# The Philippines Recommends for **Reforestation, Tree Farming, and Plantation Development**

Philippines Recommends Series No. 94
PHILIPPINES COUNCIL FOR AGRICULTURE, FORESTRY AND NATURAL RESOURCES RESEARCH AND DEVELOPMENT
Department of Science and Technology

**OFFICE OF THE EXECUTIVE DIRECTOR**

Dear Reader:

We are pleased to present to you this latest volume, The Philippines Recommends for Reforestation, Tree Farming, and Plantation Development.

This volume discusses the different forestation schemes and modalities and the various policies pertinent to each scheme. Techniques on how to do reforestation, tree farming, and plantation development are also included. Further, the corresponding forest management system, including silvicultural practices in both the nursery and in the field, harvesting and marketing of end-products, and the economics of these activities are discussed.

We hope that this publication will serve as a guide for those who are interested in planting trees for ecological, subsistence, and/or investment reasons, as well as for those who are directly assisting tree farmers.

Finally, we trust that this volume will contribute to the sustainable development of the Philippine forest for ecological, economic, and social purposes.

Sincerely yours,

**PATRICIO S.F AYLON**
Executive Director
PCARRD

# The Philippines Recommends for **Reforestation, Tree Farming, and Plantation Development**

**PCARRD Philippines Recommends Series No.49**

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# Foreword

The Philippines has been considered one of the most endangered areas, especially with its deteriorating and diminishing forests. The country has a history of logging for timber products; and lately, of its forest being cleared for farming needs and for housing development in order to accommodate its growing populace.

Several decades ago, the Philippines was covered with bountiful rainforest. Tall and sturdy dipterocarps, prized for their beautiful and straight hardwood, dominated the country's lowland rainforest. Today, the need to preserve and rehabilitate the country's forests has become a major endeavor the present and future generations must seriously undertake.

The *Philippines Recommends for Reforestation, Tree Farming and Plantation Development* presents the latest information and technologies on reforestation, tree farming, and plantation development in the Philippines generated in more than ten years.

The myriad of practices that evolved through the years from dedicated research and development activities from various government and private institutions in the country are also discussed in this volume. Some are adaptation of foreign technologies, while the rest are locally developed.

Policies, programs, economics, and marketing are likewise discussed to complete the scenario, from seed to timber market.

**PATRICIO S.F AYLON**
Executive Director
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# Contents

APPENDICES



## List of Figures

## List of Tables

# Reforestation, Tree Farming, and Plantation Development Technical Committee, 20

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# Glossary of Terms

**Afforestation** – Artificial establishment of forest on lands previously not covered with forest vegetation.

**Agroforestry** – Sustainable management of land that increases their productivity by properly combining agricultural crops with forest crops simultaneously or sequentially over time through the application of management practices, which are compatible with the local climate, topography, and slope.

**Bacteria** – Unicellular microorganisms that reproduce asexually through binary fission. Some produce thick-walled endospore to resist adverse conditions.

**Biomass** – The amount of living matter expressed in terms of weight per unit area or unit volume of water. It is the total mass of life in an ecosystem at any given time. It is an indicator of the productivity of the ecosystem.

**Biotechnology** – Any technological application that uses biological systems, living organisms or derivatives therof, to make or modify products or processes for specific use.

**Bole** – The stem or trunk of a tree of size sufficient to yield lumber, veneer, or poles.

**DBH** – Diameter of the stem of a standing tree measured at 1.3 m from the higher ground.

**Deforestation** – The conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10% threshold.

**Degradation** – A decline in the productivity of an area of land or in its ability to support natural ecosystems or types of agriculture.

**Fungi** – These are spore-producing organisms generally multicellular that reproduces sexually and asexually. The vegetative body is often filamentous.

**Incendiarism** – Fire is purposely set out of revenge or personal grudge.

**Insects** – These are organisms distinguished from other classes through the head, thorax, and abdomen. The destructive insects are the defoliators, skeletonizer, shoot borers, bark beetles, wood, or stem borer.

**Kaingin** – A portion of the forest land, whether occupied or not, which is subjected to shifting and/or permanent slash-and-burn cultivation having little or no provision to prevent soil erosion.

**Nematodes** – Wormlike organisms, eel-shaped with unsegmented body. It has reproductive and digestive systems. Plant parasitic nematodes produce stylet.

**Pasture management** – Burning pasture areas is practiced by cattle owners to induce new growth of grasses, which is more palatable than the old and dry grasses for the cattle.

**Plantation forest** – Forest stands established by planting or seeding in the process of afforestation or reforestation.

**Reforestation** – The establishment of forest plantations on temporarily unstocked lands that are considered as forest. It is also called as artificial regeneration.

**Seed health** – Refers primarily to the presence or absence of disease-causing organisms such as fungi, bacteria, viruses, and animal pests such as worms or insects.

**Timber** – Wood material, which include standing trees in a form suitable for construction, carpentry, joinery, or for reconversion for manufacturing purposes.

**Tree farm** – Any small forestland or tract of land purposely planted with tree crops.

**Virus** – Submicroscopic living entities composed of nucleic acid (virion) with protein coat (capsid). They are obligate parasites.

# List of Abbreviations and Acronyms

| | |
|---|---|
| A&D | Alienable and Disposable Land |
| AKECOP | ASEAN-Korea Environmental Cooperation Project |
| AMF | Arbuscular Mycorrhizal Fungi |
| ANZAP | Australian and New Zealand Association of Psychotherapy Ltd. |
| AO | Administrative Order |
| APAFRI | Asia Pacific Association of Forestry Research Insitution |
| asl | Above sea level |
| ATSC | Australian Tree Seed Centre |
| B | Billion |
| BA | Basal Area |
| BAGE | base age in years |
| BIOTECH | National Institute of Molecular Biology and Biotechnology |
| BFD | Bureau of Forest Development |
| BFI | Bukidnon Forest Industries, Inc |
| BSWM | Bureau of Soils and Water Management |
| Ca | Calcium |
| CALC | Certificate of Ancestral Land Claim |
| CALT | Certificate of Ancestral Land Title |
| CAR | Cordillera Autonomous Region |
| CBFM | Community-Based Forest Management |
| CBFMA | Community-Based Forest Management Agreement |
| cc | Cubic Centimeter |
| CDMP | Comprehensive Development and Management Plan |
| CENRO | Community Environment and Natural Resources Office |
| CFNR | College of Forestry and Natural Resources |
| CLO | Certificate of Lumber Origin |
| cm | Centimeter |
| CBFMS | Community-Based Forest Management Strategy |
| $CO_2$ | Carbon dioxide |
| CRMF | Community Resource Management Framework |
| CSIRO | Commonwealth Scientific and Industrial Research Organization |

| | |
|---|---|
| CSO | Clonal Seed Orchard |
| CV | Coefficient of Variation |
| CY | Calendar Year |
| DAO | Department Administrative Order |
| DANIDA | Danish International Development Agency |
| DBH | Diameter at Breast Height |
| DENR | Department of Environment and Natural Resources |
| DNA | Deoxyribonucleic Acid |
| DTI | Department of Trade and Industry |
| EMB | Environmental Management Bureau |
| EO | Executive Order |
| ERDB | Ecosystems Research and Development Bureau |
| FAO | Food and Agriculture Organization |
| FERD | Forestry and Environment Research Division |
| FLAg | Forest Land Agreement |
| FLGLA | Forest Land Grazing Lease Agreement |
| FLM | Forest Land Manager |
| FLMA | Forest Land Management Agreement |
| FLMP | Forest Land Management Program |
| FMB | Forest Management Bureau |
| FOB | Freight on Board |
| FRD | Forest Research Department |
| FSS | Forestry Statistics and Systems |
| G | Gram |
| GA | Gibberellic Acid |
| GIS | Geographic Information System |
| GNP | Gross National Product |
| GPS | Global Positioning System |
| GTI | Green Tropics International |
| ha | Hectare |
| HCl | Hydrochloride |
| $H_2O_2$ | Hydrogen peroxide |
| HP | Horsepower |
| HRDD | Human Resources Development Division |
| $H_2SO_4$ | Sulfuric acid |
| IAOP | Integrated Annual Operations Plan |
| IBA | indole-butyric acid |
| ICRAF | World Agroforestry Centre |
| IEC | Information, education and communication |
| IFMA | Industrial Forest Management Agreement |

| | |
|---|---|
| IFMP | Industrial Forest Management Program |
| IFPs | Industrial Forest Plantations |
| IRR | Internal Rate of Return |
| IRR | Implementing Rules and Regulations |
| ISR | Induce Systemic Resistance |
| ISTA | International Seed Testing Association |
| ITP | Industrial Tree Plantation |
| ITTO | International Tropical Timber Organization |
| IUFRO | International Union of Forest Research Organizations |
| JBIC | Japan Bank for International Cooperation |
| K | Potassium |
| kg | Kilogram |
| l | Liter |
| LGU | Local Government Unit |
| M | Million |
| m | Meter |
| $m^3$ | Cubic Meter |
| MAI | Mean Annual Increment |
| MAO | Ministry Administrative Order |
| masl | Meter above sea level |
| MAUS | Maintenance Activity Update Slip |
| MC | Moisture Content |
| Mg | Magnesium |
| ml | Milliliter |
| mm | Millimeter |
| Mo | Molybdenum |
| MBSFI | Manila Seedling Bank Foundation Inc. |
| N | Nitrogen |
| NAA | Napthalene-Acetic Acid |
| NALCO | Nasipit Lumber Co. |
| NaOCl | Sodium hypochlorite |
| NEDA | National Economic Development Authority |
| NFP | National Forestation Program |
| NGO | Non-Government Organization |
| NIPAS | National Integrated Protected Areas System |
| NPV | Net Present Value |
| NVS | Natural Vegetation Strips |
| OCTs | Original Certificate of Titles |
| OGA | Other Government Agency |
| ORED | Office of the Regional Executive Director |

| | |
|---|---|
| P | Phosphorous |
| PAI | Periodic Annual Increase |
| PBA | Predicted Basal Area |
| PCARRD | Philippine Council for Agriculture, Forestry and Natural Resources Research and Development |
| PCASTRD | Philippine Council for Advanced Science and Technology Research and Development |
| PD | Presidential Decree |
| PENRO | Provincial Environment and Natural Resources Office |
| PFDA | Private Forest Development Agreement |
| PFDF | Philippine Forestry Development Forum |
| PFDPIN | Philippine Forestry Development Programme in Ilocos Norte |
| PGPR | Plant Growth Promoting Rhizobacteria |
| pH | Acidity |
| PICOP | PICOP Resources Incorporated |
| PIR | Plantation Incident Report |
| PO | People's Organization |
| PTFI | Philippines Provident Tree Farms, Inc. |
| PTPOC | Private Tree Plantation Ownership Certificate |
| PWPA | Philippine Wood Producers' Association |
| $R^2$ | Coefficient of Determination |
| RA | Republic Act |
| RCBD | Randomized Complete Blocked Design |
| R&D | Research and Development |
| RD | Relative Density |
| RED | Regional Executive Director |
| RENRO | Regional Environment and Natural Resources Office |
| ROI | Return on Investment |
| RP | Republic of the Philippines |
| RTD | Regional Technical Director |
| S | Sulfur |
| SD | Standard Deviation |
| SEV | soil expectation value |
| SIFMA | Socialized Industrial Forest Management Agreement |
| SIFMP | Socialized Industrial Forest Management Program |
| SMF | Self-Monitoring Form |
| Sp; spp | Species |
| SPA | Seed Production Area |
| SPLTP | Special Private Land Timber Permit |

| | |
|---|---|
| SQ | Seed Quality |
| SQ | Sturdiness Quotient |
| SS | Seed Stands |
| SSO | Seedling Seed Orchard |
| TCTs | Transfer Certificate of Titles |
| TLA | Timber License Agreement |
| TSI | Timber Stand Improvement |
| UPLB | University of the Philippines Los Baños |
| USEC | Undersecretary |
| VAM | Vesicular-Arbuscular Mycorrhiza |
| YEAL | Year Elapsed After Logging |
| Y | Yield in cubic meters per ha |

# Introduction

There is more to reforestation, tree farming, and plantation development than just forest rehabilitation. Essentially, these are viewed as strategies to cope with the food, wood, energy, ecology, and poverty crises.

Four hundred years ago, the Philippine forest cover was estimated to be 92% or 27.5 million (M) hectares (ha) of the country's total land area. However, as the years went by, there was a systematic conversion of forestlands to agricultural lands to open and create lands for the swelling population. For instance, in the span of 77 years (1920–1997), forest cover of the country declined from more than 61% to less than 18% of the total land area. Figure 1 shows the increase in population and the resultant decrease in the forest cover.

In the 1969 and 1988 nationwide inventories, the average forest loss scored at 210,000 ha annually or 2 ha for every five minutes. Deforestation peaked in the mid-1970s when the annual loss was almost half million hectares.

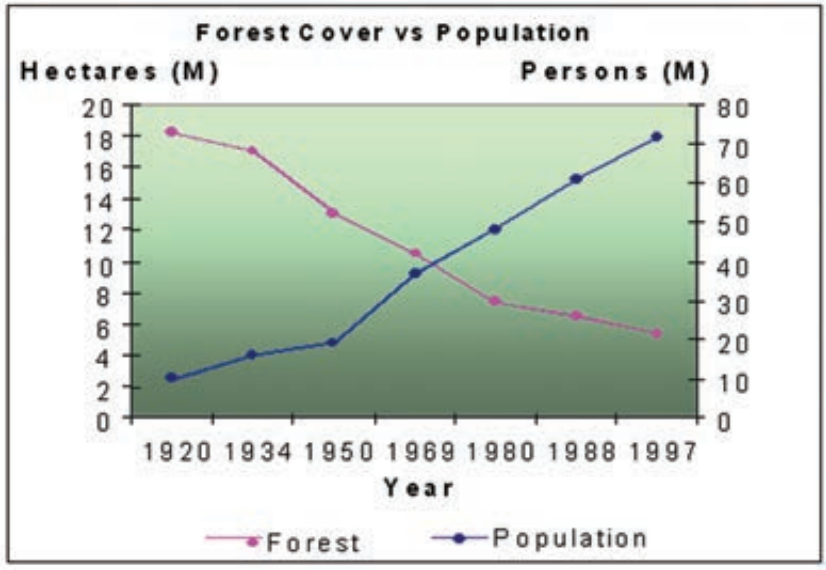



**Fig.1. P hilippine forest cover and population through the years.**

Forest losses were primarily attributed to logging during the late 1970s when the Philippine forestry sector contributed significantly to the national economy. Apparently, the exploitation of timber resources, illegal logging, and "kaingin" or shifting cultivation became rampant due to the increasing need for land for agricultural farming. Conversion of forests to other land uses also contributed to the decrease of forest cover and quality.

The alarming rate of forest destruction brought along adverse environmental consequences. The Environmental Management Bureau (EMB) in 1990 estimated that 8.4 M ha of land in the country are severely eroded. Soil erosion caused the siltation of rivers similar to that in the Cagayan Valley River basin (Conservation International, 2001). Loss of vegetative covers of watersheds resulted in extreme and unpredictable water routine. Forest destruction has also led to an increased atmospheric carbon emission that contributed to global warming/climate change. It has been assessed that the destruction of the world's forests contributes about 2 billion (B) tons (t) of carbon each year to the atmosphere (FAO, 2005).

Another adverse effect is the possible reduction of 52,177 described species in the country wherein 453 species are already listed in the 2000 International Union for the Conservation of Nature and Natural Resources (or World Conservation Union) Red List of Threatened Species (Ong et al., 2002; and Catibog-Sinha and Heaney, 2006). The continuous destruction and reduction of our forests may lead to the extinction of our major wildlife and game species.

Recognizing the urgency of the deforestation problem, the government, hand-in-hand with nongovernment and peoples' organizations, started the massive rehabilitation of the national forest in the late 1980s. The emerging interest of the people to venture into tree farming also started to gain ground. Forestation came to be viewed not only from the environmental perspective, but more popularly as a sustainable economic development strategy as well. This made the shift from the government reforestation to contract reforestation involving family and corporate groups, and the introduction of innovative schemes to involve the local people in the management of established plantations.

One main reason for the establishment of tree plantations is to augment the requirement of the wood-based industry (Carandang, 2000). Unless the establishment of industrial plantations and community tree farms is accelerated and given proper incentives from

the government, wood supply from natural forests would fail to meet the needs of the country. It would be inadequate to merely protect our forests if the demand for wood cannot be satisfied.

**Potentials of Reforestation, Tree Farming, and Plantation Development/Biodiversity and Environmental Considerations**

With the growing concern over the global problem on increasing greenhouse gases in the atmosphere, the role of trees in the removal of atmospheric $CO_2$ for the build-up of their biomass during the process of photosynthesis cannot be denied. The planting of trees to sequester atmospheric $CO_2$ has been considered to be the most effective long-lasting means and a significant approach to address the problem of increasing amounts of $CO_2$ in the atmosphere.

In addition, the planting of trees can fill in the need for environmental protection of watersheds in the production of water for domestic, irrigation, industrial, hydropower, and other important uses. Leaves and branches of planted trees intercept rainfall, thus reducing their erosive energy. The plants' roots and litter improve the soil structure and enhances infiltration of rainfall. Trees not only minimize the amount of eroded soil, but these also retard the rate of runoff. Erosion and subsequent sedimentation have a direct impact on watershed's water yield and quality. Trees also give better flood protection than a natural covering of undesirable brush and grass species.

**Economic Considerations**

Establishment of forest plantations provides an attractive and profitable undertaking for income opportunities and employment generation, while filling in the expected scarcity of wood from the natural stands.

Large volumes of roundwood were being produced in our country yearly for various end products used by the wood-based industries (Table 1).

A ready market for wood-based products, whether for local consumption or for export, is assured for those who want to invest in forestation. There are markets for logs for lumber and construction, veneer and plywood, wood chips for pulp and paper production, poles and piles, furniture, fruit and vegetable crates, woodcrafts, and

**Table 1. Roundwood production: 1994–2004 (in '000 $m^3$)[a].**

| Year | Grand Total | Logs | | | | Fuelwood/Firewood | |
|---|---|---|---|---|---|---|---|
| | | Total | Sawlog/ Veneer log | Pulp-wood | Poles & Piles | Upland | Charcoal |
| 2004 | 934 | 768 | 410 | 355 | 3 | 38 | 128 |
| 2003 | 699 | 506 | 349 | 151 | 6 | 39 | 144 |
| 2002 | 541 | 403 | 288 | 106 | 9 | 28 | 110 |
| 2001 | 713 | 571 | 319 | 241 | 11 | 58 | 84 |
| 2000 | 912 | 800 | 384 | 400 | 16 | 33 | 79 |
| 1999 | 860 | 730 | 568 | 160 | 2 | 49 | 81 |
| 1998 | 690 | 634 | 546 | 82 | 6 | 34 | 22 |
| 1997 | 593 | 556 | 241 | 312 | 3 | 25 | 12 |
| 1996 | 804 | 771 | 400 | 365 | 6 | 33[b] | - |
| 1995 | 868 | 758 | 589 | 167 | 2 | 105 | 5 |
| 1994 | 1,063 | 957 | 805 | 149 | 3 | 104 | 2 |

[a]2004 Philippine Forestry Statistics.
[b]Including charcoal.

wooden accessories, panel products (particle boards, woodwool cement boards), or firewood.

From 1994 to 2004, export earnings from wood products registered a yearly average of US$39 M (Table 2).

Among the primary products from tree farms and plantations, lumber has the greatest volume and value exported. This shows that there is a big opportunity to export more roundwood from tree farms and plantations considering that the country exported about 5,000 $m^3$ in 2001. Moreover, there is an increasing volume trend to locally supply roundwood to be processed into lumber for export.

Among the wood products, furniture has the most value in terms of export value or freight on board (FOB). Average export earnings of furniture, mostly made of wood, amounted to US$1 15 M annually. Average annual export earnings from other wood-based articles were US$132 M, and US$7 M for paper and paperboard. The traditional wood products (roundwood, lumber, plywood, and veneer) earn an average of US$2 M/year.

In 2004, the forestry sector contributed about ₱1.221 B at constant prices of 1985 or a 0.09% share to the country's gross national product (GNP). This record grew by 42.14% compared to the 2003 level at constant prices of 1985 (FMB, 2004).

The domestic demand for wood products is expected to increase considerably in the future due to the ever-increasing population. In this regard, massive establishment of commercial plantations will have to

**Table 2. Export of wood products FY 1994-2004 (In thousand US$, FOB)[a].**

| Year | Roundwood | | Lumber | | Plywood | | Veneer | | Other wood-based | Paper/ Board | | Furniture | | Total Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Vol ('000m$^3$) | Value | Vol ('000m$^3$) | Value | Vol ('000m$^3$) | Value | Vol ('000m$^3$) | Value | Value | Quantity (kilo) | Value | Quantity (pc) | Value | |
| 2004 | 2 | 60 | 124 | 9,737 | 42 | 15,466 | 7 | 3,251 | 121,679 | 136,420 | 78,774 | 4,599 | 225,525 | 454,492 |
| 2003 | A | 1 | 119 | 12,129 | 10 | 3,287 | 4 | 2,382 | 131,161 | 150,419 | 71,260 | 2,766 | 116,639 | 336,859 |
| 2002 | 1 | 43 | 91 | 10,267 | 7 | 3,029 | 6 | 3,089 | 112,534 | 175,375 | 72,522 | 4,235 | 222,774 | 424,258 |
| 2001 | 5 | 156 | 105 | 15,958 | A | 200 | 3 | 1,547 | 118,514 | 147,944 | 74,490 | 3,757 | 206,490 | 437,355 |
| 2000 | A | 16 | 120 | 20,457 | 2 | 2,056 | 5 | 2,962 | 213,610 | 134,096 | 91,398 | 4,416 | 260,518 | 591,017 |
| 1999 | A | 4 | 69 | 8,738 | A | 343 | 5 | 2,890 | 128,591 | 104,963 | 72,347 | 3,879 | 245,192 | 458,105 |
| 1998 | - | - | 41 | 5,543 | A | 80 | 32 | 11,784 | 77,285 | 113,500 | 78,587 | 4,057 | 235,361 | 408,604 |
| 1997 | 4 | 266 | 141 | 21,852 | A | 17 | 31 | 14,385 | 132,266 | 54,021 | 51,987 | 4,413 | 240,210 | 460,983 |
| 1996 | - | - | 145 | 23,196 | A | 78 | 26 | 12,856 | 150,013 | 30,486 | 52,620 | 4,453 | 220,654 | 459,417 |
| 1995 | - | - | 84 | 1,461 | A | 101 | 32 | 13,487 | 134,554 | 26,177 | 54,688 | 4,238 | 210,624 | 428,115 |
| 1994 | 4 | 207 | 37 | 6,116 | 4 | 2,101 | 30 | 11,891 | 130,049 | 12,590 | 33,232 | 4,105 | 183,317 | 366,913 |

[a]2004 Philippine Forestry Statistics.
A – less than 1,000 m$^3$.

be done both by the government and the private sectors to yield more logs than is necessary to meet the domestic demands (Carandang, 2000).

### Availability of Public Lands for the Establishment of Large Forest Plantations

At present, the country has enough potential lands for the establishment of quality forest tree plantations that can support raw material needs of the wood-based industries. Based on the Philippine Forestry Master Plan (1990), the country needs to develop at least 500,000 ha of quality forest tree plantations as the source of raw materials for the industry to be self-sufficient in plantation wood and surplus for export.

The country has large tracts of sub-marginal lands (475,100 ha) and brushlands (2.23 M ha), which could be used for the establishment of commercial plantations (FMB, 2002). This is attainable considering that in the last 20 years the average annual plantation development rate in the country was around 50,000 ha. However, both the government and the private sectors must invest on massive establishment of industrial tree plantations and on the protection and improvement of existing stands.

### Availability of Funding Mechanisms to Prospective Investors

There are banks (e.g., Development Bank of the Philippines and Land Bank of the Philippines) that provide loans to prospective investors who would like to venture into reforestation, tree farming, and plantation development. At present, there is a growing interest in tree farming and plantation development because of their bright economic prospects and income opportunities. Entrepreneurs can approach the Department of Trade and Industries (DTI) for assistance.

### Existence of Government Assistance Programs

The government has launched several national forestation programs. There are existing policies and various tenurial instruments governing different schemes on reforestation, tree farming, and plantation development.

## Availability of Forestation and Tree Farming Technologies

There are technologies available generated through research and development (R&D) by research institutions, the academe, and the private sector that can be used to enhance the production of forest plantations.

Research institutions can be tapped to provide technical assistance in the production of high quality planting materials of forestation species and appropriate development and management techniques to improve survival and increase productivity of forest plantations.

## The Philippine Experience in Reforestation, Tree Farming, and Plantation Development

Reforestation efforts in the country reached its peak in 1990 (Fig. 2) where a total of 191,663 ha were reforested. Of which, the government planted 80% of the area and the remaining by the nongovernment sector. In 2004, total reforestation efforts reached 15,088 ha with 61% of the area-planted by government and the rest by the nongovernment sector. The gap in attaining the average rate of established plantations is a reason and opportunity to further reforest and establish new tree farms and plantations.

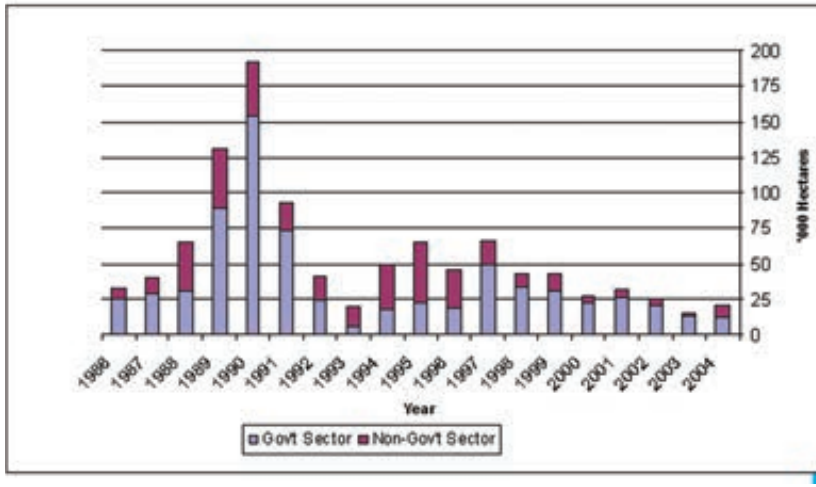



**Fig.2. Area forested by the government and nongovernment sectors, 1986-2004.**

Reforestation and tree farming, however, are plagued with biophysical, technical, socioeconomic, and institutional constraints. Biophysical constraints include:

- extremely acidic soils;
- poor nutrient content;
- high soil erosion;
- long dry season and erratic weather patterns;
- frequent occurrence of fires; and
- profuse growth of competing weeds.

For the technical part, the following conditions hinder successful planting activities (Carandang & Lasco, 1998):

- lack of high quality seeds;
- poor quality planting stocks;
- inadequate site characterization;
- poor species-site selection;
- limited species use; and
- absence of maintenance activities.

Socioeconomic conditions that can restrict successful forestation and tree farming may include the following (Cerna, 1993; Rebugio et al., 2005):

- lack of community participation;
- lack of interest by the private sector;
- limited technical capabilities of tree farmers;
- lack of organized production and marketing systems;
- lack of funds to support production; and
- unstable price of wood.

Institutional constraints to tree farming include (Rebugio et al., 2005):

- lack of security of tenure;
- unstable forest policies, particularly for harvesting and transport of harvested trees;

- inadequacy of extension services;
- limited credit assistance and infrastructure support; and,
- limited financial support from government and private institutions.

Lasco et al., (2006) synthesized these technical, policy, financial, management, governance, and socioeconomic constraints as follows:

- poor long-term maintenance due to limited funds and staff after project ends;
- lack of species-site matching;
- inconsistent or contradictory policies;
- limited funding or poor access to funding;
- delayed released of funds;
- lack of livelihood opportunities for upland farmers;
- lack of marketing support and farm-to-market roads;
- political interference;
- apathy of villagers to rehabilitation process; and
- peace and order problems.

# Seed Technology

Seeds by far are the most common and popular reproductive material used in the Philippines for reforestation and tree farming. For most species, seeds are produced in large quantities and are readily available, making them economical to use. As a reproductive material, seeds represent unique products of fertilization thus promoting genetic diversity (Schmidt, 2000). Lastly, seeds are relatively easy to handle and store unlike many vegetatively propagated propagules. Cognizant of this fact, seed technology of forest trees becomes essential in the reforestation and tree farming activities.

## High-Quality Seeds

- Collected from the best provenance or superior source. Correct seed source is essential for the production of quality stocks. A good seed source is genetically and physiologically fit for growth in the target planting sites and is regularly available in large quantities. Specifically, the genetic makeup of the seed is such that it will produce the required product or service in the target planting site. Genetic characterization, identifying the exactly genetic makeup of a mother tree, is not seriously carried out in the Philippines to an extent and level that accurately identify the genetic makeup of a mother tree. In most cases, phenotypic selection is resorted to. In the absence of facilities and capabilities to conduct intensive genetic characterizations, this practice could be employed.
- High viability. Seeds should germinate rapidly and uniformly.
- High vigor levels. Under a wide range of environmental conditions, particularly in field nurseries, high-quality seeds should be capable of germinating rapidly and uniformly.
- Free from seed-borne pests and diseases. The presence of pests and diseases in the seeds lowers germination rate and spreads infections to other healthy seedlings in the nursery.

