PATSPO

World Agroforestry Centre

EFCC ETHIOPIA

Norway's International Climate and Forest Initiative (NICFI)

Consultancy on seed development and breeding plans for selected priority species in Ethiopia

May and October/November 2018

TECHNICAL

Consultancy on seed source development and breeding plans for selected priority species in Ethiopia

Objectives

The objective of the consultancy is to initiate the design of a national breeding programme by preparing detailed plans for establishment of breeding seedling orchards of 2-3 priority species in 2018 if deemed possible.

This will require that seed (or vegetative material) of these species are procured to enable production of seedlings in the first half of 2018 to enable establishment of the seed orchards during the rainy season in July 2018.

Species prioritization

Criteria

The consultancy aimed at this first workshop to make an additional prioritization among the 24 tree species mentioned in the annex 5 of the PATSPO project to identify up to 10 species, which are prime candidates for inclusion in the breeding programme. Finally the consultancy aimed to identify two species which could be used for highland breeding seed orchards located at ILRI, Addis Ababa.

The following criteria were used to identify prime candidates:

1. Overall demand for seed
2. Farmers preference and economic benefits
3. Existence of seed value chain
4. Multipurpose species with weight on its suitability for AF systems
5. High biomass production to provide values for local farmers through fodder, fruit production, fast and valuable timber production
6. Flowering and seed production at young ages to achieve a fast seed production and short breeding generations
7. Species with high value in restoration of degraded land
    a. High tolerance/resistance to drought and competition from weed and grass
    b. Create the right microclimate and soil conditions for regeneration of other species
    c. Soil improvement capacity
8. Tolerance/resistance to pests and diseases
9. Existence of enough genetic diversity and especially genetic variation at provenance- or individual-tree level

Prime candidate tree species

For the two BSOs at ILRI Addis Ababa, the 24 PATSPO species list was limited to some few species due to the high altitude (2200 metres) of the BSOs and further restricted to *Grevillea robusta* and *Cordia africana*. The two species are mentioned among the most important tree species in different priority lists made in connection to the PATSPO project (see annex 1 for a summary of the lists made by Roland Kindt).

Grevillea robusta

G. robusta is a multipurpose tree, suitable for agroforestry (fodder, bee forage, soil conservation) and produce valuable timber (Bekele-Tesemma, 2007). It is mentioned as one of the main species currently used in Ethiopia (ICB 2012) and is one of the species where there seems to be higher seed demand than supply (data from Amhara Forest Enterprise and Forest Research Centre Addis Ababa). In the Amhara region, this is one of the species with the highest demand (in seed number).

Grevillea is normally requiring an annual rainfall 600-2400 mm, a dry season (consecutive months less than 40 mm rainfall) less than, or equal to seven months, a maximum temperature of hottest month of 25-38 C˚ and a mean minimum temperature of coldest month of 6-16 C˚(Booth & Jovanovic 2002).

Canker and dieback is registered in East Africa with an increasing frequency with longer drought period and thus most pronounced in semiarid regions (Njuguna et al. 2011).

Genetic variation among and within provenances

G. robusta is indigenous to Australia, where it occurs in smaller separated populations and with an indication of two regional groups (Harwood et al.1997). Despite the separation in smaller populations, there is a low level of genetic differentiation between populations based on isozyme markers (Harwood et al. 1997), but large differences in vigour among provenances and without any clear geographical or climatic pattern (Harwood et al. 2002).

The genetic variation in neutral markers (isozymes) among African landraces is scarce suggesting that they have gone through a genetic bottleneck (Harwood et al. 1991). Landraces from Rwanda proved slow vigour compared to natural populations from Australia in a provenance trial in Rwanda (Kalinganire and Hall 1993) and differences were seen in stem straightness among Australian provenances and five Tanzanian landraces (Madadi et al. 2009). Field trials with indigenous Australian provenances indicate a huge possibility to select for vigour, while it is more difficult to achieve genetic gains in stem axis persistence and stem straightness (Harwood et al. 2002).

It is uncertain whether there is a substantially genotype/provenance by environment interaction.

Provenances in the BSOs

Since there is a high risk of low genetic diversity in the African landraces, the aim is to get as many provenances from Australia as possible and preferably from superior field tested trees.

Locations of breeding seed orchards (BSOs)

Both disease and climate restrict the use of the species to more humid areas and also the location of the BSOs, unless the project should aim at developing more drought- and disease resistant genotypes, but this approach is not recommended, as we do not know to what degree we have a genetic variation in disease and drought resistance/tolerance at the moment, and since there are a number of other tree species options for the more dry areas.

The climate requirement of the species and the occurrence of disease in semi-arid areas can be limiting factors for the establishment of BSOs of *G. robusta* at Mekele and Bahirdar, which are characterised by low precipitation and long dry periods (Table 1).

Beside the BSO at ILRI Addis Ababa, there is also the option of establishing BSOs at the seed centres at Sebeta and Hawassa (Table 1).

Cordia africana

Introduction

Cordia africana is widely distributed from Guinea in West Africa, to Ethiopia and south to South Africa. It occurs also at the Arabian Peninsula (Bekele-Tesemma 2007).

C. africana in Ethiopia is found over a number of vegetation zones ranging from Afromontane moist transitional forest, Afromontane dry transitional forest, Dry Combretum grassland, Upland Acacia wooded grassland and Riverine forests (Lillesø et al. 2011, Kindt et al. 2011a; Kindt et al. 2011b). The species grows in areas with altitudes between 500 and 2600 m.a.s. and with annual rainfall from 700 to 2000 mm (Orwa et al. 1009). The species is scarcely represented in the northern part of its distribution area (Derero et al. 2011).

It is one of the most used species among farmers in the central and south western part of Ethiopia where it is planted in rows, patches or woodlots (IBC 2012). The species is one of the tree species with highest number of seedlings produced in the Amhara forest Enterprise (Presentations at the inception phase of PATSPO). In the priority list for south western forests, *C. africana* is ranked fourth (IBS, 2012).

C. africana can be used for timber production, fodder, bee forage, mulch, soil conservation (IBC 2012; Bekele-Tesemma 2007). *C. africana* is a pioneer tree species and is characterized by early fast growth - about meter/year in the 7-8 years (Orwa et al. 2009).

Major problems related to timber production are a tendency for the species to produce multiple stems, poor stem straightness and twist, and solitary trees tend to have a poor axis formation (Bekele-Tesemma 2007, Derero pers. comm.). Recently, severe leaf defoliations have further been observed in provenance and progeny field trials of *C. africana* situated in Mehoni (northern Ethiopia) and Wondo (Central Ethiopia) presumably caused by different defoliators at the different sites, but with significant differences between provenances (Yirgu et al. 2017).

Genetic variation among and within populations

A population structure was not found among 22 natural populations by application of AFLPs (Derero et al. 2011).

A preliminary evaluation of two progeny trials situated at Teppi and Mehoni after 12 months shows a significant variation among provenances in height growth. There is also a significant individual-tree genetic variation, but the individual-tree genetic variation is small compared to the variation among provenances. As regards the tendency to make multiple stems, there is no significant provenance variation, but significant individual tree heritability (0.32 across two sites) and no significant genotype-environment interaction between the two sites (Derero unpublished data).

The flowering age is between three and five years. Pollination is done by insects, mainly bees (Bekele-Tesemma 2007). The species is an outcrossing and has an incompatibility system (Derero et al. 2011).

The fast growth makes it likely possible to evaluate and select for timber properties, like single stem formation, low frequency of forking and stem straightness, within five years. As regard the twist, this is likely depending on spiral grain in the wood (e.g. Harris 1989). Early age spiral grain can be measured on standing trees, but research should additionally be conducted to examine the development in spiral grain with age to be sure that a selection based on early spiral grain formation is an acceptable approach to reduce spiral grain in the whole trunk of the tree.

The overall breeding objective of the BSOs of *C. africana* is to provide climate adapted material and pest and disease resistant material with a high biomass production and high timber quality. As regards the timber quality, the focus will be on the reduction of multiple stem formation, improvement of stem straightness, reduction of forking and improvement of axis formation.

Locations of breeding seed orchards (BSOs)

Beside the overall aim of providing improved seed, the aim of the BSOs is also to provide knowledge about provenance- and genotype by environment interactions (GE), and to test for adaptation patterns concerning climate. This knowledge is of importance to develop guidelines on seed source transfers and to outline breeding zones of the species.

The locations for the BSOs should, as far as possible, reflect the variation in climate and vegetation zones within the distribution area of the species and BSOs should be located at sites with high demand for the seeds of *C. africana*.

C. *africana* is widely distributed across several vegetation zones and climates. With this respect, it could be of interest to have BSOs at minimum four locations.

Three of the seed centres, Sebeta, Mekele, Bahirdar and the site at ILRI Addis Ababa are all located in the same vegetation zone (according to the Vecea vegetation map (Lillesø et al. 2011, Kindt et al. 2011a; Kindt et al. 2011b), while the seed centre in Hawassa in the Rift Valley is characterised by another vegetation type. The seed centres at Mekele and Bahirdar are located in areas with longer dry seasons, and are additionally not located so far from the drier combretum wooded grassland

Table 1. Potental locations for the Cordia breeding seed orhcards

Name	Lati-tude	lon-gitude	altitude	Annual rainfall	Length of longest dry season	Vegetation zone
Sebeta	8.92	38.63	2200	1069	6	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins
ILRI Addis Ababa	8.94	38.75	2200	1058	6	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins
Mekele	13.48	39.46	2100	587	10	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins / dry combretum wooded grassland
Bahirdar	11.49	37.35	1890	1444	7	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins/ dry combretum wooded grassland
Hawassa	7.05	38.50	1700	1008	5	Upland Acacia wooded grassland

vegetation zone (Table 1). The annual rainfall at Mekele seems to be below the limit for *C. africana* according to Orwa et al. (2009), so a location of a *C. africana* BSO at the exact location of Mekele seed centre may not be reasonable.

None of the seed centres are located in the south western part of the distribution area or in African moist transitional zone and African Afromontane rain forest. However, the Forest Research Centre has a field station in Tepi in south west Ethiopia.

Provenances in the BSOs

It would be of high value to use a core of provenances in all BSOs (10-12 provenances), since the knowledge on adaptation patterns and genotype-environmental interactions are limited for *C. africana*. The 10-12 provenances should include local provenances from the seed centres.

For the current task of establishing a BSO at ILRI in 2018, the major obstacle is find viable seed from a sufficient number of provenances.

FRC (Addis Ababa) have seed from nine provenances, but recent seed germination tests indicate that seeds from only two provenances are viable. The two provenances, which possibly have viable seeds are from Boditi (south west of Hawassa) and Butajira (south of Addis Ababa) and are both located in the same vegetation zone (see table 2). Boditi and Butajira will likely be included in the BSO at ILRI. The viability of the seeds is tested again at FRC (AA).

Boditi and Butajira should be supplemented with two (could be more) provenances from each of the four seed centres in this project, so in total there will potentially be ten provenances from the seed centres (Table 2). Provenances from Hawassa will represent the Rift Valley. The seed centres in Bahirda or Mekele could, if we are lucky, be able to provide seed from two different vegetation zones (Table 2). To complete the test of provenances, we could aim at including a sample from the southwestern region (Tepi) and from the north eastern region.

Institute of Biodiversity Conservation (IBC) has *C. africana* population samples, but they have still not provided a list of what they have, and we do not know if the seeds are viable.

Finally, there is a search for seed lots from seed centres in Kenya, Tanzania, Malawi and Uganda.

In case we will not be able to get a reasonable number of provenances for the 2018 plantings, the BSOs will be made in two steps – 2018 and the rest in 2019. This is feasible, if we include a reference provenance in the 2018- as well as the 2019 planting.

Table 2. Suggested sampling of provenances to cover different climate- and vegetation zones of *Cordia africana* .

Provenance/region	Seed centre	Latitude	longitude	altitude	Annual precipitation (mm)	Length of dry season	Quantity of seed kg	Seed	Date	Vegetation zones
Butajira	FRC (AA)	8.167	38.567	1875	1044	5	4	Y ?	Dec-17	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins
Bodoti	FRC (AA)	6.570	37.520	2050	1009	5	4	Y ?	Dec-17	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins
NN	Sebeta	8.915	38.632	2200	1069	6		N	Dec-17	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins
NN	Sebeta	?	?	?	?	?		N	Dec-17	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins
NN	Mekele	13.482	39.464	2100	596	10		N	Dec-17	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins
NN	Mekele	?	?	?	?	?		N	Dec-17	Dry combretum wooded grassland
NN	Bahirdar	11.494	37.347	1890	1488	7		N	Dec-17	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins
NN	Bahirdar	?	?	?	?	7		N	Dec-17	Dry combretum wooded grassland
NN	Hawassa	7.050	38.496	1700	1008	5		N	Dec-17	Upland Acacia wooded grassland, Rift Valley
NN	Hawassa	?	?	?	?	?		N	Dec-17	Upland Acacia wooded grassland, Rift Valley
Tepi	FRC new sample	?	?	?	?	?		N	Dec-17	Afromontane moist transitional forest
Tepi	FRC new sample	?	?	?	?	?		N	Dec-17	Dry combretum wooded grassland
Tepi	FRC new sample	?	?	?	?	?		N	Dec-17	Afromontane rain forest
Hirna	FRC new sample	9.200	41.083	1875	1074	5		N	Dec-17	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins
Harar	FRC new sample	9.300	42.116667	1900	729	6		N	Dec-17	Complex of Afromontane undifferentiated forest with wooded grasslands and evergreen or semi-evergreen bushland and thicket at lower margins
Ileho	KEFRI	*0.250*	*34.940*	*1700*				Y		Ileho
Meru Fore	KEFRI,	*0.060*	*37.640*	*1600*				Y		Meru forest lodge
Kaberua	KEFRI	*0.800*	*34.699*	*2100*				Y		Kaberua
Chwele	KEFRI	*0.750*	*34.510*	*1400*				Y		Chwele

The seed collection of *C. africana* is from January-March, depending on region and if possible we will try to include as many of the new collections in the BSOs in 2018, and store the rest for the 2019 plantings.

Seed from the collections could be sown in late January/beginning of February 2018 and planted out after 6 months, i.e. in July. FRC has seed (though unlikely viable) from Harar (Ahmar Mountain), so they will likely have a collection from this region again in January 2018.

A timeline for activities are shown in table 3 below.

Table 3. Possible time line for activities related to the establishment of *Cordia africana* BSOs

Cordia africana	*2017*				2018			
Activity	Decembe	January	February	March	April	May	June	July
Protocol for new seed collection								
Procurement of seed lots for 2018 planting								
Procurement of seed lots for 2019 planting								
Development of manual for nursery phase								
Development of manual for the establishment of the BSO at ILRI								
Sowing of seed at FRC								
Nursery phase								
Establishment of BSO at ILRI								

Design of nursery phase

Randomisation in the nursery might mess up the identification of genetic units (provenances and families), which would be fatal for future analysis of the BSOs to estimate breeding values, genetic parameters, outline breeding zones etc. A randomisation is also less urgent as the nurseries are using containers, but it is off course urgent that all containers are treated the same way.

