruning, etc., and later to alternatives to hand-picking of seed. We would recommend attention to prospective pollinators, particularly to the role of bats. If, as is reported in many parts of south-east Asia, flying foxes are few, thought could be given to nocturnal hand-pollination of inflorescences. Where labour is cheap, it is not inconceivable to visualise imitating the action of flying foxes with pollen-collecting surfaces of wool or fur on the ends of poles. At every stage, we would suggest monitoring, particularly of inflorescence and pod populations, in order to get some analysis of the system, however rudimentary.

3.3.3 Seed production in *Leucaena* species – inital results on family and site variation from Machakos and Muguga, Kenya

(Report of work carried out by James Were, Ian Dawson, Anne Mbora, Alan Pottinger and Tony Simons, ICRAF and OFI, and presented in LEUCNET News 4).

Introduction

In the genus *Leucaena*, a large number of field trials have been undertaken to identify those species and provenances which are superior for particular products in specific geographical regions. However, less emphasis has been placed on how best to meet the seed demands for the key provenances identified in screening trials. The International Centre for Research in Agroforestry (ICRAF) and the Oxford Forestry Institute (OFI) are meeting this gap in knowledge. Seed production trials of three provenances of important *Leucaena* species, OFI Corral Falso (*L. diversifolia*), OFI Los Guates (*L. trichandra*) and OFI San Pedro Chapulco (*L. pallida*) have been established at two sites in Kenya. For the different species, the purposes of these trials are to: (i) evaluate the genetic characteristics of seed production, including heritability, relationship to tree growth characteristics and the influence of different thinning strategies on genetic constitution, (ii) determine the influence of different management strategies (such as coppicing) on seed production, (iii) evaluate the optimum ecological conditions for seed production; and, finally, (iv) to produce seed of key provenances which can then be made available to users for planting.

This report provides the first results based on observations made to the end of August 1998.

Materials and methods

Table 16 describes the seed lots obtained from OFI for establishment of seed production trials. Three provenances were obtained as individual tree collections from 20 trees (half-sib families). Seedlings were raised at ICRAF-Machakos field station before field planting at Machakos and Muguga in May 1996. Site characteristics are described in Table 17.

Experimental layout and assessment

Each of the three provenances was planted at both at Machakos and Muguga. Each of the six stands had a similar design, with the 20 families planted in 4-tree line plots replicated 10 or 20 times. Therefore, either 40 or 80 trees represented each family. Within rows, tree spacing was 1 m, with 4 m between rows. This design allows plots to be thinned by a factor of 2 or 4 within families, to an average spacing of 2- by 4 m or 4- by 4 m between trees. However, no thinning or other treatments were undertaken during the present observations on seed production.

Seed was collected from individual trees twice monthly, extracted and weighed. Cumulative seed yields to the end of May 1998 (August 1998 for San Pedro Chapulco) were calculated for individual trees. For the purpose of the present report, seed yield per tree was averaged on a family basis. Additional measurements were made but are not reported here: (i) trees were assessed at 6-monthly intervals for length of longest stem, (ii) the number of stems; and (iii) the diameter of all stems larger than 1 cm diameter was measured at 30 cm above ground.

Results

Seed production data is summarised in Table 18 and Figure 26. For all three provenances, considerable variation exists among families in average seed production per tree. This is particularly evident for Corral Falso and San Pedro Chapulco, less so for Los Guates. In addition to family variation, seed production varies greatly between Machakos and Muguga sites, with overall average seed yield per tree being 2- and 7-fold greater at Machakos for Los Guates (to the end of May 1998) and San Pedro Chapulco (to the end of August 1998), respectively. To the end of May 1998, Corral Falso had produced considerable seed at Machakos but none at Muguga. Comparing the two sites further, it is evident that, in the case of Los Guates, seed yield per family is strongly correlated across the two locations.

Discussion

Although the present results are preliminary and a formal analysis of variance is required, a number of important practical conclusions can already be drawn from data.