- High physical purity. Good seeds are free from impurities (e.g., leaves, twigs, fruit parts, soil, stones, etc.). These impurities could contaminate seeds, which could lead to deterioration.

The factors contributing to seed quality are numerous and could be traced even before the production of the seed itself. Figure 3 shows the various factors influencing seed quality. Figure 4 is the scope of tree seed technology and shows the relationships of the various phases of seed technology. A seed quality control system is needed to insure high-quality seeds. It is composed of seed testing, certification, and legislation. Marketing of tree seeds is the business side of tree seed technology.

## Seed Collection

Seed collection entails the collection of fruits, cones, or seeds from the mother trees or from the ground. Loosely, purchase of seeds could be considered as a part of this general activity in tree seeds.

Proper seed collection involves the identification of the appropriate seed sources, correct collection dates, suitable collection methods (including equipment and skills required), proper care and handling prior to transport, and immediate transport to the processing site or

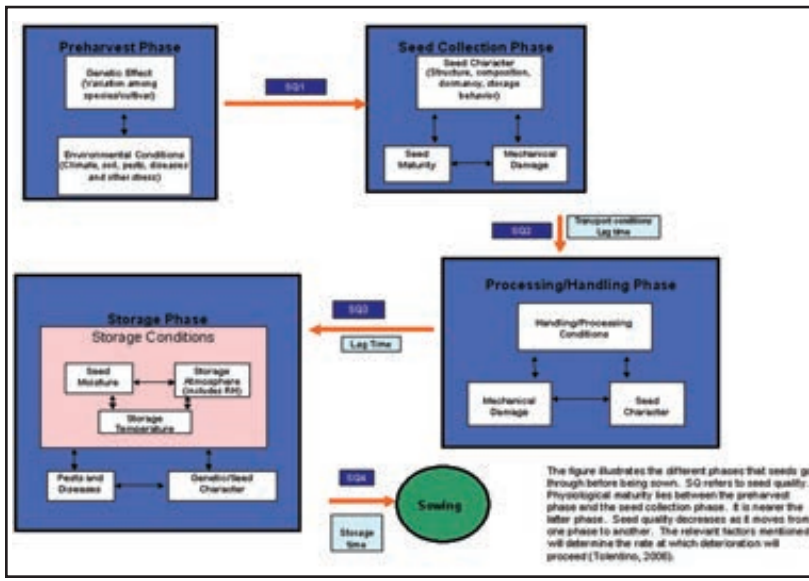



**Fig.3.F actors affecting seed quality.**

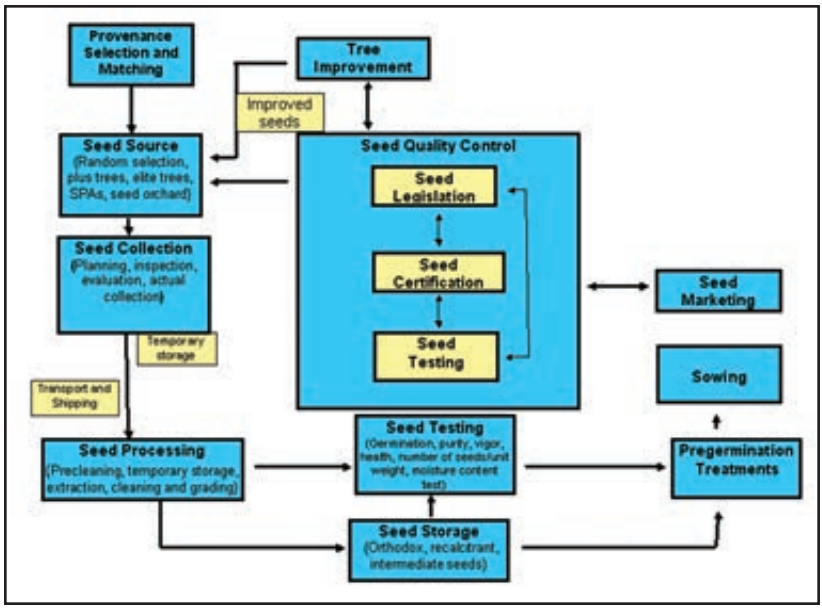



**Fig.4. The important phases of tree seed technology and their relationship to each other (Tolentino, 20 ) .**

nursery. This phase may also involve preliminary seed-processing activity.

An excellent field guide on proper seed collection, before, during, and after the activity was prepared by Dawson and Were (1997) and Mulawarman et al. (2003). Below are summarized pointers in the conduct of seed collection.

## Seed Sources

The potential sources of seeds for planting purposes are listed below:

1. Random trees in natural stands or plantations – these are any trees in the natural forests of plantations from which seeds are collected. They are generally poor, branchy, and stunted trees.
2. Seed trees – individual trees in the plantations or natural forests with superior phenotype (straight bole, rapid growth, healthy). If a rigorous grading has been conducted, these trees could be considered as select, superior, or plus trees.

3. Seed stands – group of trees either in natural forests or plantations exhibiting superior characteristics.
4. Elite tree - term reserved for selected trees that have been proven to be genetically superior by means of progeny testing.
5. Seed production areas (SPA) - a plus stand that is genetically upgraded and opened by removal of undesirable trees and then cultured for early and abundant seed production
6. Seed orchard - an area where seeds are mass produced to obtain the greatest genetic gain as quickly and inexpensively as possible; a plantation of selected clones or progenies, which is isolated or managed to avoid or reduce pollination from outside sources and managed to produce frequent, abundant, and easily harvested crops of seed.

Types of Seed Orchard

- Vegetative (clonal) - established using vegetative propagules such as grafts, cutting, and tissue-cultured plantlets.
- Seedling seed orchard - established by planting seedlings followed by a later roguing that will remove the poorest trees, generally leaving the best trees of the best families for seed production
- Seed orchard generations - Orchards maybe first, second, or advanced generations depending on the cycles of improvement these went through.

A comparison of the various seed sources and their corresponding seed quality is presented in Table 3.

**Seed Collection Time**

Timing of seed collection is critical to ensure that only the mature and best quality seeds are collected. Seed calendars are developed for this purpose. In the Philippines, Dayan (2005) prepared an excellent reference for determining the proper time of seed collection for 64 tree species, majority of which are indigenous species. Table 4 shows sample information that could be obtained from the aforementioned seed calendar.

**Table 3. Characteristics of various seed sources[a].**

| Characters | Seed Sources | | | | |
|---|---|---|---|---|---|
| | Seed Orchards | SPA | Seed Stands | Seed Trees | Unselected seed sources |
| Planting purpose | Seed production | Not for seed production | Not for seed production | Not for seed production | Not for seed production |
| Seed origin | Identified | Identified or unidentified | Unidentified | Unidentified | Unidentified |
| Quality of mother trees | Selected and tested trees | Selected stands, thinned, tested | Selected stands, unthinned (or thinned), untested | Selected trees from unselected stands | Selected trees from unselected stands |
| Seed quality | Very good | Good | Fairly good | Intermediate | Poor |
| Level of management | Very intensive | Intensive | Intermediate | Some | None |

[a]Mulawarman et al., 2003.

**Table 4. Seed calendar for selected species in the Philippines[a].**

| Species/Region | Specific Location | Collection Period |
|---|---|---|
| ***Acacia mangium*** | | |
| Region II | Diadi, Nueva Vizcaya | February |
| Region III | Mariveles, Bataan | December |
| | Fort Magsaysay, Nueva Ecija | March |
| | ANZAP, Mayantoc, Tarlac | April-May |
| | Masinloc, Zambales | November |
| Region IV | Victoria, Oriental Mindoro | February-March |
| | Ternate, Cavite | February-March |
| Region XII | Glan, Sarangani | December-January |
| CARAGA | NALCO | July |
| | PICOP | June-September |
| ***Eucalyptus deglupta*** | | |
| Region XII | Bagumbayan, Sultan Kudarat | January |
| | Malungon, Alabel, Glan, Sarangani | June |
| CARAGA | PICOP | September-October |
| ***Gmelina arborea*** | | |
| Region I | Ilocos Norte | May |
| | Manleluag Reforestation Project, Pangasinan | February-May |

**Table 4. (Continued).**

| Species/Region | Specific Location | Collection Period |
|---|---|---|
| | La Union | March-April |
| | Caniaw, Taleb, Bantay, Ilocos Sur | April |
| Region II (SPA site) | Magat, Diadi, Nueva Vizcaya | June-July |
| | Nagtipunan, Quirino | June-July |
| | Solana, Cagayan | June-July |
| Region III (SPA) | Mariveles, Bataan | June |
| Region IV-A | Pagbilao, Quezon | May-June |
| | Mt. Makiling, Laguna | May-June |
| Region IV-B | Palawan Experimental Forest Brgy. Bagumbayan, Puerto Princesa | June-July |
| Region VI | Capiz, Iloilo | June |
| | Culasi, Antique (SPA) | June |
| Region VII | Osmeña Reforestation Project, Cebu City | June-July |
| | Central Cebu Reforestation Project, Cebu City | June-July |
| Region VIII (SPA) | Nagaasan, Babatngon, Leyte | June-July |
| Region IX (SPA) | Dipolog, Zamboanga del Norte | June-July |
| Region X (SPA) | Malaybalay, Bukidnon | June-July |
| Region XI (SPA) | Nabunturan, Davao del Norte | July |
| | Sto. Tomas, Davao del Norte | July |
| Region XII | Esperanza-Tacurong, Sultan Kudarat | July |
| CARAGA | Agusan | April |

[a]Dayan et al., 2005.

The calendar is useful for planning seed collection period, but not for specifically determining the exact date(s) of collection. For this purpose, the methods of determining seed or fruit maturity is necessary.

For practical purposes, color change is the most common and widely used method of determining seed/fruit maturity. Color changes from dull green to bright colored fruits/seeds (yellow, brown, or black). Changes in texture or smell are also convenient methods of knowing mature seeds/fruits. More sophisticated but accurate methods are available to assess fruit maturity. Practical methods of determining seed maturity were listed by Schmidt (2000) and are presented in Table 5.

The most accurate method of determining seed maturity is the moisture content (MC) method, particularly for orthodox species. This is the point when the seeds have attained the maximum dry weight and the nutrients have stopped flowing from the mother tree to the seed (Wilan, 1985). While it is accurate, the practical application and

**Table 5. Practical methods of determining maturity of seeds[a].**

| Maturity Event | Method of Examination |
|---|---|
| Color change:<br>Dry fruits: green to yellow, brown, black etc.<br>Fleshy fruits: green to conspicuous | Visual |
| Dehydration (dry fruits) | • Visual, touching or 'weighing' in the hand<br>• Measurement of specific gravity |
| Dehiscence and abscission | • Observation of fruit fall or opening of dehiscent fruits<br>• Shaking or beating fruit-bearing branches<br>• Beating or manual splitting of dehiscent fruits<br>• Examination of opening structures in dehiscent fruits, (e.g., valves, scales, and margin)<br>• Breaking of fruit stalks |
| Hardening of fruit/seed coat | Cutting, pricking, breaking of seed or fruit coat |
| Hydration (fleshy fruits). Softening of fruit flesh | Squeezing |
| Loosening of fruit pulp (fleshy fruits) | Squeezing, rubbing or other separation of fleshy part from seed or endocarp |
| Accumulation of sugar substances (fleshy) | Taste (careful as some fleshy fruits are poisonous to humans); Observation of visiting frugivores |
| Endosperm and embryo development of seed | Cutting of seed |

[a]Schmidt, 2000.

economic implications of the method prohibits its widespread use in developing countries like the Philippines. A grain moisture tester developed locally could be calibrated for possible use for tree species in the Philippines. Research on the appropriate moisture for collection of these tree species is currently unavailable. X-rays, chemical content, and liquid flotation methods are also other alternatives for determining seed/fruit maturity, but they are not practical and economical considering the current condition of the country.

## Seed Collection Methods

Choosing the suitable method of seed collection depends on the factors related to the location of seed source, condition of the stand, individual trees, and type of fruits or seeds and their maturity (Schmidt, 2000). Table 6 shows the recommended methods for collecting commonly planted tree species in the Philippines (Dayan et al., 2005).

**Table 6. Seed collection methods for commonly planted tree species in the Philippines[a].**

| Species | Collection Method |
|---|---|
| *Acacia mangium* | Climb the tree and handpick the fruit or clip the fruit from the tree with pruning poles when they change from dark brown and begin to crack open. |
| *Eucalyptus deglupta* | Climb the tree and handpick the fruit or use a bamboo pole with a scythe to cut the branchlets bearing the fruit. |
| *Gmelina arborea* | Climb the tree and handpick the fruit or use a bamboo pole with a scythe to pick the fruit. Collect newly fallen fruit from the ground. |
| *Paraserianthes falcataria* | Collect the fruit/pod before the release of seeds, or when the pod turns light brown using a bamboo pole with a scythe. |
| *Pterocarpus indicus* forma *indicus* and *Pterocarpus indicus* forma *echinatus* | Climb the tree and handpick the pods or use a bamboo pole with a scythe. |
| *Swietenia macrophylla* | Climb the tree and handpick the fruit or use a bamboo pole with a scythe. |

[a]Dayan et al., 2005.

This same reference compiled collection methods for 64 tree species, majority of which are indigenous tree species.

After collection, seeds are ideally processed or transported to the nursery. However, for seed collections involving large quantities in one site, this may not be possible. Thus, a lag time between collection and processing develops. The longer the unprocessed seeds remain in the field, the more danger of deterioration due to improper handling and storage. Orthodox seeds should be maintained under cool and dry conditions. Proper ventilation is necessary. Loosely weaved sack clothes are preferred seed/fruit containers and plastic bags should be avoided. Recalcitrant seeds (e.g., dipterocarps) should be protected from desiccation thus the use of plastic bags is recommended.

If temporary storage of seeds in the field is required, then the recommended conditions for the specific types of seed behavior are necessary. Storage in the shade with adequate ventilation (e.g., hanging the sacks on support poles or use of improvised hammocks) is recommended for orthodox seeds. Sun drying of orthodox species could also be employed. On the other hand, recalcitrant species should

be maintained under moist conditions but protected from possible decay.

Proper documentation of the collected seeds is an important practice that should be maintained. This insures that excellent sources are adequately conserved and propagated. Seed documentation includes: species name, date of collection, place of collection (Global Positioning System [GPS] fixes are ideally recorded), collector(s), and stand conditions (number of trees from which seeds are collected, distance between mother trees). Labeling of collected seeds, particularly those collected from selected mother trees, should be made. Labels should be made inside and outside of the container using durable materials (plastics) and indelible ink.

Immediate transport of collected seeds or fruits is also essential to prevent any or further seed deterioration. The following precautions should be observed during transport to maintain seed quality: 1) use of durable or sturdy containers to protect seeds with soft or thin seed coats from mechanical damage; 2) provide adequate ventilation especially for orthodox seeds, closed vans are not recommended; 3) protect seeds from direct sunlight, particularly recalcitrant species; and, 4) keep recalcitrant seeds moist and avoid desiccation (Schmidt, 2000). A directory of selected sources of seeds is in Appendix 3.

**Table 7. Seed processing methods for commonly planted tree species in the Philippines[a].**

| Species | Seed Processing Method |
|---|---|
| *Acacia mangium* | Sun-dry the pods; extract the seeds manually. Air-dry the seeds under the shade to reduce MC to 7%. |
| *Eucalyptus deglupta* | Sun-dry the fruit on a double-layered, 1/8 mesh wire screen. The fruit would then dehisce. Rub the fruit slightly against a wire to get the seeds. |
| *Gmelina arborea* | Soak the fruit in tap water for two days. Then macerate it under running water to clean the seeds. Air-dry the seeds to lower the MC to 7–8%. |
| *Paraserianthes falcataria* | Sun-dry the pods to release the seeds. Then air-dry the seeds up to 6–7% MC before storage. |

**Table 7. (Continued).**

| Species | Seed Processing Method |
|---|---|
| *Pterocarpus indicus* forma *indicus* and *Pterocarpus indicus* forma *echinatus* | Sun-dry the fruit to make the capsule brittle. Extract the seeds manually. Alternatively, the fruits are simply dewinged and sown as a fruit. |
| *Swietenia macrophylla* | Sun-dry the fruit to enhance the breaking up of capsules. Extract the seeds manually; remove the wings. Air-dry the seeds to reduce MC to 5–7%. |

[a]Dayan et al., 2005.

## Seed Processing

After the fruits are transported, prompt processing is required. Seed processing prepares seeds for either sowing or storage. Pure and clean seeds are the end-product of the procedure(s) (Table 7).

### Techniques/Methods in Seed Processing

Depending on the fruit type or characteristics, fruits/cones could undergo any of the following procedures during processing to obtain pure and clean seeds.

- Pre-cleaning and storage – when the fruits/cones are received in the nursery or processing plant, they are not immediately processed, thus some precleaning and temporary storage is necessary.
- Extraction – the separation of the seed from the fruit and may require any of the following procedures (Table 8):

    1. drying;
    2. tumbling;
    3. threshing;
    4. depulping (maceration); and
    5. separation.

**Table 8. Summary of extraction methods for various fruit types[a].**

| Fruit Type | Extraction Procedure |
|---|---|
| Dry dehiscent fruits (dehiscent pods, follicles and capsules and cones) (pines eucalypts and most Leguminosae) | Drying ⇒ shaking/tumbling |
| Dry indehiscent fruits (indehiscent pods of *Acacia nilotica* and *A. sieberiana)* | Drying ⇒ threshing |
| Serotinous fruits (cones, capsules plus some dry compound fruits) | Kiln heating ⇒ tumbling<br>Scorching ⇒ tumbling |
| Fleshy fruits with very thin pulp (*Vitex* spp. and *Ziziphus* spp.) | Drying<br>Soaking ⇒ maceration ⇒ washing |
| Fleshy fruits with soft pulp (*Prunus, Olea, Ficus)* | Soaking ⇒ fermentation ⇒ washing<br>Soaking ⇒ maceration ⇒ washing |
| Fleshy fruits with soft, fibrous pulp (*Gmelina)* | Soaking ⇒ maceration ⇒ washing ⇒ abrasion/polishing |
| Fleshy fruits with felty pulp (*Tectona grandis, Sclerocarya* spp. and *Vitex* spp.) | Soaking ⇒ abrasion/polishing |

[a]Schmidt, 2000.

- Cleaning – after seed extraction, there are fruit parts (e.g., wings) that remain attached to the seed which may interfere with sowing or storage. The following cleaning procedures could be used to yield pure clean seeds:

  1. dewinging;
  2. screening/sieving;
  3. sorting according to length;
  4. blowing;
  5. liquid flotation;
  6. friction cleaning;
  7. specific gravity separation;
  8. electronic and electrostatic separation;
  9. magnetic separation;
  10. electronic color separators; and
  11. shaking.

- Seed upgrading - Many people clean their seeds but never upgrade. Upgrading does not make good seeds from bad but can certainly improve seedlot. It improves the potential performance of a seedlot by removing empty, damaged, weak, immature, or odd-sized seeds. There are several methods of seed grading but the simplest and most economical is floatation in water.

## Seed Storage

When seeds are collected at the time, which does not coincide with the required sowing time[1], seeds should be stored to preserve seed quality. Storage under this condition is generally from a few days to a few months. There are species, which exhibit seed periodicity or seed masting and when they produce abundant seeds, the excess seeds should be stored in optimum condition so that seeds could be made available during seed-off years. This is a medium-term storage period lasting for about 3~~5~~ years. Seed storage is also used as a strategy for genetic resources conservation when the practice and facilities for such need are available. This is the longest storage period, which could range for five or more years.

### Classification of Storage Behavior

Storing seeds require adequate understanding of its storage behavior. Below are the commonly accepted storage behaviors of tree seeds and specific examples (Schmidt, 2000; Dayan et al., 2005) (Tables 9 and 10):

**Table 9. Storage behavior of seeds and their recommended storage moisture content and temperature[a].**

| | Orthodox Seed | Intermediate Seed | Temperate Recalcitrant Seed | Tropical Recalcitrant Seed |
|---|---|---|---|---|
| Storage MC | Low | Low | High | High |
| Storage temperature | Low | High | Low | High |

[a]Schmidt, 2000.

**Table 10. Summary of behaviors of the orthodox, recalcitrant, and intermediate seeds.**

| Seeds | Behavior |
|---|---|
| Orthodox | • Easiest to store<br>• Allows even ambient storage<br>• Controlled conditions (MC and temperature) allow long-term storage.<br>• Mis-classified recalcitrants are actually orthodox if improved harvesting and processing techniques are used.<br><br>**Seed moisture and air humidity**<br>• High moisture and temperature favors the development of molds. MC of <10% and <10% °C conditions arrest growth of fungi.<br>• Seeds should be stored at 5–10% MC.<br>• Sealed (airtight) storage prevents re-absorption of moisture. Vacuum storage is recommended. When this is not possible, leaving as little airspace as possible minimizes the absorption of moisture from the air that could be inside the storage containers.<br>• Frequent opening of the airtight containers should be avoided. When sampling needs to be done, individual small packs of weighed (or counted) seeds could be prepared to avoid opening the whole batch of seeds.<br><br>**Temperature**<br>• Low MC would allow storage even under ambient conditions. Protection against pests and diseases is important under these conditions.<br>• Cold storage is expensive.<br>• Cold storage may be practiced for sensitive seeds and for very expensive or rare seeds.<br><br>**Atmosphere**<br>• Reduction in oxygen pressure (replacement by $N_2$ or $CO_2$) has little effect on seed longevity as long as temperature and MC are kept low.<br>• Replacement of $O_2$ is an effective seed treatment against pests and diseases.<br><br>**Containers**<br>• Orthodox seeds dried to low MC should be stored in sealed (airtight) containers.<br>• Examples of containers are glass jars, bottles, jerry cans, metal tins, and drums. |
| Recalcitrant and intermediate seeds | • Desiccation sensitive. Lowest safe MC is 60–70% for some extremely recalcitrant species and 12–14% for some intermediate species.<br>• Chilling sensitive. Injury depends on species, MC, and possible duration of chilling. For sensitive species, chilling injury may occur below 20°C. Some species are tolerant of low temperatures (2 – 5°C).<br>• Metabolically active when shed<br>• No dormancy |

- Orthodox - seeds that could be dried to low MC (5–8% MC, fresh weight basis) and tolerate low temperatures (<10°C), even subfreezing temperatures. Examples are pine, narra, bagras (*Eucalyptus),* acacia, gmelina, and molave.

- Recalcitrant - seeds that could not be dried below a relatively critical MC (30% [desiccation intolerant]) and could not tolerate low temperatures (<10°C). Examples are dipterocarps, *Theobroma cacao, Durio zibethinus, Lansium domesticum, Nephelium lappaceum, Artocarpus heterophyllus, Agathis philippinensis, Diospyros philippinensis, Palaquium luzoniense,* and mangrove species. Storage for these kinds of seeds is very much different with the orthodox seeds. Although differences between the recalcitrant and the intermediate seeds exist, some common traits will allow the discussion of the storage methods as a group.

- Intermediate - does not follow the above storage behavior. Longevity of dry seeds (7–10% MC) is reduced with reduction in storage temperature below about 10ºC. Examples are *Averrhoa carambola, Carica papaya, Polyscias nodosa, Azadirachta indica, Calophyllum inophyllum, Lagerstroemia speciosa, Toona calantas,* and *Swietenia macrophylla.*

**General Guidelines, Practices, or Considerations (Schmidt, 2000)**

- Store seeds at lowest possible temperature that will not damage the seeds.
- Store seeds at lowest possible moisture that will not damage the seeds.
- Eliminate as many pathogens as possible before storage.
- Protect seeds from pathogens during storage.
- Store in the dark.
- Store orthodox and intermediate seeds with low MC in airtight containers.
- Store recalcitrant seeds in material permeable to gases but with retention of moisture.

## Seed Dormancy and Pretreatments

Many forest tree seeds fail to germinate upon sowing due to seed dormancy. This could be expressed either by delayed or staggered germination. This could be due to hard seed coat, mechanical restrictions to the emerging embryo, physiological, or chemical causes. Such phenomenon could disrupt nursery stock production schedules and planting operations. Consequently, there is a need to neutralize seed dormancy to effect rapid and uniform seed germination. Table 11 enumerates the recommended pretreatments to neutralize seed dormancy of selected tree species (Dayan et al., 2005). Other information could also be found in Salim et al. (1998).

Other species like mahogany, bagras, and many dipterocarps do not require pretreatment except for removal of wings.

## Seed Quality Assessment

The science of evaluating the planting value of seeds in order to minimize the risks of planting low quality seed is termed as seed testing. Below is a brief discussion of the different seed quality tests, their objectives, and procedures obtained from various sources (Schmidt, 2000; Poulsen, 1994; and Edwards, 1987).

### Purpose of Seed Testing

Before collection:
- Assess crop (e.g., will collection be worthwhile?)
- Test maturity (establish optimal time for collection)

During processing, determine the need for the following:
- after-ripening
- drying
- cleaning

After processing, determine the following:
- if seed is suitable for plant production
- the potential for production of viable plants from the seedlot
- if dormancy releasing treatment is needed
- the appropriate sowing density

**Table 11. Pretreatments in neutraliz ng seed dormancy.**

| Species Name | Germination Pretreatment |
|---|---|
| *Acacia auriculiformis* | Soak the seeds in boiled water for 3–4 minutes, then in tap water overnight; or soak the seeds in boiled water until the water turns cold for 24 hours (for stored seeds). Soak the seeds in tap water overnight (for newly collected seeds). |
| *Acacia mangium* | Soak the seeds in boiled water for 3–4 minutes, then in tap water overnight (for stored seeds); or soak the seeds in boiled water until the water turns cold for 24 hours. Soak the seeds in tap water overnight (for newly collected seeds). |
| *Aleurites moluccana* | Crack the seed coat and soak the seeds in tap water overnight. |
| *Calliandra calothursus* | Soak the seeds in hot water (70°C) for 10 minutes, then in cold water for 12–24 hours (for large volumes). Nick the seed coat and soak the seeds in tap water overnight (for small volume). |
| *Gliricidia sepium* | Soak the seeds in tap water overnight. |
| *Gmelina arborea* | Soak the seeds in tap water overnight. |
| Smooth narra and Prickly narra | Soak the seeds in tap water overnight (for small quantities). Nick the seed coat then soak the seeds in tap water overnight (for large quantities). Cut the edge of the samara and soak it in tap water overnight (for mass propagation) |
| *Paraserianthes falcataria* | Soak the seeds in boiled water for three minutes and let water cool for 24 hours. |
| *Samanea saman* | Nick or cut the seed coat and soak the seeds in tap water, or in 0.02% fungicide solution overnight (for small volume of seeds). Soak the seeds in concentrated sulfuric acid for 30 minutes, and rinse them with tap water several times. Soak the seeds in tap water, or in 0.02% fungicide solution overnight (for large volume of seeds). |
| *Vitex parviflora* | Cut the apical portion of the seed and soak the seeds in tap water, or in 0.02% fungicide solution overnight (for small volume of seeds). Treat the seeds with 5% HCl and 10% $H_2SO_4$ for 10–30 minutes and soak the seeds in tap water overnight (for large volume of seeds). |

- if seed suitable for storage
- the price of the seed – seed trade

## Sampling

Sampling aims at obtaining a sample size suitable for tests, in which the probability of a constituent being present is determined only by its level of occurrence in the seedlot.

**Sampling intensity and size.** Minimum requirements as prescribed by the International Seed Testing Association (ISTA) for sampling intensity of primary samples are in Table 12.

**Table 12. Sampling intensity guide.**

| | |
|---|---|
| Up to 5 containers | Sample each container. Always take at least 5 primary samples |
| 6–30 containers | Sample 5 containers or at least 1 in every 3 containers, whichever is greater |
| 31–400 containers | Sample 10 containers or at least 1 in every 5 containers, whichever is greater. |
| 401 or more containers | Sample 80 containers or at least 1 in every 7 containers, whichever is greater. |

**Seed trier.** It is a probe, long enough to reach all areas of the container and designed to remove an equal volume of seed from each area through which it travels; also named stick sampler (Fig. 5).

**Random cup divider.** This could be a manual procedure for sampling small seed lots. Several cups are placed on top of the table, then seeds are scattered uniformly in the table. Those caught by the cups are used as seed samples.

## Purity Analysis

To determine the composition by weight of the sample being tested.

Procedure:

- Working sample should contain at least 2,500 seeds.
- Obtain the total weight of the working sample.

**Fig.5. Seed trier.**
*(DANIDA Forest Seed Centre in Wilan,* .

- Separate working sample into pure seed, other seed, and inert matter and get their individual weights.

  - Pure seed - It includes undersized, shriveled, immature, and germinated seed, provided they can be definitively identified as the species under consideration. It also includes seed pieces resulting from breakage that are more than half their original size.

  - Other seed - A pure seed of other species.