So, it is acceptable to have the genetic units (provenances and families) in groups in the nursery. So a procedure could be to sow the genetic units sown in their own batches and **label all** containers with sticks with name/number of genetic unit

Before the seedlings are going into the field, the trees should be labelled. It is recommended to use labels, which could be pasted around the trees, to avoid that the labels are lost during handling and planting.

Labels, which could be pasted around the trees and with genetic unit number and barcodes, could be printed in Denmark, but it would be good to have this facility in Ethiopia. The full advantage of using barcodes will require a barcode reader in the field. An alternative to bar codes could QR codes, which could be read by mobile phones as well.

Design of the BSOs

The general model for the BSOs will be randomised complete blocks, and **with row plots of four trees of each genetic unit** (family or provenance). This will ensure that

- Superior provenances and/or families are not located as big plots surrounded with few trees in the end.
- The possibility to evaluate the BSO to estimate genetic parameters and breeding values of trees in the BSO. Genetic parameters and breeding values are an aid to judge for what traits it is worthwhile to make a selection for.
- The first selections within family plots will be reasonable precise, if based on phenotypic mass selections, as the environment in the small plots are small. A phenotypic mass selection is based on the performance of the individual tree compared with its neighbour trees and not based on an estimated breeding value.

Before any seed harvest in the BSOs, it is required that three out of the four trees in each plot are felled to avoid pollination among neighbour trees of same family.

Examples of establishment reports are given in annex 2 including and maps and design for the Danish tree species (*Quercus robur*), *Dalberhia sissoo* and *Bauhinia Teelkane*.

The spacing is in the Ethiopian BSOs are adjusted according to number of genetic units and land available for the BSOs. More final designs are made at time where the final number of genetic units is known and a final design when the number of genetic units as well as trees per genetic units is known.

There are off course some basic things to recall

- The location of the BSOs should be mapped on an overview map of 1:10000 or 1:100000 and a detailed map (see examples in annex 3)
- GPS coordinates of at least the south-west corner of the BSO, but preferably all corners
- Make a detailed map in exel (or libre office calc) showing the location of the plots with genetic units in the field trial and coordinates of the trees in the field trial
- Make a protocol for measurements with genetic units and positions (coordinates) of each tree in the BSO (se examples in annex 3)
- Make a registration of the position of genetic units after planting
- Make establishment reports including information on (see also annex 3)
    - Year of sowing and establishment of BSO
    - GPS coordinates of the BSO
    - Responsible person for the establishment of the BSO
    - Purpose of establishment
    - A description of the design e.g.
        - complete block design
        - four tree row plots
        - spacing between rows and columns
    - A short description of the plant material
    - Size of BSO in ha
    - Notes on the establishment

- How long the BSO is expected to last
- Formal agreements made at the establishment of the BSO
- Planned measurements and thinnings in the BSO
- Provenances and families represented in the BSO by name and number
- Overview maps showing the location of the BSO
- Detailed maps showing the location of genetic units (families and provenances)

- The replications are made to adjust for different environments so each replication (block) should as much as possible represent the same environment, while different replications could represent different environments. E.g. different replications could represent different altitudinal levels in an area with slopes.

Steps for collection of seeds for establishment of BSOs

A practical procedure to follow concerning the sampling of seed for the BSOs is proposed below. A technical guideline is developed for the sampling of seed in the field, along with forms to be filled in the field (see annex 4).

Scenario 1: Getting seeds from an existing seed source (national or international)

a. Project an informed requirement of seeds considering germination percentage and mortality during nursery and establishment phase.
b. Contact the supplier well in advance to procure the appropriate quantity of seeds as it might take time to get clearance from both the sides.
c. Arrange for all the import permits and licenses well in advance.
d. Before importing, or sourcing the seeds agree with the specifications like expected germination percentage, seed treatments, recommended nursery management practices etc.
e. Raise purchase order for seed procurement at an agreed cost.
f. Upon receipt of the seeds, prepare a proper receipt record and label the samples using a self-explanatory code.
g. Store the imported or purchased seeds in a cold storage with appropriate humidity to avoid loss of seed viability.

Enablers: Identify following key enablers with their names and organizations with assurance of their timely availability.

i. Systems and processes: Local ICRAF and EEFRIs arrange for all the documents adhering to the Ethiopian government requirements. Field book will be maintained by the EEFRI and other system files will be maintained by ICRAF and copies with the EEFRI.
ii. Seed sourcing: ICRAF (for international import) and EEFRI and ICRAF (for local collections)
iii. Beneficiary of the activity: EEFRI and ICRAF

Scenario 2: Collecting seeds from a natural tree stand (wild, semi-wild or farmer's field)

h. Tag the tree, or at least the locality earmarked for collection well in advance to arrange for collection logistics.
i. Understand phenology of the tree species to mark tentative dates of collection in the collection calendar.
j. Place a local on-field contact with routine access to the tree, for intermittent physical inspection of the tree(s) for signs of flowering, fruit bearing and readiness for fruit harvesting. Send out seed sample guidelines and forms to the on-field contact (see annex 4 for general seed sample guidelines and seed collection forms)
k. Upon reaching proper collection stage, the local on-field contact intimates the seed collectors based at ICRAF and EEFRI's office.
l. Before starting collection, physically mark the tree, record the GPS coordinates of the tree and record this in the field notebook and the forms in annex 4.
m. The collector's reach at the site of collection and collect and store the fruits under dry and cool place to avoid infection and loss of seeds.
n. The seeds are processed following standard processing method (dry or wet method) to separate the seeds from seed coat, pulp and other inert material. Process one seed samples at a time and add the forms from the seed collection in the seed bag and attach a copy of the form to the bag as well.
o. The seeds are recorded for weight and stored as per recommended storage conditions of temperature and humidity.
p. Once the seeds are ready to sow, a lab test is conducted for germination percentage and recorded.
q. Based on the recent germination test, an approximately 2-2.5 times more seeds are sown in nursery considering germination percentage. This is to take care of loss of seedlings in the nursery and mortality during transplantation and establishment of the seedlings post transplantation.

Enablers: Identify following key enablers with their names and organizations with assurance of their timely availability.

i. Systems and processes: Local ICRAF (logistics) and EEFRI (as holder of germplasm). Field book will be maintained by the EEFRI and other system files will be maintained by ICRAF and copies with the EEFRI.
ii. Seed collectors: EEFRI and ICRAF staff, on-field contact
iii. Beneficiary of the activity: EEFRI, ICRAF

Application of genetic markers

The establishment of BSOs with many genetic units is time consuming and require careful labelling, control and separation of families- and provenances from the harvest of seed trees, to the nursery and to the planting in the BSO as seen above and could implicate risk of mislabelling, loss of labels etc. Genetic markers offer following services to achieve the goal of high quality BSOs:

1. DNA bar codes for mother trees- This would help in identifying sampled mother trees in forest and field, and for any future revisit and resampling. The DNA bar code from mother trees can help in tacking flow of genetic material and contribution to the future generations.

2. DNA bar code for trees in the BSOs- This would help in assessing quality of replicated BSOs by tracking the flow of breeding material from one location to another by identity confirmation.
3. DNA variation to understand genetic diversity of BSOs- New generation DNA tools based on single nucleotide polymorphism (SNPs) can help to understand extent, quality of sampled genetic diversity, structure of the population and the gene flow.
4. Parentage analysis: DNA markers will help in tracking parental identification and contributions in a specific cross or a progeny.
5. Breeding without breeding (BwB)- SNPs present in the next generation will help in understanding maternal and paternal contributions in a half sib family. This along with phenotyping data will help to select and retain high performing but genetically diverse parents.
6. SNPs for trait association and next generation breeding: A properly established and phenotyped, replicated BSO will help to associate traits with DNA variation in the form of SNPs. These linked or associated SNPs will help in designing a bi-parental and/or a mixed type of advanced second generation breeding orchard which are more targeted to serve demands from farmers and other stake holders.

In this context, an option is to sample DNA from the seed trees and later the offspring in the BSOs to establish the parentage of the offspring in the BSOs (e.g. Hansen and McKinney 2009) and hopefully to use the parentage analysis to assign the offspring in the BSOs to provenances. The application of genetic markers and parentage analyses means that it would not be necessary to keep track of families from seed trees, but only seed and seedlings from provenance samples without any DNA samples of their seed trees. The application of the DNA markers would further help to tell to what degree families from seed trees are half- or full sibs or are inbred. Finally, as a side effect, the DNA sampling could be used for population genetic studies.

Still, it would be required to plant the trees accurately in rows and columns in the BSO to adjust for spatial variation and for post-blocking to adjust environmental variation.

So, the application of genetic markers will simplify the establishment of BSOs and contribute with knowledge on the genetic composition of the trees in the BSO, save time, and largely remove the risk of mistakes due to loss of labels, mislabelling etc. The only requirement is that the DNA samples of the seed trees are kept separately and can be identified concerning provenance.

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Annex 1. Summary of priority list

Scientific name	Taxon_final	Top 25	Top 96	Top10plus10
Eucalyptus camaldulensis	Eucalyptus camaldulensis	YES	YES	exotic
Eucalyptus globulus	Eucalyptus globulus	YES	YES	exotic
Grevillea robusta	Grevillea robusta	YES	YES	exotic
Acacia decurrens	Acacia decurrens		YES	exotic
Acacia saligna	Acacia saligna		YES	exotic
Casuarina equisetifolia	Casuarina equisetifolia		YES	exotic
Eucalyptus citriodora	Corymbia citriodora		YES	exotic
Eucalyptus grandis	Eucalyptus grandis		YES	exotic
Eucalyptus saligna	Eucalyptus saligna		YES	exotic
Jacaranda mimosifolia	Jacaranda mimosifolia		YES	exotic
Acacia senegal	Acacia senegal	YES	YES	indigenous
Podocarpus falcatus	Afrocarpus falcatus	YES	YES	indigenous
Cordia africana	Cordia africana	YES	YES	indigenous
Acacia albida	Faidherbia albida	YES	YES	indigenous
Hagenia abyssinica	Hagenia abyssinica	YES	YES	indigenous
Juniperus procera	Juniperus procera	YES	YES	indigenous
Acacia abyssinica	Acacia abyssinica		YES	indigenous
Acacia nilotica	Acacia nilotica		YES	indigenous
Acacia tortilis	Acacia tortilis		YES	indigenous
Olea europaea subsp. cuspidat	Olea europaea		YES	indigenous
Adansonia digitata	Adansonia digitata	YES	YES	
Boswellia papyrifera	Boswellia papyrifera	YES	YES	
Catha edulis	Catha edulis	YES	YES	
Coffea arabica	Coffea arabica	YES	YES	
Commiphora myrrha	Commiphora myrrha	YES	YES	
Cordeauxia edulis	Cordeauxia edulis	YES	YES	
Cupressus lusitanica	Cupressus lusitanica	YES	YES	
Moringa stenopetala	Moringa stenopetala	YES	YES	
Oxytenanthera abyssinica	Oxytenanthera abyssinica	YES	YES	
Pouteria adolfi-friederici	Pouteria adolfi-friedericii	YES	YES	
Prunus africana	Prunus africana	YES	YES	
Rhamnus prinoides	Rhamnus prinoides	YES	YES	
Tamarindus indica	Tamarindus indica	YES	YES	
Vitellaria paradoxa	Vitellaria paradoxa	YES	YES	
Arundinaria alpina	Yushania alpina	YES	YES	
Ziziphus mauritiana	Ziziphus jujuba	YES	YES	

Compiled by Roland Kindt

Annex 2. Examples of BSO designs

BSO of *C. africana*. Expected spacing is 2 x 2 metres, but this will be adjusted according to number of genetic units, i.e. provenances and families. An example is shown below. In this example the spacing is so narrow that it will require an early thinning where slow growing trees and trees multi-stem formation are felled within the family plots.

	N popu-lations	N families	Number of genetic units	Spacing_row	Spacing_col	N trees per plot	Plot size (m2)	N replications	Ha	N trees per unit
Population samples	2	-	2	2	1.5	4	12	5	0.01	20
Population with families	10	20	200	2	1.5	4	12	5	1.20	20
								Total	1.21	

Examples of establishment reports are given below including maps and design for the species *Quercus robur*, *Dalberhia sissoo* and *Bauhinia Teelkane* along with an extract of the measurement protocol from the BSO F374 with *Quercus robur*. The establishment reports include as minimum the following information:

- Year of sowing and establishment of BSO
- GPS coordinates of the BSO
- Responsible person for the establishment of the BSO
- Purpose of establishment
- A description of the design e.g.
  - complete block design
  - four tree row plots
  - spacing between rows and columns
- A short description of the plant material
- Size of BSO in ha
- Notes on the establishment
- How long the BSO is expected to last
- Formal agreements made at the establishment of the BSO
- Planned measurements and thinnings in the BSO
- Provenances and families represented in the BSO by name and number
- Overview maps showing the location of the BSO
- Detailed maps showing the location of genetic units

SKOV & LANDSKAB

Establishment Report - F374 / FP287 *Quercus robur*

Propagation of trees and shrubs for landscape purposes 2001-2010

Working Report SKOV & LANDSKAB 100/ 2009

BSO in landscape program / FP287
Year of sowing: E. 2001, Planting year: S. 2002 True forest, SNS Søhøjlandet

Viggo Jensen

DET BIOVIDENSKABELIGE FAKULTET
KØBENHAVNS UNIVERSITET

Title
Establishment Report - F374 / FP287 Quercus robur East Pole - Propagation of Trees and Shrubs for Landscape Purposes 2001-2010

Author
Viggo Jensen

Series
Working Report Forest & Landscape No. 100-2009
The report is published electronically only at www.sl.life.ku.dk

ISBN
978-87-7903-453-2
DTP
Melita Frølich Jørgensen

Publisher
Forest & Landscape University of Copenhagen Hørsholm Kongevej 11
2970 Hørsholm
Tel. 3533 1500
www.sl.life.ku.dk

For quoting
Jensen, V. 2009. Establishment Report - F374 / FP287 (Quercus robur) East Pole - Propagation of trees and shrubs for landscape purposes 2001-2010. Working Report No. 100-2009. Forest & Landscape.

Propagation for Landscapes: Improved planting material of Danish landscape plants for forest, wildlife plantings and hedges is a cooperation project between the Forest and Nature Agency (Environment Ministry) and Forest & Landscape (University of Copenhagen). The project was started in 2001 and is briefly called 'Bush Program'. The program maps, collects and multiply the Danish gene pool for approx. 30 resident plants in order to ensure sustainable use.