First, the high variation observed among families in seed production, particularly for Corral Falso (*L. diversifolia*) and San Pedro Chapulco (*L. pallida*), suggests strong genetic control of this character. This provides an indication of what may be expected when bulking seed from production stands in which family structure is not accounted for. It is evident that a considerable reduction in the genetic base, and a large shift in the genetic constitution of seed, may occur. Collected seed may consist primarily of a small number of high-producing families, with a considerably narrower genetic base than the original population. As two of the three species studied (*L. pallida* and *L. trichandra*) are self-incompatible, this narrowing will likely lead to inbreeding depression and loss in subsequent performance. Furthermore, a genetic shift toward high seed-producing families may also result in changes in performance. In this preliminary analysis, the relationship between seed production and growth characteristics was not assessed, and this will be the subject of further study. However, it is possible that high seed production may be negatively correlated with growth characteristics such as leaf and woody biomass. In this situation, sampling of seed from production stands in which family structure is not maintained may lead to a loss of performance in subsequent generations. The correlation in seed yield per family across the Machakos and Muguga sites, for Los Guates (*L. trichandra*), is further evidence of the genetic control of seed production. In the case of San Pedro Chapulco, a correlation may also exist across sites among families, but the overall low level of seed production at the Muguga site precludes firm conclusions from being drawn at present.

Second, the differences in seed production observed between Machakos and Muguga sites provide an indication of the ecological range and preferences of the different provenances for producing seed. At Machakos, with a lower altitude and rainfall, higher temperatures and haplic lixisol soil, seed production of all three provenances is higher than at Muguga, for the first two years after stand establishment. For all provenances, seed production began earlier at the Machakos site. Since early seed production is a desirable characteristic of seed stands, it is apparent that Machakos is the preferred site for the three provenances tested. Most interesting is the relative difference between Corral Falso and Los Guates stands at the two sites. While the average seed production at Muguga of Los Guates is half that at Machakos, Corral Falso had produced a similar quantity of seed as Los Guates at Machakos but no seed at all at Muguga. This difference in relative production is not surprising when the different altitudes of the two populations in their native ranges (Corral Falso = 800 m, Los Guates = 1450 m) (Hughes 1998) are compared with the altitudes of the Machakos and Muguga sites (1660 m and 2150 m, respectively). Corral Falso is clearly outside its ecological limits for good seed production at the Muguga site, although small quantities of seed have been produced subsequent to May 1998.

Conclusion

In conclusion, our preliminary results indicate the role of family structure and site in determining seed production in three *Leucaena* provenances representing three different species. More detailed analysis, combined with on-going work evaluating the relationship between seed production and tree growth characteristics, the influence of selective and systematic thinning and the effect of coppicing on seed production, will shed further light on the factors influencing seed production in the genus *Leucaena*. Together, data will enable optimum strategies for the sustainable supply of good quality seed of *Leucaena* species, in the quantities required by users, to be devised.

Table 16. Provenances, species and OFI collection numbers of seed used for the establishment of seed production trials at Machakos and Muguga, Kenya

Provenance (country)	Species	OFI seed lot ID
Corral Falso (Mexico)	*Leucaena diversifolia* (Schltdl.) Benth. Hooker	45/87/1 to 20
San Pedro Chapulco (Mexico)	*Leucaena pallida* Britton & Rose *	52/87/1 to 20
Los Guates (Guatemala)	*Leucaena trichandra* (Zucc.) Urban	53/88/1 to 20

* according to Hughes (1997), San Pedro Chapulco may represent a hybrid species, the parentage of which is unknown