  - Inert matter - Comprises seed-derived structures like seed-wings, as well as other matter not defined as pure seed.

$$\% \text{ Purity} = \frac{\text{Weight of pure seed fraction}}{\text{Total weight of working sample}} x\,100$$

**Number of Seed per Unit Weight Test**

To determine the number of seeds per kilogram.

- Allows calculation of weight of seed to be sown
- Seed weight is positively related to seed quality.

Procedure:

- The procedure for calculating the number of seed per kilogram is presented in Appendix 4.

**Moisture Content**

- Crucial during seed storage and handling
- Determines the biochemical and physiological activity of the seed

*Low constant temperature oven-method*

- Prior to drying it is recommended to cut tree seed larger than 10 mm diameter into 4–5 pieces to promote complete drying.
- Two samples (replicates) are dried in two containers for 17±1 hours at 103±1°C. Weights could vary from 5 g to 50 g, depending on seed size.
- Do not overload with samples.
- After drying, the containers are immediately transferred to a desiccator and allowed to cool.
- Weights are expressed in three decimal places (use analytical balance).
- Moisture is expressed on a fresh weight basis:

$$\%\,MC = (M_2 - M_3) \times \frac{100}{(M_2 - M_1)}$$

where:

$M_1$ = weight of container in grams;
$M_2$ = weight of container and its content in grams before drying; and,
$M_3$ = weight of the container and its content in grams after drying.

- The results are averaged and the MC expressed to one decimal place.
- Tolerance limits between replicates should be followed as suggested below. Tests are repeated when the limits are exceeded (Table 13).

**Table 13. Tolerance limits for the moisture content test[a].**

| No. of Seeds/kg | Initial Moisture Content (%) | | |
|---|---|---|---|
| | <12 | 12–25 | >25 |
| > 5000 | 0.3 | 0.5 | 0.5 |
| < 5000 | 0.4 | 0.8 | 2.5 |

[a]Poulsen, 1994.

## Germination Test

Establish the maximum number of seeds that can germinate under optimum conditions in terms of light, moisture, and temperature.

Why use standardized ideal conditions?

- Difference between results can be ascribed to true difference between seed samples and not to different test methods.
- Results obtained from a given seedlot in one laboratory should be identical to results obtained in any other laboratory, and results are reproducible.

    - The germination capacity is not equal to the field nursery germination, but in most cases the two figures are strongly related.

*General Principles*

- Consists of four replicates at 100 seeds per replicate.
- Uniformly spread the seed, 1.5–5 times the seed width.
- Multigerm units (e.g., *Pterocarpus indicus*) are not broken but tested as a single seed.
- Very small seed (e.g., *Eucalyptus)* are tested by weight, four replicates of 0.1–1.0 g. Germination is expressed as number of germinants per gram.
- ISTA prescribes period of light, day and night temperatures, test duration, type of substrate, and pretreatment method.

- Germination is defined as the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether or not it is able to develop further into a satisfactory plant under favorable conditions in the soil.

*Classification of Germinants*

- Normal germinants – intact seedlings with all essential structures (i.e., root, shoot axis, cotyledons, terminal bud) complete, healthy, and well-developed. Included also are seedlings with slight defects but capable of developing into satisfactory plants, and seedlings which have been infected secondarily.
- Abnormal seedlings – seedlings, which are discolored, glassy, split, broken, stunted, twisted, with missing parts, etc.
- Hard seeds – did not absorb water due to impermeable seedcoat.
- Fresh seeds – other than hard seeds, which failed to germinate but remain clean and firm and probably have the potential to germinate.
- Dead seeds – seedlings, which at the end of the test have failed to germinate and are neither hard nor fresh.
- Empty seeds - seeds without cotyledon/endosperm and embryo.
- Insect-damaged seeds -seeds infested by insects.

**Indirect Tests of Viability**

Rapid methods of assessing seed viability are also employed, particularly in cases where quick tests results are necessary. Below are examples of these rapid tests.

- Cutting Test
  - Simplest and fastest using a knife or scalpel
  - Good seed – endosperm is of normal color and texture with well-developed embryo
  - Overestimates viability

- Topographical Tetrazolium Test
  - Distinguishes between living and dead tissues
  - Uses 2,3,5-triphenyl tetrazolium chloride (or bromide); reacts with hydrogen ion (produced only in areas where

dehydrogenases are active – respiratory enzyme to form a red-colored triphenyl formazan.
- Seeds imbibed to make the enzymes active.
- Soaked at 25–30°C in a 0.5–1% solution of the chemical for 6–24 hours.
- Seed coat maybe removed, cutting/exposing the embryo to allow penetration of solution.
- Protect from light during the soaking time.
- Seeds washed after staining and the staining pattern is evaluated.

• Hydrogen Peroxide ($H_2O_2$) Method
  - Simple and economical.
  - Biochemical basis uncertain, but it could be that $H_2O_2$ enhances the early phases of germination by increasing the ambient oxygen level thus stimulating respiration.
  - Sample (e.g., 100 seeds in 4 replicates) soaked overnight in 1% $H_2O_2$ solution.
  - For medium and large seeds, 150–200 ml solution is required. Nicking maybe required.
  - Place seeds in the solution in the dark at alternating temperatures of 20 °C and 30°C.
  - Replace with fresh solution after 3–4 days.
  - Evaluation is done after 7–8 days.

• Excised Embryo Test
  - Used for slow-germinating or dormant seeds.
  - Performed on 400 seeds, some seeds used as replacement for damaged seeds.
  - Seed is imbibed followed by embryo excision.
  - Moderately aseptic working conditions, use 70% alcohol solution.
  - Fruit or seed could be sterilized using 5% NaOCl for 15 minutes then washed thoroughly.
  - Embryos are placed in petri dishes lined with filter and incubated at 20–25 °C for up to 14 days with an 8-hour light regime.

- X-ray Test

    - X-ray radiography is a quick and nondestructive test to determine or distinguish filled, empty, insect- and physically damaged seed, degree of seed development, number of seeds in a fruit, and viability.
    - Contrast agents could be used like BaCl or chloroform.

**Seed Health Test**

Determines the health status of a seedlot.

Importance

1) Seed-borne inoculum may give rise to progressive diseases in the nursery/field and may reduce the commercial value of the crop.
2) Imported seedlots may introduce diseases into new regions; test to meet quarantine requirements may therefore be necessary.
3) Seed health testing may provide seedling evaluation and supplement germination testing.

# Nursery Development and Management

## Nature and Importance of Forest Nursery

The forest nursery is a place or establishment for raising or handling of young forest tree seedlings until they are ready for permanent planting. A good nursery employs the best nursery practices. The objective of the best nursery practices is to produce high-quality seedlings (i.e., seedlings fit for the purpose of planting) of the desired species employing the most cost-effective, environment-friendly, and socially acceptable technologies in sufficient quantities available during the prescribed planting season.

One of the major reasons for the failure of many reforestation programs is the use of inferior planting stocks. Frequently, the planting programs simply fulfill its planting goals irrespective of the quality of the stocks used. Consequently, inferior stocks that are normally significant in numbers fail to survive, and if ever they do, the resulting seedlings develop poorly.

There are several reasons for establishing forest nurseries. Some of the identified reasons are as follows:

- Flowering and subsequent seed production of most tree species are irregular;
- Some planting sites are not suitable for "direct seeding";
- Nurseries provide maximum care and attention to plants during germination to seedling stage, the most critical period of plant development;
- Abundant seed crops during seed years are taken advantage of; and
- Only the best quality seeds are used for nursery propagation, hence, producing the best or most vigorous and healthy seedlings.

## Classification of Forest Nurseries

Nurseries could be classified according to its objective of production, serviceability, facilities available, level of management and personnel involved, and the institutions or groups administering the nursery. The general categorization of the nurseries in the Philippines is as follows:

- **Permanent Nursery** (Fig. 6). It is a large nursery that can accommodate huge number of seedlings produced for several years (>500,000 seedlings; > 5 years) usually managed by professional foresters. It is built with permanent structures located in the central area, which is accessible for transportation. This type is mostly government or institutional nurseries.

- **Temporary Nursery.** It is also known as subsidiary or satellite or small nursery, capable of producing limited number of planting stocks for a particular plantation area, which is abandoned afterwards. Is usually located adjacent to the plantation area having no permanent structures.

- **Research Nursery** (Fig. 7). It is the type of nursery wherein the major objective is generation of technologies/knowledge for planting stock production instead of seedling production. It is small but with permanent structures and sometimes with sophisticated equipment for research in some cases. It involves intensive management or operations manned by researchers and usually based on institutions either government or private companies. Being an institutional nursery, its serviceability is dependent on the life of the institution.

- **Community/Family/Individual Nursery.** This is used for community forestry projects by people's organization, individual farmers, or families (Fig. 8). It is a small nursery with temporary structures. It could be a family enterprise wherein management is not intensive.

**Fig.6. A permanent nursery producing millions of seedlings.** *(E.L. Tolentino,J r.)*

**Fig.7. Research nurseries in the Philippines.** *(E.L. Tolentino,J r.)*

**Fig.8 A communal nursery in Mindanao.** *(E. L. Tolentino,J r.)*

- **Commercial Nursery** (Fig. 9). It is the type of nursery wherein seedling sales is the primary objective. Usually, the quantity and species raised are demand driven.

**Fig.9 An example of a commercial nursery where seedling sales is the primary objective.** *(E. L. Tolentino,J r.)*

## Nursery Site Selection

There are factors to be considered in selecting an ideal site for a forest nursery mainly for institutional or large nurseries although some factors are critical even for nurseries of smallhold tree farmers (Agpaoa et al., 1976; PCARRD, 1992; Tolentino, 2006).

### Water Supply

The adequacy of water supply during the dry season should be determined. During this season, the streams have the least amount of water, and the plants have the highest demand for water. In addition, water loss both from soil and seedlings is at its peak. If the supply of water during summer is not enough, a storage tank should be constructed. Generally, for a planting area of 100 ha, a tank capable of holding 4,000 L (2 m x 2 m x 1 m) water would be sufficient.

The amount of water needed depends on the size of the nursery, kind of soil, species to be raised, quantity of seedlings, and method of watering to be employed. More water is needed in porous and sandy soils than in clayey soils, since the former have lower water-holding capacity than the latter.

For permanent nurseries, it is recommended to install an overhead water system (sprinkling) by conducting water to the nursery through pipes and distribute it over the seedlings as a fine spray (Fig. 10). The

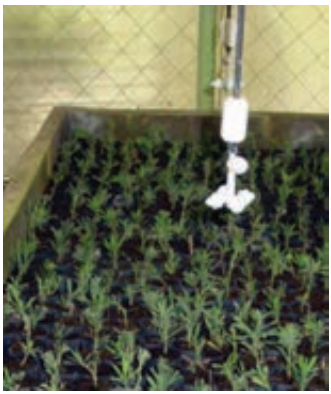


**Fig.10 Overhead sprinkler**
*(A.M. Foronda).*

kind of sprinkling system that can be employed will depend on the operating pressure in the pipe. A low-pressure system can be operated with a water pressure of 30 psi or more.

Water should be of good quality for the seedlings. It should not be of high salt content or contain toxic materials. Water sources should not pass through areas with seed-bearing weeds.

**Location**

The nursery should be centrally located with respect to the planting areas to minimize transport expenses and injury to the seedlings.

Areas that are often flooded should not be considered a nursery site. The site should have good light exposure. If the nursery is located in a windy or a typhoon-belt area, sufficient greenbelts, such as agoho and madre de cacao, should be planted around it.

**Accessibility**

If possible, the nursery should be located near an established national highway or public road to facilitate operations, communication, transport, and protection in case of fire. Otherwise, an access road for vehicles should be constructed. Road layout should be done on a topographic map, and construction should be done ahead of planting operation. A person with sufficient knowledge on road construction in forest areas should be employed for this purpose.

**Slope/Topography**

The most ideal site for a nursery is one with a level or flat terrain. For drainage consideration, a slightly sloping ground up at 10% is recommended. Terracing should be done if the slope is very steep.

**Soil**

To give the seedlings a good start in the field, they should be raised in a good soil medium in the nursery. The soil should have a sandy-loam texture, topsoil of 30 cm, about pH 5.5~~6~~.5 for broad-leaved species and pH 4.5–6.0 for conifers, and have high amounts of organic matter. Deficient soils can be improved with the application of humus, animal manure or green manure, or commercial (inorganic and organic) fertilizers.

## Nursery Design, Layout, and Establishment

The nursery is similar to a factory production line. Components are "assembled" at various points until the "finished" product is obtained. In like manner, germplasm are raised towards plantable size and they move along a "production line". Thus, the layout and design of nurseries should take into account this production feature.

This is particularly important for the production facilities of the nursery. Nonproduction facilities should be located logically, depending on their relevance to the production. Those activities/facilities needing inputs from materials coming from the outside should be located near access roads. Similarly, beds from which seedlings will be dispatched from and transported out of the nursery should be near the main road. Layout of facilities should consider the chronology of activities in the nursery to insure smooth flow or movements of materials and personnel within the nursery. Facilities could be modified, depending on the objective of production, serviceability of nurseries, and financial factors. The following are facilities that could be found in a large permanent nursery:

- office;
- workers' mess hall;
- germination shed;

- seedling shed for pricking out and initial growth of seedlings in shade;
- potting shed for making and filling of containers;
- store of potting soil;
- transplant beds (for bareroot stocks);
- water pump;
- water tank;
- hardening beds (open to full light where seedlings are grown to plantable sizes);
- composting area (shed or pit);
- storage sheds (for tools, chemicals, fertilizers, seeds); and
- garage/vehicle shed.

Paths, trails, and road systems are necessary for the efficient movement of materials and personnel within the nursery. Vehicles, particularly for transporting seedlings, are essential for large nurseries producing significant quantities of planting stocks.

The nursery could be provided with a pH meter for testing soil acidity; a standard rain gauge for recording rainfall data in the area; binoculars, measuring container with different capacities (1,000 cc, 500 cc, 250 cc, and 50 cc) for measuring and estimating the quantity of seeds; and a weighing balance. These instruments and equipment are necessary for large nurseries but are considered optional for small nurseries, particularly for smallholder tree farmers' nurseries.

**Size or Area of Nurseries**

The size of the nursery (Table 14) depends on the following factors:

- *Level of annual plant production* – the more seedlings to be raised, the larger the area.
- *Method of raising plants* – bareroot production system will require more area due to lower seedling density per unit area.
- *Nursery life of plants* – the longer it takes the seedling to reach plantable size, the longer is its period of stay in the nursery, thus production years could overlap, which means larger area is needed for most commonly species raised in the Philippines.

**Table 14. General guide for nursery size [a].**

| Production Capacity | Nursery Life of Plants | Area of Nursery (ha) | Remarks |
|---|---|---|---|
| 1 M | > 1 year | 4 | Includes space for sheds, access tracks, storage areas, etc. |
| 1 M | 4 months to 1 year | 1.5–2 | |
| 1 M | < 4 months | 1.0 | |

[a] Estimations, 1992.

PCARRD (1992) recommended that the area of the nursery should be at least 450 $m^2$ for every 100,000 seedlings to be raised, or for every 33 ha to be planted.

The area should be big enough to accommodate required facilities in a nursery as mentioned above. An adequate area is also needed for future expansion of the nursery.

## Planting Stock Production

This refers to the composite technology for the production of high-quality seedlings. It begins with the sowing of seeds and ends when the seedlings are dispatched and transported from the nursery to the planting site. Figure 11 shows the various phases of planting stock production or the nursery seedling culture, including some aspects of tree seed technology.

### Planting Stock Source

Seedlings could be raised from seeds, wildlings, or asexually propagated stocks. As discussed earlier, seeds are the most commonly used propagation material. Wildlings or those natural regenerations obtained from the forest are used to augment the short supply of seeds, or when seed collection has been missed. Asexually propagated stocks are also utilized in some nurseries for varying reasons.

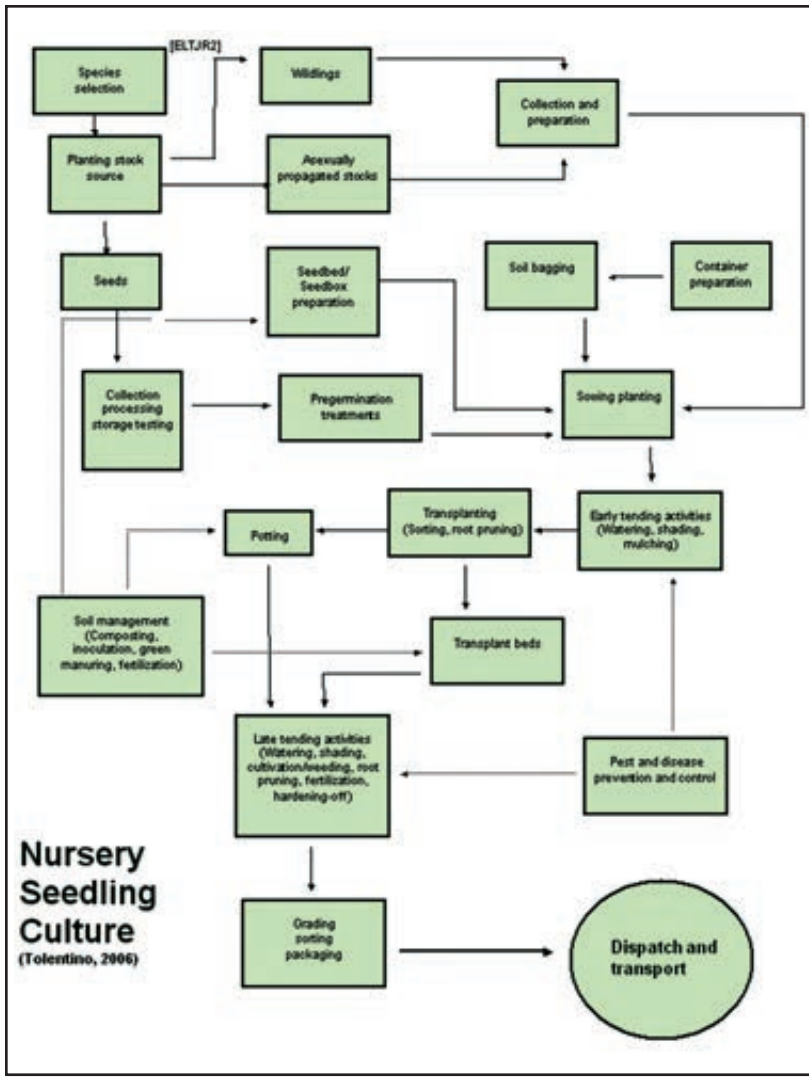



**Fig.1 1. Phases of seedling stock production.**

## Tree Nursery Practices

The following are practical guidelines for good tree nursery practices, which have been obtained from various sources (Wightman, 1999 and Poynton, 1996):

### Seedling Quality

- Consult farmers as well as forestry technicians when selecting the seed sources for the nursery. They are knowledgeable and experienced about field conditions and know the best seed sources. Seed directories that provide adequate information about the seed sources can also be consulted.
- Select the parent trees well in advance and design a strategy to ensure sufficient seed is collected. Mark the trees to easily locate and protect them. Seed documentation as described earlier would be the best source of information when available.
- Collect seed from at least 30 parent trees. A large number of mother trees ensure genetic diversity. Mother trees should be spaced at least 100 m apart.
- Judge seedling quality by several traits. Frequently, height is used as the main factor for judging quality. However, height and shoot sizes are poor indicators of seedling survival in the field. Root collar diameter is a better indicator of seedling field performance. Also, health and form should be considered during seed quality evaluation.
- Conduct regular plant quality surveys. Regular monitoring and evaluation of seedling is necessary to maintain or to employ corrective measures when needed.
- Sacrifice a few plants to improve total nursery production quality. The elimination of poor quality seedlings is a prudent practice not only to improve total nursery production quality, but also to put down the cost of production. Seedling cost becomes economical in the long run because poor seedlings are no longer planted in the field and are eliminated right away in the nursery.
- Use plant quality surveys to correct problems through appropriate nursery practices. Monitoring and evaluation of planted seedlings is a rare or an unknown practice in most planting programs in the country. However, corrective practices for planting stock production could not be instituted if the problem encountered

in the field is not properly reported to the nursery personnel. Performance in the field of nursery stocks should be regularly assessed. Causes of mortalities should be accurately identified and appropriate corrective measures should be carried out. On the other hand, high survival rates and good development of seedlings in the field should still be reported to the nursery staff so that good practices could be continuously applied.

- Discard poor quality trees as soon as detected. The "sayang" mentality and the emphasis on number of seedlings produced (instead of quantity and quality combined) are major reasons why many nurseries continue to produce and dispatch inferior seedlings to plantations where they either die or grow poorly.

**Sowing**

- Sow seed as soon as possible after harvest. Quality diminishes with seed age. Freshly collected seeds are at the peak of seed quality and would be expected to produce quality seedlings.
- Pretreat seed, if germination takes more than a week. Uniform and rapid germination is the goal of every nurseryman. Staggered and delayed germination disrupts nursery operations (e.g., delayed transplanting) and even outplanting.
- Test old seeds before planting to know if it will germinate. Wasting time sowing large quantities of nonviable seeds could be avoided if seed testing is performed for old seeds. Of course, this could be established if proper labeling of seeds in storage is religiously practiced.
- Carefully control the light, water, and shade during seedling growth. Early seedling growth is a delicate stage and requires careful control of light, water, and shade. Too little or too much of one or more of these factors can lead to poor growth or worse, mortalities.
- Sow seed directly in the container. Applicable for medium to large seeds, the practice should be done when the viability of the seeds are known. For seed lots with more than 75% germination, one seed per container is sown. For seeds with 50–75% germination, two seeds per container are sown. Blank containers are re-sown with seedlings from containers with two germinants. Sowing directly in containers also prevents root deformation resulting from careless pricking out. In addition, direct sowing in

containers reduces pricking out operations, thus facilitates nursery operations.

- The main objective of sowing directly in pots is to save transplanting costs. With this method, the cost for seedbed preparation, sowing, and weeding are avoided; susceptibility to diseases is minimized; and diseased plants could easily be eliminated.
- Ideally, to determine the proper sowing time, count back, from the beginning of the rainy season (or time of planting), the number of months required to raise an adequate number of planting stock. When large amounts of planting materials are to be raised, sowing should be phased over 6–8 weeks with at least one-week intervals. This is particularly recommended where seedlings have to be potted.

The following are the tips for sowing in seedbeds and seedboxes:

a. Large seeds can be sown directly in seedbeds, like those of lumbang, which are sown 15–20 cm between rows and 5–10 cm between seeds. The seed are sown in a furrow or hole properly covered with soil.
b. Medium-sized seeds like those of teak, yemane, narra, and mahogany are drill sown 10–15 cm between rows. For a 1-m row, seeds sown should not exceed 300.
c. Fine seeds like those of pine and agoho are best broadcast in seedboxes to attain uniformity and higher output per area. A very thin layer of fine sand is applied over the surface and covered with tissue paper or newspaper mulch. The seedlings will later grow and germinate through the mulch.
d. Very fine seeds like those of eucalyptus and kaatoan bangkal should first be mixed with a filler, such as sieved wood ash or very fine sand, before they are broadcast for even distribution of seeds. For every 1 cc of seeds, 200 cc of sand is added.
e. As a general rule, large- and medium-sized seeds are sown to a depth equal to their average diameter. The seeds are put in rills running across the bed for easier weeding.
f. Species, which germinate with difficulty, need special care. With rare and expensive seeds, sowing into a seedbed is preferable.

g. The seeds sown in the seedbeds and seedboxes are covered with sand or soil, which is gently pressed.

Mycorrhiza, a fungus that helps in the absorption of nutrients from the soil to the growing seedlings, is applied 1–2 weeks after sowing the seeds and is recommended for all forest tree species. The recommended ratio is 10–20 g of mycorrhiza per 20 L of water. Apply the solution by drenching it through the seedbeds or seedboxes where the seeds are directly sown. Construction of propagation beds and seedboxes

There are two types of propagation beds in a forest nursery: seedbed and transplant bed (PCARRD, 1992).

**Seedbed**

This is used where seeds are directly sown in close spacing. The young germinated seedlings are raised until these are ready to be transplanted. The composition of layers is gravel, then humus-rich soil and the fine mixture of sand and soil.

**Transplant bed.** The seedlings raised in the seedbeds are transferred from the seedbed or seedflat to the transplant beds to induce the production of fibrous lateral roots and healthy top. The transplant bed is also referred to as hardening bed since seedlings are conditioned here or acclimatized to enable them to withstand the conditions in the planting area.

The following are guidelines in the construction of propagation beds:

a. The seedbed and transplant beds should be constructed on the best portion of the nursery (i.e., soil, exposure and accessibility).
b. Before the beds are prepared, the soil is loosened first. Roots, rhizomes, and undecomposed organic materials are removed; and the soil pulverized thoroughly and then leveled.
c. Seedbeds and transplant beds are separated from each other by paths of about 40 cm wide to facilitate movement.
d. Seedbeds are generally 1.2 m wide and 5 m long; transplant beds are generally longer.
e. After pulverizing, the soil in the seedbeds must be firmed and settled but not compacted. To achieve the right degree of

firmness, the bed is thoroughly soaked with water and allowed to stand for 2–3 days before sowing.

f. Whenever practicable, the sides of the beds should be bordered with treated wood planks, adobe, or stone to keep the soil from being washed away.

For very fine seeds, which produce delicate seedlings, generally, seedboxes are used for sowing or broadcasting.

The following are guidelines in the construction of seedboxes:

1) Generally, sizes of seed boxes being used are the following:

   - 46 cm x 46 cm x 12 cm
   - 40 cm x 60 cm x 15 cm

2) The seedbox is constructed using 1-1.5 cm thick boards.
3) If the bottom is wooden, holes (about 1 cm) are bored to provide good drainage.
4) The bottom layer is fine gravel, 2 cm thick; the second layer is sand, 2 cm thick and the surface or uppermost layer is a mixture consisting of top soil, humus, and fine sand (4:2:1 in proportion).
5) The soil level is 1 cm lower from the rim of the box.
6) The soil being used in filling the seedboxes should be sterilized.

**Mulching**

Mulching protects the seeds from intense heat, strong wind, and the impact of raindrops. It also prevents rapid evaporation of soil moisture. Decomposed mulch increases the fertility of the seedbed.

Chopped grass and rice straw, rice hull, compost, decomposed saw dust, fine sand, or finely chopped organic material can be used as mulch.

The kind and amount of mulching material will depend on the time of sowing, type of seed, and rate of growth of seedlings. In general, apply only a thin mulch. For fine seeds, use fine sand or finely chopped organic matter.

Mulching of transplants is done only for those that are grown in transplant beds and occasionally for those grown in pots. The same

methods and practices in mulching seedbeds are followed for mulching transplant bed.

**Pricking-Out/ Transplanting/Potting**

After germination, seedlings develop and thus they should be given appropriate space for optimum growth and development. From the seedbeds, seed boxes, or greenhouse benches, seedlings could be transplanted to transplant beds or any container (Fig. 12).

Nursery Practices:

- Throw away any seedlings that appear sick or deformed. Inferior seedlings should be eliminated early.
- Transplant when the taproot emerges or seedlings are still small (5 cm), before secondary roots are formed. Smaller seedlings are easier to transplant. Furthermore, bigger or overgrown seedlings when transplanted are frequently with deformed roots, especially those raised in seedboxes.
- Water the bags well one night before you prick them out so that water penetrates to the bottom of the seedbed. This ensures

**Fig.12.S eedlings in polyethylene bags** *(E. L. Tolentino,J r.)*.

that the soil receiving the seedlings has sufficient moisture to supply the seedlings to be transplanted into them. Failure to do so will result in water loss from the seedlings.

- Ensure that the area where the transplanted seedlings will be kept is well shaded before you begin pricking out. Planning ahead will prevent the seedlings from desiccation after pricking out. Young seedlings are very vulnerable to heat damage by direct sunlight.
- Water the seedlings a day before, and one hour before pricking out. This will make the cells of the young and delicate seedlings turgid and capable of withstanding the possible desiccation during pricking out. Watering during late afternoon or early evening is preferable. Recovery from desiccation during the day takes place efficiently in the evening where there is practically no water loss due to transpiration or evaporation.
- Delicate and young seedlings suffer from excessive water loss during hot days, thus pricking out should be done in the early morning or late afternoon. Transpiration and evaporation is high. It is rather low during early morning or late afternoon. Additionally, workers tend to slow down in their work during hot days. Flexi-time schedules should be followed during these periods.
- Use a shovel or stick to gently loosen the soil around the seedlings. Using appropriate tools will minimize damage, particularly to the tender and delicate root systems.
- Remove seedlings by grasping their cotyledons or lower leaves – do not lift them out by the stem. The conducting tissues (xylem and phloem) are vulnerable to damage when the stems are carelessly pulled.
- Put seedlings in water as soon as you take them from the germination bed. Desiccation stress is minimized if not totally eliminated when seedlings are placed in plates with water. Letting them lie down without water even under the shade will unduly cause moisture stress that are sometimes fatal.
- Prepare planting holes with a stick and ensure they are sufficiently wide and deep. Proper depth and width of the transplanting hole is important to prevent root deformation. Narrow and shallow holes cause L- or J-shaped roots.