Print from the Forest Breeding Database

Location [F374]

Stilkeg DK-plus

Progeny trial F374

Seed Stand FP287

District	S&N. SØHØJLANDET
Forest	TRUE Forest
Region	REGION MIDTJYLLAND
Country	Denmark
Title	SSO in landscape program/FP287 Oak DK+(*Quercus robur*) 2002
Parallel trial	F375
Objective	General objective: development of a significant part of the breeding population in the pool of oak in Denmark and aiming at conversion to a seed producing SSO. The available gene resource is an essential part of the national breeding program in oak (see Jensen. J.S. 2009). Specific objective: progeny assessment of 97 plus trees selected in Danish crowned stands, forward-looking selection in the trial and strong selective thinning in order to promote early and sustained flowering and seed setting. And at a landscape level propagation of Danish trees and shrubs for use in forests, wildlife and windbreaks. The input is based on genetic broad pools and the provision of local plant material that resists the climate of the open landscape. The popularity of the species in landscape plantings has caused a need to find better and sufficient seed of Danish origin.
Design	The trial is planned and established as a randomized and unbalanced 27-block block experiment, planted in a continuous series of designs. There are about 90 families represented in the 27 blocks, planted in 92 rows. Range distance 3.0 m. Plant spacing 1.5 m. The design is established with to departments A and B so that dept. A goes from position A0101-A9260 in each row and dept. B starts in row 2, Going from position B0201 - B9216 (above B2560-B6160). The rows are oriented approx. S-N, and the trial starts in the southwest corner. Marking between departments A and B is with round wooden piles in each 5th row.

Plant material The plants are single tree and progeny of Danish-crowned stands in Petersgaard Viemose and Vintersbølle forest, Stenderup Nørreskov and Bregentved Grevindeskov, -Tureby Dyrehave, - Østerskov, -Torp, -Boholte, -Børsted and -Varke Vænger. The plants are produced at "Odlarne i Falkenberg, SE" as container plants. They were ready as 1/0 seedlings for autumn planting, but were kept over the winter at the Arboretum and planted in autumn 2001 and spring 2002 because the experimental area was not ready.

Trial area Approximately 4.5 ha. The area is a wooded area, former farmland, where other seed stands of different shrubs are established in between a mixed forest of traditional deciduous species. The soil is a stone and clay-mixed moraine soil. The area is located along 'Munkevejen' from the parking lot and 250 m west of this. The earth slopes somewhat down north and east. The border to the north and east is a forest trail, and to the west, a beech culture is planted.

Establishment The area has been laid out and registered by forest fitter Jørgen Andersen, and the planting is done by local forest workers. There has been a very good plant establishment, and the plantation has started very well, although many of the plants have been exposed to hare bid.

Duration The duration of the experiment depends on the development and p production of the seed stand.

Agreements with the forest district Reference is made to the Forest and Nature Agency Øresund's common agreements for seed stands in the forest districts, ie, that maintenance and cleaning of BSO is carried out by the Forest and Nature Agency Øresund. In case of doubt, contact the Forest and Nature Agency Øresund.

Reference Jensen, J.S. 2009. Indsamling af frø fra stilkeg (*Quercus robur* L.) i 2007 - Fremavl af træer og buske til landskabsformål 2001-2010. Arbejdsrapport nr. 93-2009, Skov & Landskab.

Jensen, V. 2009. Anlægsrapport for F375 under udarbejdelse.

Measurements

Planed		**Done**	
Height	2002	Height	2003
Height	2006		
Height	2011		

Content Vnr.	**Material nr.**	**Provenance**	**Type**	**Numbers**
Børsted677C	S1385901	Børsted677C	Seedlings	67
Børsted687	S1386001	Børsted687	Seedlings	79
Boholte322A	S1386101	Boholte322A	Seedlings	87
Grevinde359	S1386201	Grevinde359	Seedlings	78
Grevinde405	S1386301	Grevinde405	Seedlings	92
KværedeV.290	S1386401	KværedeV.290	Seedlings	53
KværedeV.292	S1386501	KværedeV.292	Seedlings	90
Østerskov615	S1386601	Østerskov615	Seedlings	93
ThurebyDy483	S1386701	ThurebyDy483	Seedlings	77
Torp8	S1386801	Torp8	Seedlings	96
Viemose108	S1386901	Viemose108	Seedlings	80
Vintersbølle407	S1387001	Vintersbølle407	Seedlings	92
V14448	S1388501	Boholte322A	Seedlings	47
V14450	S1388601	Boholte322A	Seedlings	103
V14451	S1388701	Boholte322A	Seedlings	114
V14452	S1388801	Boholte322A	Seedlings	115
V14453	S1388901	Boholte322A	Seedlings	104
V14454	S1389001	Boholte322A	Seedlings	118
V14463	S1389401	Børsted677C	Seedlings	78
V14465	S1389501	Børsted677C	Seedlings	12
V14467	S1389601	Børsted687	Seedlings	114
V14469	S1389801	Børsted687	Seedlings	82
V14472	S1389901	Børsted687	Seedlings	105
V14473	S1390001	Børsted687	Seedlings	115
V14477	S1390101	Børsted687	Seedlings	105
V14478	S1390201	Børsted687	Seedlings	93
V14479	S1390301	Børsted687	Seedlings	55
V14480	S1390401	Børsted687	Seedlings	110
V14481	S1390501	Børsted687	Seedlings	120
V14482	S1390601	Børsted687	Seedlings	83
V14484	S1390701	Børsted687	Seedlings	102
V14488	S1390801	Grevindeskov359	Seedlings	114
V14489	S1390901	Grevindeskov359	Seedlings	78
V14491	S1391001	Grevindeskov359	Seedlings	57
V14494	S1391101	Grevindeskov359	Seedlings	107
V14499	S1391201	Grevindeskov359	Seedlings	76
V14504	S1391301	Grevindeskov359	Seedlings	44
V14506	S1391401	Grevindeskov359	Seedlings	113
V14507	S1391501	Grevindeskov359	Seedlings	60
V14508	S1391601	Grevindeskov359	Seedlings	111
V14511	S1391801	Grevindeskov359	Seedlings	87
V14514	S1391901	Grevindeskov359	Seedlings	102
V14517	S1392001	Grevindeskov359	Seedlings	47
V14518	S1392101	Grevindeskov405	Seedlings	118
V14519	S1392201	Grevindeskov405	Seedlings	7

V14520	S1392301	Grevindeskov405	Seedlings	81
V14523	S1392401	Grevindeskov405	Seedlings	82
V14524	S1392501	Grevindeskov405	Seedlings	107
V14526	S1392601	Grevindeskov405	Seedlings	59
V14531	S1392701	Grevindeskov405	Seedlings	35
V14538	S1393001	Grevindeskov405	Seedlings	102
V14539	S1393101	Grevindeskov405	Seedlings	104
V14549	S1393401	KværedeV.292	Seedlings	11
V14556	S1393701	ThurebyDy483	Seedlings	63
V14557	S1393801	ThurebyDy483	Seedlings	119
V14558	S1393901	ThurebyDy483	Seedlings	104
V14559	S1394001	ThurebyDy483	Seedlings	118
V14560	S1394101	ThurebyDy483	Seedlings	79
V14561	S1394201	ThurebyDy483	Seedlings	57
V14562	S1394301	ThurebyDy483	Seedlings	103
V14563	S1394401	ThurebyDy483	Seedlings	56
V14564	S1394501	ThurebyDy483	Seedlings	82
V14565	S1394601	ThurebyDy483	Seedlings	31
V14571	S1394701	ThurebyDy483	Seedlings	80
V14573	S1394801	ThurebyDy483	Seedlings	59
V14582	S1395001	Torp8	Seedlings	105
V14584	S1395101	Torp8	Seedlings	114
V14590	S1395301	Vintersbølle418	Seedlings	79
V14593	S1395401	Vintersbølle418	Seedlings	82
V14599	S1395501	Viemose108	Seedlings	118
V14600	S1395601	Viemose109	Seedlings	79
V14604	S1395701	Vintersbølle418	Seedlings	83
V14607	S1395901	Østerskov615	Seedlings	101
V14608	S1396001	Østerskov615	Seedlings	54
V14610	S1396201	Østerskov615	Seedlings	107
V14612	S1396301	Østerskov615	Seedlings	114
V14613	S1396401	Østerskov615	Seedlings	32
V14614	S1396501	Østerskov615	Seedlings	35
V14615	S1396601	Østerskov615	Seedlings	35
V14617	S1396701	Østerskov615	Seedlings	106
V14618	S1396801	Østerskov615	Seedlings	59
V14619	S1396901	Østerskov615	Seedlings	64
V14620	S1397001	Østerskov615	Seedlings	74
V14623	S1397101	Østerskov615	Seedlings	91
V14627	S1397201	Østerskov615	Seedlings	59
V14642	S1397301	Vintrsbølle407	Seedlings	55
V14643	S1397401	Vintrsbølle407	Seedlings	53
V14647	S1397501	Vintrsbølle407	Seedlings	102
V14648	S1397601	Vintersbølle416	Seedlings	36
V14650	S1397701	Vintersbølle408	Seedlings	30
V16470	S1397901	Grevindeskov359	Seedlings	58
V16471	S1398001	KværedeV290	Seedlings	83
V16472	S1398101	Viemose108	Seedlings	93
V16473	S1398201	Vintersbølle418	Seedlings	86
V16474	S1398301	Torp8	Seedlings	116
V16478	S1398401	Boholte322A	Seedlings	102

V16479	S1398501	Boholte322A	Seedlings	111
V16484	S1398701	KværedeV292	Seedlings	78
V16487	S1398801	Børsted677C	Seedlings	117
V16488	S1398901	Børsted677C	Seedlings	35
V16490	S1399001	Børsted677C	Seedlings	99
V16491	S1399101	Børsted687	Seedlings	112
V16492	S1399201	Børsted687	Seedlings	106
V16493	S1399301	Østerskov615	Seedlings	102
V16498	S1399501	StenderupN.749	Seedlings	102
V16499	S1399601	StenderupN.749	Seedlings	24
V16500	S1399701	StenderupN.740	Seedlings	84
V16501	S1399801	StenderupN.718	Seedlings	68
V16502	S1399901	StenderupN.745	Seedlings	70
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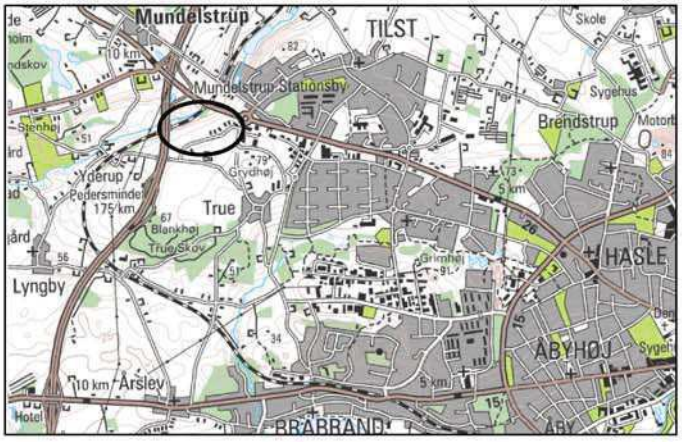
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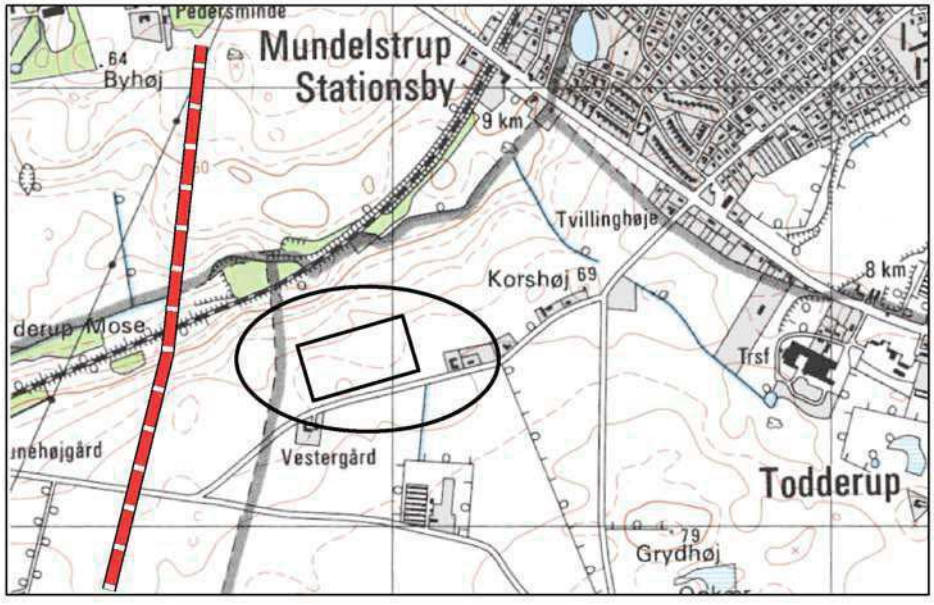
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			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
120	B	60																														13988	13939	13944	13967	13920	13941	13951	13900	13980	13908	13998	13887	13954	13974	13885	13914	13906	13993	13975	13931	13946	13911
119	B	59																														13988	13939	13944	13967	13920	13941	13951	13900	13980	13908	13998	13887	13954	13974	13885	13914	13906	13993	13975	13931	13946	13911
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116	B	56																					13888	13868	13887	13887	13921	13990	13902	13907	13988	13988	13921	13983	13901	13980	13919	13960	13913	13951	13971	13911	13868	13859	13998	13967	13995	13940	13918	
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98	B	38		13902	13888	13912	13939	13869	13860	13967	13984	13907	13943	13924	13867	13972	13894	13998	13863	13990	13972	13959	13962	13997	13900	13951	13982	13919	13888	13931	13977	13947	13947	13999	13991	13941	13909	13972	13908	13948	13924	13997	13865	13925	13996	13885	13938	13972					
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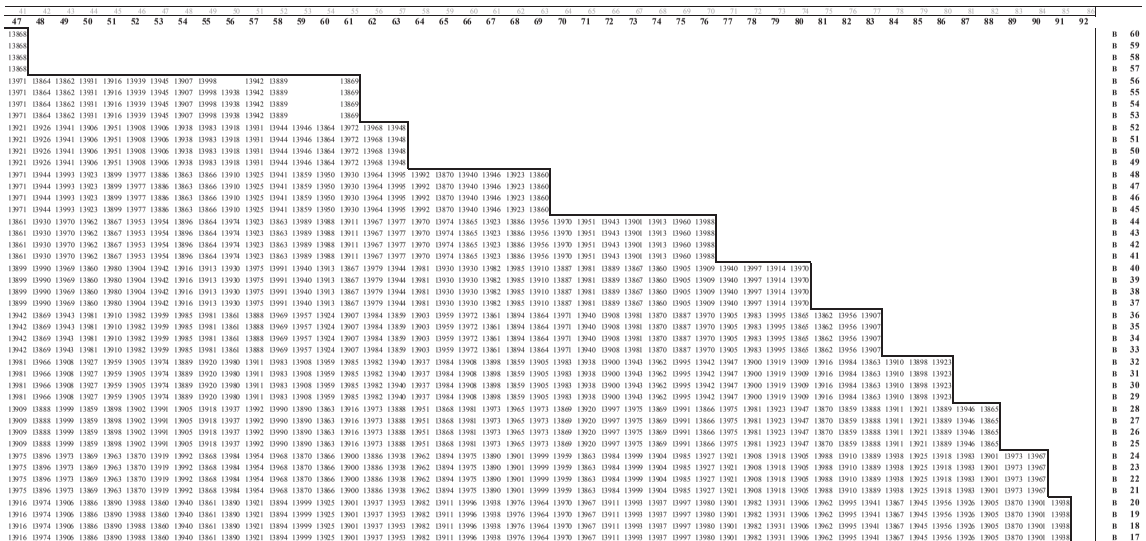
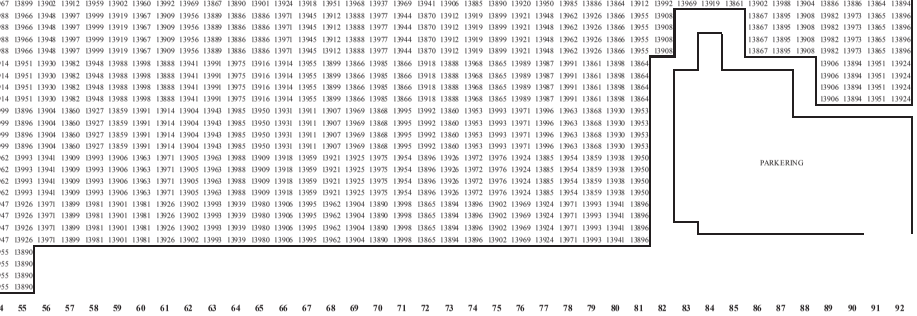