Table 17. Site characteristics of Machakos and Muguga field stations

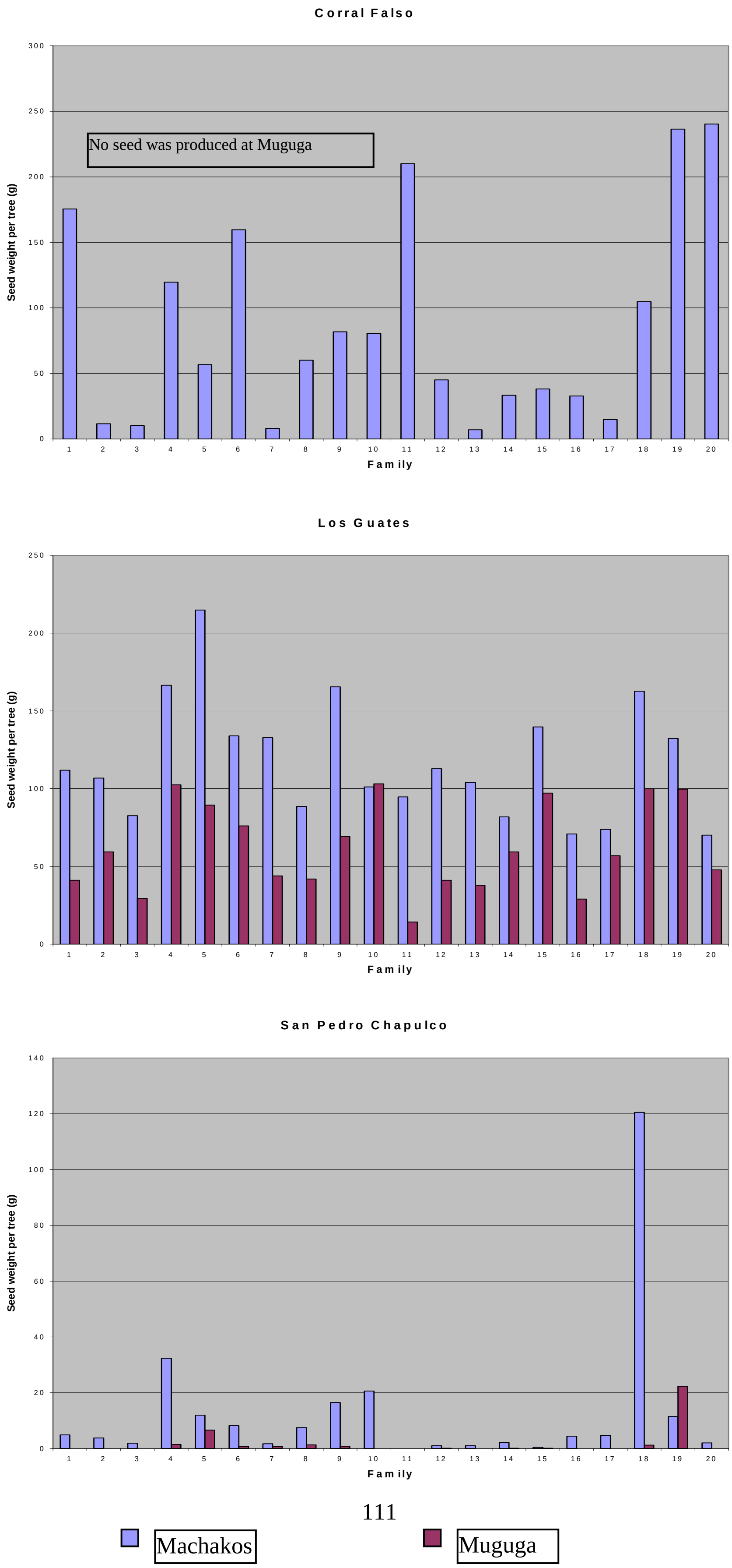
Station	Altitude (m)	Latitude	Longitude	Mean Annual Rainfall (mm)	Mean Annual Temperature (^{0}C)	Soil type (FAO classification)
Machakos	1660	1^0 33' S	37^0 08' E	740	24-26	Haplic Lixisol
Muguga	2150	1^0 14' S	36^0 38' E	970	18-21	Rhodic Nitisol

Table 18. Summary of seed production data for three *Leucaena* provenances at Machakos and Muguga field stations, Kenya