- Clip long or very branched roots to ensure they are pointed downwards. Long and very branchy roots not root pruned prior to transplanting results in coiled root systems. Being geotropic, it is also possible that they will initially grow upwards before it senses that the gravity is the other way around and this causes root deformations.
- Gently pull the seedling upward after placing it in the hole to straighten out roots. The practice will orient the roots downward into the soil.
- Pack the soil against the roots, starting at the bottom of the hole. This will prevent air pockets in the planting hole where roots are not in complete contact with the soil. Such conditions will result in seedling desiccation due to poor contact with the moisture-supplying soil.
- Water the plants immediately after transplanting, and again when they wilt. Moisture stress is a major cause of transplanting-related mortalities, thus adequate moisture is necessary to prevent it.

The most common dimensions of the plastic (polyethylene) pots being used with the corresponding volume of potting soil needed are as follows:

a) 3" lay flat x 6" long (250 cc) – generally too small
b) 4" lay flat x 6" long (500 cc) – very useful size
c) 6" lay flat x 8" long (1300 cc) – for fast growing broadleaved species
d) 8" afloat flat x 16" long (3,500 cc) – for saplings intended for urban tree planting which generally requires bigger planting stocks.

However, in most tree planting operations, it is not the size of the containers that matters but the physical and chemical characteristics of the growing medium. A big-sized container will not necessarily result in better growth if poor medium is used. Additionally, the transport of large containers in mountainous terrain will pose serious constraints for seedling haulers. Using smaller containers with rich medium will be a better option to balance better growth of seedlings and ease of transport.

## Watering

- Keep potting mix moist but not wet. Adequate moisture is important for optimum growth. Too much water results in poor aeration (anoxia) and roots may be severely affected. Additionally, wet conditions favor decay-causing organisms.
- Water so that seedlings are not damaged and potting mix is not washed away. Big and pressurized water droplets can damage delicate and tender seedlings. Mist or spray can be used, depending on seedling age. The use of fine nozzle (different sizes) is advised. Potting mix could be washed away, this does not only lessen the substrate for the seedling but creates another problem – when potting mix is reduced, the rim of polyethylene bags tends to fold inwards due to available space, thereby creating some sort of a shield that covers the potting media, which could result in reduced watering. During watering, most of the water just finds its place outside of the bags instead of inside because of the "plastic shield." To prevent this, the plastic bags are folded outward or better still the splash effect of watering is minimized if not totally eliminated. Do not make the nursery very wet. Wet conditions may cause anoxia, traffic of personnel and materials more difficult, and favor decay-causing organisms.
- Check seedlings after watering to make sure that the potting mix in all pots is watered all the way to the bottom. Haphazard watering keeps moisture only in the upper soil surface of the media, thus inadequately watering the roots of the seedlings. Supervisors or nurserymen in charge of watering should check if the lower part of the media is moist. Another common problem in nurseries using polyethylene bags is the "plastic shield effect" earlier mentioned. Watering is preferably carried out late afternoon or early evening. Seedlings recover from water stress at night when there is practically no transpiration and evaporation. Watering is thus maximized and economized. More water is lost through evapotranspiration during morning or day watering. Automatic sprinklers or flexi-time arrangements could address this situation.
- The conventional type of water system sprinkler can with nozzle and or hose with spray nozzle is highly recommended.

The following watering techniques can be used for each type of species:

a) Fine-seeded species. It is a species with fine seeds like *Eucalyptus* spp. are easily damaged and must be watered only using a fine mist sprayer.

   - It is strongly recommended that spray be directed upward so that water falls back as a fine mist.
   - Do not spray directly at the seedlings because the strong pressure from the nozzle can damage them.
   - Do not use a watering can or hosepipe.

b) Medium- or large-seeded species
   - Germinants of medium-sized seed species are less fragile than of fine ones. However, they should still be treated with care.
   - A hand sprayer, backpack sprayer, watering can, and hosepipe with fine mist nozzle are suitable for these types of species.
   - Spray upward so that the water drops gently like a rain shower.

**Shading**

- Cut back the branches of natural shade trees. Cutting branches allow more light penetration. Natural shade should have leaves during summer and none during rainy season. Natural shade trees compete for water and nutrients, especially when producing bareroot seedlings.
- Repair and replace shade material in time to prevent damage to seedlings.
- Regulate the amounts of shade and water together. At young seedling stage (germination), shade is usually at 40–50%, although this may vary with species. Relationship between shade and water requirement is inverse. With heavy shade, less water is needed and vice-versa.
- Align beds or rows of plants with the sun's path (east-west direction). Although this would maximize the need for shade, the light factor is more critical.

- Add shade to the sides of the bed or let shade cloth overhang, if sun is directly on plants most of the day.
- Gradually remove the shade as the plants grow. Too much shade produces spindly seedlings (tall, slender, succulent stems). Seedlings should be trained to grow under full light conditions, which is the general condition in planting areas.
- Observe how the plants react to shade removal and adjust your treatment as necessary. Test a few seedlings to the new light condition before putting all seedlings under the new light condition. This will facilitate work.
- The care applied on seeds after sowing greatly influence their germination, development, and survival. Very young seedlings are susceptible to sun scorch. Provide shade capable of excluding 50-75% of direct sunlight. Seedlings must also be protected from heavy rains by placing plastic sheets attached to a light frame as shading material.

- Shading requirements for seeds directly sown on pots/seedbeds:

  a) 75% shade upon sowing
  b) 50% shade, a week from germination
  c) 25% shade, three weeks from germination
  d) No shading, four weeks from germination (e.g., mahogany seedlings, 25% shade until two weeks prior to outplanting)

- Shading requirements for pricked out seedlings:

  a) 75% shade upon pricking
  b) 50% shade, two weeks from pricking
  c) 25% shade, three weeks from pricking
  d) no shading, four weeks after pricking

**Substrate Quality**

Soil testing is necessary to assess the soil properties and nutrient status. It is necessary to determine the kind and amount of fertilizers and other materials to be added to the soil.

A desirable nursery soil or substrate should have the following characteristics:

- light in weight to ease transport to the planting site. Hold cuttings or seedlings firmly in place;
- retain enough moisture to avoid need for frequent watering;
- porous enough to drain excess water easily;
- allows sufficient aeration of the roots;
- free from seeds, nematodes, and diseases;
- can be sterilized without changing its properties;
- has enough nutrients for a healthy initial development of plants;
- does not have a high salinity level (except for halophytes);
- has suitable pH (generally 5.5–6.5); and
- stable, does not swell or shrink excessively or crust over in the sun.

Sterilize mix to reduce diseases and weeds. This is important under conditions where the available substrate is infected with soil-borne diseases that could threaten the seedlings. Likewise, weeding could be minimized if weed seeds are eliminated. Soil heating by steam or cooking are common practices.

Sieve germination mixes so that particle size is less than 2 mm. Sieve potting mixes so that particle size is less than 5 mm

Recommended mix (topsoil: fine gravel: well-decomposed organic matter):

- For heavy clayey soils – 1:2:2
- For medium (loamy) soils – 1:1:1 and
- For light (sandy) soils – 1:0:1.

Alternatively, the following mixture could be used:

- six parts forest top soil;
- two parts fine sand;
- three parts compost (from sawdust, peat, or organic matter); and
- 2–4 tbsp complete fertilizer (e.g., 14-14-14) with nitrogen, phosphorus, and potassium (N, P, K).

Improve the substrate's physical and chemical characteristics with compost. With compost, there is better aeration; increased water-holding capacity; reduced plasticity and cohesion; better supply and

availability of essential nutrients like N, P, S, Ca, Mg; and increased cation adsorption capacity (clay is 8–150 millequivalent (meq)/100g; humus is 150–300 meq/100 g).

Add beneficial mycorrhizae and rhizobia after sterilizing the substrate. Harmful soil organisms are killed in the process. On the other hand, adding the beneficial microorganism after the soil sterilization process ensures that only the beneficial soil organisms are present in the soil substrate.

Plan ahead and start the compost well before you need it. Organic materials do not decompose overnight, thus advance planning is required to produce compost at the right time.

Test a variety of organic materials to find the right mixture for each species. Different organic materials have different components. When decomposed, it yields different nutrients and other residues. Tree species vary in substrate requirement. Identifying the suitable mix ensures optimum growth and development of seedlings.

Keep the compost pile well aerated and moist at all times. Decomposing microorganisms operate optimally under well-aerated and moist conditions. This will hasten the decomposition process. Wet and poor aeration slows down decomposition process.

Monitor compost frequently. Problems can be immediately identified and corrective measures instituted. This would include poor aeration or improper moisture conditions (dry or wet). Furthermore, the need for turning and mixing the materials could be known.

The potting soil has to be properly mixed. A cement-mixing machine can be useful, particularly where large quantities of potting soil have to be prepared. The potting soil mixture should be sterilized to eradicate pest and disease-causing organisms that may infect young seedlings. The organisms could either be small insects, fungi, virus, bacteria, or nematodes. A practical method of soil sterilization is to allow hot steam to pass through the pile of potting soil. An empty 200-L gasoline drum can be converted into a steam-sterilizing apparatus. Another practical method is to heat the soil in open vats or on galvanized iron sheets over an open fire. However, only a small volume of potting soil can be treated this way. Another method is to just pour boiling water over the soil at the rate of 2–4 L/$m^2$. This is appropriate for soils already placed in the seedbed or transplant bed.

## Production Methods

Use bareroot production if soil fertility is maintained in the nursery beds and ideal planting conditions are guaranteed. This is seldom practiced in the Philippines since most of the target planting sites are degraded and thus containerized stocks are preferred. Nevertheless, if the two aforementioned conditions are met, bareroot production method is cheaper and easier to practice.

Use small bags with a rich substrate such as compost, instead of large ones. Small bags or containers (e.g., root trainers) are compact (space in nursery is maximized) and lighter to transport (more convenient for planters).

Invest in alternative containers such as root trainers to improve plant quality. Root trainers have ribbed walls that "direct" the roots downward. Unlike polyethylene bags that cause root deformation, root trainers train the roots down. Furthermore, automatic or air root pruning is accomplished thus preventing laborious but essential cultural practice. Consequently, roots are compact and branched making absorption of water and nutrients more efficient. Root trainers can be used several times. Initial investment is high but it becomes economical in the longrun.

## Plant Nutrients

- Carefully monitor the leaves for signs of nutrient deficiencies, and correct them with compost or fertilizer. Regular monitoring of seedling growth and development is a vital task of nurserymen. The leaves are the "tell-tale" sign of plant problems. Chlorosis (or yellowing) and other color or structural changes in the leaves should alert the nurserymen that something is wrong with the seedlings.
- Understand the fertilizer labels so that the right nutrients are applied. Fertilizers are "food" to plants, thus only the right food should be fed to them. Excessive nutrients are detrimental and wasteful.
- Thoroughly dissolve and dilute the granular fertilizer in warm water and apply it only to the soil, not the leaves. Granular fertilizer becomes potent only when it is dissolved thoroughly. Warm water enhances the dissolving process. It is the roots that absorb the nutrients in fertilizers not the leaves.

**Inoculation of rhizobia.** For leguminous species like *Acacia mangium*, it is advisable to inoculate the seedlings with Rhizobia. This will help facilitate the production of nodules, which contain nitrogen-fixing bacteria that can help in the growth of the seedlings. This procedure is done during the pricking period.

The following are the steps to be followed in pricking seedlings and inoculation of *Rhizobia*:

1) Water first the seedbed/box to make the soil soft and easy to prick. Use pointed stick and insert it beside the seedlings. Use the stick as lever in lifting the seedlings from the seedbed or seed boxes. Prick out all healthy and vigorous seedlings. All badly formed seedlings, especially those with bent roots, should be culled, as this will only produce poor quality trees. To avoid damage to the seedlings, do not hold the succulent stems, only the leaves or the seed wings if still attached.
2) Prepare slurry water by mixing 10–20 g of Rhizobia in 100–200 ml of water.
3) Place uplifted seedlings immediately in a basin with slurry water to protect the root hairs from exposure.
4) Before transplanting the uplifted seedlings into the polybags, water the polybags thoroughly to maintain the same moisture as the seedbeds/seed boxes to avoid stress or shock to the seedlings.
5) Use the same pointed stick to punch a small hole on the soil media on the polybags, and then carefully insert the roots of the seedling into it with great care to avoid bending the roots. Simply nip off the bottom portion of the root before transplanting.
6) Fill the gap of the hole using the pointed stick by inserting it beside the hole and push enough soil to cover, and gently press the soil around the stem down to the root collar.

## Fertilization

Growing seedlings take up large quantities of nutrients from the potting mix. Use of fertilizer is essential to ensure fast and healthy growth of seedlings and to reduce their time of stay in the nursery. N, P, and K are the macroelements needed by the plant. Other trace

elements are required to boost their growth (e.g., Mg, Bo, Mo, and other useful trace elements).

The most common inorganic fertilizers used in the nursery are the following: urea (46-0-0), di-ammonium phosphate (18-46-0), ammonium sulphate (16-20-0), and complete (14-14-14 or 15-15-15) fertilizer at the rate of 10 g/L of water. All these fertilizers are available in granules. Mode of application is done by mixing them with water and applied by drenching them to the seedlings. There are also controlled-release fertilizers that could be used in nurseries (Table 15).

## Weeding and Cultivation

Weeding is the removal of unwanted vegetation. Some measures to control weeds include a thorough preparation of the soil before sowing; the use of sowing media and manure, which are free of weed seeds; and the removal of all growing weeds inside and within the vicinity of the nursery whose seeds might be dispersed by wind or water. Mulching and sterilization by heat or chemical treatment are factors needed to eliminate weeds in the nursery.

**Table 15. Examples of controlled-release fertilizers[a].**

| Fertilizer | Analysis (N-P-K) | Release Mechanism | Length of Time it Lasts at 21ºC | N Source |
|---|---|---|---|---|
| Lesco | 20-6-12 | Temperature | 4-6 months | sulphur coated urea and ammonium nitrate |
| MagAmp | 7-40-6 + 12Mg | Moisture | 4-12 months | magnesium ammonium phosphate |
| Osmocote | 18-6-12<br>14-14-14<br>13-13-13<br>19-6-12<br>17-7-12 | Temperature, coating thickness; no change with media moisture | 8-9 months<br>3-4 months<br>8-9 months<br>3-4 months<br>12-14 months | ammonium nitrate and ammonium phosphate |
| Sulphur coated urea | 36-0-0 + 17S | Temperature, media moisture, coating thickness | Up to 6 months, approx. 1% per day | sulphur coated urea |
| Ureaform | 38-0-0 | Increase with temperature, maximum at pH 6.1 and 50% water saturation; bacterial action | 60% in 6 months | urea-formaldehyde |

[a]Jaenicke, 1999.

The following are recommended practices in weeding:

- Weeding should be done as weeds come out.
- In removing the weeds, no portion of the root system should be left behind.
- Weeding should be done only when the soil is moist.
- Whenever practical and convenient, mechanical weeding tools may be used. These tools could be used when the spacing between the rows of seedlings in seedbed and transplant bed is wide enough (i.e., 15 cm or wider).
- The soil in between rows of the seedlings may be cultivated for aeration and absorption of water. It also fosters the activity of soil microorganism essential for maintaining soil fertility.
- Weeds removed should be properly disposed of in a rubbish heap. They are good bedding materials for compost making.
- Herbicides may be used on paths, along fences, and even in beds where total eradication of weeds is necessary. The manufacturer's instructions must be followed closely.

**Root Pruning**

Regular monitoring of seedling growth is necessary to attain the prescribed quality. In some cases, root penetration underneath the polyethylene pots can be observed. This may result to uneven height growth of seedlings, some will become spindly and thin and once outplanted, high mortality percentage is expected. To correct the condition, lifting of each pot from the ground should be done. Roots that have penetrated the ground should be cut off to inhibit unwanted growth. This is to allow the seedlings to develop a sturdy and strong stem, and a vigorous and abundant number of lateral roots in the pot. A good root system is important to ensure survival of the seedlings after outplanting in the field.

One week prior to outplanting, roots should be pruned by cutting the bottom end of each polypot, about half an inch from the bottom. This is done to get rid of the spiraling root system, and to ensure that each seedling will develop new roots that grow straight downward.

## Prevention and Control of Pests and Diseases

Control of pests and diseases should be a matter of prevention than cure. Seedlings grown in the nurseries prior to outplanting in the field may be affected with diseases commonly caused by pathogens. Small organisms like fungi, bacteria, and viruses or animals like nematodes and insects can cause damage to seedlings. A very common disease, dumping-off, in nurseries is caused by fungi. It can cause the seed to rot before germination; roots to decay before the shoot appears; or the shoot to become thin at its collar and collapse. Their susceptibility to diseases may be attributed to the conditions under which the seedlings are grown in addition to the cultural treatments employed. The infection by pathogens is often a result of exhausted soil fertility, unskilled fertilization, use of pathogen-inviting green manure crops, excessive watering, or the building up of large populations of introduced pathogenic organisms. Careful management of the nursery soil is one of the requirements for protecting the planting stock from disease. The occurrence of diseases can set back nursery operations especially due to the adverse effects on the quantity of seedlings for plantation establishment. Below are good practices for preventing and controlling pests and diseases in the nursery:

- There is no water lying in the nursery. Wet conditions favor the development of pests and diseases.
- There is good air flow across and around seedlings. There is adequate aeration. Reduces the chances of the development of decay-causing disease.
- There should be no disease in the nursery. Sterilize or disinfect to eliminate sources of diseases.
- There should be no animals in the nursery. Animals moving around the nursery destroy seedlings or they could be carriers of pests and diseases.

## Safe Pesticide Use

- Make safety part of your normal work routine and make your safety your responsibility. Pesticides can kill small insects but can also cause harm to a careless nurseryman. It is important that staff handling and using pesticides are conscious of their safety.

- Insist that you be provided with safety materials. This is part of responsible consciousness when using pesticide. Staff welfare should come first before seedling production.
- Prepare and plan ahead of time – you can always delay application if necessary. With important preparations necessary (e.g., safety materials), applications could be delayed.
- Read instructions and ask for help if necessary. Instructions were written to provide proper directions and obtain optimum results. Likewise, warnings are contained in the instruction material to avoid accidents or remedies in case one occurs.
- Mix chemicals in well-ventilated area. Fumes of pesticides are harmful to humans and should not be inhaled.
- Wear long sleeves, pants, gloves, and a mask when applying pesticides. The human skin could absorb the chemicals, thus protective attire is required. Likewise, inhalation of these chemicals should be avoided and therefore the use of masks is important. Contaminated hands can carry the deadly chemicals to the eyes, nose, or mouth and so gloves must be used.
- Keep extra clothes in the nursery and change clothes immediately after spraying. Clothes used during the spraying process are contaminated with chemicals and should therefore be removed to avoid contaminating other people or yourself.
- Wash immediately. Keep soap handy. Taking a bath after the spraying operations will wash down the residues that could have been deposited in any of the body parts.
- Dispose of leftover chemicals in a responsible manner. Pesticides could harm other organisms of the environment including humans if disposed in an irresponsible manner (e.g., dumping in rivers or even in soil).

The following are natural pesticide recipes, which could be used in nurseries that are more environment-friendly than the commercially available synthetic chemicals (Wightman, 1999):

**Insecticides**

Insects are destroyed either by making contact with or by eating the insecticides. Some insecticides only keep away the insects by a strong stench.

- **Neem** (*Azadirachta indica*). A tree native to India and Pakistan, but planted widely around the world for its use as a natural pesticide. It has been used also as a control against fungi, worms, and bacteria. There are commercial products made with neem. The active ingredient in neem is similar to an insect hormone and keeps away insects, as well as restrains their digestion, metamorphosis, and reproduction. It has been used effectively on over 10 leaf-eating insects. To use neem, collect mature seeds, wash, remove the husk, and allow to dry completely. Take 12 handfuls of dry seeds (or use 500 g/L of water) and grind them into a fine powder. Mix the powder in 12 L of water and soak overnight. Strain the liquid and apply.
- **Chilli, pepper** (*Capsicum frutescens*). Collect two handfuls of chillies and dry. Grind into a fine powder, taking care not to inhale too much of the highly irritating dust, mix with 2 L of water, and soak overnight.
- **Tobacco** (*Nicotiana tabacum*). Only real tobacco contains nicotine, the substance acting as an insecticide. Collect healthy, fresh leaves, which are free of spots. Mix 80 g of dry leaves and stems per liter of water and soak for two days. Best if applied in the early morning because the solution escapes as a gas. Tobacco is toxic to people, do not breath the vapors, or allow to touch the skin.
- **Kakawate, gliricidia** (*Gliricidia sepium)*. Roots, seeds, and leaves are poisonous to rats and other small animals. It is an insecticide against aphids.
- **Garlic** (*Allium savitum*). Finely chop three bulbs of garlic and mix with 10 L of water. You can store this for up to two weeks unstrained, although its effect on the plant lasts only for 1-3 days after applying it.

**Virus Control**

- **Bougainvillea** (*Bougi nvillea spectabilis)***.** Mix 200 g of fresh leaves per liter of water. Mix at least five minutes in blender. Use against several virus diseases in tomatoes and beans.
- **Dahlia** (*Dahlia pinnata*). Mix 150 g of fruit per liter of water.
- **Spinach** (*Spinacea oleracea*). Mix 200 g of fresh plant leaves per liter of water and soak for one day.

### Nonplant Substances Used as Insecticides

- **Chalk.** Mix 3–5 g of chalk per liter of water. Soak for 12 hours if construction grade chalk is used; 3–4 days if natural chalk is used. Stir frequently and apply directly. It dehydrates the insect when in contact. It can burn young plant tissue and should therefore only be used on mature leaves.
- **Mineral oil.** Use high-grade oil such as ultra fine spray oil. Mix 10–30 ml mineral oil in a small amount of water, then add 1 L of water. Stir constantly. Cooking oil can be used instead of mineral oil if soap is added. It dehydrates or suffocates the insects or their eggs when in contact.
- **Animal urine.** Collect cow or goat urine and mix with a small amount of soil. Allow to ferment for two weeks. Dilute with 2–4 L of water per liter of urine. Urine is very high in N and thus can burn tender leaves. Do not apply in full sun and dilute further, if necessary. Human urine can also be used.
- **Cow's milk.** Mix ½ cup of fresh, unpasteurized milk with 4 cups of flour and 20 L of water. It kills insect eggs and acts against some insects which carry viruses.

### Fungicides

Fungi thrive in areas of high humidity and shade. Reducing these two factors helps control them. Fungi often appear first on the lower leaves of the plant because the spores are released from the soil. Always apply fungicides to the soil and the bottom leaves.

- **Papaya** (*Carica papaya*). Finely chop 1 kg of dry leaves and mix with 1 L of water. Stand overnight. Dilute with 4 L of water.
- **Garlic and onion** (*Allium sativum, A. cepa*). Mix 500 g finely chopped materials in 10 L of water. Allow to ferment for one week. Dilute with another 10 L of water. Incorporate into the soil.

## Nursery Hygiene

To prevent and control the spread of pests and diseases, good nursery hygiene is necessary.

- Clean potting shed. Prevention of the occurrence of diseases and pests in the nursery begins with good hygienic practices in the potting sheds. Proper removal of garbage is necessary to avoid breeding places for these harmful organisms.
- Clean germination shed. Damping-off and decay-causing organisms commonly infect germinating seeds. As a preventive measure, cleanliness should be maintained.
- Sterile germination mix and sterile potting mix. This has earlier been described as important when soil-borne diseases or weed seeds are significant in the soil substrate.
- No water ponding, weeds, rubbish, or animals. Excessive moisture invites decay-causing organisms. Weeds should be eliminated in the nursery. Garbage should be properly disposed of. Animals should be excluded and not allowed in the nursery for they could damage seedlings or carry infesting pest or disease.
- Good air circulation. Poor air circulation favors the development of decay-causing organisms. Good air circulation limits their growth and ability to infect.

## Planting Stock Production

### Vegetative Propagation of Planting Stocks

When high-quality seeds are not readily available, production of seedlings can be done by vegetative propagation. Vegetative propagation improves the volume of harvest and quality of logs, shortens the rotation cycles, and cut down cost of silvicultural operation. Cuttings of eucalyptus have been successfully used in Brazil for industrial tree plantation. In the Philippines, cuttings of fast-growing species such as *Acacia mangium* and *Gmelina arborea* were used in industrial tree plantations conducted by Provident Tree Farms, Inc. (PTFI) in Tacloban, Agusan del Sur.

**Cuttings.** A cutting is a portion of the root, shoot, branch, stem, leaf, or bud cut from selected parent plant (PCARRD, 1992). With the aid of a hormone or other suitable rooting media, they are induced to produce roots and shoots. Their field survival depends largely in their preparation, handling, and capacity to produce roots. Forestation

species that favorably respond to cutting as a method of propagation are shown in Table 16.

Stem cuttings are prepared by cutting the branches into sections of the desired length using a saw, knife, or a pruning shear. The ends of each cutting should be slanted and smooth. To prevent infection of the mother tree, it should be coated with paint or grafting wax immediately after cutting. To prevent termite attack, both ends of the cutting should be coated with enamel paint.

There should be at least three nodes in a single cutting. Flower buds should be removed as they retard root formation.

Cuttings are bundled and placed in an upright position with about half their length in water to keep them fresh until planting time. When they are to be transported to distant places, cuttings should be wrapped with gunnysack or mountain moss.

There are two methods to induce root formation: by wounding and by the use of root hormones. The most popular active ingredients of

**Table 16. Planting materials of selected forest tree species[a].**

| Direct Seeding | Bareroot Planting | Wildlings | Cuttings |
|---|---|---|---|
| Akleng parang | Agoho | Akleng parang | African tulip |
| Baguilumbang | Alibangbang | Alibangbang | Cypress |
| Benguet pine | Alnus | Almaciga | Fire ball |
| Ipil-ipil | Alupag | Bagalunga | Kakawate |
| Kakawate | Anchoan dilaw | Ipil-ipil | Mahogany |
| Cashew | Baguilumbang | Giant ipil-ipil | Moluccan sau |
| Lumbang | Bagras | Golden shower | Narra |
| Mahogany | Balsa | Lumbang | Palosanto |
| Moluccan sau | Banaba | Mahogany | Mulberry |
| Palosanto | Bitaog | Molave | Paper mulberry |
| Rain tree | Fire tree | Narra | Rain tree |
| Siar | Ipil-ipil | Palosanto | Yemane |
| Teak | Giant ipil-ipil | Rain tree | Nangka |
| Vidal's lanutan | Kakawate | Spanish cedar | Tuai |
| Yemane | Molave | Teak | Banaba |
| | Moluccan sau | Yemane | Alnus |
| | Narra | | Binayuyu |
| | Paper mulberry | | Ipil-ipil |
| | Para rubber | | Giant ipil-ipil |
| | Rain tree | | Teak |
| | Talisai | | Japanese cedar |
| | Teak | | |
| | Yemane | | |

[a]PCARRD, 1992.

plant hormones are indole-butyric acid (IBA), gibberellic acid (GA), and napthalene-acetic acid (NAA).

Moisten the lower part of the cuttings and dip them into the rooting hormone powder to a depth of 5 cm. Excess powder is carefully shaken off. Liquid formations into which cuttings are placed are diluted in water as prescribed by the manufacturer.

Prepared root-promoting materials should not be kept or stored for a long time because they may lose their potency. Weak concentration losses its potency in 14 days, while an uncontaminated solution may stay effective for about a year.

Rooting by wounding is done by making two opposite slice cuts 2 cm long at the base. The cut should be deep enough to reach beyond the cambium layer.

Propagation beds for cuttings should be properly aerated and the rooting medium should have enough moisture. It should have a high relative humidity, good light, and the right air temperature (not higher than 27ºC). The recommended soil medium is fine, sandy soil because it allows proper drainage and aeration.

Cuttings may be planted either in vertical or slanting position with the basal portion in the hole. About ¼ of the total length of the cutting is buried. The soil around the cutting should be slightly firmed and then watered.

Delicate and hard-to-root cuttings are given facilities, such as high shade of opaque plastic cover or fiberglass and mist-watering device. It should be provided with a 50–70% shading in sunny days. Shoots usually sprout after two weeks, followed by callous and root formation. Application of complete fertilizer in liquid form in beds with sand medium helps to induce root formation. After the cuttings have all sprouted, remove plastic cover gradually. The watering interval has to be lengthened to harden the new plants.

Cuttings are transplanted after producing sufficient roots with a maximum length of 3–5 cm. Extra care must be taken so as not to break or injure the roots. After transplanting, cuttings are treated like ordinary seedlings.

For species that easily produce root and thrive, the cuttings could be directly planted in the field during the rainy season. Species of this type include kakawate, mulberry, ipil-ipil, African tulip, and yemane.

Clonal propagation of dipterocarp species by cuttings has been successful using a nonmist system (Fig. 13) (Pollisco, 1995).

**Fig.13. Nonmist chamber at DENR, Bislig, Surigao del Sur** *(A.M.Foronda)*.

**Stump or root cuttings.** Another method of vegetative propagation is the use of rootstocks as planting materials (PCARRD, 1992). This is, however, possible only for a limited species such as paper mulberry (*Broussonetia papyrifera*), yemane (*G. arborea*), and teak (*Tectona grandis*). These are treated in the same way as stem cuttings. Adequate shade should be provided.