PARKERING

SUMMARY INFORMATION

TITLE:	*Dalbergia sissoo* intermediate-level (open pollinated, family identity maintained) breeding seed orchard (BSO)
ESTABLISHMENT DATE:	July 1994
MAJOR OBJECTIVES:	To produce a supply of improved seed sufficient to meet most of the Central Development Region's demand. To identify and conserve superior genotypes that could be used in future breeding cycles.
LOCATION:	Adjacent to the Khorsor Range Post and Elephant Breeding Centre, at Khorsor Sauraha, Chitwan District, Central Development Region of Nepal. Approximately 20 kilometres east of Narayanghat. See maps 1 & 2.
AREA:	Gross: 2.7 hectares. Net (planted): 2.3 hectares.
ORIGIN OF PARENT MATERIAL:	84 superior phenotypes selected from trees located across the natural terai range in Nepal.
DESIGN:	Randomised complete block design. In each block each family is represented by a plot of 16 seedlings. The family plots are located at random in the blocks. There are seven blocks in the BSO.
DURATION:	For the life of the stand.
LAND OWNERSHIP:	His Majesty's Government of Nepal (HMG) National Forest.
ESTABLISHED BY:	HMG/Danida Tree Improvement Programme (TIP)

ACKNOWLEDGEMENTS

The successful establishment of this BSO was made possible by the commitment to quality, and dedication to the task at hand, that was exhibited by the TIP staff who were involved in the work described in this report.

Rangers Hari Panthi, Abdul Sahim Ansari, Nirmal Bikram Thapa and Ramchandra Gupta very successfully ran the nursery operation. Ranger Hari Panthi and Nirmal Bikram Thapa were responsible for all the work that was done to prepare, layout and establish the site. At a time of the year when it is difficult both to hire and to motivate casual labour, they managed to do so.

It is rewarding to be able to note that those staff who have actively participated in the establishment of this BSO now have a good understanding of the field operations that are necessary to establish field trials and seed orchards. Their levels of skill are high and they have every reason to be proud of their accomplishment.

Chitwan District Forest Officer R.B. Chand and his staff are to be thanked for their support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF MAPS

LIST OF FIGURES

BREEDING SEED ORCHARD ESTABLISHMENT REPORT

DALBERGIA SISSOO Roxb. (Sissoo/Shisham)

Sauraha, Chitwan District

---

1. INTRODUCTION

1.1 This report documents the establishment of an intermediate-level *Dalbergia sissoo* breeding seed orchard (BSO)[1/] by the HMG/Danida Tree Improvement Programme (TIP). The 2.74 ha. BSO was established with seedlings propagated from the seed of 84 superior phenotypes, selected from across the species natural range in Nepal (Thomson, 1994a.).

1.2 *D. sissoo* is a species of considerable economic importance, particularly in Nepal, Pakistan and India. But Nepal is the only country that has significant resources of high quality natural *D. sissoo* forests remaining--and they are rapidly disappearing. Trials in Nepal, (White et.al., 1990) and Pakistan. (Shams-ur-Rehman, 1993) indicate that the far-western provenances of Nepal are genetically superior in terms of vigour and stem form. It is therefore likely that the material used to establish this BSO (TIP's *D. sissoo* "Base Breeding Population") represents the most valuable genestock remaining and available for breeding. The role of gene conservation in the BSO is therefore of utmost importance.

1.3 For tree-breeding initiatives to be of any significance, it is important that they follow a strategy or breeding plan. The government forestry institutions of Nepal have agreed to a breeding strategy for *D. sissoo* in Nepal (Gibson, 1994). Under the strategy, the first generation "production units" are a series of intermediate-level BSOs--one in each of the Development Regions. This is the first of those BSOs to be established.

1.4 This is also the first "intermediate-level" BSO to be planted for any species in Nepal. Accordingly, it will provide a number of opportunities to explore and test BSO methodology, as well as an important resource for the training of forestry personnel and students in Nepal.

1/ An introduction to BSOs (Thomson, 1994b.) is attached as Annex 1.

1.5 Given the levels of interest being shown in *D. sissoo* internationally, and the demands for improved planting material and gene conservation that accompany that interest, it should be clear that TIP's *D. sissoo* BSOs are an asset of international importance.

2. OBJECTIVES

2.1 To provide, in perpetuity for the Central Development Region, a supply of improved seed that has been bred for local conditions.

2.2 To identify and conserve superior genotypes that could be used in the next (second generation) breeding cycle.

3. PROPOSED ACTIVITIES AND DURATION

3.1 To realize its value the BSO will require regular maintenance as well as selection and thinning. The maintenance, assessment and selection will be more-or-less according to the model proposed in Table 1. Most probably the timing of the operations will need to be adjusted in response to the rates of growth that are realized.

3.2 The first four selections (of individuals within the family plots) will be done on the basis of apparent phenotypic advantage. The final selection (of the best 50% of the families) will be based on a comprehensive statistical analysis.

4. LOCATION AND ACCESS

4.1 The BSO is at Sauraha in Chitwan District, in the Central Development Region of Nepal. Latitude 27°40'N and longitude is 84°30'E. The elevation is approximately 250 meters above sea level. The BSO is located adjacent to the elephant breeding centre, on the western bank of the Khagedi Khola, near it's confluence with the Rapti River. See Map 1.

4.2 To reach the BSO it is necessary to ford two kholas (streams) and in the monsoon it is often not possible to do so. There is an alternative route from Parsa Bazaar to Sauraha, for which a local guide is desirable unless the driver is familiar with the route. The use of this alternative route saves crossing the first ford on the Budhi Rapti. Except in times of peak water flow, it is usually possible to wade the Khagedi Khola from directly opposite the BSO.

5. SITE DESCRIPTION

5.1 Vegetation: Originally mixed hardwood forest (dominated by *Shorea robusta*) and riverine forest dominated by *Bombax ceiba*, the site has most recently been used as common grazing land. The vigorous growth of *Cassia tora*, thatching grass (commonly known as Siru grass) and other grasses, between the months of July and September, indicates that regular weeding will be necessary until the seedlings are well established.

Table 1. Model *D.sissoo* intermediate-level BSO management regime

Age	Average spacing (m)	Tree/ plot	Trees/ hectare	Operations
For the first 5 years, regular visits to the BSO to check on health, damage, weed growth, condition of fences and "anti-rhino" trench, and to pay the watchman, are vital.				
0	1.5	16	4,444	Plant and assess survival
1	1.5	16	4,444	Replanting as required using stump cuttings propagated from seedlings leftover from establishment.
1 - 5				Cleaning as required
1-2				Weeding/cultivation, probably 2 times a year
1-5				Maintenance of "anti-rhino" trench and fence
3	2.1	8	2,222	Assess height and form. Select and thin 50%
6	3	4	1,111	Assess height and form. Select and thin 50%
9	4.2	2	556	Assess height and form. Select and thin 50%
12	6	1	278	Assess height and form. Select and thin 50%
11+	8.5	50% of plots with 1 tree	139	Assess height and form. *Select and thin 50% of families.* Operational seed production, collection and/or crosses for the next generation.

5.2 Soils: The deep rich sandy-silt-loam alluvium indicates that the area is part of an old flood plain. To a depth of two meters, two clearly distinguishable horizons are evident: (i) directly under the organic horizon to a depth of 0.5 meters, a chocolate-brown horizon; and, (ii) an underlying lighter coloured horizon containing negligible organic matter. It can be assumed that the base material is alluvial stone and rock. The site appears fertile and good rates of growth are expected. No formal soil survey has been carried out.

5.3 Drainage: The area is more-or-less entirely level, though with several small depressions in which surface water remains for some days at the height of the monsoon. These low lying areas are indicated as "swampy in monsoon" on Map 2. Shallow surface drains (draining into the surrounding "anti-rhino" trench) have been dug in an attempt to remove the water from these depressions. It can be expected that the seasonally impeded drainage in these areas will have some effect on growth.

5.4 Climate: The closest representative weather station to the site is at Jhawani, at latitude 27°35'N, longitude 84°32'E and altitude 270 meters above sea level. Summary data from Jhawani is presented in Table 2. The rates of evapotranspiration and precipitation for the site are shown in Figure 1.

5.5 Land tenure: The area is gazetted National Forest land that has most recently been used as common grazing land by the local villagers. TIP has been assured of management control of the area.

5.6 Disadvantages: Rhinoceros are a problem in this area and this has necessitated the building of an "anti-rhino" trench around the perimeter of site. It will be important that this is maintained for at least five years.

5.7 In summary, the site is very uniform and promises both good growth rates and limited edaphic variation. In terms of both edaphic and climatic conditions, it is representative of the sites upon which *D. sissoo* should be established.

6. PLANTING MATERIAL

6.1 Origin: The seed origin is fully documented in Thomson, 1994a. A summary description of the location of each of the mother trees and the family number assigned to each of them, follows in Tables 3a.-3c. The regional distribution of the mother trees is illustrated in Figure 2.

6.2 Nursery: The seedlings were grown in the Manohari Range Post nursery, Makwanpur, Central Development Region.

6.3 A sand and forest soil mix in 4 inch x 7 inch polypots was chosen to encourage rapid growth and strong root development. The pots were thoroughly watered for several days before sowing. To inhibit "damping of", INDOFIL M-45 fungicide was applied at the last watering before sowing, and thereafter on a weekly basis for eight weeks.

6.4 Shade was erected over the beds and remained until the fourth or fifth pair of leaves developed.

6.5 Approximately 65 grams of pod segment [2/] were prepared for each of the 84 families. Between the 6th and 8th of April, three segments of pod were placed on the surface of the potting mix in each pot and were covered with a thin layer of sandy soil. There were 312 polypots sown for each family. Family identitiy was maintained in the nursery by dividing the seedbeds into family areas and marking each of them with a peg bearing the family number.

2/ Where each segment contained a single, apparently viable seed.

Table 2. Climatalogical data - Jhawani station (903)

Years of record: Precipitation 23, Temperature?
(from Jackson, 1987)

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July
Mean Precipitation, mm	462	279	82	12	7	18	17	18	39	93	331	459
Mean Temperature, C (est.)	28	27	25	20	16	16	18	23	27	29	29	28
Evapotranspiration, mm (est.)	149	120	115	78	59	65	90	149	195	208	165	158
0.86 x Penman's Eo, mm (est.	128	103	99	67	51	56	77	128	168	179	142	136
Precipitation variability, mm												
Maximum	978	687	199	112	48	129	82	76	274	246	767	734
Median	407	228	67	0	1	5	6	8	19	83	273	443
Second percentile	296	156	35	0	0	0	0	0	3	36	191	347
First Percentile	260	143	5	0	0	0	0	0	0	12	164	323
Minimum	252	121	0	0	0	0	0	0	0	0	123	266

Evapotranspiration, mm (est.) = Penman's Eo which is an estimate of evapotranspiration from a free water surface.
0.86 x Penman's Eo, mm (est.) = An estimate of the evapotranspiration from forest sites.
Median = middle value exceeded by half the values recorded.
Second percentile = exceeded by 80% of values recorded, ie. in 4 out of 5 years at least the 2nd percentile is recorded
First percentile = exceeded by 90% of values recorded, ie. in 9 out of 10 years at least the 1st percentile is recorded.