	Cumulative average seed yield per tree (g)*					
	Corral Falso *L. diversifolia* OFI 45/87 **		Los Guates *L. trichandra* OFI 53/88 **		San Pedro Chapulco *L. pallida* OFI 52/87 ***	
Family no.	Machakos (Jul 1997)	Muguga	Machakos (Jun 1997)	Muguga (Oct 1997)	Machakos (Aug 1997)	Muguga (Feb 1998)
1	175.5	0.0	111.9	41.1	4.9	0.0
2	11.6	0.0	106.8	59.3	3.8	0.0
3	10.1	0.0	82.7	29.4	1.9	0.0
4	119.7	0.0	166.4	102.5	32.4	1.5
5	56.8	0.0	214.8	89.4	12.0	6.6
6	159.7	0.0	133.9	76.1	8.2	0.7
7	8.1	0.0	132.8	43.9	1.7	0.7
8	60.1	0.0	88.5	41.9	7.5	1.3
9	81.8	0.0	165.4	69.2	16.5	0.8
10	80.6	0.0	101.1	103.1	20.6	0.0
11	210.0	0.0	94.7	14.3	0.0	0.0
12	45.1	0.0	112.8	41.1	1.0	0.1
13	7.1	0.0	104.1	37.9	1.0	0.0
14	33.3	0.0	81.8	59.3	2.2	0.1
15	38.2	0.0	139.7	97.1	0.4	0.1
16	32.8	0.0	70.9	29.0	4.4	0.0
17	14.9	0.0	73.8	56.9	4.7	0.0
18	104.8	0.0	162.6	100.0	120.5	1.2
19	236.4	0.0	132.3	99.7	11.5	22.3
20	240.3	0.0	70.1	47.8	2.0	0.0
Average	86.3	0.0	117.4	62.0	12.9	1.8

* date (in brackets) indicate the first month in which seed was collected from each stand (all stands planted in May 1996)
** production figures to end of May 1998
*** production figures to end of August 1998

Figure 26. Summary of seed production data for three Leucaena provenances at Machakos and Muguga field stations, Kenya.



3.3.4 Discussion

The two studies have provided valuable information that can be used in the design and composition of seed orchards for the production of agroforestry tree seed. The major findings of direct value are:

1. The following aspect of the genetic structure of the seed producing population must be taken into consideration.

    - Family structure should be maintained
    - Seed collection should be made evenly from a range of families (even if this means collecting seed over several weeks) before bulking.
    - Seed collected from a seed orchard should not be used for the establishment of another orchard.

2. Site selection is crucial to encourage maximum seed production.

3. The design of the orchard must take into account the pollination behaviour of the principal pollinators.

Trees of the Retalhuleu provenance of Gliricidia sepium*, from Guatemala, are planted on farms in Laos only through the collaboration between DFID, local scientists and NGOs.*

4. CONTRIBUTION OF OUTPUTS TOWARDS DFID'S DEVELOPMENT GOALS

4.1 PROJECT OUTPUTS IN RELATION TO OBJECTIVES

The project achieved its objectives:

- **Network management** has been improved.
- **Uptake pathways** have been investigated and characterised.
- Recommendations for improvements to **seed orchard design** have been made.

The most important findings, with respect to the project's objectives, are:

NETWORK MANAGEMENT

- Network management can be improved by devolving responsibility with collaborators to a regional level.

UPTAKE PATHWAYS

- Uptake pathways for agroforestry tree domestication programmes can be established and impact can be demonstrated.

SEED ORCHARD DESIGN

- Genetic structure of the population and behaviour of pollinating agents needs to be considered in seed orchard design.

It is important to recognise that the use of improved provenances by farmers is a direct result of research. Without the detailed scientific programmes of exploration, seed collection and evaluation of provenance variation there would be no results to give to farmers. Tree introduction and domestication programmes that have taken short cuts and lacked scientific input have resulted in inadequate selection of germplasm for future uptake programmes. This project has shown that not only can high performing provenances be identified efficiently, but they can also be delivered directly to farmers.

4.2 ADDITIONAL PROJECT OUTPUTS

Utilisation of results by farmers can only take place within a communication framework that fosters uptake of those results. At present, FRP has not installed, or supported such frameworks and therefore faces the very real potential that research results will not be taken up by farmers. This project has illustrated the tremendous potential for impact of the FRP-funded agroforestry tree domestication programmes through the support of a small number of organisations attempting to integrate gliricidia into farming systems. At present there is no apparent commitment from FRP to either continue this work with gliricidia or, more worryingly, support the final stages of the domestication process with leucaena or calliandra. It is essential to recognise that without further input into these programmes it will not be possible to encourage uptake and therefore impossible to measure impact from what has been a substantial investment of research funds.