**Layering.** Layering is the development of roots on a stem while it is still attached to the parent plant. It produces roots more successfully than stem cutting because the stem continues to receive moisture and nutrients from the parent plant. The rooted stem is then detached or cut from the parent plant and transplanted to become a new plant growing on its own roots. A layered stem is known as a layer. This may be a natural means of reproduction, or it may be induced by artificial methods.

Layering is simple to perform and achieves a high degree of success on a minimum of skill, effort, and equipment. This is, however, applicable only for small-scale planting.

In the Philippines, tree species that could be propagated by layering include paper mulberry, fireball, etc. Layering should be done at the start of the rainy season for the new plant to be ready during the planting season of the following year.

There are two common methods of layering, the procedures of which are as follows:

a) *Simple layering* - This method is performed by bending a branch to the ground and covering it partially with soil or rooting medium but leaving about 15-30 cm of the terminal and exposed and bent sharp to an upright position. This sharp

bending of the shoot may be all that is necessary to induce rooting. An additional benefit may be gained by twisting the branch to loosen the bark. Cutting or notching the underside of the stem is often done. The bent part of the shoot is covered with soil to a depth of 8–16 cm. A wooden peg, bent wire, or stone may be used to hold this portion down. Always select low, flexible branches that can be bent easily to the ground. As a general rule, shoots older than one year are not satisfactory for layering.

b) *Tip layering* - In this method, rooting takes place at the curved part of the shoot that is bent to the ground. The shoot tip begins to grow downward into the soil but recurves to form a sharp bend in the stem from which roots develops.

When the rooted layer is removed from the parent plant, it is treated essentially in the same way as a rooted cutting of the same plant.

**Marcotting.** A branch of a healthy and vigorous mother tree is completely girdled, scraping off the cambium to encourage the development of roots. A healthy branch, ranging from 5 mm to 30 mm in diameter, is girdled 0.5–1.0 inch wide around the stem at least 15–30 cm from the tip end. Exposed surfaces should be scraped to insure complete removal of the phloem and cambium.

Root-promoting chemicals are immediately applied to the exposed surfaces. A slightly moistened rooting medium is placed around the stem to enclose the cut surfaces. Moist mountain moss with a small amount of rich, loose soil could be used.

The rooting medium is covered with polyethylene film whose two ends are twisted to make sure that no water can seep through. When it is fully developed as can be seen through the polyethylene, the branch is cut immediately below the wrapping, planted in the pot, and placed under intensive care. The soil should be kept moist at all times. Watering should be done when necessary.

**Budding.** This is a form of grafting whereby an "eye" or bud with a small portion of bark attached is taken from the young branch of the parent tree and inserted in a cut made in a branch or stem of another plant. There are several methods of budding, among which are the

shield or T-budding, ring budding, patch budding, and flute budding. The most common of these methods is T-budding.

The procedure in T-budding is as follows:

1) Scion buds are removed by slicing the bark 1–2½ cm below the bud and passing the knife under it and out at a part well above it.
2) A horizontal cut is made 1 cm above the bud, thus, permitting the removal of the shield-like bud piece.
3) The stock is prepared by making a T-shaped incision through the bark down to the wood.
4) The bark is raised and the bud inserted, sliding the shield downward under the lifted bark so that the bud is between the edges of the bark and well below the horizontal incision.
5) The tail or handle is cut off exactly at the horizontal incision, and the bud is firmly tied in place.

**Grafting.** A part of one plant, usually branch or stem, is inserted into the same or related part of another plant so that the two cut surfaces of each unite to form a new plant called a clone.

There are two essential parts of a graft: the stock and the scion. The lower part of another, which is the stock, is the plant where the scion is inserted. The stock is usually a healthy vigorous nursery-raised seedling with its top completely cut off and replaced by a scion. The scion is a freshly cut branch from a selected plus tree with genetically superior characteristics. There are five important requirements for a successful grafting operation:

1) The stock and scion must be compatible. Both the stock and scion should belong to the same genera, species, or variety.
2) The cambial region of the scion must be in intimate contact with that of the stock to allow passage of food from one to the other.
3) The grafting must be done when the stock and scion are in the proper physiological stage. Usually, this means that the scion buds are dormant.
4) Immediately after grafting operation is completed, all cut surfaces must be carefully protected from desiccation. The graft union is properly covered with grafting wax or clay, or

is tied tightly with a strip of plastic to prevent entry of water and air to the wound. The grafting wax is a melted mixture of 4 parts resin, 2 parts bees wax, and 1 part fallow. Another less costly alternative is a combination of 2 parts clay and 1 part fresh cow dung, mixed together thoroughly. Melted paraffin may also be used. The grafting tape is a strip of cotton cloth about 2 cm wide, soaked in a melted grafting wax then dried. A plastic strip is also recommended for tying.

5) The graft must be tendered for a period of time after grafting. Shoots from the rootstock must be pruned off or they will prevent growth and development of the scion.

The grafting operation should be done in a cool, moist place. During the healing and "union" processes, grafts should be placed in the shade. The grafted plant should be watered often to prevent drying. The scion maybe covered with banana stalk or thin plastic bag. There are four grafting operations; namely:

1) **Whip graft** - This method involves the grafting of stock and scion with the same diameter. A 3–6 cm slanting cut made by one clean stroke of a knife is done at the bottom of the scion. A corresponding cut is made at the top of the stock. The cut surfaces are placed together so that the cambial regions are in contact.
2) **Whip and tongue graft** - This is similar to the whip graft, except for the tongues that holds the stock and the scion together. A downward pointing tongue is made in the apical half of the slanting surface of the scion. A corresponding upward tongue is also done on the stock. When the stock and the scion are inserted into each other, the tongues interlock and the cambial regions come in firm contact.
3) **Wedge or cleft graft** - The scion may have the same or a smaller diameter than the stock. The scion is prepared with its basal end in the form of a wedge. The stock is split at its apical end and the scion inserted so that the apical portions of the cut surfaces of the scion are just visible; and at least one side of the cambia of stock and the scion is in contact. The graft requires tying and sealing.
4) **Side-tongue graft** - The scion should be slightly less in diameter than the stock. A long, flat, slanting cut is made at

the bottom of the scion. A downward pointing tongue is made in the slanting surface. A short cut is made on the opposite side to form a chisel-shaped base to the scion. An upward pointing tongue is cut in the stock to hold the base of the scion. A downward cut is made as far as the tongue to expose the cambial regions in such a position that they correspond to those of the prepared scion. The tongue covers the chisel-shaped base of the scion. Scion and stock are bound together and sealed.

**Planting Stock Production Using Wildlings**

Wildlings are seedlings growing naturally under the forest canopy. In the absence of nursery-raised planting stocks, wildlings could be used, provided they are properly hardened and taken cared of. However, their survival in the field is generally lower.

Where planting sites are favorable, wildlings can be planted in the open. Wildlings may be developed into hardy planting materials in a nursery by potting them and by transplanting them in beds.

The same procedure for lifting seedlings from nursery beds is applied to wildlings of sturdy species like narra, mahogany, and ipil-ipil. Wildlings of delicate species, such as dipterocarps, should not be lifted when they are more than 30 cm in height. They should be lifted with a ball of earth around the roots. In both cases, care should be taken to minimize injury to the roots.

Lifted wildlings are placed in any convenient container lined with moist cloth or similar material. Leaves of balled wildlings should be trimmed. Proper shade should be provided for wildlings in transport.

Proper shade and special care should be provided in order not to break the clump of soil around the earth-balled seedlings.

In the nursery, they are graded and sorted. They are then potted or transplanted in beds following the usual procedure. Balled wildlings are potted in the nursery potting shed.

Grading insures that only quality seedlings are grown in the nursery and subsequently dispatch for outplanting. Diseased and unhealthy seedlings should be immediately discarded. Further, seedlings should be sorted according to sizes so that even-sized seedlings are grouped together. A general but appropriate definition of seedling quality is “fitness for purpose” (IUFRO, 1980

in Hawkins, 1996). The seedling attributes critical for seedling survival and growth after outplanting would define seedling quality for reforestation purposes (Duryea, 1985 in Hawkins, 1996). Intuitively, it will be the degree to which planting stock realizes the objectives of management. The following are the characteristics of high-quality seedlings:

- *Rapidly produce new roots* – Production of new roots is an indicator of the ability of the new outplanted seedlings to survive in the new environment. These new roots will be the one to absorb water and nutrients in its new and permanent environment. The root growth potential is the test that determines this ability.
- *Quickly resume photosynthesis and continue growth* – Resumption of photosynthesis and growth is another indicator that the seedlings have adapted to its new environment and is starting its normal growth towards becoming a tree. Photosynthesis is the most sensitive physiological process that will indicate whether a plant is under stress. Resumption to normal levels will indicate that the plant is no longer under stress. Its measurement is carried out using an infrared gas analyzer and is very expensive equipment. The evidence of leaf flush is a latter indication of this phenomenon.
- *Have large fibrous root system* – Vigorous and healthy seedlings should be able to absorb sufficient quantities of water and nutrients. Large and fibrous root systems contain many lateral and fine root systems that are the efficient absorbers.
- *Sun- adapted foliage* – Seedlings should be able to withstand direct solar radiation that is intense in the planting areas. This should be accomplished during the hardening-off process.
- *A large root collar diameter* – This will indicate seedlings with large conducting tissues capable of moving water, nutrients, and carbohydrates within the plant to the organs needing them. Large root collar diameter is also an indicator of sturdy (wind firm) seedlings.
- *Balanced root: shoot ratios* – The absorbing and transpiring organs should be balanced. Bigger or heavier roots are preferred than spindly seedlings with small or light root systems. A 1:1 or 2:1 ratio (by weight) is ideal.

- *Good carbohydrate reserves* – There is a lag time before the seedlings could resume photosynthesis and growth. In the absence of net photosynthesis, seedlings have to rely on available carbohydrate reserves to maintain plant integrity and maintenance functions.
- *An optimum mineral nutrient content* – In like manner, seedlings do not immediately absorb nutrients from the new environment and thus a stock of these nutrients within the tissues will be vital for the first few days of "adjustments" in the new environment. It may have to wait for the new roots to grow which would definitely require these nutrients to build up the new tissues.
- *Tolerance to stress* – Seedlings will experience a variety of stress in the field and thus it is important that it has the ability to withstand these stresses.
- *Mycorrhizal or Rhizobium infection established* – These beneficial microorganisms when established in plant roots provide the seedlings with many benefits.

Grading procedures are varied. There are practical and important parameters for grading seedlings.

Shoot to root ratio is a good indication of seedling quality. A good ratio is 1:1–1:2 shoot:root mass (Jaenicke, 1999). This may be difficult to measure because it is hard to observe the roots and it requires destructive sampling of the seedlings. The most reliable expression of this ratio is biomass (i.e., dry weight of the shoots and roots). Nevertheless, in the absence of balance and oven in a nursery, shoot and root length could be substituted. However, it must be emphasized that it is a prudent practice to sacrifice a few seedlings in order to ascertain the quality of the seedlings. Moreover, examining the roots, especially for seedlings raised in polyethylene bags, is important to determine root deformation that is prevalent in this production system.

A second method of determining seedling quality is the sturdiness quotient. Unlike the first test, this is simpler and nondestructive. It takes the quotient of the height (in centimeter) and the root collar diameter (in millimeter).[2] For example, a seedling with a height of 30 cm and a root collar diameter of 5 mm has a sturdiness quotient of 6[3]. A low quotient is desirable meaning it is sturdy. Values exceeding 6 are undesirable. The root collar diameter that is also measured for

this parameter could be likewise utilized, bigger diameter indicates better seedlings.

A compact root system with several fibrous lateral roots and a short taproot is most desired. Root pruning and transplanting in beds encourage the formation of a compact root system.

The crown should be symmetrical in shape with several small side branches, if any, and an erect terminal stem or shoot.

The stem should be straight and with a wide diameter in proportion to the height of the seedlings. It should be firm with a strong root collar and woody, not succulent.

Generally, in a single-aged planting stock, the tallest or dominant seedlings are better in quality. Undersized seedlings are left in the beds or transplanted to grow to plantable size, whereas oversized ones are trimmed or pruned.

The seedlings should be free from pests, diseases, and lesions. They should not have any damage caused by mechanical injuries. They are normally green, fresh, robust, and properly hardened.

The hardening process, commonly applied to nursery-raised seedling stocks, is also applicable to wildlings developed in the nursery. Hardening-off prepares the seedlings to the adverse conditions that outplanted seedlings encounter in the field. It is a series of progressively applied treatments that train or accustom the seedlings to the unfavorable conditions once outplanted. Intensity of treatment gradually increases towards the time that seedlings will be outplanted. In a typical planting area, the following adverse conditions threaten seedling survival: moisture stress, heat stress, light stress, nutrient stress, acidic soil, and windy conditions. To prepare the seedlings to these conditions, the following treatments should be judiciously applied:

- **Root pruning** – applied during transplanting and two more times the last one made a month before outplanting. This treatment promotes the development of lateral root systems (i.e., compact and ramified root system). For bareroot seedlings, the use of sharpened shovels thrust into the nursery beds at an angle of 45$^{o}$ is done. Taut piano wire pulled underneath nursery beds is a more efficient way of accomplishing root pruning for bareroot stocks. For seedlings in polyethylene bags, a sharp sickle is used to make a slit through the middle portion of the bags. This is tedious and

laborious. Seedlings in root trainers are automatically root pruned when the root penetrates through the holes of the root trainer at the bottom (Fig. 14). Roots become dry due to the absence of moisture and this "drying-up" simulates exactly the root pruning procedure.

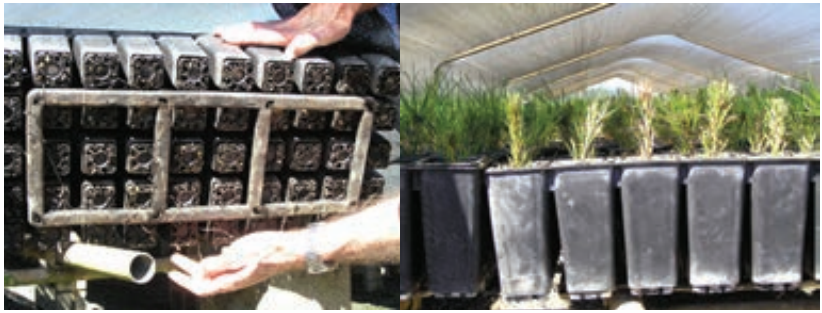


**Fig.14. Root trainers are effective in accomplishing air pruning of roots.** *(E. L. Tolentino,J r.)*

- **Moisture-stress conditioning** – hardy plants are capable of growing in soils with low moisture. In the nursery, watering should be carefully regulated, particularly in the later stage of seedling development. Water (amount and frequency) should be progressively reduced. This should be prolonged and much less towards the end of the nursery stage. This treatment should be done at least one month before outplanting. Nurserymen should regularly monitor and check the response of seedlings. Since the end of the nursery growing stages coincide with the rainy season (planting season), appropriate measures should be done to prevent rainwater from disrupting the structured watering regime. In some nurseries, they place a transparent polyethylene sheet over the seedlings to ensure that the prescribed watering regime is followed.

  Before seedlings are transported for outplanting, seedlings should be thoroughly watered.

- **Reduce or eliminate fertilizer application** – the soil substrate should have adequate nutrients to supply the seedling requirement for optimum growth. In some cases, supplemental fertilization is necessary but should be progressively reduced towards the end of the nursery growing stage. Too much fertilizer, particularly N, results in heavy crown/leaf

production, causing unbalanced root to shoot ratio and makes it attractive to many pests. Reduction in fertilizer application should be made prior to outplanting.

- **Heat- and light-stress conditioning** – planting areas are frequently open and hot. Tough seedlings should be capable of growing in hot and fully exposed conditions. The transparent polyethylene sheet cover will accomplish this goal. This cover intensifies heat, while at the same time, providing full light to the seedlings.

- **Shocking** – is a term used to describe the lifting and moving of seedlings in the nursery to ensure that they are tough and hardy to withstand the transport stress during outplanting.

**Preparation of Planting Stock for Field Planting**

The survival and growth of plants in the field depends, to some extent, on the treatments received prior to field planting (PCARRD, 1992). Preparation usually varies, depending on the condition of the stock to be outplanted (i.e., bareroot or potted).

**Bareroot stocks.** There are a number of forestation species (Table 16) that are outplanted bareroot (i.e., without a soil around their roots). Bareroot planting are stocks that are easily and conveniently transported, handled, and planted. However, this kind of preparation is limited to a few species only and on very favorable planting sites.

a) *Lifting* - Before removing the seedlings from the seedbeds or transplant beds, these are watered a day ahead so the seedlings can be easily lifted without much injury to the rootlets. Seedlings are loosened from the soil with a digging fork or spade then gently pulled and the soil shaken off. Duration of root exposure should be minimized.

b) *Grading and Sorting* - Quality stocks have more chances for survival and early growth in the planting site than poor quality planting stocks. The quality of planting stock could be determined by grading. Seedlings of good quality and appropriate size are used for planting.

c) *Trimming* - This means cutting the leaves and roots to reduce transpiration and to balance the proportion of the shoots and root. Immediately after grading and sorting, the injured roots and branches including extra long tap root and lateral roots are pruned with either a sharp knife or a pruning shear. Leaves should be pruned more than the roots so that transpiration will not exceed the absorbing capacity of the roots. Oversized hardwood seedling may be cut to the desired length of both the stem and the taproot.

Shoot pruning may be carried out among broadleaf species, not in pines.

d) *Mud-puddling* - Mud-puddling consists of coating the roots with a thin film of gel-like mud to protect the root system from drying between lifting and outplanting.

A hole is filled up gradually to ¾ of its depth with pulverized clay-loam soil and sufficient water mixed to a consistency of paint. Clumps, grit, and large particles in the mud are removed.

The sorted seedlings are bundled and their roots dipped into mud with just enough thin, wet, and soft coating. Mud-puddled roots are kept moist by wrapping.

e) *Packing* - Packing is done to give maximum protection to the seedlings during transport from the nursery to the planting site. About 25 seedlings are bunched to each bundle. Around the mud-puddled roots are packed enough wet sawdust, fine leaves, chopped rice straw, or mountain moss to keep the roots moist until planting.

Each bundle is wrapped with any packing material. In the absence of wrapping materials, the mud-puddled seedlings may be placed in pails, basket, etc. Packed seedlings should be placed in shady spots.

f) *Heeling in* - This is done for seedlings removed from the bundles and which are not planted on schedule. This operation involves the temporary setting in of the seedling stocks in moist soil under shade until these can be planted. It is not advisable to keep mud-puddled seedlings in package for more than two days. Heeling-in may be done as follows:

- A trench equal to or a little deeper than the roots with a 45° slant on one side is dug in a shady, moist area or near a riverbank. The seedlings are arranged along the slanting side and the roots are covered with moist soil firmed down with the fist or heel. A mulch of glass may be placed over the soil to keep it from drying.

**Potted stocks.** For potted planting stocks, all operations performed for bareroot stock except grading, sorting, and packing are eliminated.

The same principles and criteria for bareroot stock grading and sorting apply to potted planting stocks. Prior to transporting, potted planting stocks are simply bundled in groups of 10-20, depending on the size of the pots. For better protection, a burlap or banana leaf sheath may be wrapped around the group of seedlings, and then tied properly. Another way of packing is by loading them in a carriage box or basket specially made for this purpose.

## Nursery Management

Nursery management will be essential for large-scale nurseries, particularly for institutional nurseries. However, smaller nurseries would require some form of management if high-quality seedlings were to be produced. Management will address issues on plans and schedules in the nursery. An important constraint that should always be addressed in nursery production is the seasonal requirements for seedlings, considering the tree-planting season in the Philippines that depend on the rainy season. Jaenicke (1999) listed the main tools for planning nursery operations that are essential in most nurseries in the Philippines:

- **Nursery calendar.** This shows the production schedule in the nursery. Specifically, it contains information on date for sowing seeds and how long it will take to reach the plantable size. The date can be determined by counting backwards from the time of outplanting. Knowing this information will aid the nursery manager to plan and schedule the purchases of supplies (e.g., seeds), materials, and equipment. Furthermore, hiring of casual or seasonal laborers is easily determined.

- **Plant development register.** It gives the nursery manager information about specific species information. This register contains records or data about each species by seedlot. The information includes: seed sources, pretreatments, sowing date, time of germination, germination percentage, percentage of germinants, pricked out, potting substrate, microsymbionts used (origin and type), plant development, and condition under they are produced. Cultural treatments (mulching, shading, watering, hardening-off, root pruning, etc.) are also recorded. Problems like pests and diseases are also included. If possible, nutrient analyses of soil substrate used should be also recorded. The information contained in the plant register becomes valuable in nurseries with regular staff turnovers.

- **Nursery inventory.** The inventory aids the manager in knowing if the required seedling production will be met by the planting season. For commercial nurseries, this will also be valuable in knowing if seedling orders could be adequately met on time. Information about species, age/size, quantity, and bed location are essential.

- **Record of experiments.** This is advisable even for smaller nurseries to provide valuable information regarding the experiments conducted in the nursery. Simple experiments like watering, shading, substrate mix, and seed pregermination treatments generate much needed information for many nurseries. Recorded information is essential to ensure that the practice could be repeated if successful.

- **Staff training.** It is an important component of effective nursery management to insure that even nontechnical personnel, particularly the seasonal laborers, are capable to performing the various aspects of nursery stock production. Going through the whole spectrum of seedling production, from germination to seedling packaging, and transport will be beneficial in ensuring that high-quality seedlings are produced. Safety practices are also important to avoid accidents and sickness in the nursery.

# Plantation Development and Management

## Plantation Development

### Establishment of Forest Plantations

Establishment of forest plantations operations commence with the site survey and analysis, with the information generated used as inputs for the development of the planting plan. The planting plan will spell out the various operations and activities in the plantation beginning with the site preparation, which will create a favorable planting environment for the seedlings to be outplanted. Next is the actual tree planting where the seedlings are set in its new environment and are expected to grow into a mature tree.

According to the current policies on tree plantation development, the planted trees have to be registered with the local DENR office. Subsequently, maintenance and protection operations are employed to prevent and control agents that could slow down growth and development of seedlings as well as check or arrest damaging or injurious agents. Silvicultural treatments to improve quality and growth of young trees are employed later in the life of the stand. (e.g., pruning for knot-free timber and thinning to induce diameter growth). Upon reaching its economic rotation age, the trees are harvested in accordance to the existing policies and regulations.

The typical plantation described here is a large-scale plantation. Figure 15 is a comprehensive representation of the various operations. A smallholder tree farm may not require all the activities contained in the chart. But ideally, despite the limited scale of the operations, even smallholder tree farms will have some semblance of all the activities contained in the chart but in a scaled-down degree.

**Planting survey and plan.** Any forestation program must be based on planting surveys and planting plans with proper plantation records and a simple but efficient reporting and monitoring system. The failure of most forestation programs is primarily due to the lack of systematic planting plans. Planting plan is also a must to assure

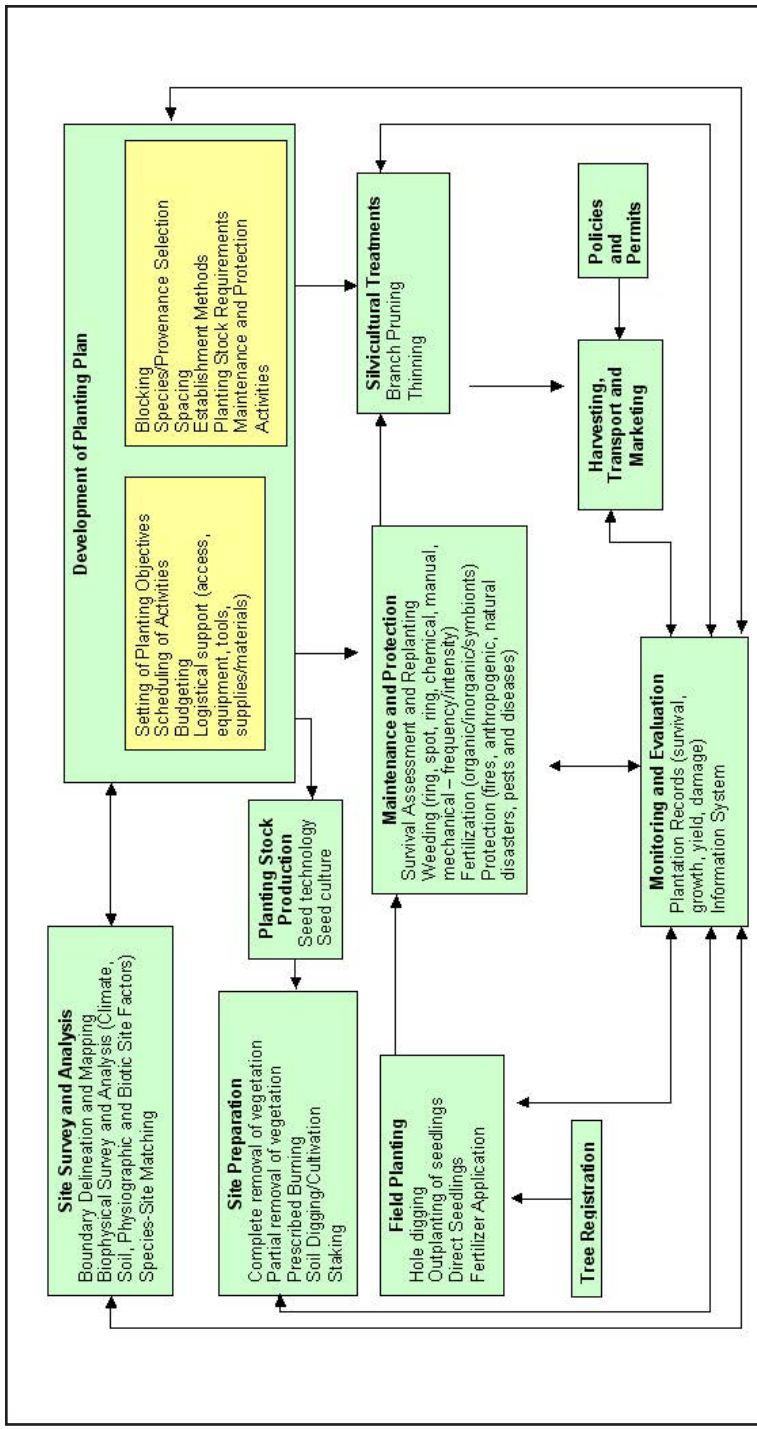



**Fig. 15. Flowchart of activities for the development and management of forest plantations.** *(E. L. Tolentino, Jr.)*

continuity of the implementation of the project. The forestation plan has to indicate clearly the objectives of planting and how these objectives could be achieved.

- **The planting survey.** Before a big project on reforestation or plantation development is started, a planting survey is undertaken as a basis for the planting plan. The method in the conduct of a planting survey can be described as follows:

  - survey the area taking note of existing structures like roads, trails, creeks, etc. even without using sophisticated surveying instruments;
  - record all relevant data as detailed as possible; and
  - mapping can be done using field sketches with the use of box compass and by pacing.

  The field report on the planting survey covers the following items:

  - general topographical description of the area including main ridges, streams, rivers, roads, and trails;
  - brief land use description or history of the area;
  - location and boundaries of the area;
  - compartmentalization of the area;
  - soil condition;
  - possible species to be planted; and
  - site of nursery, if necessary.

- **The planting plan.** The planting plan contains all-important information gathered in the planting survey. The planting plan must include the following information:

  - objectives of planting;
  - geographic location of the proposed planting area;
  - other biophysical data of the area, such as climatic type, rainfall, edaphic factors (soil structure, soil pH, soil fertility, soil temperature, etc.), physiographic factors (topography, elevation, slope, exposure/aspect), biotic factors (flora and fauna), and possibly anthropogenic factor (man and his influence over the development,

establishment, as well as destruction of the forest vegetation);
- choice of species for possible planting, choice of suitable methods of site preparation, choice of establishment techniques, spacing, and estimate of quantity of seeds or seedlings needed;
- subdivision of the area for planting and indicating those that can not be planted (too wet, dense brush, forested, needed for other purposes);
- budgetary requirements for all activities for at least a period of 5 years;
- equipment and supplies needed; and
- maps (preferably with a scale of 1:10,000). Williamson (1993) recommended procedures for the production of base maps.

**Soil survey and analysis.** Information about the geology and geomorphology of the area can be obtained from DENR and the Bureau of Soils and Water Management (BSWM). Actual ground survey is also important.

Information from the soil survey will serve as the basis for the choice of species, nursery locations, camp sites, and roads. It can serve as reference to determine the degree of soil erosion. Soil analysis should include the following:

- Soil depth determination wherein the soil should be measured from the surface to the unweathered parent materials and should be classified as follows:

  a) 30 cm – and less: shallow
  b) 31 cm – 100 cm: medium
  c) 100 cm – 200 cm: deep
  d) 200 cm and deeper: very deep

- Soil physical properties that includes pH, organic matter content, structure, and bulk density.
- Soil nutrients especially the macronutrients, N, P and K, which are important for the growth of the plants.

Guidelines for site classification and determination of fertilizer requirements based on the soil analysis are provided in detail by Richards (1993).