Figure 1. Rates of evapotranspiration and precipitation for the site

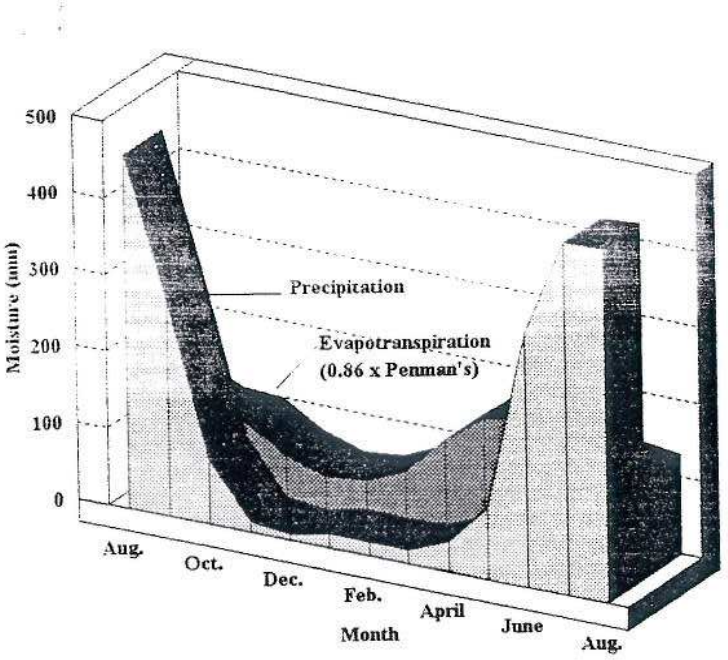


Table 3a. Family numbers and location of mother trees

FAMILY NUMBER IN BSO	DISTRICT	V.D.C	CANDIDATE NUMBER
CENTRAL REGION			
1	Dhanusa	Dhanusa Gobindapur	ST2 001
2	Dhanusa	Dhanusa Gobindapur	ST2 002
3	Dhanusa	Dhanusa Gobindapur	ST2 006
4	Dhanusa	Laptoli	ST2 007
5	Dhanusa	Kurtha	KST2 011
6	Mahottary	Prakauli	KST2 008
WESTERN REGION			
7	Kapilbastu	Buddi	WT 009
8	Kapilbastu	Motipur	WT 008
9	Kapilbastu	Sippur	WT 0010
10	Nawalparasi	Ramnagar	WT 002
11	Nawalparasi	Ramnagar	WT 003
12	Nawalparasi	Ramnagar	WT 004
13	Nawalparasi	Ramnagar	WT 005
14	Nawalparasi	Ramnagar	WT 006
15	Nawalparasi	Ramnagar	WT 007
16	Nawalparasi	Sunawal	WT 001
17	Rupandehi	Shankernagar	WT 0011
MID-WESTERN REGION			
18	Bardiya	North of Danda Gaon	BDNS 029
19	Bardiya	West of Hatisar	BDNS 030
20	Bardiya	Manaughat Forest	BDNS 031
21	Bardiya	Thakurdwara	BDNS 032
22	Bardiya	Bardiya National Park	BDNS 033
23	Bardiya	Manaughat Forest	BDNS 034
24	Banke	Sisaura Ban	BDNS 035
25	Bardiya	Manaughat Forest	DMN 036
26	Bardiya	Manaughat Forest	DMN 037
27	Bardiya	Nth. of Danda Gaon	DMN 038
28	Bardiya	Manaughat Forest	DMN 039

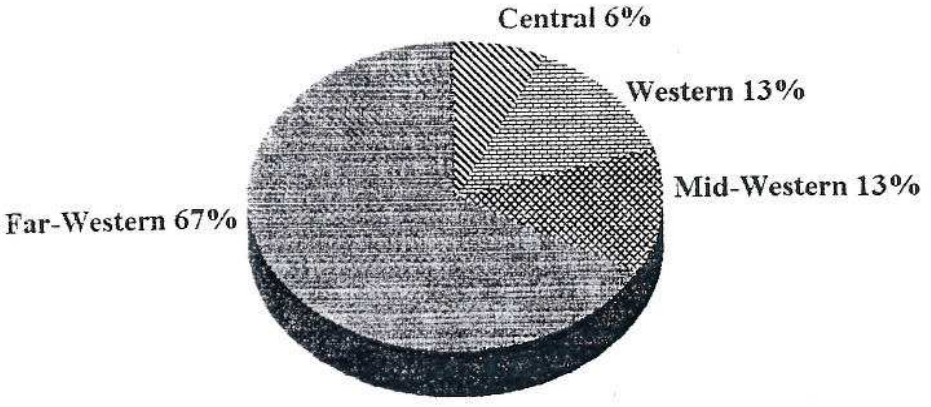
Table 3b. Family numbers and location of mother trees (cont'd)

FAMILY NUMBER IN BSO	DISTRICT	V.D.C	CANDIDATE NUMBER
FAR-WESTERN REGION			
29	Kanchanpur	Chandani	SSP 004
30	Kanchanpur	Chandani	SSP 005
31	Kanchanpur	Chandani	SSP 006
32	Kanchanpur	Chandani	SSP 007
33	Kanchanpur	Chandani	SSP 008
34	Kanchanpur	Chandani	SSP 009
35	Kanchanpur	Chandani	SSP 010
36	Kanchanpur	Chandani	SSP 011
37	Kanchanpur	Chandani	SSP 012
38	Kanchanpur	Dodhara	BDNS 027
39	Kanchanpur	Dodhara	BDNS 028
40	Kanchanpur	Jhaladi	BDNS 022
41	Kanchanpur	Jhaladi	BDNS 023
42	Kanchanpur	Jhaladi	BDNS 024
43	Kanchanpur	Jhaladi	BRS 001
44	Kanchanpur	Jhaladi	BDNS 025
45	Kanchanpur	Krishnapur	BDNS 020
46	Kanchanpur	Krishnapur	BDNS 021
47	Kanchanpur	Mahendranagar Munic.	BDNS 026
48	Kanchanpur	Sukla Phanta	SSP 001
49	Kanchanpur	Sukla Phanta	SSP 002
50	Kanchanpur	Sukla Phanta	SSP 003
51	Kanchanpur	Sukla Phanta	SSP 013
52	Kanchanpur	Sukla Phanta	SSP 014
53	Kanchanpur	Sukla Phanta	SSP 015
54	Kanchanpur	Sukla Phanta	SSP 016
55	Kanchanpur	Sukla Phanta	SSP 017
56	Kanchanpur	Sukla Phanta	SSP 018
57	Kanchanpur	Sukla Phanta	SSP 019
58	Kailali	Bachhediya	BT2 0032
59	Kailali	Baliya	BT2 0014
60	Kailali	Chaumala	BT2 004
61	Kailali	Chaumala	BT2 005
62	Kailali	Chaumala	BT2 007
63	Kailali	Chaumala	BT2 008
64	Kailali	Chaumala	BT2 0026
65	Kailali	Chaumala	BT2 0027

Table 3c. **Family numbers and location of mother trees (cont'd)**

FAMILY NUMBER IN BSO	DISTRICT	V.D.C	CANDIDATE NUMBER
66	Kailali	Chaumala	BT2 0028
67	Kailali	Chaumala	BT2 0029
68	Kailali	Chaumala	BT2 0030
69	Kailali	Chaumala	BT2 0031
70	Kailali	Godawari	BT2 001
71	Kailali	Godawari	BT2 002
72	Kailali	Lathuwa	BT2 009
73	Kailali	Lathuwa	BT2 0010
74	Kailali	Lathuwa	BT2 0011
75	Kailali	Lathuwa	BT2 0012
76	Kailali	Lathuwa	BT2 0013
77	Kailali	Ram Sikhar	BT2 0033
78	Kailali	Ram Sikhar	BT2 0034
79	Kailali	Ram Sikhar	BT2 0035
80	Kailali	Ram Sikhar	BT2 0036
81	Kailali	Ram Sikhar	BT2 0037
82	Kailali	Ram Sikhar	BT2 0038
83	Kailali	Ram Sikhar	BT2 0040
84	Kailali	Sirganga Forest	BT2 0015

Figure 2. The regional distribution of the mother trees



6.6 Germination commenced six days after sowing and was complete after 12 days. Subsequently, extra germinants were pricked out into pots where no germinants had appeared.

6.7 Urea, applied in solution at the rate of one heaped dessert spoon per 12 litre watering can per 800 pots, was applied weekly for eight weeks. This appeared to contribute to healthy and vigorous growth.

6.8 To minimize mortality and to enhance initial growth following outplanting, a regime of regular root conditioning of the stock was undertaken. This commenced in the last week of June (10 weeks after seed sowing) with an undercutting of the taproot. This was done by inserting and rotating a short knife at a height of three to four centimetres above the bottom of the polypot. After this initial treatment, all pots were lifted from their beds and rolled (between the hands) at weekly intervals. The effect of these treatments was to:

- Encourage lateral root development and stop the taproot spiralling inside the pot; and,
- Reduce the rate of soft top growth, instead encouraging the development of a hardier seedling that could better withstand transport and out-planting stress.

6.9 Following planting the surplus seedlings for each family were established in open beds, strictly maintaining family identity. There is sufficient stock remaining in the nursery to both replace dead stock in this BSO next monsoon, and, to establish next year's BSO from stump-cuttings.

7. INTERMEDIATE-LEVEL BSO DESIGN

7.1 Reasoning behind the choice of design: An intermediate-level (family identity maintained, open pollinated) BSO design was chosen because that design will, in the minimum possible time, most satisfactorily deliver large quantities of improved seed and identify superior genotypes that could be used in a second generation breeding initiative.

7.2 Design and layout: The design is a randomized complete block design. There are seven blocks, within each of which the 84 families are each represented once in randomly located family plots containing 16 trees. Blocks A, B, F and G are in a 6 plot x 14 plot configuration. Blocks C, D and E are in a 5 plot x 17 plot configuration--with one corner plot empty. The location of the blocks in the BSO is shown in Map 2. In each family plot, there are 16 seedlings planted in a 4 x 4 configuration. The location of the family plots within each block is shown in Figures 1a.-1g.

7.3 The establishment spacing is 1.5 meters between trees within rows, and 1.5 meters between rows-equivalent to 4,444 stem per hectare. Each family plot is therefore 6 meters x 6 meters in size. There are 9,804 seedlings planted in the BSO.

Figure 3a. Location of family plots in Block A

KEY: [15] = family number in plot

BLOCK [A]
(14 x 6 plots)

NEIGHBOUR = NONE (FENCE)

19		32		72	74		34	15	20	14	56	58	24
7		50		30	59		31	11	51	55	52	33	16
57		53		71	84		5	21	68	65	18	64	77
47		13		22	10		42	1	79	39	41	27	69
12		75		3	6		46	26	44	36	35	80	62
4		49		78	25		45	76	73	63	82	67	8

9		81		29									
40		70		54									
17		38		66									
83		23		2									
60		28		37									
48		43		61									

NEIGHBOUR = BLOCK B

Figure 3b. Location of family plots in Block B

BLOCK **B**
(14 x 6 plots)

KEY: [15] = family number in plot

NEIGHBOUR = BLOCK A

5	54	19	4	36	21	75	52	61	20	83	15	7	28
24	47	18	74	32	10	26	44	34	27	33	29	59	22
1	40	65	58	64	46	84	30	11	9	2	6	73	14
50	80	53	82	67	70	38	69	41	13	45	66	78	8
77	17	42	49	57	79	16	39	76	25	37	71	60	35
31	56	43	51	62	23	12	63	72	48	81	3	68	55

NEIGHBOUR = BLOCK C

BLOCK **C**

(17 x 5 plots with one corner plot blank)

KEY: 15 = family number in plot

NEIGHBOUR = BLOCK B

82	56	37	72	66	55	6	39	60	53	80	24	62	4	61	22	15
81	65	7	49	12	29	78	75	68	2	23	46	59	57	21	5	70
54	28	47	10	41	40	31	63	20	76	34	3	1	58	25	74	19
30	69	79	18	67	45	27	26	17	52	35	83	38	43	14	36	73
33	71	16	64	13	84	42	77	32	48	51	44	9	11	8	50	

NEIGHBOUR = BLOCK D

Figure 3c. Location of family plots in Block C

BLOCK **D**

(17 x 5 plots with one corner plot blank)

KEY: 15 = family number in plot

NEIGHBOUR = BLOCK C

41	1	83	51	23	80	68	44	27	12	57	34	74	40	9	45	82
28	42	8	62	13	48	32	64	69	14	20	65	72	24	67	50	81
63	70	60	11	75	26	15	25	7	30	19	79	77	36	5	53	61
58	46	16	6	33	2	52	3	29	55	21	54	84	76	39	56	66
47	22	17	73	4	35	10	49	38	31	59	78	71	18	37	43	

NEIGHBOUR = NONE (TRACK)

Figure 3d. Location of family plots in Block 'D'.

BLOCK **E**

(17 x 5 plots with one plot blank in middle of top row)

KEY: 15 = family number in plot

NEIGHBOUR = NONE (FENCE)

23	57	38	35	45	7	15		73	6	70	12	53	14	28	67	69
16	21	3	19	83	9	72	77	63	50	48	56	25	40	55	47	75
4	8	74	42	54	36	58	84	52	61	24	65	79	49	51	34	39
26	10	18	29	32	76	20	41	43	11	37	59	1	2	46	5	62
68	31	17	64	30	13	81	33	27	71	60	66	78	80	44	82	22

NEIGHBOUR = BLOCK F

Figure 3e. Location of family plots in Block E

Figure 3f. Location of family plots in Block F

BLOCK **F**
(14 x 6 plots)

KEY: [15] = family number in plot

NEIGHBOUR = BLOCK E

67	22	76	37	28	62	65	11	34	56	17	79	25	16				
60	84	6	69	20	32	47	70	72	27	4	31	41	54				
45	3	39	2	30	21	64	48	24	52	49	73	7	35				
55	23	42	50	8	81	12	74	68	14	51	58	46	1				
63	71	83	43	5	13	33	78	36	38	18	29	53	15				
61	57	80	59	75	44	26	40	10	66	77	9	19	82				

NEIGHBOUR = BLOCK G

Figure 3g. Location of family plots in Block G

BLOCK G
(14 x 6 plots)

KEY: [15] = family number in plot

NEIGHBOUR = BLOCK F

2	38	42	48	72	31	6	70	64	41	50	17	39	11
29	10	60	51	84	81	1	27	82	20	57	16	67	32
66	43	37	79	47	26	25	4	68	5	23	9	45	65
19	33	58	36	8	12	78	22	63	75	7	71	21	35
74	83	24	30	77	55	3	44	62	34	54	53	18	15
28	76	80	13	56	73	69	59	52	14	40	46	61	49

NEIGHBOUR = NONE (FENCE)

ESTABLISHMENT

8.1 Site preparation: During the months of June and July the site was prepared for planting. The preparation included:

- Removal of five non-commercial trees:
- Erection of a nine-strand barbed wire fence around the perimeter of the site;
- Digging of a conventional 1.5 meter wide by one meter deep "anti-rhino" trench around the perimeter, outside the barbed wire fence line;
- Application of a 2 % mixture of "Roundup" herbicide (in 6 blocks only) to remove weeds and grasses for the pre- and immediate post-planting period;
- Marking of the corners of the seven blocks with 4 inch x 4 inch rectangular wooden pegs;
- Labelling each of the family plots with a steel plate and angle iron marker peg, painted with the family number; and,
- Erection of a steel plate signboard identifying and describing the BSO.

8.2 Layout: In the first week of July the BSO was laid out and each seedling planting site was marked with a spot of paint.

8.3 Preparation of the seedling planting sites: In the second week of July, immediately before planting, the seedling planting sites were cultivated to a radius of 45-50 centimetres and planting holes 45 centimetres deep were prepared.

8.4 Planting: The planting of BSO is carried out in the third week of July.

COSTS

9.1 The cost of establishing this BSO are estimated to be NRs. 622.344. This does not include salary overheads for HMG staff, advisors' costs, or vehicle maintenance and depreciation costs. A total of 266 mandays of TIP staff time and 554 mandays of casual labor were necessary. A summary breakdown of costs is shown in Table 4.

9.2 Where applicable, government standard norms were used to develop budget estimates. However, some serious errors are apparent in these norms. For example, the norms allow 10 mandays for the mixing and sieving of one cubic meter of sand and soil potting mix. A maximum of one manday was required.