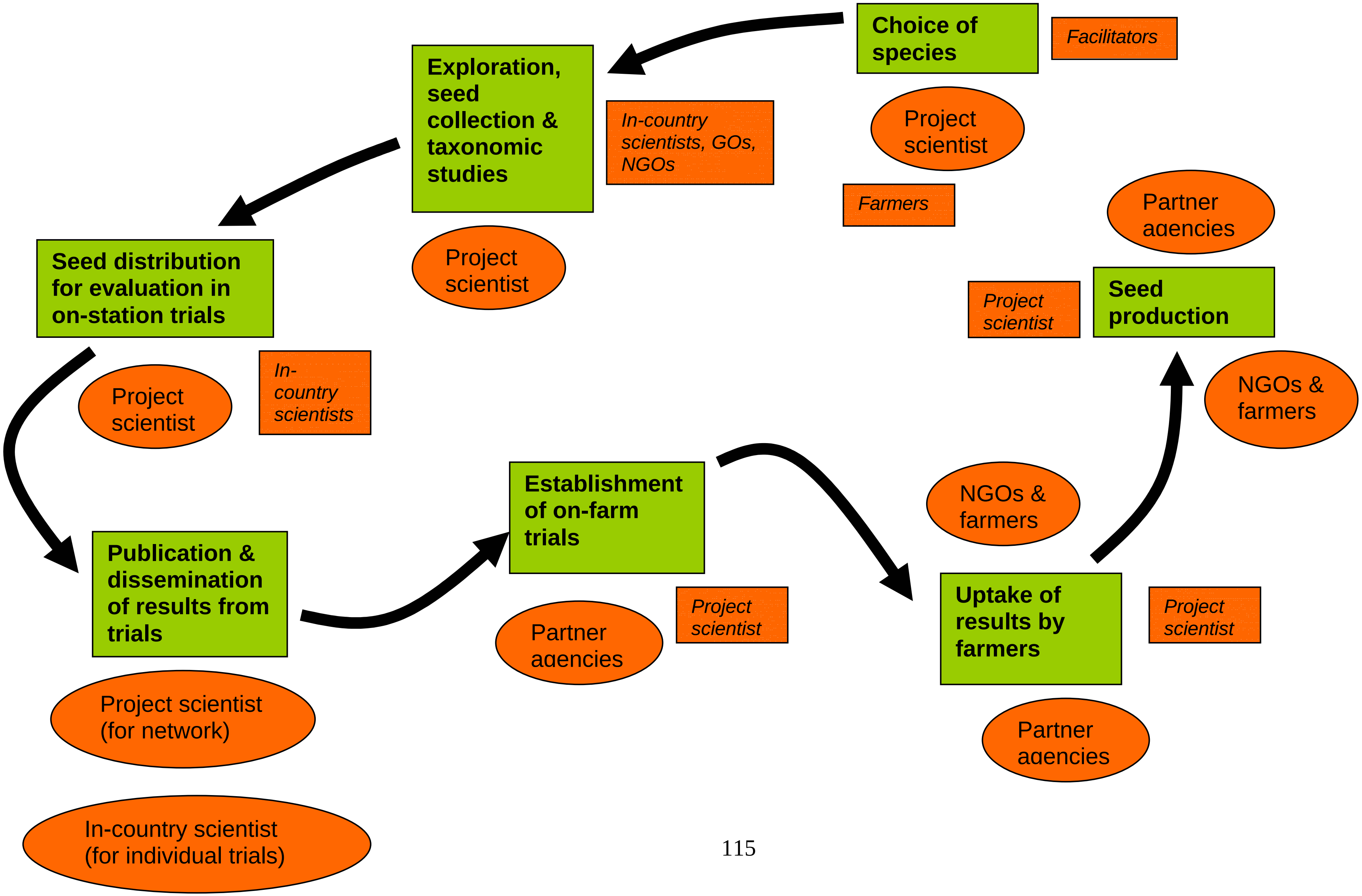
This project has shown that FRP support for uptake-related activities does not have to be substantial in order to facilitate the process. Although FRP-funded researchers have been key players in the domestication of agroforestry trees they do not have to play the most significant role in all stages of the tree domestication process (see Figure 27). This project has highlighted the key stages in the domestication process and the type of organisations required to facilitate them. Recognition of the roles that these organisations play is vital to understanding how to encourage uptake of results. Towards the latter stages of the process it is the organisations working most closely with farmers that take the lead but it essential that a certain level of scientific guidance is available at all stages (Arnold, 1998).