**Species-site compatibility.** Species selection is a complex interaction of forces and factors that encompasses aspects related to the following environments: biophysical (the site), socioeconomic (market, policies, farmer/planters needs and preference), technological (processing), and project management (objectives of planting [i.e., production, protection, service, availability of germplasm, knowledge on tree propagation and management]) (Fig. 16). Proper species selection results in high survival, greater productivity, and reduced risk of plantation failure. Different forest tree species respond to different ecological conditions such as soil, rainfall, and elevation since they have different site requirements for optimum growth. However, many forestation efforts have failed in the past because the species and the sites were incompatible. Tree growers just plant any available species with abundant supply of planting materials without considering its ecological requirements, hence, the seedlings do not grow satisfactorily on the sites.

A computer-based software on species-site matching procedure has been developed by ERDB and Green Tropics International or GTI (Lantican et al, 2003). The procedure makes use of mathematical models to determine the appropriate forest tree species to be planted in a particular site. It provides an easy and simple procedure to classify sites into good, average, or poor sites for establishing plantations of priority species, such as mangium, yemane, bagras, auri, neem, agoho, red gum, narra, mahogany, teak, falcata, and Benguet pine.

World Agroforestry Centre (ICRAF) has published a comprehensive tree species selection guide for 350 fruit and timber species, rattan, and bamboo in the Southeast Asian region (ICRAF, 2006). From the biophysical information available in the database (mean annual rainfall, mean annual temperature and altitude), maps matching species to sites in Southeast Asia could be generated. The information contained in this database could be also accessed in the web (http://www.worldagroforestry.org/sea/Products/AFDbases/AF/index.asp).

Although proper species-site matching is the initial step in planting forest trees, there are other equally important factors, such as the use of seedlings/planting materials of high genetic and physiological quality,

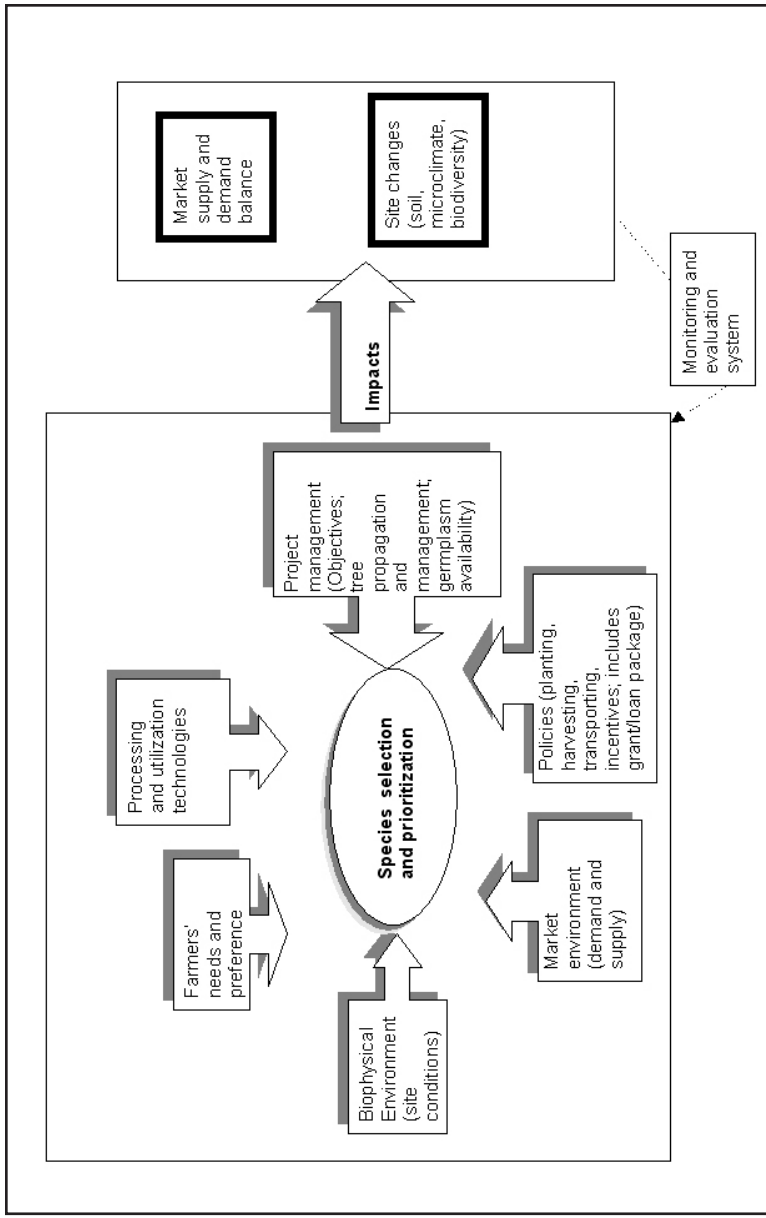



**Fig. 16. General framework for species selection and prioritization** *(E.M. Tolentino, Jr., unpublished).*

to bring about better tree form and wood quality. In addition, some silvicultural practices must also be considered to achieve successful planting of tree.

**Site preparation for field planting.** On areas with steep gradient (20º and above) and with erodible soil, precaution must be observed so as not to induce soil erosion when clearing the area of vegetation. There are two methods of site preparation (PCARRD, 1992).

- **Complete removal of vegetation.** In this method, all vegetations (usually grass) growing in the area is cut. It is applicable in less erodible sites and for relatively flat to moderately sloping areas. When establishing monoculture plantations, the method of site preparation is efficient. It is, however, laborious, time consuming, and costly. Besides, the planted seedlings will be exposed to extreme weather conditions and erosion.

- **Partial removal of vegetation.** Only the selected portion of the area to be planted is cleared of vegetation. This is usually done in erodible sites and farms with intercrops. The vegetation left uncut protects the planted seedlings and also controls soil erosion. The vegetation can be partially removed through strip and spot clearing.

  Strip clearing is employed when the vegetation is 1~~2~~ m tall. Clearing is done by strips usually a meter wide, preferably following the contour lines. Cut or slashed vegetation is laid below the strip, which also holds the soil up. Planting is done in the middle of the strip. Distance is provided between strips.

  In spot clearing, spots or patches are cleared close to the ground, usually 1 m in diameter, where the seedling is to be planted. This method is cheaper than strip clearing, but movement between patches is made difficult when the vegetation is very dense.

- **Prescribed burning.** Depending on the type of vegetation, burning involves slashing of grasses, herbs, and brush cover; felling of undesirable shrubs and trees; and subsequent burning.

When burning is adapted, it must be prescribed and controlled. When controlled, burning is a cheap and easy way of clearing vegetation and reducing the debris on site. This method involves careful planning and practices, such as construction of fireline, organization of firefighter, and good weather conditions, in order to prevent extension of fire around the area to be reforested.

Burning is preferably conducted in the early rainy season and end of dry season with necessary control measures. It can be done early in the morning or late in the evening when the wind is low and the fire can be controlled easily. Coordination with firefighters and other institutions concerned should be done before operation starts.

However, burning should be avoided in steep slopes as this would expose and facilitates erosion of surface soil.

## Methodologies for Plantation Establishment

### Using Nursery-Raised Seedlings

**Outplanting.** After proper packing and bundling, the seedlings are carefully transported to the planting site, either manually or mechanically, with the use of an animal-driven cart or haul track.

While in transport, the seedlings should be properly provided with shade. Severe shocking should be avoided to avoid injury.

In outplanting, which is the actual planting of the seedlings in the field, several techniques (PCARRD, 1992) can be used, depending upon the condition of the seedlings to be planted; that is either bareroot, potted, or stumped.

- **Bareroot seedlings.** Some species are commonly planted bareroot. Bareroot seedlings could be outplanted using the dibble method, except that a bigger dibble is used.

  Bareroot seedlings may also be planted using the hole method. The transplant is held by the root collar and shaken to spread the root system. Then, it is set in the hole at 20–25 cm deep. This is done with one hand while filling the hole with the other. The topsoil is drawn over the roots and thumped down with the fist. The rest of the soil is thrown in and pressed firmly with the heels or the back of the planting hoe.

- **Potted seedlings.** The seedling is removed from the container, except if degradable materials like paper pot are used. Plastic bags can easily be torn or cut with a small knife. Care must be taken not to break the earth ball. When setting the seedling into the planting hole, the upper part of the earth ball must be slightly deeper than the edge of the hole. Soil is filled into the spaces and pressed firmly all around.

- **Stumped seedlings**. A stump is taken from seedlings of 0.75+ m high. The stem is cut 3–5 cm above the root collar. Long lateral roots and taproots are shortened leaving about 10+5 cm long root system.

  Stump planting eliminates transpiration losses. Stumps are easy to transport and store. These can be planted just before the rainy season. Species that can be planted successfully by stumps include teak, dita, yemane, golden shower, and banaba.

  In outplanting using stumps, the dibble or the hole method is employed. The taproot should not be bent. The root collar should be level with its original position in the nursery. The best soil is used to cover the root system of the planted stump.

**Spacing to be used.** The manner of distributing seedlings over an area (PCARRD, 1992) varies from 1 m x 1m to 10 m x 10 m, depending on various considerations, such as:

- *Rate of growth* – Species with protruding branches such as molave, narra, and teak, must be planted closely if grown for timber production purposes to induce formation of long cylindrical boles. Spacing of 2 m x 2 m is recommended.
- *Site conditions* – Seedlings must be spaced wider on good sites than in poor sites.
- *Objectives of the plantation* – If the plantation is intended for timber production, the recommended spacing is 2 m x 2 m or 3 m x 3 m. However, progressive thinning should be done later until the desired spacing is adopted. If planting is for productive purposes, spacing must be close to produce an immediate cover. For beautification purposes along roadsides, a spacing of 10 m x 10 m is recommended.

- *Expected percentage of mortality* – If the percentage of mortality is expected to be high, closer planting must be observed to maintain the desired stem density after death of weaker seedlings.

Generally, there are two spacing methods being used in forest planting: regular and irregular. In regular spacing, the seedlings are set in straight lines. The planting spots are stalked to serve as guide to planters. The square and the rectangular methods are often used. The rectangular or line planting is applicable for reforestation in cogonal areas wherein the cost for strip brushing can be reduced by adopting a wider spacing between the row and a closer spacing between the individual plants in the rows.

In irregular spacing, seedlings are not planted in straight lines resulting in varied patterns of small groups and individual trees. This method is applicable on very rocky and rough sites where only the most favorable microsites are considered for planting. Knowing the regular spacing to be adopted, the exact number of seedlings to be planted on a hectare basis can be computed using the formula:

$$T = \frac{K}{S}$$

where: T = Total number of trees to be planted per hectare
K = Area of a hectare which is equal to 10,000 $m^2$
S = Spacing in meters

Based on this formula, the total number of trees to be planted per hectare (for the different alternative spacings) used in reforestation is as follows:

| Spacing (m) | Total No. of Trees per Hectare |
|---|---|
| 1 x 1 | 10,000 |
| 1.5 x 1.5 | 4,444 |
| 1 x 2 | 5,000 |
| 2 x 2 | 2,500 |
| 2 x 3 | 1,667 |
| 3 x 3 | 1,111 |
| 3 x 4 | 833 |
| 4 x 4 | 625 |
| 5 x 5 | 400 |

**Time of planting.** Outplanting can be started as early as the beginning of the rainy season when a depth of 18 cm soil is already moist. It can be continued up to the middle of the rainy season. Planting towards the end of the rainy season will not give seedlings enough time to be established prior to the dry season, thus, resulting in a great percentage of mortality.

**Schedule of activities.** The schedule of various activities is best presented either in tabular form or Gantt Chart. The schedule includes time, manpower, equipment, and outplantable seedling requirements by species.

**Direct Seeding**

Direct seeding is the oldest method of artificial regeneration (Weidelt, 1975). This method has been replaced by planting for most species that gives better results. But there are still a number of species, which are easily propagated by direct seeding because they:

- produce plenty of seeds;
- grow fast at the early stages;
- have large seeds with plenty of reserves;
- produce a long taproot at an early age; and
- have seeds with a high germinative capacity that can be maintained well under ordinary conditions.

Species which have been successfully established in the Philippines by direct seeding include ipil-ipil, lumbang, baguilumbang, akleng-parang, and teak.

*Methods of Direct Seeding*

- Sowing on cultivated patches 1-3 ft in diameter is applicable for larger seeds, which are sown at a wider spacing (e.g., lumbang and kasoy).
- Sowing on cultivated strips 2-4 ft wide is usually practiced with finer seeds such as ipil-ipil, which are sown more densely.
- Broadcasting the seed without soil preparation gives good results only under very favorable conditions (moist sites, loose

soil, not too much ground vegetation). There is a possibility that grasses intercepted the seeds before it reaches the ground.
- Broadcasting the seeds from planes can be successful only under very favorable conditions.

Generally, direct seeding gives good results only when soil preparation has been carried out to facilitate root penetration. It is also important that the seeds are covered with a soil layer 1–2 times the thickness of the seed and, if possible, with a light mulch. To ensure establishment during the rainy season, direct sowing must be carried out at the very start of the rainy season, so that the seedlings are already strong enough to survive the heavy rains later in the year. Success depends on so many unforeseen factors. It is strongly recommended to conduct small-scale experiments first before embarking on any larger operation.

The quantity of seeds needed can be estimated from the number of viable seeds per kilogram, but ample allowance has to be given for losses due to birds, rodents, and insects.

There are some chemicals (e.g., 1 kg red lead powder for 8 kg of seeds) available to treat the seeds before sowing to make the seeds less attractive to rats and birds.

To ensure even distribution of seeds, the quantity of seeds for one line across the area must be measured in a tin can or similar container as a guide.

*Advantages of Direct Seeding*

- No nurseries are required.
- More flexible. It does not depend on the availability of nursery stock.
- The shock of transplanting is avoided.
- Species, which produce a long taproot at an early stage, are generally difficult to transplant. Direct seeding is likely to give better results in those cases.
- Due to a greater density in direct seeding (if successful), the quality of the future timber stand may be better.

*Disadvantages of Direct Seeding*

- Sometimes the total costs of establishment are higher than planting, because of higher weeding expenses. The initial cost may be lower, but the total cost of establishment must also include weeding expenses, which in direct seeding can be very high.
- Poor survival of seedlings, if conditions are not very favorable, because these cannot be watered just like in a nursery. If the seedlings cannot reach soil layers, which keep sufficient moisture during the dry season, an initial success may turn into a complete failure.
- Rodents, birds, and insects attack many of the seeds and young seedlings.

The success is very uncertain, because there are many unpredictable factors.

## Plantation Development Without Planting

Previous presentations usually show the conventional system of plantation development via nursery-raised seedlings and/or clonelings/ cuttings.

Plantation development does not necessarily mean planting activities; it can also be done without planting.

This may look unusual or not following the common procedure in the development of plantation, but through the years of PICOP experience, the leguminous tree species, particularly falcata and mangium, can be redeveloped without planting. On areas previously planted with falcata and mangium, two methods of plantation development can be applied – either through coppicing or natural regeneration. Natural regeneration is being practiced, particularly on *Acacia mangium* (Fig. 17) and coppicing for *Paraserianthes falcataria.*

This means silvicultural treatments are required for natural regeneration of mangium, mainly through thinning, which is done by eliminating all other vegetations competing with the species and leaving adequate number of regenerations per hectare. In the case of PICOP, it is 625 trees or a spacing of 4 m x 4 m, and maintenance through clear weeding must be done for a period of up to 2 years.

**Fig.17. One-year old mangium plantation developed without planting ready for silvicultural treatment** *(D.R. Tumambing)* **.**

Coppicing or sprouts selection shall be practiced for falcata species; and 2~~3~~ sprouts nearest to the ground shall be selected. The number of sprouts to be initially tended will be about 1,000–2,000 hills and by the end of 6$^{th}$ to 8$^{th}$ year will be 600–800 trees, which shall have a yield of no less than 200 m$^3$/ha.

Below is an example of the elemental activities of mangium plantation development done without planting but with the application of appropriate silvicultural treatments, as follows:

| | | ₱/ha | Man-days/ha |
|---|---|---|---|
| Staking | ₱ | 945 | 5 |
| Clearing at age 6 months | | 3,780 | 20 |
| Thinning at age 2 years | | 2,835 | 15 |
| Protection/Maintenance | | 945 | 5 |
| Supervision | | 3,000 | - |
| Total | **₱** | **11,50~~0~~** | **45** |

Clear felling is done at age four years with an approximate pulpwood volume of 110 m$^3$/ha. This shows that plantation development under this approach is viable, as currently practiced by PICOP in supplying its mangium pulpwood to the pulp and paper mills,

in addition to the normal plantations developed using nursery-raised seedlings and clonelings.

## Plantation Records and Management Prescriptions

Records of plantation activities should be maintained for future reference. These are important in decision-making.

In a large-scale forestation project, budgetary requirements should first be determined. The budget includes items like personal services (salaries and wages), supplies and materials, transportation and communication equipment, and infrastructure. It should cover and reflect all the operations from seed sourcing, nursery establishment to plantation establishment and maintenance.

## Maintenance

Plantation improvement treatments and treatment activities are important in a plantation. It is some sort of a corrective measure to an unfavorable condition that has developed and may reduce the quality of the trees as they mature. It may also serve as a protective measure that prevents, if not, reduces the risks of exposure when a particular unfavorable condition reoccurs.

### Fertilization

**Fertilization in plantations.** The use of fertilizers in plantation forestry is required in three situations: to correct nutrient deficiency; to establish a tree crop in nutrient impoverished soils; and to stimulate growth of trees (Evans, 1992). The same author listed four stages in the life of a plantation where fertilizers are applied: 1) at establishment; 2) during the postestablishment phase up to canopy closure when deficiencies begin to show; 3) pole-stage fertilizing during early thinnings to stimulate growth; and 4) prefelling application to add increment before harvesting. Most of the researches in the Philippines focused on applying fertilizers in the first two stages.

**Diagnosis of nutrient deficiency.** There are three approaches in determining the deficiencies in nutrients: fertilizer trials, foliar analysis, and soil analysis (Evans 1992). The first approach sets up experiments to evaluate the effects of fertilizers, either singly or in

combination. The second approach performs a chemical analysis of the leaves or needles to quantify the mineral content of the tissues. The third approach involves the analysis of nutrients present in the soil. The analysis of soils is the most commonly used approach in Philippine plantation forestry.

**Fertilizer application.** Hand application is the most common method of applying fertilizers in the plantations. Care should be exercised not to put the fertilizer too close to the young seedlings so as to cause "fertilizer burns" or too far as to make the nutrient unavailable for seedling use. ERDB (1998) recommended the drip line method, which corresponds to the imaginary line below the canopy of the seedlings or approximately the radius of the roots. Many planters add 15θ g or 1 tbsp of complete fertilizer during outplanting at the bottom of the planting hole to boost the growth of the newly planted seedlings.

There are studies, which suggest that the form of nutrient is also important. Evans (1992) cited studies of better seedling response to N as $(NH_4)_2SO_4$ but not as urea. Also soluble phosphate is accordingly best for high pH soils, while mineral phosphate is recommended for acid soils.

Fertilizers should also be employed together with other cultural operations, particularly weeding. Fertilizers could be lost to weeds if competing vegetation are not removed prior to fertilizer application. Conversely, fertilizers, which enhance tree growth, concomitantly causes immediate canopy closure, thereby creating an environment less favorable for weed growth that consequently reduces weeding operations.

a) All weeds or competing vegetations around the base of the tree up to the crown drip line shall be removed/uprooted before applying fertilizer to eliminate, if not, reduce nutrients competition.
b) At level areas, four holes shall be bored on the ground and apply fertilizer along the cardinal points (north, east, west, south) at half the radius of the canopy spread.
c) On sloping grounds, three holes shall be bored on the ground and apply fertilizer at half the radius of the canopy spread – one hole directly above the base of the stem and the other two holes at the opposite sides.

d) The bored holes must be covered with soil to prevent the fertilizer from being washed away.
e) Trees in the areas of plantation that show sign of deterioration/ malnutrition must be attended to immediately and the areas must be fertilized.

**Ditching/Drainage**

- Clogged-up waterways/ditches that could be cleared manually and does not need any mechanical and mobile equipment shall be worked out immediately.
- All drainage problems that cannot be handled manually shall be promptly referred to and coordinated with the local public works office.
- Drainage shall be constructed, in coordination with the local public works office if necessary, on all low-level areas to prevent clogging up of water during rainy days.
- Ditches leading to creeks/rivers shall be maintained and kept free of debris to prevent clogging up of water.
- Waterways shall be constructed, if possible, to irrigate dried-up areas of the plantation.

**Liming**

Extremely acidic areas of the plantation shall be limed to achieve the favorable pH level favorable for the tree species.

**Maintenance of Roads/Trails**

- Trails shall be established with markers erected within the plantation that are inaccessible from spur/major roads and shall be continually maintained to facilitate access during the conduct of activities. The established trails shall be indicated/outlined on the plantation maintenance map for easy location.
- Brushing shall be conducted on trails or spur roads that are already covered by thick vegetations.
- Necessity of road repair or road construction within the maintained plantation shall be referred by the industrial tree plantation maintenance manager to the local public works officer for action/ disposition.

**Weeding/Cleaning**

- All grasses shall be brushed/cut down to 20 cm or shorter.
- Young and small vines shall be uprooted. If vines are thick, it shall be cut with bolos or sprayed with chemicals.
- Wild bananas shall also be cut flushed to the ground.
- Soil around the base of the young tree shall be ringweeded to remove competing vegetations and shall be cultivated if hard and compact.

**Thinning**

- Trees of undesirable form and condition shall be cut/removed to give way to trees within its immediate environment to improve its composition, form, and/or growth.
- Selected dominant trees shall be cut/removed to free intermediate trees, which will become potential crop trees.
- Trees that show attack/dominated by balete shall be cut.

**Sanitation Cutting**

- Trees that show sign of disease or have been infested with insects shall be cut/removed in order to maintain the health of the timber stand.
- One or two layers of trees that surround the perimeter of defective/diseased trees shall be cut/removed to provide a safety factor and prevent the spread of the disease.

**Pruning**

The trees shall be pruned to improve its quality by cutting and removing some of its branches (Fig. 18).

## Protection

Unless adequately protected, the plantation can easily be subjected to pests and diseases, fires, human and animal trespassers, and adverse effects of climate, among others. The objective of protecting the plantation is to control these destructive agents by managing

**Fig.18 P runing a tree branch using handsaw.** *(E. L. Tolentino,J r.)*

the plantation in a way where conditions conducive to destructive outbreaks are minimized.

**Pests and Diseases in the Forest Nurseries and Plantation**

Pests and diseases in the forest nurseries and plantations are equally important problems in the production of planting stocks for the establishment of successful plantations and tree farms. The native and introduced pests and diseases may cause mortality of seedlings and trees in the plantation.

Damage and losses on forest crops due to insects and pathogens vary with the type of host plant, their susceptibility, environmental conditions, the causal agent(s) and the cultural activities in the forest nursery and plantation. The direct losses include reduction in yield, quality, income, revenues, while the indirect losses affect quality of environment or loss in the social sphere.

To recommend a control measure, the following information are needed:

- Pest and Disease Diagnosis

  Diagnosis is the process of identifying the problem, causal organism(s), including the predisposing and contributory

factors. Proper diagnosis is a prerequisite before appropriate control measures are recommended.

Correct identification of the problem and the causal agent may be based on symptoms and signs. However, for new pest and disease, Koch's postulates may be applied as follows: 1) constant association of causal agent and host plant; 2) isolation or mass rearing of pathogen or insect; 3) inoculation or introduction of organism to healthy seedlings; and 4) reisolation of the causal agent.

- Biology and life cycle of pathogen

  Insect pests may undergo simple or complete metamorphosis. The former produces eggs, nymphs, and adults, while the latter produces eggs, larvae, pupae, and adult.

  The life cycles of the pathogens vary widely. Certain fungi have the ability to become saprophytes and are able to attack a wide host range. Others are completely dependent on the host for survival and may only attack a single species in a genus. Similarly, the ways in which pathogens are spread may vary considerably. This includes airborne spread of minute spores, transport of infested material or spores by man and animals. Many pathogens can only grow and reproduce under specially favorable conditions, which need some form of resistant resting stage to survive prolong and adverse conditions.

- Economic Impact

  Disease control measures cannot be economically effective unless they relate to losses that are incurred. In the early stages of a new problem, this information is difficult to obtain, but an estimate of its potential impact is essential before practical steps are undertaken.

**PICOP pest and disease management procedure.** The following procedure is practiced at PICOP in protecting its tree plantation against insect pests and diseases:

a) A trained pest and disease control team supervised by a section head shall always be maintained to be responsible in

conducting the necessary action/treatments when there is an outbreak of pests or diseases.

b) All detected infestation by insects and/or occurrence of diseases shall be reported immediately by concerned personnel to their respective section heads.
c) The section head shall inspect the area together with the "reporter" to assess the extent of damage. If and when possible, he shall institute immediate corrective measures in the area.
d) A plantation incident report (PIR) shall be accomplished by the section head to contain all necessary information and shall be submitted promptly to the industrial tree plantation (ITP) maintenance manager.
e) If the infestation/disease is a recurrent problem, the ITP maintenance manager shall issue instructions to the concerned section head to conduct necessary treatments. However, if not a recurrent problem, the ITP maintenance manager shall refer the problem to the forest research department (FRD) for advise. If necessary, the ITP maintenance manager shall personally see the situation in the field.
f) Upon receipt of advice from FRD, the ITP maintenance manager shall issue instructions to the concerned section head to implement the recommendation of FRD.
g) The section head shall mobilize the control team to conduct chemical spraying and/or other treatments.

**Pests of Forest Trees and Their Control**

- **Seed Borer** (*Araecerus fasciculatus*) - Attacks seeds of *Leucaena leucocephala*, *Cassia* spp. and other legumes. Infestation starts on green pods. Damaged seeds fail to germinate.

  Control:
  a) Burn infested seeds.
  b) Spray young developing pods with systemic insecticide to prevent infestation.

- **Cutworm** (*Spodoptera litura*) - The larvae feed on the leaves causing defoliation and death of *Paraserianthes falcataria* seedlings.

Control:

a) Handpick larvae at night (when insects are actively feeding) and burn them.

- **Aphids** (*Aphis craccivora, A. gossypii*, etc.) - They feed on immature parts of the trees. Adults and nymphs suck the sap of the plant and may cause serious damage.

  Control:

  a) Spray with insecticides or with 20% soap solution.
  b) Remove and properly dispose infested parts of the plant

- **Bakauan beetle borer** (*Poecilips fallax*) - It infests *Rhizophora* spp. by feeding on the inside of the hypocotyls causing death of seedlings.

  Control:

  a) Air-dry seeds for about one week.
  b) Plant other mangrove species that are not host plants of the beetle.

- **Bee-hole borer** (*Xyleutes* sp.) - This beetle infest *Gmelina arborea* and mangium. The larva bores into the wood and tunnels upwards and downwards (Figs. 19 and 20). The tree may produce thin crown, abnormal growth or stem may break at the base.

**Fig.19. Bee hole at base of yemane trunk** *(Lapis, 9 .*

**Fig.20. Section of a tree trunk showing tunnel made by the borer** *(Lapis, 9 .*

Control:

a) Probe the hole with a flexible but strong wire to puncture the larva.
b) Squirt hole with contact insecticides and seal with putty.
c) Cut severely damaged trees.

- **Ipil-ipil jumping lice** (*Heteropsylla cubana*) - The adults and young of this insect feed on the sap of ipil-ipil and may cause leaf curling, yellowing, defoliation and stunted growth.

  Control:

  a) Spray with insecticide or with 20% soap solution.
  b) Biological control with *Curinus coeruleus* or *Paecilomyces farinosus.*
  c) Plant resistant varieties/provenances of *Leucaena.*

- **Ips beetle** (*Ips calligaphus*) - This beetle feed on the bark and wood by boring and tunneling causing the tree to die.

  Control:

  a) Cut and debark dying trees.
  b) Cut infested trees and destroy inside by burning or exposure under the sun.
  c) Apply silvicultural treatments such as thinning, fertilization, etc.

- **Mahogany shoot borer** (*Hypsipyla robusta*) - It attacks the shoots by boring and feeds on soft tissues inside (Fig. 21). Affected shoots dry up and breaks off.

**Fig.21. Shoot infected by a borer** *(Lapis,9 .*

Control:

a) Cut affected shoots and destroy by burning to kill the insect.
b) Maintain a healthy vigorous tree at its early stage.
c) Mixed planting with other nonhost trees.

- **Pine shoot moth** (*Dioryctria rubella*) and pine tip moth (*Petrova cristata*) - These pests attack shoots of Benguet pine, Mindoro pine, and Caribbean pine.

  Control:

  a) Spray chemical insecticide (e.g., fenitrothion) on seedlings.
  b) Promote development of native parasites (*Eriborus* sp.).
  c) Avoid planting pines at elevations lower than their habitat range.

- **Varicose borer** (*Agrilus sexsignatus*) - This insect pest feeds and breeds mainly on *E. deglupta*. They produce zigzag tunnel on the wood that may cause death of trees.

  Control:

  a) Maintain healthy trees.
  b) Plant resistant variety.

- **Mangium wood borer** (*Anoplophora lucipor*) - The larvae of this beetle tunnel between the bark and the wood and form irregular patches. Later, they bore into the heartwood and may cause tree mortality.