9.3 In summary, the overall costs are high, but acceptable and justified. The establishment and maintenance of BSOs demands standards of quality, precision and supervision beyond those given to routine plantation establishment. There is a high cost implicit in that excellence.

Table 4. Summary of Costs

Item	Mandays	Cost (Rs.)
1. Nursery		
- materials		29,840
- casual labour	554	24,600
- TIP staff (@ 90 Rs/day plus allowances)	75	32,095
2. Site preparation & planting		
- clearing trees and scrub	contract	6,860
- fencing materials		234,339
- fencing labour	contract	31,779
- digging "anti rhino" trench	contract	15,000
- "Roundup" spray & sprayers		16,200
- paint for marking planting spots		4,500
- pitting labour	contract	10,000
- spraying/spot marking/planting labour	contract	18,587
- family plot marker pegs		97,003
- signboard		21,900
- concrete block marker pillars		6,000
- TIP staff (@ 90 Rs/day plus allowances)	191	64,279
3. Miscellaneous (telephone, tractor hire, materials)		9,362
TOTAL	779	622,344

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TREE IMPROVEMENT USING BREEDING SEED ORCHARDS; AN INTRODUCTION TO THE CONCEPTS AND METHODOLOGY

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ntroduction and Background

Most foresters in Nepal are aware of the benefits of, and the need for, tree improvement. There s a realization that, at the basic level necessary to meet immediate needs, District level tree nprovement activities should concentrate on the development and management of local seed sources. 'or species where existing stands are not available for management as seed sources (in particular those ommonly utilised for fodder and fuelwood), seed production areas will need to be planted to uarantee a supply. The establishment of those seed production areas needs to be based on sound enetic principles.

Tree improvement is still considered by many foresters to be the work of specialists. This need ot be the case. Major improvements in the quality of the trees being planted, and secured supplies of eed at District level, can be achieved by the application of simple robust practices, such as the stablishment and management of breeding seed orchards (BSOs).

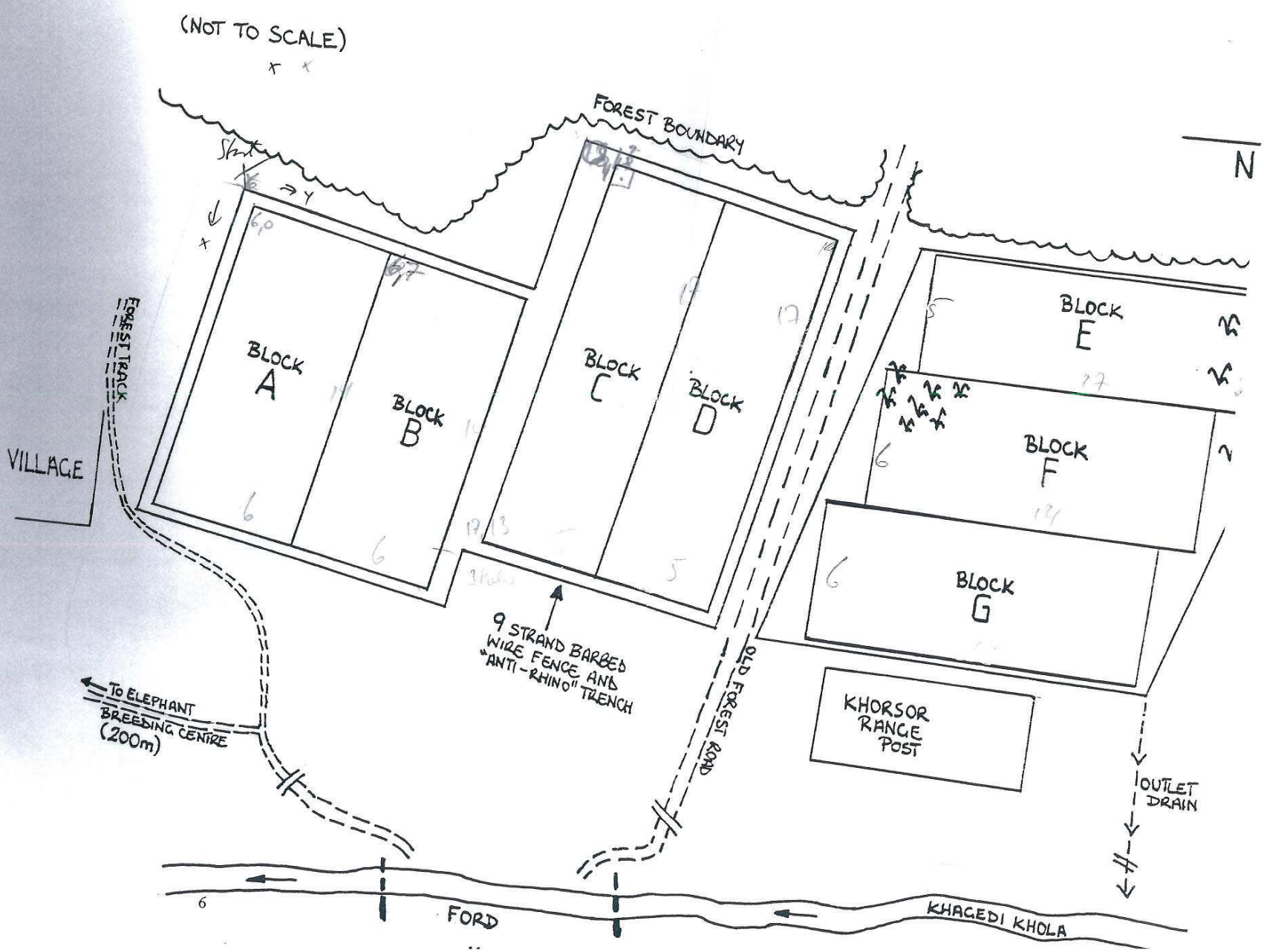
BSOs are an appropriate alternative to conventional breeding strategies which are based on ecurrent selections from a single breeding population, and seed production from progeny-tested clonal eed orchards. In their simplest form, BSOs can be established at District level to provide a secure upply of improved seed in a relatively short time.

The HMG/Danida Tree Improvement Programme (TIP) has established its first simple-level 3SO in 1994. More advanced, intermediate-level BSOs are being used by TIP to establish first eneration *Dalbergia sissoo* seed orchards.

This paper introduces the BSO concept. It is not intended as a "do-it-yourself" manual. Those ntending to develop BSOs will need to refer to the available literature[1/], and to consider the experience lready gained in Nepal.

1/ A more complete account of the use of BSOs in breeding programmes can be found in Barnes (1984) and Barnes and Mullin (1989).

Map 2. **The BSO and immediate surroundings**



ESTABLISHMENT REPORT

BAUHINIA PURPUREA
(Tanki)
BREEDING SEEDLING ORCHARD

Prepared by: Sagar Kumar Rimal (Asst. Tree Improvement Officer)
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HMG/Danida Tree Improvement Programme
Kathmandu, NEPAL

Danida Ref. No. 104. Nepal.17

October 1995

SUMMARY INFORMATION

TITLE:	*Bauhinia purpurea* (Tanki) Breeding Seedling Orchard (BSO)
ESTABLISHMENT DATE:	July 1995
MAJOR OBJECTIVES:	To produce improved seed sufficient to meet a major part of the national demand. To maintain a gene base that could be used for future breeding initiatives.
LOCATION:	Adjacent to the Teel Kane plantation and the "35 families from Kailali" *Dalbergia sissoo* progeny trial (est. 1993), and the "*Dalbergia latifolia* BSO" (est.1994). Six kilometres from Narayanghat, Chitwan District, Central Development Region of Nepal. See Map 1.
AREA:	Gross (fenced): 2.10 hectares Net (planted): 0.41 hectares
ORIGIN OF: PARENT MATERIAL	32 trees on farmers land in Dhading District (Central Development Region)
DESIGN:	Randomised block design. In each block, each family is represented by a plot of 30 seedlings. There are 3 blocks in the BSO.
DURATION:	For the life of the stand
LAND OWNERSHIP:	His Majesty's Government of Nepal (HMG) Forest Department (National Forest).
ESTABLISHED BY:	HMG/Danida Tree Improvement Programme (TIP)

ACKNOWLEDGEMENTS

The successful establishment of this BSO was possible because of the commitment to quality and dedication to the task at hand that was exhibited by the TIP staff who were involved in the work described in this report.

RC Gupta initiated the site preparation. Rajan Shrestha supervised herbicide spraying, fencing, digging of the anti-rhino trench and pitting. Rajeswor Shrestha, who joined TIP in June, assisted in the operations, showing competence and interest.

It is rewarding to be able to note that the experience that TIP staff have gained over the past three years in all aspects of BSO establishment and management is shown in their competence and ability to work independently, maintaining the necessary standards of quality and meeting tight deadlines.

Mr Y.B. Thapa (DFO, Chitwan) and his staff at the Chitwan District Forest Office, were Chitwan very helpful in assisting us to establish the BSO.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF MAPS

LIST OF FIGURES

Breeding Seedling Orchard Establishment Report
Bauhinia purpurea (Tanki)
Teel Kane, Chitwan

1. INTRODUCTION

1.1 This report documents the establishment in 1995 of an intermediate-level *Bauhinia purpurea* (Tanki) Breeding Seedling Orchard (BSO)[1] by the HMG/Danida Tree Improvement Programme (TIP). The 0.41 ha BSO was established with seedlings propagated from seed collected from 20 trees on farmers land in Dhading District. Having made selections and thinnings in favour of the vigour and the attributes desired by farmers, the trees that remain will be managed to produce seed.

2. OBJECTIVES

2.1 In Nepal, *B. purpurea* is used mainly for fodder, though its buds and flowers are also eaten as vegetables. Farmers of Dhading, Lalitpur, Makwanpur, Parbat, Kavre and Sindhupalchowk, and to a lesser extent those in other districts, prefer Tanki, considering it to provide valuable fodder. Heavy lopping and bud and flower collection makes it difficult to collect seed in quantity.

The practices of collecting buds and flowers and lopping for fodder mean that it is often difficult to get sufficient quantities of good seed. To date there have been no initiatives to improve the genetic quality of Tanki in favour of those attributes preferred by farmers.

Accordingly, the primary objective in establishing this BSO is to produce quantities of improved seed sufficient to meet a major part of the demand in the lower and middle hills of Nepal.

3. PROPOSED ACTIVITIES AND DURATION

3.1 The BSO will require regular maintenance as well as selection and thinning to realise its potential. Little is known about the silviculture of Tanki, but the maintenance, assessment and selections should more-or-less be according to the model proposed in Table 1.

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[1] An introduction to BSOs is given in Thomson (1995) which is attached as Annex 1

However, the timing of operations is flexible and should be adjusted in response to the growth that is realised.

The guiding principles are that: (i) selections should be made in favour of those attributes farmers desire in Tanki; and (ii) the trees must be provided with the best possible growth conditions possible on this site, thus allowing maximum crown development and production, in the shortest possible time.

Table 1. Model *B. purpurea* intermediate-level BSO management regime.

Age	Average Spacing (m)	Trees/ plot	Trees/ hectare	Operations
For the first ten years, regular visits to the BSO to check on health, damage, weed growth, condition of fences and "anti-rhino" trench, and, to pay the watchman, are vital				
0	1.5	30	4,444	Plant, replace and assess survival
1				Replanting as required using stump cuttings propagated from seedlings leftover from establishment and laid out in cutting beds.
1 - 5				Cleaning as required
1 - 2				Weeding/cultivation - probably 2 times a year
1 - 8				Maintenance of "anti-rhino" trench and fence
3	2.1	15	2,222	Assess for vigour and fodder production/quality. Select and thin 50%
5	2.9	8	1,185	Assess for vigour and fodder production/quality. Select and thin 50%
7	4.1	4	593	Assess for vigour and fodder production/quality. Select and thin 50%
9	5.8	2	297	Assess for vigour and fodder production/quality. Select and thin 50%
11+	8.2	1	149	Assess for vigour and fodder production/quality. Select and thin 50% Operational seed production and collection.

4. LOCATION AND ACCESS

4.1 The BSO site is in Chitwan District, in the Central Region of Nepal at latitude 27° 40' N and longitude 84° 30' E. The elevation is approximately 300 meters above sea level. Vehicle access is by secondary road and four-wheel-drive track on the road from the Chitwan District Forest Office to Jutpani, immediately south-east of the ford across the Khagadi Khola, adjacent to the Teel *Kane D. sissoo* plantation; the "35 families from Kailali" *D. sissoo* progeny trial (established in 1993) and the *D. latifolia* BSO established in 1994. The ford crossing can be difficult in the monsoon if the Khagadi Khola is in flood. Refer to Map 1 and Figure 1.