The key findings of the project that lie outside the initial objectives are:

- A strategy for agroforestry tree domestication should be compiled by FRP.
- Selection of partners to assist in development of uptake pathways is an area of key importance.

Figure 27. Low-value agroforestry tree domestication strategy with introduced species showing uptake pathways

(Activity in green boxes, principal players in orange ovals and partners in orange boxes).



- Impact assessment must be considered and incorporated into tree domestication projects.

A tree domestication strategy

A strategy for tree domestication of agroforestry trees is long overdue for FRP. Millions of pounds have been invested into the process of improving the trees available to farmers yet there has been no process by which FRP can gauge what still needs to be done. A strategy for tree domestication would not only enable FRP to explain precisely why it has carried out work but also to plan for the future. The limitations to establishing medium-term research programmes by short-term research funding should not act as an obstacle to this process. It should be a process of scientific planning rather than one of financial commitment. Unless such a strategy is established FRP will continue to be seen at best as being unclear on its objectives and at worst as failing to deliver its results. A practical outcome of establishing such a strategy would be to assist FRP in planning what, if anything, it wants to do with the leucaena and calliandra domestication programmes.

Selection of project partners

This project relied heavily on the participation of project partners for implementation of results. This reflected the acceptance that forage seed delivery pathways frequently lie outside the formal sector (Cromwell and Zambezi, 1993; Horne, et al, 1997). Government support is often weak so the importance of the NGO is paramount. The selection process of partners was relatively informal, relying mainly on experience of working with certain organisations and personal relationships with senior research managers. This approach was taken largely because the nature of the study was investigative. However, it is also true to say that there was a lack of appreciation of the importance of the key role that such organisations play in the uptake process. It was to some extent fortunate that the main collaborators, BAIF and FSP, were so effective in their approach to delivering research results to farmers. If such work is to be undertaken in the future it is essential that the process of partner selection be given a high priority. Pre-project studies could play a vital part in this process. There are a number of projects that could take results forward. The challenge is not so much in finding them, but in having the commitment to look for them.

Impact assessment

This study investigated uptake pathways but was not designed to quantify impact. However, it is essential to undertake meaningful assessment of the value of the research to farmers in order to assess the success of the research investment. Quantifiable measures exist by which to evaluate the value of domestication programmes, such as benefits to household income, but are currently not being employed. It is essential for FRP to have a better understanding of what is happening to their research investment in the area of agroforestry tree domestication. Areas that require investigation include

- Who are the beneficiaries?
- What access do different groups have to the results?
- What impacts are being made?
- How sustainable is the approach?

Monitoring and evaluation of research projects based in Central America and funded by DFID appears to have been undertaken but, strangely, not the research projects based in the UK that relied heavily on germplasm from Central America and Mexico (DFID, 1998).

The access to information and germplasm by different sectors of rural society needs to be evaluated. Adoption is not always widespread or uniform amongst all sectors of the community. Frequently formal groups are the immediate interface (Lawrence, 1999; Ondieki, 1999) and there is less impact with the poorest sectors.

FRP should also pursue means of illustrating the impact of its research programmes to the general public, other scientists and development workers. ACIAR and IFPRI have established good examples with the "Partners in Research and Development" series (see Shelton, 1998) and "Good News from Africa" (Schi✱ler, 1998).

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