  Control:

  a) Cut trees and destroy insects manually.
  b) Replace mangium with other more resistant tree species.

- **Teak defoliator** (*Hyblaea puera*) - The larvae of this moth feed on teak leaves, although it attacks other tree species. Damage is serious during the early part of flushing season.

  Control:

  a) Spray with *Bacillus thuringensis* preparation.
  b) Handpick eggs, larvae, and pupae and destroy.

c) Preserve natural vegetation to harbor natural enemies (spiders, etc.).
d) Monitor for alternate host in the vicinity.

- **Teak skeletonizer** (*Eutectona machaeralis*) - The larvae of this moth feed on all tissues between the network of veins leaving a fine skeleton of the leaf.

  Control:
  a) Apply *B. thuringiensis* preparation.
  b) Destroy eggs, pupae, and larvae.
  c) Preserve natural vegetation to encourage spiders that can parasitize Teak skeletonizer.

**Diseases of Forest Trees and Their Control**

- **Seed Deterioration**

  **Hosts**: Improperly collected, processed, and stored seeds of all tree species may be infected by the pathogens.

  **Symptoms and Signs:** Infected seeds are:
  a) discolored and deformed
  b) moldy or mummified
  c) have obnoxious odor
  d) empty and light

  **Effects of Seed-borne Pathogens:**
  a) killing of the seed
  b) formation of abnormal seedlings
  c) loss of seedling vigor
  d) damping-off (preemergence)
  e) erratic germination
  f) soil contamination

  Common genera of fungi associated with seed deterioration include: *Penicillium, Aspergillus, Cylindrocladium, Trichoderma, Cladosporium, Fusarium, Curvularia, Pestalotia, Botrydiplodia, Phoma, Cephalosporium, Alternaria*, *Macro phomina, and Pestalotia* (Fig. 22).

**Fig.22.F ungi-contaminated seeds.**
*(E.P. Militante)*

**Preventive/Control Measures for Seed Diseases:**

a) Collect mature seeds.
b) Clean or process seeds immediately.
c) Dry seeds gradually.
d) Store seeds properly in plastic bags at low temperature.
e) Treat seeds with chemical protectants, such as: Captan, Carboxin, Chloroneb, Chloranil, Dichlone, Maneb, Zineb, Thiram, Ceresan, and Arasan.

- **Damping-off** - There are three types of damping-off disease, as follows:

a) Preemergence – seeds are infected before emerging from the soil
b) Postemergence – infection occur after seedling has emerged
c) Top damping-off – top portion of seedling, shoots and young leaves and cotyledons may be colonized by the pathogen

Favorable conditions for damping-off:

a) high organic content of the soil
b) high water holding capacity of the soil
c) dense and deep sowing
d) overshading
e) overwatering

**Host:** All tree seedlings are susceptible to damping-off.

**Causal Agent:** Species of *Pythium debayanum Phytophthora* sp.*, Rhizoctonia solani, Fusarium oxysporum, F. solani, Cylindrocladium scoparium*

Control:
a) Avoid heavy soil.
b) Avoid dense and deep sowing.
c) Maintain good drainage.
d) Cultivate soil with formalin or methyl bromide. Apply any of these chemicals before sowing of seeds and leave the soil covered for five days. Allow the chemical to evaporate for another week before sowing.
e) Soil maybe sterilized by baking or use of boiling water.

- **Root Rot of Seedlings**

**Host:** *Swietenia macrophylla, Gmelina arborea, Pterocarpus indicus, Acacia* spp.*, Aleurites trisperma*, and other tree species.

**Causal Agent:** *Sclerotium rolfsii, Cylindrocladium scoparium*, *Macrophomina phaseolina*.

**Symptoms:** Wilting, death of shoots, necrosis at stem base. For *Macrophomina* root rot the common symptom is dieback and gummosis of stem with death of roots starting from extremities. Thin black line and black sclerotia are formed in the wood and bark of roots.

Control:
a) Maintain healthy plant.
b) Practice sanitation.
c) Thin out seedlings for good aeration.
d) Avoid overwatering.
e) Practice crop rotation.
f) Avoid sites where the pathogen is known to occur.
g) Use fungicide.

- **Pine Blight/Wilt**

  **Host:** *Pinus kesiya,P. caribaea*

  **Causal Agent:** *Fusarium solani*

  **Symptoms:** Yellowing of needles, pink discoloration of the stem and wilting

  **Control:** Sterilize the soil with methyl bromide or drench with formalin solution. Soil may be sterilized by baking.

- **Leaf Spot/Black Ray/Anthracnose**

  **Host:** *Acacia* spp., *Pterocarpus indicus, Alnus* spp., *Anthocephalus chinensis, Eucalyptus* sp., *Leucaena leucocephala, Lagerstroemia speciosa, Swietenia macrophylla, Gmelina arborea*, and other host trees.

  **Causal Agent:** *Phyllachora pterocarpii, Phaeoseptoria* sp., *Glomerella cingulata, Pestalotia* sp., *Colletotrichum gloeosporioides,Cercospora* sp., *Phyllosticta sweitenia*.

  **Symptoms/Signs**: Brown to dark brown spots, small black pustules or tar spot, defoliation, stunted growth.

  Control:
  a) Collect and burn infected leaves.
  b) Spray with Bordeaux mixture and other fungicides.
  c) Avoid overcrowding of seedlings.

- **Powdery mildew (Fig.23)**

  **Host:** *Acacia auriculiformis, Hevea braziliensis, Eucalyptus* sp., and other trees.

  **Causal Agent:** *Oidium* sp. (imperfect stage). Species of the following genera: *Erysiphe, Phyllactinia, Podosphaera, Sphaerotheca,Uncinula*

**Fig.23. Typical powdery mildew symptom.** *(E.P. Militante)*

**Symptoms/Signs:** White cottony mycelia on the leaves, yellowing, defoliation, stunted growth.

Control:
a) Burn infected leaves.
b) Spray with sulfur and other fungicides.

- **Leaf Rust**

**Host:** *Tectona g andis,M orus alba, Coffea arabica, Alnus* spp.

**Causal Agent:** *Olivea tectona, Hemileia vastatrix, Melampsoridium* sp.

**Symptoms/Signs:** Orange powdery pustules on leaves, stunted growth

Control:
a) Chemical spray with Maneb-dithane.
b) Collect infected leaves and burn them.

- **Sooty Mold**

**Host:** *Acacia auriculiformis, Gmelina arborea,* and many other host plants

**Causal Agent:** *Meliola koae, M. clerodendricola, Capnodium* sp.

**Symptoms/Signs:** Curling and deformation of leaves and shoots. Black mass of hyphae and spores on the infected plant part. The mold utilizes the honeydew secreted by the insects (aphid, mealy bugs, etc.)

**Control:** Control the associated insects or spray 20% soap solution.

- **Needle Blight**

  **Host:** *Pinus kesiya, P. merkusii, P. caribaea, Cryptomeria japonica*

  **Causal Agent:** *Cercospora pini densiflorae, Pestalotia* sp.

  **Symptoms:** Yellow spots on needles, whole leaf turn yellow and then brown

  Control:
  a) Practice sanitation.
  b) Plant mix species.
  c) Control watering.
  d) Avoid overcrowding of seedlings.

- **Crown Gall** (Fig. 24)

  **Host:** *Eucalyptus camaldulensis, E. deglupta,* and other host trees.

  **Causal Agent:** *Agrobacterium tumefaciens*

**Fig.24.Crown gall infected** *Eucalyptus camaldulensis.* *(Militante)*

**Symptoms:** Formation of irregular galls at the base of seedling causing stunted growth, defoliation, and mortality.

Control:
a) Remove infected seedlings.
b) Minimize wound of crown portion and roots by root chewing insects.
c) Use *A. radiobacter* K84 as biocontrol.
d) Treat seedlings with antibiotic streptomycin.

- **Gall Rust**

**Host:** *Paraserianthes falcataria* (Moluccan sau) and other legumes.

**Causal Agent:** *Uromycladium tepperianum*

**Symptoms:** Gall on stem, branch and midrib leaves, fasciation, stunting, death of seedlings and large trees (Fig. 25).

Control:
a) Eradicate by burning all infected seedlings.
b) Cut all heavily infected large trees.
c) Plant resistant variety.
d) Apply/use antagonistic microorganisms.

**Fig.25.G all rust infected Moluccan sau** *(Militante)***.**

- **Canker or Pink Disease** - This disease is characterized by a necrotic often sunken lesion on a stem or branch of a plant. The fungus invades the living tissue (cambium, phloem, and outer xylem). Spore of the fungus infect through wounds. The host produces callus wound tissue around the invaded area in an attempt to wall off the infection.

  **Host:** *Paraserianthes falcataria, Eucalyptus* spp., *Acacia mangium Hevea braziliensis* and other host plants

  **Causal Agent:** *Corticum salmonicolor* (*Pellicularia salmonicolor*), "Corticium" stage produce basidiospore, "Necator" stage produce asexual spores. The other pathogens of canker are *Bortyodiplodia theobromae* and *Diaporthe eres.*

  **Symptoms/Signs:** Yellowing and wilting of shoots, silvery white mycelium, and white to pinkish crust-like fruiting bodies are produced by *C. salmonicolor*. Based on the signs this disease is also known as "pink disease" in other countries.

  Control:
  a) Practice sanitation.
  b) Thin to improve growth.
  c) Plant superior stock.
  d) Use site with good soil and air drainage.
  e) Plant mix tree species.
  f) Avoid wounding.

  Bordeaux mixture applied as spray or as paste (1:2:3, copper sulphate; lime; linseed oil in water) has been prove effective. Paranitrophenol has also shown promise for effective control.

- **Root Rot**

  **Host:** *Swietenia macrophylla, Gmelina arborea, Pterocarpus indicus, Acacia* spp., *Aleurites trisperma*, and other tree species.

  **Causal Agent:** *Sclerotium rolfsii, Cylindrocladium scoparium, Macrophomina phaseolina*

**Symptoms:** Wilting, death of shoots, necrosis at stem base. For Macrophomina root rot the common symptom is dieback and gummosis of the stem with dieback of roots. A thin black line and black sclerotia are formed in the wood and bark of roots.

Control:
a) Maintain healthy plant.
b) Practice sanitation.
c) Thin out seedlings for good aeration.
d) Avoid over watering.
e) Practice crop rotation.
f) Avoid sites where the pathogen is known to occur.
g) Use appropriate fungicide.

- **Pine Wilt**

**Host:** Pinus kesiya

**Causal Agent:** *Bursaphelenchus lignicolus* (Pine wood nematode)

**Symptoms:** Thinning and yellowing of crown, stunting, death of trees

Control:
a) Control cerambycid beetles that serve as carrier of pine wood nematode.
b) Plant resistant pines.

- **Root Knot**

**Host:** *Paraserianthes falcataria, Acacia mangium, Eucalyptus deglupta,Paulonia taiwaniana,Pinus* spp., and other host trees

**Causal Agent:** *Meloidogyne incognita* (Root knot nematode)

**Symptoms/Signs:** Deformation and enlargement of roots, forming galls with lesions. Defoliation and wilting.

Control:

a) Plant marigold (*Tagetes* sp.) to prevent hatching of nematode eggs.
b) Baking the soil will kill nematodes.
c) Apply nematicides.

- **Root, Butt, and Stem Rot** (Fig. 26)

**Host:** *Acacia mangium, Hevea braziliensis, Eucalyptus* spp. *Paraserianthes falcataria, Swietenia macrophylla,* and other host trees.

**Causal Agent:** *Phellinus noxious, Fomes annosus, Armillaria mellea, Ganoderma applanatum*

**Symptoms/Signs:** Yellowing and defoliation, thinning of the crown, infected trees are killed. The sapwood is fibrous with black specks, mat of mycelia white to brown in between the bark and wood. Sporocarps develop at the base of heavily infected trees.

Control:

a) Burn or uproot infected stumps.
b) Establish plantations in good sites.
c) Trench or dig a canal around groups of infected trees to minimize spread through root grafting.

**Fig.26. Tree buttress infected by rot** *(E.P. Militante)***.**

d) Avoid wounding.
e) Salvage cutting.

- **Stem and Root Stain Disease**

**Host:** *Pinus kesiya* and other pine trees

**Causal Agent:** *Trichoderma koningi* /*Verticicladiella wageneri*

**Symptoms:** Thinning and yellowing of crown, black stain on cambial layer of stem and roots, death of infected trees.

Control:
a) Eradicate infected trees.
b) Replace pine trees.

**Fire**

Fire is the most destructive agent in plantations adjacent to grasslands or pine-dominanted stand. Fire detection, prevention, control, and suppression are, therefore, indispensable during dry months.

As a safety measure, periodic surveillance of the plantation is necessary during summer. Fire protection monitoring usually takes about 5–6 months every year, at least during the first three years of plantation development. Also, construction of buffer lines against fire is necessary in pre-identified fire-risk areas of the plantation.

Causes of forest fires include pasture management, *kaingin*, incendiarism, carelessness, and lightning.

Fire Management Strategies

**Preventive measures.** The most important phase in fire control is a consideration of the following preventive approaches:

- *Information, education and communication campaign (IEC)*. The general public must be aware and well informed of the dangers of forest fire and the importance of fire protection. Radio and television broadcast, press releases, and lectures are some of the channels of communication. These activities

must be pursued as part of the plantation development support activities.

- *Community organization*. LGUs and NGOs should be organized, trained, mobilized, and act/serve as the implementor of forest fire prevention plans/programs.

- *Law enforcement implementation*. Strict enforcement of forest laws relative to fire prevention and control in the kaingin and pasture areas must be undertaken. Heavy punishment of offenders can be imposed.

- *Establishment of firebreaks and greenbelts*. A firebreak or fireline of sufficient size/dimension should be established in identified priority fire protection sites. A minimum width of firebreak ranges from 10–20 m. A greenbelt is a fire buffer strip, which has a width of 10–20 m. In establishing a greenbelt, the species to be used should consist of evergreen plants like Maguey, lantana, sunflower, 'binatang hambog,' and other appropriate vegetation. Close planting (i.e., 0.5 m x 0.5 m) should be adopted to provide protective buffer cover.

- *Forest patrol*. Intensive guarding and patrolling in fire prone areas must be undertaken by regular forest rangers assigned in the different patrol sectors. The guards must be equipped with two-way radio communications. An adequate road and foot trail system is essential for the guarding and patrolling activities.

**Fire detection.** Forest fires can be easily detected using the following facilities:

- Fire lookout tower. This should be strategically located in fire-risk areas to allow observation of the widest area possible. It should be equipped with efficient communication instruments linking the fire control office and other lookout towers (Fig. 27). It must be accessible by motor vehicles.

- Fire/weather observation station that is accessible. A fire danger rating system should continuously be made, the result

**Fig. 27. A fire lookout tower** *(E. L. Tolentino,J r.)***.**

of which shall provide the necessary signal for the likely occurrence of fire. The following complete set of equipment are necessary for a functional fire/weather station: wind instruments, minimum-maximum atmospheric thermometer, sunshine duration instrument, hygrothermograph recording raingage, standard raingage, binocular, set of two-way radio, map, standard alidade, and all other equipment/instruments for a complete microweather station.

*Fire Suppression*

- *Direct attack* – This is only possible for small forest fires progressing with low speed. For large fires progressing fast, it is advisable to do a flank attack.

- *Indirect attack* - For every intensive fires burning uphill. New firelines, of at least 50 m in width, must be constructed at strategic points before the advance of the fire front. A wider fire line is required on steep slopes and on intense fires. Existing fire lines in the area should be widened. New firelines should be constructed on roads, trails, ridges, creeks, or other natural firebreaks.

Bulldozers can be used for rapid construction of defense lines in a flat terrain. Remove from the area vegetation cleared from the firelines.

There are two ways for firefighters to create a defense line: each firefighter is assigned a complete section; or, each completes a 3 m section, after which the team moves to another section.

Constant patrolling at weak points should be done to prevent eventual spot fires developing from sparks beyond the line.

A backfire or counterfire can also control forest fires. The firefighter should let the backfire burn slowly towards the direction of the main fire. If the backfire gets into the suction of the main fire, it increases velocity and when it reaches the main fire, both die off due to lack of fuel.

- *Mopping up after a forest fire* - The smoking remnants should be thoroughly extinguished until no embers are left on the burnt-over area. In mopping up, burning fuels are separated and covered with soil; firelines are strengthened; and all sparks are kept out.

  Very often there is a new outbreak of the fire the following day at about noon, when a fresh breeze comes up. The second fire might do more damage than the first. Therefore, the burnt-over area must be guarded for one or two days.

  The equipment needed for fire fighting include the following**:**

  - Fire swatters with flexible steel blades mounted on long handles (200 cm) to extinguish light grass or ground fires. These are more effective than pine branches, but a little heavy and difficult to use on steep slopes.
  - Bolo to chop down branches and to clear firelines and trails.
  - Shovel and hoes to construct firelines.
  - Backpack pump can with 20 L of water. The water should be used only to: create gaps in frontal attacks; break up fire concentrations; and mop up the remaining embers.
  - Drinking water containers with at least 2 L.
  - First aid kit. The first aid kit is the responsibility of the team leader. All medicine must be fresh and clean, and be replaced from time to time.

Described in the succeeding part are guidelines in protecting the plantation against people, animals, and adverse effects of climate and the procedures and form on how to report the incidents properly for prompt action/disposition and to capture the required data/information and update the computer files. Appendices 5 and 6 provide the procedures.

**Protection of Forest Against People**

- The ITP maintenance manager coordinates with the Forest Protection Department on surveillance and intelligence operations to detect and neutralize actual and potential violators.
- All detected violations are reported immediately by concerned personnel to their respective section heads.
- The section head, together with the personnel who detected the violation, go to the area where the violation occurred and make an assessment.
- The section head issues some immediate corrective/preventive actions, if necessary, to remedy the situation at hand.
- A PIR is accomplished by the section head and the following information are indicated.

    - Blocks affected
    - Area per block affected
    - Number of trees per block affected
    - Estimated volume ($m^3$) of trees per block affected
    - Description of incident
    - Remedial measures taken
    - Preventive/protective measures taken
    - Comments/recommendations, if any

- The incident report is submitted immediately to the ITP maintenance manager for prompt action/disposition.
- Plantation boundary lines are cleared of vegetations by brushing for demarcation.
- Markers are repainted every other year or as the need arises.
- Appropriate posters, markers, or signboards are installed at conspicuous places for anyone to see and read the instructions printed on it.

- Vigorous information drives are conducted on forest conservation through printed materials, seminars, meetings, or lectures.
- In-service trainings are conducted in coordination with Human Resource Development Division (HRDD) Training, for concerned personnel (e.g., Foreman, etc.) to update their skills and knowledge on public relations/information.

**Protection of Forest Against Animals**

- All detected damages by grazing animals are reported immediately by concerned personnel to their respective section heads. The grazing animal (including the owner, if domestic) must be identified.
- The section head inspects the area together with the personnel who made the report and assess the damage.
- The section head issues some immediate corrective/ preventive actions, if necessary, to remedy the situation at hand.
- A PIR is accomplished by the section head and indicates the necessary information.
- The incident report is submitted immediately to the ITP maintenance manager for prompt action/disposition.
- The ITP maintenance manager issues the necessary instructions which might be the following:

    - Imposition of warning/fines/penalties to the owner of the domestic animal that have grazed and caused damage to the plantation.
    - Erecting necessary fences or barriers at the perimeters/ boundaries of the plantation to prevent intrusion of animals.
    - Posting of signboards at conspicuous places informing citizens living within or around the vicinity of the plantation to control movements of their animals.

**Protection of Forest Against Adverse Effects of Climate**

- A natural barrier is erected to protect the plantation from strong winds by planting trees in closed spacing around the perimeter of the plantation.
- A drainage system is constructed on all low-level areas of the plantation to prevent clogging up water on those areas during rainy season.

- During long dry season when rainfall is not so frequent, cloud seeding is conducted in coordination with the proper authorities, to effect rainfall on the plantation.
- Occurrence of unfavorable weather conditions that have caused damage to the plantation is reported immediately and the PIR is used.

Below are the basic principles to minimize erosion and sedimentation and prolong the service life of access roads:

- Identify areas vulnerable to erosion and landslides and make plans to minimize such erosion or landslides.
- Divert runoff water, originating upgrade from the construction site in order to avoid accelerated erosion.
- Limit the amount of area being graded on site at any one time to lessen vast structures of bare soil.
- Minimize exposure of a given area to elements by planting it immediately with grasses (star grass, paragrass, stylo).
- Slow down or reduce the velocity of flowing water to retard erosion and allow sediments to settle down.
- Prepare drainage systems that can accommodate heavy runoff.
- Trap run-off in temporary or permanent basin by filtering it using silt fence, wood chips barriers, or brush barriers.
- Maintain erosion-control facilities and inspect them after each rainfall.

# Tree Improvement

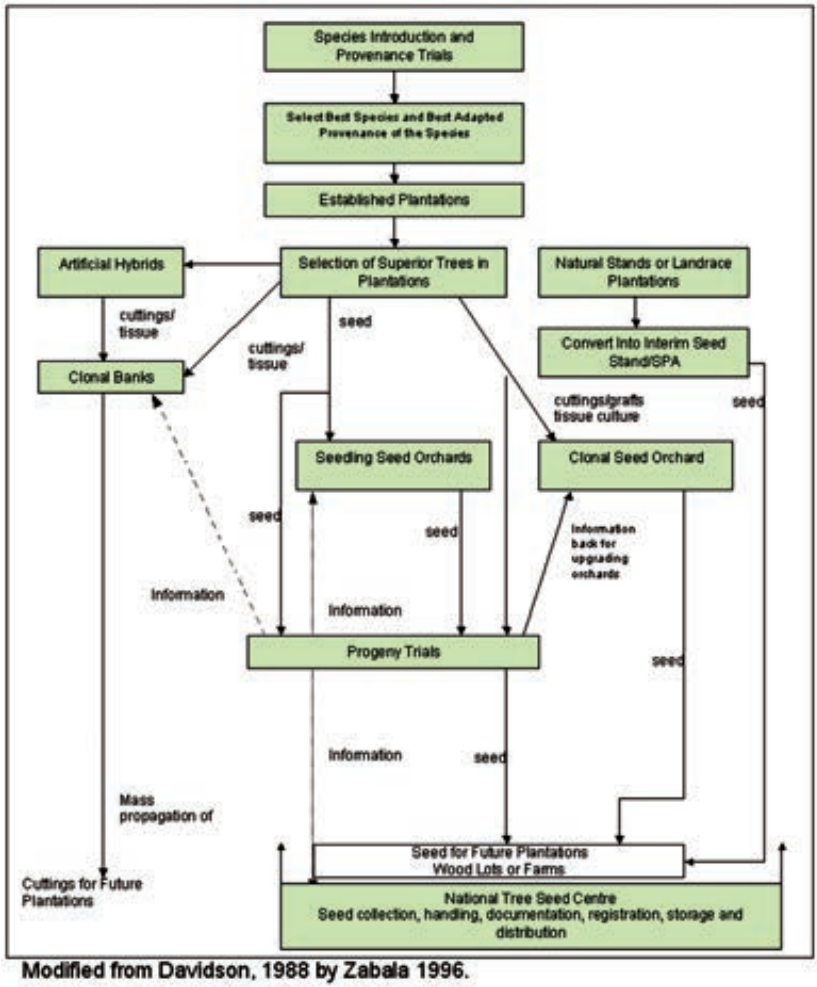
To ensure high percentage of field survival and increase the productivity of plantations and tree farms, it is important that good quality seeds and propagules be used in planting. Improved seeds can only be obtained from selected good mother trees, adapted proven sources, seed orchards, or SPAs, which are of genetically superior quality. However, in practice, tree planting activities in the country usually use planting materials from unknown sources because they are usually bought or acquired from dealers or from anybody who have no regard for genetic quality.

Tree improvement is necessary to ensure sustained supply of genetically improved seeds and propagules to meet the planting material requirement of the tree planting activities nationwide. Tree improvement is the technique used to alter a species' genetic set up in order to make it more useful to people. It can be attained using a short-term or a long-term approach although the latter provides the optimum genetic gains.

The short-term approach to tree improvement uses natural stands or existing land race plantations, which have already adapted to local environment conditions, although they have narrow genetic base (high level of co-ancestry due to improper seed collections for planting). This approach is a temporary solution for the supply of improved planting materials until the genetically improved seeds and propagules shall have been produced by the long-term tree improvement output. The approach includes, but not limited to, the establishment of seed production areas in natural stands or plantations, establishment of interim seed orchards, and timber stand improvement in natural forests.

The long-term approach, on the other hand, includes more advanced activities, such as species/provenance trials, progeny trials, clonal tests, and hybridization.

Figure 28 shows a flow diagram that highlights the interaction, feedback, dynamism, and aim of the different steps in tree improvement. In order for a tree improvement activity to succeed, strong networking, support, and determination of management are necessary.




Modified from Davidson, 1988 by Zabala 1996.

**Fig.28 An illustration of the approach to tree improvement strategy.**

## Seed Production Areas

SPAs or seed stands (SS) provide the primary source of phenotypically superior planting materials. They serve as the direct link to the establishment of seed orchards, the advanced sources of improved planting materials. Primarily, they function as an interim source until progeny tested seeds are obtained from the seed orchards.

SPAs are established in natural stands or plantations with a high frequency of phenotypically good planting materials. The stands are upgraded and managed entirely for seed production. Undesirable trees (with crooked trunk, very irregular bole form, diseased or badly damaged by insects, broken branches, and those trees which are below the average in diameter and height of the population of trees) are removed or rouged, retaining only about 150–250 trees/ha, which are tall, big in diameter, with straight bole, and have balanced crown. Appendix 5 lists potential SPA areas in the country.

### Preconditions to be Fulfilled for a Plantation or a Natural Stand to be Upgraded into SPA

- The origin of the seeds from which the plantation has been established, should be known.
- The area should contain a large number of good phenotypic planting materials, viz 100–200/ha.
- The stand should be mature or near mature for seed production (the seeds produced from too young or too old trees have generally a lower quality than those produced from mid-age trees).
- The plantation should be accessible throughout the year.
- The area is not exposed to natural disasters (strong winds, typhoons, fire, etc.).
- The plantation should be protected from destructive animals.
- The plantation/stand must be free from pest and diseases.
- The trees should have been proven to flower and produce seeds in the area.
- The necessary management operations should be possible, no risk of social or other implications after e.g. rouging, thinning, etc.

**Establishment of SPA**

- Conduct reconnaissance survey of preferred species, either exotic or indigenous species, within a plantation area or in natural stands.
- Delineate at least 5 ha more or less of the best natural stand or plantation of the desired species, if possible with high priority for the most accessible areas and properly identified on a suitable map of the area. The area is distinctly demarcated with signs or posts.
- Conduct 100% inventory of each selected stand to include information for each tree such as diameter breast height (DBH), clear bole height, total height, crown height, crown information, etc.
- Fence the area with a barbed wire and/or surround it with fire lines to ensure proper management and protection from occurrence of forest fires.
- Provide signboards indicating the following information: SPA, location, species common name, species scientific name, area in hectares, age of the stand, site condition, elevation in meters (asl), average annual precipitation in millimeters, soil fertility, and annual seed production in liters/gantas.
- Conduct thinning, liberation, and/or sanitation cuttings to give selected trees full dominance over the areas. The final spacing should be decided: for most tree species the final spacing should be 6–10 m, leaving a stock of 100–200 trees/ha. Inferior trees should be marked for thinning even if it will create a large opening in the stand. In case two trees are of equal appearance, selection should be based on thinning.
- Remove cut materials. Residues from rouging and thinning impede traffic in the area, can be a fire hazard and may attract pests and diseases.
- Establish a pollen-dilution zone. Inferior trees of the same species or other trees that can hybridize with the selected species are removed in a zone around the SPA in order to avoid pollen contamination. If a pollen dilution zone can not be established, the selection of the stand should be such that it is the better core of a larger stand with good phenotype individuals.

Keep the records of selected plantations or natural stands.

A 5.6-ha SPA for *Acacia mangium* and *Eucalyptus urophylla* (Fig. 29) has been established in 1996 by ERDB in collaboration with the CSIRO Division of Forestry's Australian Tree Seed Centre (ATSC). The seedlots used in the establishment of the SPA came from provenance bulk collections of ATSC. The SPA had an initial spacing of 5.0 m x 1.5 m (or 1,333 trees/ha). Thinning/rouging was conducted in two stages, with the first thinning at about two years after planting when the trees were around 6 m tall and the second thinning at age 3 when the trees averaged 9 m tall. The final stocking is 150–200 trees per hectare. The SPA now serves as a source of high-quality seeds and planting materials for the two species.

**Fig.29** *Eucalyptus urophylla* **SPA in Bansud, Mindoro Oriental** *(ERDB)***.**

**Maintenance and Management of SPA**

**Regular weeding.** The trees in an SPA have a wide spacing, which will benefit the upgrowth of secondary vegetation. During the first years after rouging/thinning weeding will be a major task.

**Fertilization.** Seed production will generally be favored if fertilization is applied. N usually favors only the vegetative growth and not flowering. N fertilizer may be applied during crown establishment. NP-granulated fertilizer with micronutrients is applied during flower differentiation. The amount and timing is important to obtain an optimal effect.