Map 1. Location of the BSO and the mother trees

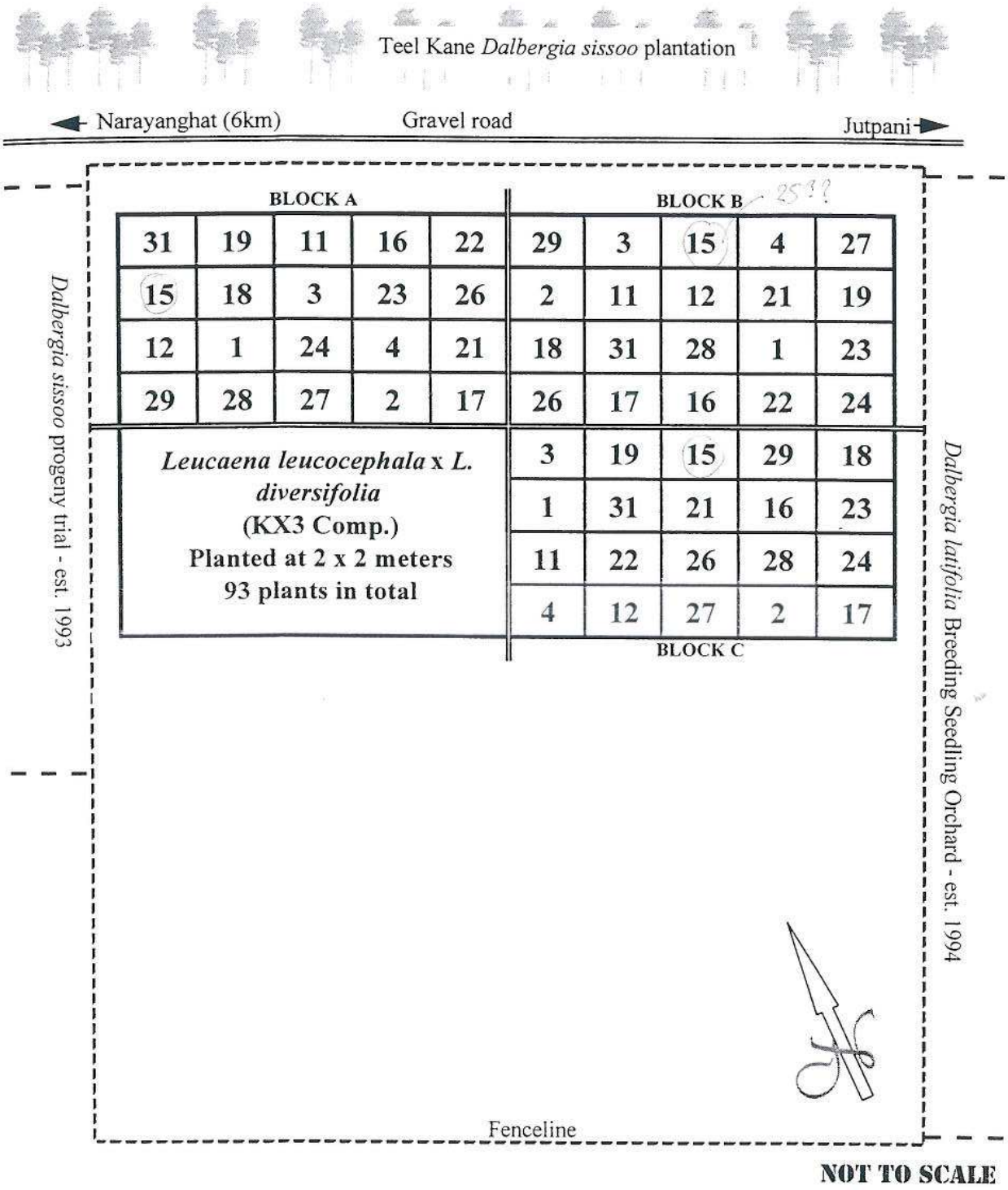


Figure 1. **The BSO and immediate surroundings. Location of the family plots within each block.**

5. SITE DESCRIPTION

5.1 Vegetation: Originally a mixed hardwood forest (dominated by *Shorea robusta*), the site was cleared and cultivated some years ago. Most recently it has been used as common grazing land. Vigorous *Cassia tora* and grass growth between the months of July and September indicates that regular weeding will be necessary until the seedlings are well established.

5.2 Soils: The deep, rich, sandy silt loam soil indicates that the area is part of an old flood plain. To a depth of two meters, two clearly distinguishable horizons are evident: (i) directly under the organic horizon to a depth of 0.5 meters, a chocolate-brown, A-horizon; and, (ii) an underlying lighter coloured horizon containing negligible organic matter. It can be assumed that the base material is alluvial stone and rock. The site appears fertile and good rates of growth can be expected. No formal soil survey has been carried out.

5.3 Drainage: The area is more-or-less entirely level. Generally for this site, the depth of the water table appears to be about five meters in the dry season and between 0.5 and two meters in the wet season.

5.4 Climate: The closest representative weather station to the site is at Jhawani, at latitude 27° 35'N, Longitude 84° 32'E and altitude 270 meters above sea level. Summary data from Jhawani is presented in Table 2.

5.5 Land tenure: The area is gazette national forest land that has most recently been used as common grazing land by the local villagers. TIP has been assured of management control of the BSO area.

5.6 Water balance: The water balance for the site is presented in Figure 2, from which it is clear that, in the pre-monsoon months of April and May, there will be significant deficit in the moisture available to the planted trees. It is unclear what effect this will have on *B. purpurea*, though other trees of this species observed in the locality appear clearly able to cope with this seasonal deficit.

5.6 Disadvantages: Rhinoceros are a problem in this area and this has necessitated the building of an "anti-rhino" trench around the site. It will be important to maintain this. Smaller deer and rabbits have also been a problem on the neighbouring sites. Following its establishment in 1994, the *D. latifolia* BSO was browsed heavily. The same happened to this BSO immediately after planting. The addition of an additional strand barbed wire at the bottom of the surrounding fence seems sufficient to keep small deer and goats out and since , and alternative methods are now being considered.

5.8 In summary, the site is very uniform and promises both good growth rates and limited environment variation within the site.

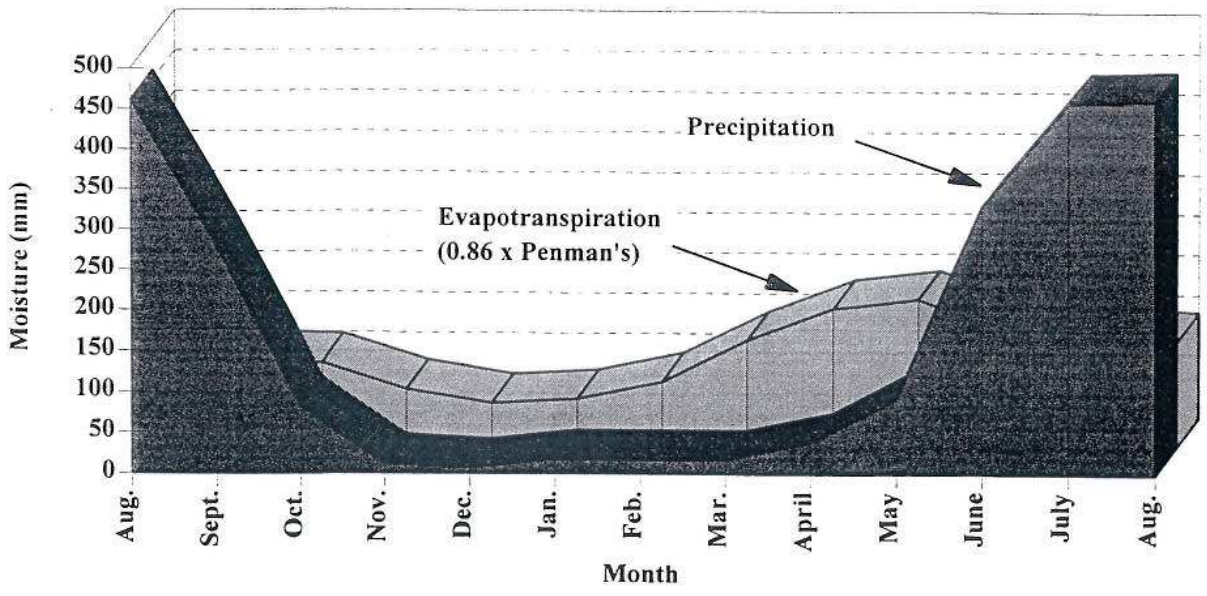
Table 2. Climatalogical data - Jhawani station (903)

Years of record: Precipitation 23, Temperature?
(from Jackson, 1987)

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	YEAR
Mean Precipitation, mm	462	279	82	12	7	18	17	18	39	93	331	459	462	1817
Mean Temperature, C (est.)	28	27	25	20	16	16	18	23	27	29	29	28	28	24
Evapotranspiration, mm (est.)	149	120	115	78	59	65	90	149	195	208	165	158	149	1551
.86 x Penman's Eo, mm (est.	128	103	99	67	51	56	77	128	168	179	142	136	128	1334
Precipitation variability, mm														
Maximum	978	687	199	112	48	129	82	76	274	246	767	734	978	2772
Median	407	228	67	0	1	5	6	8	19	83	273	443	407	1855
ive-year low	296	156	35	0	0	0	0	0	3	36	191	347	296	1541
en-year low	260	143	5	0	0	0	0	0	0	12	164	323	260	1455
Minimum	252	121	0	0	0	0	0	0	0	0	123	266	252	1283

vapotranspiration, mm (est.) = Penman's Eo which is an estimate of evapotranspiration from a free water surface.
.86 x Penman's Eo, mm (est.) = An estimate of the evapotranspiration from forest sites.
Iedian = middle value exceeded by half the values recorded.

igure 2. Rates of evapotranspiration and precipitation for the site



6. PLANTING MATERIAL

6.1 The status of *B. purpurea* in Nepal: In its natural state in Nepal, *B. purpurea* is generally associated with S. *robusta* and *Schima-Castanopsis* forest types. Now, it is mainly found on farmers land. It is an important source of fodder and its buds and flowers are used as vegetable, though they are considered inferior to *B. variegata* (Koiralo). Due to these uses, seed is rarely available and there is a demand for a steady supply.

6.2 Studies of yields from lopping, as well as studies on increased milk production from buffaloes fed with this high protein fodder, have been made and documented. Otherwise, references to *B. purpurea* in Nepali forestry literature are scanty, probably because the species has never been used extensively for plantation establishment. Jackson's entry for *B. purpurea* (Jackson, 1987. Annex 2) provides a short general description of the occurrence, silviculture, utilisation and economic value.

6.3 There are no managed *B. purpurea* seed production areas in Nepal. The availability of a steady supply of improved seed could increase the degree of cultivation of this species, as well as enhancing the economic returns from its utilisation. This BSO will be managed to produce improved seed, by making selections in favour of those trees producing the greatest quantities of high quality fodder. Distribution and deployment of this seed should assist in improving livestock holders' income through animal husbandry.

6.4 Location of the mother trees and seed collection: A total of 39.2 kilograms[2] of pod were collected from 32 trees. The locations and ownership of those trees is shown in Table 3.

6.5 The collection was made hurriedly at the end of the season[3] and this probably explains the reason behind the seed lot being so variable. 12 of families germinated so badly in the nursery that they had to be discarded. Accordingly the BSO had to be established with seedlings from only 20 families - the absolute minimum acceptable to maintain a reasonably broad genetic variation.

6.6 Propagation : The seedlings were grown at the Manohari Range Office Nursery, Makwanpur District. Polypots were set up in 32 family blocks, each containing enough polypots to plant 4 replicates of 30 seedlings each, plus a safety margin of 50 %; ie. (32 families x 4 replicates x 30 seedlings per replicate) x 1.5 = 5,760 polypots in total. A 1:3 sand and forest soil mix in 4 inch x 7 inch polypots was used. The pots were thoroughly watered before sowing.

6.7 The seed was sown from the 27th to the 30th April working only in the cooler morning and afternoon hours. Two seeds were sown in each pot. The seed had been pre-treated by soaking 24 hours in cool water, changing the water 2-3 times to help reduce the risk of fungus attack.

6.8 The polypots were covered with mulch until germination was well under way (seedlings approximately 2 cm tall). Due to very bright, hot sunny weather, the beds were shaded during the midday hours (11 am. to 3 pm.), for 2 weeks.

6.9 Urea, applied in solution at the rate of one heaped dessertspoon per 12 litre watering can per 800 pots was applied once. The growth rate was fast, so, to prevent the seedlings from producing too much soft unlignified stem growth, the application of urea was not repeated.

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[2] A mean harvest of 1,222 grams per tree, ranging from 180 to 7000 grams.

[3] The seed of the first lot of trees identified for collection was lost to monkeys before the seed could be harvested.

Table 3. Origin of the seed trees. Central Development Region - Dhading District

Family no. in BSO	Tree owner	Location (VDC)	Tree no in field	Seed Qty. kg collected
1	Lila Nath	Palpa Bhanjya	40	7.0
2	Ram Thapalia	Kumpur	52	1.6
3	Ram Thapalia	Kumpur	53	1.8
4	C.K. Thapalia	Kumpur	54	0.3
11	K. Bd. Ghale	Kamrang	92	1.2
12	TejBar Ghale	Kamrang	88	1.3
16	Lila Bdr. Ghale	Kamrang	87	0.3
17	Ran Bd. Ghale	Kamrang	90	0.6
18	S. Gh. Kanchha	Kamrang	91	0.4
19	R.P. Thapalia	Kumpur	93	1.6
21	Hol Bd. Magar	Kamrang	95	1.4
22	Pit Bd. Magar	Kumpur	97	0.8
23	Yandi Magar	Kumpur	98	0.8
24	Dhana Magar	Kumpur	99	0.2
25	B.Bd. Magar	Kumpur	100	0.2
26	Puspa Thapalia	Kumpur	101	0.4
27	Megh Thapalia	Kumpur	69	0.7
28	Megh Thapalia	Kumpur	70	3.5
29	Megh Thapalia	Kumpur	103	0.7
31	L. Lamichane	Kumpur	102	1.7

6.10 The sowing was done too late to carry out hardening off operations such as root pruning or bag rolling.

7. INTERMEDIATE-LEVEL BSO DESIGN

7.1 Design and layout: The design is a randomised complete block design with three replications. Each family is therefore represented by 90 seedlings at establishment. In each block the 20 families are represented by one plot containing 30 trees in a 6 x 5 configuration. The 20 family plots are randomly located within each block. The location of the blocks, is shown in Figure 1.

7.2 Generally this species would have been established as a simple-level (family identity not maintained) BSO. However, because only 20 families are present in the BSO, it was necessary to retain family identity as a means of keeping as broad genetic variation present in the BSO as possible.

7.3 The establishment spacing is 1.5 meters between trees within rows, and 1.5 meters between rows, equivalent to 4,444 stems per hectare.

7.4 Future selections will be based on the family plots, each of which contains 30 trees at initial stocking. These plots will be progressively thinned down to one tree per plot (see Table 1). Accordingly, when the selections and thinnings are completed and only seed producing trees remain, there should be 60 seed trees standing at a density of 148 stems per hectare.

8. ESTABLISHMENT

8.1 Site preparation: During the months of May and June the site was prepared for planting. The preparation included:

- Removal of two non-commercial trees and clearing of undergrowth in the southern half of the area.
- Erection of a nine strand barbed wire fence around the perimeter of the site
- Digging of a conventional 1.5 meter wide by 1 meter deep "anti-rhino" trench around the perimeter, outside the barbed wire fence
- Application of "Round-Up" herbicide at the rate of 6 litres per hectare
- Marking of blocks and planting spots to secure exact layout
- Cultivation of each seedling planting site at 50 x 50 x 50 cm
- Erection of a steel plate signboard identifying the BSO.
- Placement of the corner of each family plot of a steel marker indicating the family number.

8.2 Planting : The seedlings were planted out on the 7th of July, in rainy cloudy weather.

8.3 Replanting: Three weeks after establishment, approximately 15% of the seedlings were considered dead and were replaced. The cause of death was by-and-large browsing by barking deer and/or rabbits. Because these replacements were made so close to the original time of planting, they will not be registered as being different.

8.4 Fertiliser: Three weeks after planting each of the seedlings was given a 15 gram dose of urea. It was hoped that this would accelerate initial growth and minimise weed and grass competition, particularly for light.

8.5 Post establishment growth: Three months after establishment and virtually without mortality, the seedlings are performing remarkably well, as is shown in Figure 3. Many of the seedlings are approaching 2 metres in height and they appear very healthy. Some of the seedlings have already begun producing flowers.

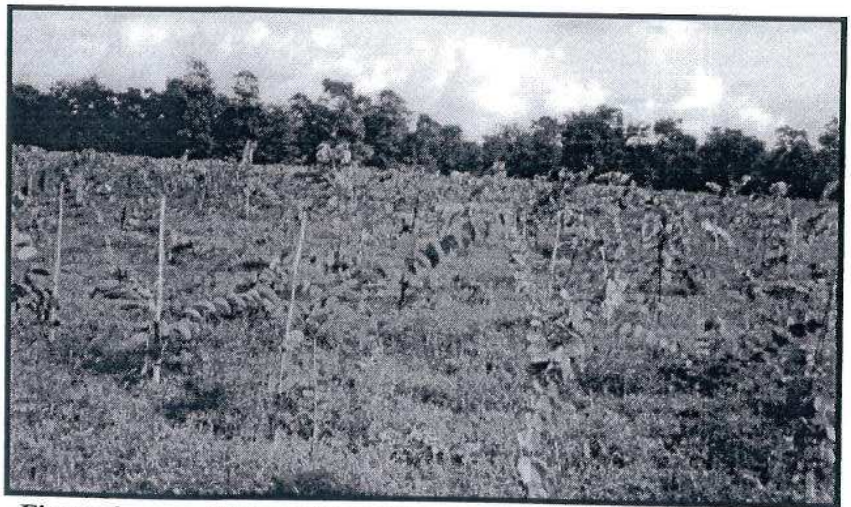

Figure 3. The seedlings three months after establishment

9. ACCOMPANYING ESTABLISHMENT OF *LEUCAENA LEUCOCEPHALA* X *DIVERSIFOLIA* (KX3 COMP. HYBRID)

9.1 TIP was fortunate to obtain a very small quantity of the above fourth generation hybrid from the University of Hawaii. This material has been bred to retain the nutrient value, palatability and vigour of *L. leucocephala*, as well as being resistant to the Psyllid "jumping lice".

9.2 From the seed provided, 93 seedlings were propagated and planted in the fourth quadrant of the BSO. See Figure 1. These seedlings were planted at 2 x 2m, at the same time as the *B. purpurea*. Although the seedlings have suffered badly from deer and rabbit browse, at the time of writing perhaps 70 - 80% were still alive and appearing healthy, though they are stunted from the browsing.

9.3 This is valuable and potentially important material and these seedling must be very carefully protected. If they grow well, they can be expected to produce very high quality fodder and fuelwood trees, from which a large amount of seed will be available.

10. COSTS

10.1 The financial costs incurred in the establishment of this BSO have been calculated to be 203,574 rupees. This does not include salary overheads for HMG staff, advisor's costs, or, vehicle running, maintenance and depreciation costs. A total of 134 mandays of TIP staff time and 587 mandays of casual labour were necessary. A summary breakdown of costs is shown in Table 4.

10.2 As expected, this BSO cost less than the previous year's BSOs, since fencing and rhino trench digging only had to be done on the two short sides of the area. Apart from the general cost increases as a result of inflation, individual cost increases can be explained as follows:

- A 6' high, 9 strand barbed wire fence was built, instead of the 4'6" fence used around the progeny trial.
- To provide protection from rhinoceros, a 1.5 meter wide x 1 meter deep continuous trench has been dug instead of the King Mahendra Conservation Trust design which was used around the progeny trial.

10.3 Where applicable, government norms were used to develop budget estimates.

10.4 Overall, the costs are acceptable and justified. The establishment and maintenance of BSOs demands standards of quality, precision and supervision beyond those given to routine plantation establishment. There is a high cost implicit in that excellence.

Table 4. Summary of costs

Item	Mandays	Cost (Rs.)
1. Nursery		
- materials		15,500
- casual labour	212	10,600
- TIP staff (@ 90 Rs/day plus allowances)		12,100
2. Site preparation & planting		
- clearing trees and scrub	contract	15,725
- fencing materials		83,430
- fencing labour	177	10,640
- digging "anti rhino" trench	102	6,120
- Roundup spray & sprayers	33	1,980
- paint for marking planting spots		1,200
- pitting labour	48	2,850
- planting	15	870
- family plot signposts		22,000
- TIP staff (@ 90 Rs/day plus allowances)	134	45,720
3. Miscellaneous (telephone, tractor hire, materials)		13,039
TOTAL	779	203,574

11. REFERENCES

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TREE IMPROVEMENT USING BREEDING SEEDLING ORCHARDS; AN INTRODUCTION TO THE CONCEPTS AND METHODOLOGY

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Introduction and background

Most foresters in Nepal are aware of the benefits of, and the need for, tree improvement. There is a realization that, at the basic level necessary to meet immediate needs, District level tree improvement activities should concentrate on the development and management of local seed sources. For species where existing stands are not available for management as seed sources (in particular those commonly utilised for fodder and fuelwood), seed production areas will need to be planted to guarantee a supply. The establishment of those seed production areas needs to be based on sound genetic principles.

Tree improvement is still considered by many foresters to be the work of specialists. This need not be the case. Major improvements in the quality of the trees being planted, and secured supplies of seed at District level, can be achieved by the application of simple robust practices, such as the establishment and management of breeding seedling orchards (BSOs) .

BSOs are an appropriate alternative to conventional breeding strategies which are based on recurrent selections from a single breeding population, and seed production from progeny-tested clonal seed orchards. In their simplest form, BSOs can be established at District level to provide a secure supply of improved seed in a relatively short time.

The HMG/Danida Tree Improvement Programme (TIP) established its first simple-level BSO in 1994. More advanced, intermediate-level BSOs are being used by TIP to establish first generation *Dalbergia sissoo* seed orchards.

This paper introduces the BSO concept. It is not intended as a "do-it-yourself" manual. Those intending to develop BSOs will need to refer to the available literature[4]

[4] A more complete account of the use of BSOs in breeding programmes can be found in Barnes (1984) and Barnes and Mullin (1989).

Extract of measurement protocol for the BSO F374 with *Quercus robur*

Afdeling	Block	Row	Column	Family	Height_2004	Label_2004	Stemform 2012	Height2012	Label 2012
A	1	1	1	13990	.	M			
A	1	1	2	13990	.	M			
A	1	1	3	13990	.	M			
A	1	1	4	13990	5	.	6	56	
A	1	1	5	13911	4	.	4	49	
A	1	1	6	13911	8	.	3	59	
A	1	1	7	13911	7	.	5	60	
A	1	1	8	13911	8	.	6	61	
A	1	1	9	13905	7	.	4	69	
A	1	1	10	13905	5	V	5	65	
A	1	1	11	13905	.	M			
A	1	1	12	13905	8	N	2	54	
A	1	1	13	13886	9	.	7	53	
A	1	1	14	13886	6	V	5	49	
A	1	1	15	13886	6	.	7	61	
A	1	1	16	13886	6	.	5	61	
A	1	1	17	13963	6	.	8	67	
A	1	1	18	13963	6	.	5	61	
A	1	1	19	13963	9	.	6	70	
A	1	1	20	13963	.	M			
A	1	2	60	13980	.	M			
A	1	2	59	13980	6	.	6	52	
A	1	2	58	13980	4	.	1	33	
A	1	2	57	13980	5	.	4	45	
A	1	2	56	13983	8	.	5	52	
A	1	2	55	13983	4	.	6	49	
A	1	2	54	13983	5	.	4	50	
A	1	2	53	13983	7	.	6	61	
A	1	2	52	13982	10	.	6	68	
A	1	2	51	13982	.	M			
A	1	2	50	13982	.	D			
A	1	2	49	13982	4	V	3	46	
A	1	2	48	13968	12	.	5	70	
A	1	2	47	13968	6	.	1	57	
A	1	2	46	13968	12	.	7	64	

Annex 3. General guidelines for seed collections

Background/purpose of project

One of the objectives of PATSPO project is the establishment of breeding seed orchards (BSOs) for a number of species to improve the supply of superior well-adapted forest genetic material in the future. Additionally, the BSOs can be used to point out valuable provenances and outline seed deployment zones. BSO consists of offspring from healthy, fast growing trees of high quality concerning e.g. stem properties for timber species. In the BSOs Inferior trees are removed from the BSOs over time and seed is then harvested from the remaining superior trees.

When establishing BSOs, it is essential to make a good representative sampling of the provenances (=populations) if it is to be used to point out valuable provenances and outline seed deployment zones, besides serving as seed source. Generally, it is better to collect fewer seeds from more individual trees as opposed to collecting more seeds from fewer trees. If seed is sampled in existing seed orchards, be careful not to sample from same families and if it is a clonal seed orchard with clones be aware that seed is not collected from ramtets of the same clone. In case the origin of the plantation or seed orchards is known this shall be noted in the forms A or B (see forms in annex A and B).

General guidelines for seed collections

- Ideally every seed tree shall contribute equally to the seed harvest.
- Collect seed from a minimum of 20 seed trees per provenance
- Preferably, collect DNA samples (leaves) of at least the seed trees
- The seed trees must be located with a minimum distance of 50 m between all pairs of seed trees. It is important to avoid seed trees standing close to each other, as these have a greater chance of being closely related and will contribute to inbreeding in the BSO.
- The trees must be evenly distributed throughout the area identified as the provenance or population
- The seed trees shall be healthy and fast growing and in case they are standing among other trees of the same species, they shall at least be dominant. For trees aiming at timber, select trees with:
    - Straight stems
    - And avoid trees with multi-stems and forks
- The desired amount of seed will be specified in the species specific guidelines.

Keep track of information

For each provenance it is mandatory to fill out seed collection forms on location (see annex 1 for the standard forms). Form A is for the collection of seed, where the harvested seed of different trees is bulked in one seed lot. Please, note if you have sampled leaves for DNA analysis in form A.

Form B is for the collection of seed, where the seed from different seed trees is kept separate. In case the collection aims at keeping track of seed from individual seed trees, a label with the seed tree identification number (provenance + specific number of seed tree) is put into the seed bag with the seed of the seed tree and a label with the tree identification number shall be attached to the seed bag. Please, remember to have unique provenance names/provenance abbreviations. The number of the seed trees is added to form

B, and if possible along with the geographical coordinates of the place where the seed trees are growing. Place the seed tree seed bags in one big bag for each provenance and put form B in the bag and attach form B to the bag as well.

Seed is bulked into one seed lot representing a provenance

One copy of form A shall be retained by the employee in charge of the actual collection and later handed over to the respective seed centre. A scanned copy of form A should be sent to the project leader in Ethiopia. Two copies shall be shipped together with each seed bag in a way so it will eventually arrive together with the seeds at the relevant nursery/nurseries. One copy shall be in the seed bag and one copy shall be attached to the seed bag.

Seed is kept separately for each tree

One copy of form B shall be retained by the employee in charge of the actual collection and later handed over to the respective seed centre. A scanned copy of form B shall be sent to the project leader in Ethiopia. Two labels with the seed tree identification number shall be shipped together with the seed bag from each tree. One copy shall be in the seed bag and one copy shall be attached to the bag along with a copy of form B before they are shipped to the relevant nursery/nurseries.

DNA sampling

Take leaf/needle samples of all selected seed trees + from additional trees, giving a total of minimum 30 samples from different trees. Keep the leaf/needle samples separate for each tree in named/numbered plastic bags (provenance name + number of seed tree) with silica gel. If seed is kept separately for each seed tree, be sure to use the same number for the seed bags of the seed trees and for the DNA samples of the seed trees. The DNA samples shall be shipped to the project leader in Ethiopia along with form A or form B.

Before collection at any site

Make a correct species identification. The degree of flowering and fruiting in the collection area as well as the fruit ripening stage must be assessed before collection, and noted in form A or B. If degree of flowering is low it might be better to find another site.

Form A- seed collection from provenances

1) Date

2) Place/region

3) Species (latin and common name):

4) Name of site/provenance:

5) Geographic position coordinates (degrees):

6) Altitude above sea level:

7) Name of employee in charge of collection:

8) Collection method:

From the tree ☐ Cover on ground ☐ From the ground ☐

9) Number of seed trees:

10) Total quantity of seed collected, kg:

11) Total number of seed bags collected at the site:

12) Identity numbers and names on labels on all seed bags:

13) Estimated size of the seed crop in the population:

good ☐ intermediate ☐ poor ☐

Approximate percentage of trees with seed:

14) Condition of the seed (e.g. pests attack, mechanical damage, maturity):

15) Cutting test?: **yes** ☐ no ☐

% filled seeds:

16) Description of collection site:

Farmland ☐ Natural forest ☐ Plantation* ☐

Seed orchard* ☐ Other ☐

Approximate number of trees of the species per ha:

*Origin of plantation or seed orchard:

17) Leaf/needle samples DNA extraction taken from seed trees + 10 additionnal trees:

yes ☐ no ☐

18) Photos of seed trees yes ☐ no ☐

19) Associated tree species and other notes and observations from collectors:

19) Signature of person in charge (name and institution):

Form A. Supplement. Collection of DNA from individual seed trees

1) Date

2) Place/region

3) Species (latin and common name):

21) Photos of seed trees

Seed tree no.	Photo no.	See tree no.	Photo no.
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	

22) Height, diameter and height of bole of seed trees

Seed tree no. (as in 9)	DBH (cm)	Height (m)	Bole height (m)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

Form B- seed collection from individual seed trees

1) Date

2) Place/region

3) Species (latin and common name):

4) Name of site/provenance:

5) Geographic position coordinates (degrees):

6) Altitude above sea level:

7) Name of employee in charge of collection:

8) Collection method:

From the seed tree ☐ Cover on ground ☐ From the ground ☐

9) Identity numbers of seed trees:

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

10) Leaf/needle samples DNA extraction taken from seed trees + 10 additional trees:

yes ☐ no ☐

DNA samples of seed trees shall have the ID numbers as the tree seed ID numbers above (point 9). Use continued numbers for the 10 additonal trees and with the provenance abbreviation

11) Photos of seed trees yes ☐ no ☐ if yes, see page 2

12) Estimated size of the seed crop in the population:

good ☐ intermediate ☐ poor ☐

Approximate percentage of trees with seed:

13) Condition of the seed (e.g. pests attack, mechanical damage, maturity):

14) Cutting test?: yes ☐ no ☐

% filled seeds:

15) Description of collection site:

Farmland ☐ Natural forest ☐ Plantation* ☐

Seed orchard* ☐ Other ☐

Approximate number of trees of the species per ha:

*Origin of plantation or seed orchard:

16) Associated tree species and other notes and observations from collectors:

17) Signature of person in charge (name and institution):

Form B- seed collection from individual seed trees

1) Date

2) Place/region

3) Species (latin and common name):

18) Photos of seed trees

Seed tree no. (as in 9)	Photo no.	See tree no.	Photo no.
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	

19) Height, diameter and height of bole of seed trees

Seed tree no. (as in 9)	DBH (cm)	Height (m)	Bole height (m)
1			
2			
3			
4			
5			
6			
7			
8			
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17			
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19			
20			

PATSPO
Provision of adequate tree seed portfolios

World Agroforestry Centre

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