**Thinning and pruning.** The tree crown should be kept open and exposed to light. Small additional thinning and pruning after the main one may be undertaken to maintain an open crown and consequently promote flowering.

**Flower induction.** The operation of inducing flowering by imposing stress on the tree or by applying hormones is usually not applicable to seed stands due to the high cost involved.

**Records.** Records should, except for general information on site (location, climate, soil, age of stand, etc.) include all major operations like rouging, thinning, pruning, etc. The number of trees in the SPA is an important figure because it is an indication of the genetic base.

## Seed Orchards

A seed orchard is a plantation of selected clones or progenies which is isolated or managed to avoid or reduce pollination from outside sources, and is managed to produce frequent, abundant, and easily harvested crops of seeds.

Seed orchard represents a more advanced step than SPA. The purpose of establishing a seed orchard is not only to produce large quantities of improved seeds but it can be regarded as a breeding population as basis for further tree improvement.

There are two main types of seed orchards (Table 17), named according to the way of establishment:

- Clonal – Seed orchard raised from selected clones vegetatively propagated by grafting, cutting, marcotting, budding, air-layering, or tissue culture.
- Seedling – Seed orchard raised from seedlings produced from selected parents through natural or controlled pollination followed by a rouging that will remove the poorest trees, generally leaving the best of the best families for seed production.

A seed orchard can be operative as long as the trees are physiologically capable of producing seeds. In practice, however, a seed orchard will only be operative until a new improved seed orchard

**Table 17. Some characteristics of the two types of seed orchards.**

| Seedling Seed Orchard (SSO) | Clonal Seed Orchard (CSO) |
|---|---|
| Established from seedlings (i.e., by seed propagation from selected parents) | Established by the use of grafts, cuttings, air-layered plants, tissue culture plantlets, or other methods of vegetative propagation. |
| Preferred if a genetic test can be converted into a SSO (i.e., fulfilling both the testing and seed production function at one time)<br>Necessary when incompatibility between scion and stock or other constraints make vegetative propagation difficult. | Generally preferred when vegetative propagation is possible and the seed orchard only serves as a production area for seeds and/or vegetative propagules |
| Broader genetic base than CSO but less selection differential | Narrower genetic base than SSO but higher selection differential |
| An outstanding genotype will appear only once. | An outstanding genotype will appear many times. |
| Testing is on family level. | Testing is on individual level. |
| First flowering and fruiting usually occur later than CSO, applicable for species with early physiological flowering. | Generally, first flowering occurs earlier than in SSO. Applicable for species with late physiological flowering |
| Harvest of fruits/seeds generally more difficult than from CSO | Harvest of fruits/seeds easy due to low crown branching |

has been established, based on next generation progeny test. Seed orchards are usually referred to by generation, 1st, 2nd, 3rd, etc.

## Choosing a Site for the Establishment of Seed Orchard

Since the seed orchard will be in production for quite sometime, selection, therefore, of the site must be given due attention and consideration.

Some of the requirements for the site are:

- The site should be accessible for ease of operation, protection, and management, inasmuch as its establishment is labor intensive.

- It must have good drainage, preferably with sandy loam soil.
- For species that are easily damaged by salinity, the orchard must be away from the coastal areas.
- The site is not exposed to natural disasters (strong typhoons, fire, etc.).
- Since the seed orchard is established entirely for the production of seeds, the species to be planted should flower and produce fruits in the chosen site.
- The seed orchard should be protected from destructive animals.
- The seed orchard should be placed as far as possible to stands of the same species or species which they can hybridize.
- The seed orchard should be placed in an area where land tenure is assumed or settled for several years.

**Steps and Procedures in Seed Orchard Establishment**

1) Individual Tree Selection

This involves the selection of superior genotypes in plantations of fully fruit-bearing or seed-bearing trees.

The planting site must be thoroughly cleaned by removing debris and big stumps. All standing trees are felled, slashed, and dumped in the sides of the orchard site where they are burned. As much as possible, the soil of the area must not be disturbed, except loosening it if compacted.

2) Propagation of Rootstock

Rootstock to which a scion or bud is grafted or budded is usually grown in containers (usually polyethylene bags) in about a year's time, depending on the kind of tree species. Usually bigger or older rootstock is not preferred because only one-year old branches are grafted and their sizes are small.

3) Scion Collection and Propagation for Vegetative Orchard

For clonal orchard, the scions or buds or cuttings and others are collected from trees, preferably that are 1-2 years old. The time

of collection is the same as discussed in the previous sections on vegetative propagation.

The methods of propagating grafted materials, budded, marcotted, rooting cuttings, tissue culture, etc., were also discussed in the previous sections (vegetative propagation methods).

4) Collection of Seed and Propagation for Seedling Seed Orchard

Seeds are collected from selected plus trees and these are germinated and raised in the nursery. Following the cultural morphological grading is required to select only those seedlings, which are vigorous for outplanting. This nursery selection will more or less contribute to increase the low selection differential attributed to this seed orchard.

There are many designs that can be used following experimental designs subjected to statistical analysis. What should be kept in mind in arranging clones or families is that no two seedlings coming from the same clone or family shall be planted close or near each other to avoid selfing.

5) Initial Planting Distance

*Clonal or vegetative orchards.* The decision on what spacing or how wide the trees are to be planted in the seed orchard is governed by the natural crown development of the species and the need to maximize cross-pollination in the orchard. If the natural crown formation of the species is broad, the wider spacing it would require and vice versa for narrow crown species. Based on the tree improvement activities in the Philippines, initial spacing of 9 m x 9 m was used for *Gmelina arborea, Swietenia macrophylla, Pterocarpus indicus, Anthocephalus chinensis*, and *Leucaena leucocephala.* After ten years, the crown of the trees is already overlapping as there was no rouging conducted. It would be desirable at this point to consider an initial spacing of about 12 m x 12 m for all these species except for *Leucaena leucocephala*, which can be spaced at 9 m x 9 m.

*Seedling seed orchard.* The spacing is almost similar to that of vegetative orchard but it may require closer spacing to give allowance for rouging. Otherwise, the natural crown development

of the species should guide how ramets are to be spaced in the orchard.

6) Planting Pattern

A square or rectangular arrangement of plants is often used. Rectangular patterns will provide access to machinery or vehicle. The square patterns are more common, they follow the long established traditions of commercial fruit grower and are well-adapted for mechanical between-row tending in two directions.

7) Number of Clones or Families

Most clonal orchard designs are based on between 20 and 50 clones. Higher number is recommended because of difficulties associated with finding sufficient plus trees, or clonal failures, which occur during propagation and to permit rouging on the basis of progeny test results.

In seedling seed orchards more open-pollinated families are included, as many as 100 or more.

**Silvicultural Management of Seed Orchards**

Special care should be given to the plants during the first year of establishment during which they are especially vulnerable.

**Weeding.** The plants should be kept from weed competition during establishment. Complete weeding should be done at least around each plant. Weeds between the plants maybe cut or completely removed. If chemical weeding is applied, care should be taken in terms of time, weather condition, and doses of application.

**Rouging.** Once the result of the progeny test is available, the undesired families or ramets are cut and removed.

**Thinning and pruning.** In addition to rouging, the trees may be thinned and the branches systematically pruned in order to make an open crown with large flower production, and facilitate seed harvest.

**Fertilization and watering.** Water and fertilizer should be applied whenever necessary to give the trees optimal growth conditions. Conditions are especially important during flowering and fruit development. The amount and type of fertilizer differs from species to species.

**Flower induction.** If flowering fails or is unsatisfactory, it may be induced or promoted by imposing stress or by applying flower-inducing hormones during flower differentiation.

## Species/Provenance Trials

It is generally understood that some species will outgrow others in a particular environment, but it is not so well known that within a single species there is often a great range of genetic variation, with some provenances (populations from particular geographic areas) growing much faster than others. Species and provenance rankings will often change between different environments, so trials should be made on the particular soil type and climate in which plantations are to be established.

One of the objectives of provenance trial is to identify those provenances whose seeds will produce well-adapted and productive plantations. Productivity itself may not always imply rapid growth but also good survival, resistance to adverse environmental factors and pests, improved wood quality, and good seed production. Another objective is to establish SPAs as source of improved seeds for wide-scale planting.

In collecting seeds for local provenance trial, at least 50 plus trees have to be selected which are at least 100 m apart in each particular stand. This is to ensure that the trees are not closely related, thereby providing wider genetic base, and to avoid inbreeding depression to occur in the population. The seeds are then bulked in approximately equal amount from each tree per provenance.

For exotic introduced species, only about 25 good trees per provenance may be selected. Similarly, the trees must be 100 m apart. Seedlots from individual trees should also be mixed for each provenance.

It is necessary that provenance trials be conducted, for both the exotic and endemic species, in several sites in order to obtain important information on genotype-environment interactions, which could be

used by tree planters on deciding on which sites adapted provenances should be planted. There are important factors to be considered in establishing provenance trials and these are the appropriate design to be used, appropriate spacing distance, optimum number of replications, necessary characters to be assessed, proper recording, and management.

## Progeny Trials/Clonal Tests

Progeny trials/clonal tests are conducted to assess the genotype of an individual or the performance of a parent by a study of its offsprings (progenies) under controlled conditions. The information obtained from the trial can be used for upgrading or rouging seed orchards/clone banks and maintaining/keeping superior parental genotypes in the natural stands or plantation for further breeding/improvement purposes. The trial is usually run for about half the rotation age of the species and the sites. Nursery and field activities are those common for the commercial growing of the species. The common experimental design used, depending on the number of families and replications, is either Randomized Complete Blocked Design (RCBD) or lattice designs.

Progeny testing facilitates the evaluation of the combining ability of trees, subpopulation or lines for specific uses in breeding populations, individuals for the purpose of continued selection; and estimation of genetic parameters (variance, correlation, etc.).

There are two types of progenies involved: a) half-sibs which consists of individuals that come from one mother tree pollinated by some of the surrounding trees—only the female parent is known; and b) full-sibs, where both parents are known—as in the case with controlled crosses. The common crossing designs used are diallel, tester, or pollen mix.

The most important requirement of a progeny test is the use of an appropriate experimental design. Spacing should be the usual planting distance in a normal plantation activity. Tending should, as far as possible, be the same as for large plantations. Characters that are usually assessed depend on the end-product, and these are common to the majority of uses, such as survival, growth, vulnerability to pests, and wood properties.

## Hybridization

The intention of hybridization is to produce seedlings with hybrid vigor for certain characters, such as wood properties, resistance against pest and diseases, good form, and growth. Open-pollination method (ordinary type), such as in seed orchards/hybridizing seed orchard *(*i.e., *Acacia mangium x A. auriculiformis)* and the partial diallel mating design in controlled pollination for unsynchronized flowering of species (i.e., small leaf x large leaf mahogany, *Pinus kesiya)* could be used in intra- and inter-specific hybridization to get some information on the genetic parameters (breeding value, general combining ability, and specific combining ability) of all the selected trees of a species in the breeding population. In order to capture and utilize the genetic gain so far achieved, the hybrids should be clonally mass propagated into wood production populations.

## Commercial Timber Stand Improvement Practice

To ensure sustainability of woods supply and to maintain environmental stability, the application of intensive silvicultural treatments in residual forests has to be followed.

After harvesting operations, residual inventory is carried out to assess the degree of alteration and determine corrective measures to apply. Intensive silvicultural treatments are then conducted. These treatments are applied in three intervals, right after logging or YEAL (Year Elapsed after Logging) 0, at YEAL 5 and YEAL 10. Basically, all the silvicultural treatments to be applied fall under two broad categories—supplemental/enrichment plantings and timber stand improvement (TSI). These activities are required in compliance with existing government rules and regulations, particularly DENR Administrative Order No. 125, Series of 1989.

Furthermore, intensive TSI and supplemental/enrichment planting in the residual forest are meant to attain much higher wood yield and quality at harvest time with lower extraction cost. The intensity of treatments shall be conducted on strips up to 250 m from both sides of the road. For easier monitoring, evaluation, and effective control, the identification of silviculturally treated areas is linked to the road number, kilometer number, and set-up number.

TSI shall become a major component of the forest management system. Hence, the areas to be applied with TSI shall be increased

more than what is stipulated in the memorandum of agreement with the government. The number of blocks that really need TSI based on the inventory shall dictate the degree.

Accumulated evidence lends increasing support to the claim that TSI treatment pays. For instance, the following information generated by the RP-German TSI Project (Bascos and Weingart, 1987) points out that TSI could increase the total annual increment per hectare up to 29% over a four year period in the second-growth forest of Great Pacific Timber Development Corporation. Results of a ten year observation on TSI study conducted in 1976–1986 by Bureau of Forest Development (BFD)-German Development Project in the PICOP concession area, as cited by Veracion (1987) was as follows:

| | Treated Plot | Control Plot | Increase |
|---|---|---|---|
| Periodic Annual Increase (PAI) | 10 $m^3$/ha | 7.4 $m^3$/ha | 35 |
| Ave. Annual dbh Increment | 1.15 cm | 0.56 cm | 105 |

On the other hand, a residual forest without any TSI treatment is bound to produce miserably low wood volume and of poorer quality.

**TSI at YEAL 0 ( Management Cut)**

TSI shall be conducted immediately after a management cut. Major activities include the removal of residues and badly damaged trees during logging operation and trees of undesirable quality. This is to give room to the growth of the newly liberated dipterocarp wildlings and residuals. An average of 10-15 $m^3$/ha shall be retrieved in the form of forest residues and shall be delivered and processed in the mills either for pulpwood or fuelwood.

**Second TSI at YEAL 5**

An inventory at YEAL 5 shall be conducted to determine the actual stocking, distribution of species and diameter classes, inadequately stocked portions, and status of forest occupancy. The inventory shall be designed in such a manner that the needed information in the diagnostic sampling of the RP-German TSI scheme shall also be gathered.

The inventory is necessary because the results will be the basis for the following:

- what management block/unit needs TSI treatment;
- what silvicultural treatment is necessary to put the stand into its optimum productive state;
- how much intensity should the silvicultural treatment be;
- when should the treatment be conducted; and
- how much will be the cost.

It was found out that the peak of species diversity occurred five years after logging in the PICOP concession and hence, TSI shall be conducted at this time to favor the dipterocarp species present in the area.

The data gathered shall be inputted into the computer to form part of the natural forest database of the geographic information system (GIS).

The conduct of TSI at this point should also be innovative. Instead of plain girdling of the unwanted trees and leaving them to rot, extraction shall be introduced. The reason is two-fold. First, it will form part of the volume of wood for the mills. Second, TSI activity is very expensive such that the volume extracted will hopefully offset the cost of treatments. However, to date, no extraction method has yet been considered acceptable in terms of technical feasibility and cost. This is one area in which research should be directed.

**Third TSI Treatment at YEAL 10**

At YEAL 10, another inventory shall be conducted to monitor the effect of the treatments introduced five years earlier. The same inventory procedures shall be used. Again, using the information gathered, the same key questions shall be used as guide to determine the treatments to be introduced in the area.

**Economics of TSI (Return-on-Investment)**

To determine the financial feasibility of TSI inside the PICOP forest concessions three scenarios were evaluated, namely:

a) Conduct TSI at YEAL 0 (Management Cut)

Plant falcata at 4 m x 4 m spacing along cableways, log landings and poorly-stocked areas (20% of set-up area). Conduct TSI on the fifth and tenth year then harvest falcata for fuelwood and sawtimber on the 10th year.

b) Same as in a, except that bagras is used in supplemental planting.

c) Same as in a, except that dipterocarps are used in supplemental planting.

Based on the above scenarios, TSI using falcata/bagras as supplemental planting species is the most financially attractive. Using dipterocarps as supplemental planting species will yield 60–73% lower than falcata or bagras during the 20-year horizon as shown below:

| Scenario | Harvestable Volume ($M^3$) | Income (P) |
|---|---|---|
| A | 119.16 | 38,212.00 |
| B | 101.64 | 39,068.00 |
| C | 32.00 | 2,603.00 |

These data are based on a one-hectare model over a 20-year time horizon.

**Supplemental Planting**

To fill up the gaps which were opened in the course of timber extraction, dipterocarp and fast-growing species shall be planted in landings, cableways, skidways, and other open spaces to bring back the area into its normal state. Dipterocarp species to be planted shall follow the established matching as to elevation and physiography as shown below:

**Dipterocarp Species Distribution by Elevation (Normal State)[6]**

| Elevation | Species | Elevation | Species |
|---|---|---|---|
| **Class 1** | 1. Almon* | **Class 2** | 1. Almon |
| | 2. Bagtikan | | 2. Bagtikan |
| 80–400 | 3. White Lauan* | 401–600 | 3. White Lauan |
| masl | 4. Tangile* | masl | 4. Tangile |
| | 5. Mayapis* | | 5. Mayapis |

| Elevation | Species | Elevation | Species |
|---|---|---|---|
| | 6. Apitong<br>7. Hagakhak<br>8. Gisok-gisok<br>9. Guijo – grows only in Class 1 elevation | | 6. Apitong<br>7. Hagakhak<br>8. Gisok-gisok<br>9. Panau |
| Narig*<br>Panau | | | |
| **Class 3**<br><br>601–800 masl | 1. Almon<br>2. Bagtikan<br>3. White Lauan<br>4. Red Lauan<br>5. Tangile<br>6. Mayapis<br>7. Apitong<br>8. Hagakhak<br>9. Narig | **Class 4**<br><br>1000 masl | 1. Almon<br>2. White Lauan<br>3. Red Lauan**<br>4. Tangile**<br>5. Tiaong<br>6. Mayapis<br>7. Narig |
| **Class 5**<br><br>1001–1225 masl | 1. Almon<br>2. White Lauan<br>3. Red Lauan<br>4. Tangile<br>5. Tiaong<br>6. Mayapis<br>7. Narig | | |

*Found in all elevation classes and not sensitive to elevation.
**Mid to high elevation species.

## Physiographic Distribution of Dipterocarp Species (Normal State)

| Tree Species | Tree Species |
|---|---|
| **Ridge** | **Side Slope** |
| Almon | Almon |
| Bagtikan | Bagtikan |
| White Lauan | White Lauan |
| Red Lauan | Red Lauan |
| Tangile | Tangile |
| Tiaong | Tiaong |
| Mayapis | Mayapis |
| Apitong | Apitong |
| Hagakhak | Hagakhak |
| Panau | Gisok-gisok |
| Gisok-gisok | Guijo |

| Tree Species | Tree Species |
|---|---|
| Guijo<br>Narig | Narig |
| **In Valleys** | **Near Creeks/Rivers** |
| Almon<br>Red Lauan<br>Tangile<br>Mayapis<br>Narig | Almon<br>Bagtikan<br>White Lauan<br>Red Lauan<br>Tangile<br>Tiaong<br>Mayapis<br>Apitong<br>Hagakhak<br>Panau<br>Gisok-gisok<br>Narig |

It is also envisioned that dipterocarp shall be cloned to produce high-quality and fast-growing dense dipterocarp species. The current 4 m x 4 m spacing shall temporarily be maintained. Thereafter, continuing research shall be conducted to determine the more appropriate spacing and suitable species for each annual coupe.

**Enrichment Planting**

As a general rule, enrichment planting shall now be focused to rehabilitate the low-density residual forests. The results of the inventory at YEAL 10 (with diagnostic sampling) shall be the basis for the intensity of planting or treatment to be applied in a specific management area.

Enrichment planting leadtime shall be tied up with the cyclic cuts of area for enrichment. For example, if falcata is desired to be introduced, considering its rotation age of 8–10 years, the planting time should also be 8–10 years before the management cut or during YEAL 10 or 12 (i.e., the harvest year of the introduced trees shall then coincide with the management cut). Through this strategy, the long gestation period from the time of planting to the next management cut is taken cared of. However, priority shall be given to dipterocarp seedlings and clones for planting based on elevation and physiographic

factors to augment the natural dipterocarp forests. The strict adherence by the concession holder to reforestation rules and regulations, and the assurance from the DENR to credit additional enrichment planting as a reforestation accomplishment, shall encourage, all the more, the corporate holder to intensify this silvicultural practice.

**Liberation Cutting/Thinning**

In addition to the current scheme of conducting TSI, the introduced species shall also be extracted together with the nondipterocarps. The rationale for this is to open up spaces for the upcoming ditperocarp saplings, which are now in the intolerant stage. It is during this stage when dipterocarp needs ample amount of direct sunlight to accelerate apical and lateral growth.

# Application of Forest Biotechnology

Biotechnology is any biology-based technology that uses living organisms or their parts, as well as recombinant deoxyribonucleic acid (DNA); cell and tissue culture, and other advanced processing techniques to make or modify products, or improve plants, animals, and microorganisms (Smith, 1985). It is the application of biological knowledge for the production of new products and the development of alternative and more efficient processes (http://www.sei.dost.gov.ph/finals_hs/hs03/biotech1.html).

Biotechnology is a powerful tool because it has the ability to transfer a useful gene from one organism to another (genetic engineering or gene cloning). Biotechnology provides mankind with different sorts of enzymes such as:

- restriction enzymes, which can split DNA in a precise location so that it can be transferred to a recipient DNA; and
- ligase enzyme, which can join together spliced DNA pieces and finally the expression of a useful character/trait/product derived from the donor organism in the acceptor organism.

The application of biotechnology aims towards improvement of:

- rate of growth and yield;
- wood quality;
- disease and insect pests resistance;
- high/low temperature and drought tolerance;
- heavy metal tolerance;
- competitiveness against parasitic plants;
- capacity to fix nitrogen; and
- growth and survival in marginal sites.

Biotechnology plays an important role in the production of high-quality seedlings (with the aforementioned traits) for reforestation, whether from seed, cuttings, tissue culture, or somatic embryos.

The potential of genetic engineering to produce herbicide- and insect-resistant plants by gene transfer is nevertheless considerable, though it cannot yet be applied on a large scale (Dean et al., 1997).

## Mychorrhizal Technology for Reforestation

Some microorganisms present in nature are beneficial to plants, thus, they should be considered in the establishment of tree plantations. They promote nutrient cycling and play an essential role in mineralization, solubilization, immobilization, nitrogen fixation, production of photoactive substances, and provision of nutrient requirements of trees. Their importance can be very evident in the reforestation of marginal lands where they promote the survival and growth of trees. Soil microorganisms that are important for ITPs are mycorrhiza and nitrogen fixers.

The National Institute of Molecular Biology and Biotechnology (BIOTECH) of the University of the Philippines Los Baños (UPLB) has already available technologies utilizing fungi and bacteria to solve the aforementioned problems. The technology is called biofertilizers.

These biofertilizers contain strains of living fungi and bacteria that are useful in different biological activities such as N-fixation and solubilization of specific elements from the soil. These microorganisms are naturally occurring in the soil, thus, they are beneficial to plants, environment friendly and safe to use. There is no overdose in using biofertilizers.

Mycorrhiza is a root-fungus association. The association is symbiotic where there is give and take relationship between the fungus and the plant. The plant provides the fungus with carbohydrates produced in the leaves through the process of photosynthesis. Carbohydrates are required by the fungus to survive and proliferate. On the other hand, the fungus provides several benefits such as:

- increase the absorption of water and nutrients from the soil;
- improve growth and survival of seedlings in the field;
- increase drought tolerance of plant;
- increase tolerance to heavy metals;
- decrease incidence of pathogenic root infections; and
- safe to use and does not pollute the environment.

There are two types of mycorrhiza, which are important for industrial tree plantations and agroforestry. These are ectomycorrhiza and endomycorrhiza. Ectomycorrhiza infected roots are usually enlarged, the outer surface covered with a fungal mantle and mycelia (rhizomorphs) radiating outward into the soil that may reach up to 8 meters away from the plant. The fungi involved are mostly basidiomycetes producing typical fruit bodies such as mushrooms and puffballs. Some of these fungi can be isolated into pure culture. Ectomycorrhizal fungi are found in roots of pines, eucalypts, acacias, *Casuarinas*, and dipterocarps.

Endomycorrhiza-infected roots are not enlarged and can be detected only under a microscope. The fungus forms a loose network of hyphae on the root surface and may infect root hairs or directly through epidermal cells. These fungi form vesicles (food storage organs) and arbuscules (site of food and nutrient exchanges between host and fungi). Endomycorrhizal fungi are commonly referred to as vesicular-arbuscular mycorrhizal fungi or VAM. Recently, taxonomists changed the name of VAM into Arbuscular Mycorrhizal Fungi (AMF) accordingly, with the reason that some endomycorrhizal fungi do not have vesicles. AMF are of wider occurrence than the ectomycorrhiza. They are found associated with agricultural, ornamentals, horticultural, and forest trees.

## Commercial Mycorrhizal Inoculants

**Ectomycorrhizal tablet.** *Pisolithus* and *Scleroderma* fruit bodies (puffballs) are collected under forest plantations during rainy season. The spores are extracted, air dried, mixed with sterile soil (as carrier plus a binder), passed into a tabletting machine and finally converted into tablets. This tablet is found effective in promoting the survival and growth of tree species like pines, eucalypts, acacias and casuarinas. Tablets specific for dipterocarps are also available at BIOTECH, UPLB, Laguna.

For inoculation, one tablet is put at the center (1~~2~~ in depth) of plastic bag during potting. For potted seedlings, one tablet is placed in a 5-cm deep hole, 1 cm away from the base of the seedling (Fig. 30).

**Mycelia in alginate bead.** Most ectomycorrhizal fungi produce mushroom as fruit bodies. Mushrooms do not have numerous spores similar to that of *Pisolithus* and *Scleroderma*.


**Fig.30 Effect of a tablet form soil inoculant on pine trees** *(BIOTECH)***.**

More importantly, the appearance of fruit bodies is unpredictable and inconsistent. There are times when no or few fruit bodies are found and collected during a trip. In other words, the supply of abundant spores for tablet making is not certain. In order that supply of ectomycorrhizal fungi is ready at all times, the fungi are cultured vegetatively. Mycelia of ectomycorrhiza can be isolated and grown in solid substrate or in liquid culture (fermentors). BIOTECH has different sizes of fermentors ranging from 1 L to 1,000 L-capacity vessels, depending on how much inoculant is required at a time. Mycelia produced in fermentors can be incorporated in alginate bead, thus, application or inoculation technique is similar to that of the soil inoculant tablet containing ectomycorrhizal fungi. One bead containing mycelia is enough for one seedling.

**Soil-based biofertilizer.** This is a soil-based biofertilizer containing spores, mycelia, and chopped roots infected with a variety of endomycorrhizal fungi effective in promoting plant growth. These mycorrhizal fungi were previously shown for their growth promoting capabilities on agricultural crops, fruit trees, and reforestation species under nursery and field conditions.

This biofertilizer is applied by putting about 2.5–5g or ½–1 softdrink cap full of the biofertilizers 5–10 cm below the seeds or roots of seedlings. For seedlings grown in pots or containers (e.g., reforestation species and fruit trees), the containers are half filled with the potting medium. This biofertilizer is placed at the center of the pot. The bag is filled again with the potting medium after which the seedlings are planted. In some nurseries where potting is done by fully filling the plastic bags/containers with the potting medium, the inoculant is put in a hole (1–2 in depth) made at the center of previously watered bags. In germination boxes, the biofertilizer can be

placed as layer or mixed with the germination medium. In marcotting, the biofertilizer can be used instead of coconut coir dust or other media. For field application, the biofertilizer is applied by hand under the furrows at a rate of 20 g/linear meter (provide unit) prior to seeding or transplanting.

The general rules to get the maximum benefits from mycorrhizal inoculation are: 1) Inoculate seedlings as early as possible, inoculation during seed sowing will have greater chance of getting the most beneficial effects of mycorrhizal fungi; 2) Initially, a minimal chemical fertilizer (about 25% of the recommended rate) is required as booster for the plant, high fertilizer rates kill the fungi; 3) Apply contact fungicides not systemic whenever needed because the former kills mycorrhizal fungi present inside the roots; and 4) Inoculation of seed or seedling in sterile media will definitely favor root colonization by the introduced mycorrhizal fungi. Mycorrhizal fungi are naturally occurring, thus, the indigenous species in a nonsterile medium may infect the roots and not by the introduced ones.

**Biological nitrogen fixers**. Biological N fixation is the natural process that permits growth of leguminous plants on soils low in N. In turn, the legume crops could help maintain soil fertility and thereby permits cultivation of other crops as in agroforestation (Garcia, 1984).

Biological N-fixing bacteria infect the roots of crops and convert the atmospheric nitrogen into forms that can be used by plants. *Rhizobium* is one of the many bacteria that are capable of converting atmospheric N into plant usable forms. It has been reported in 1998 that approximately 140 M t of global N is estimated to be fixed biologically each year as against 210 M t produced by human industrial activities (World Resources, 1998). They enhance plant growth and provide 30–100% of the N requirement of crops. The bacterium forms nodules in the host of compatible leguminous trees. The bacterium contains the enzyme nitrogenase that has the ability to convert nitrogen gas into organic compounds that can be utilized by the plant. In this way, *Rhizobium* provides the N requirement of the host tree.

Strains are isolated from nodules collected from roots of leguminous trees in the field. Root nodules are swellings produced when the $N_2$-fixing, rod-shaped bacteria (rhizobia) infect the roots of certain legumes, including most acacias. After isolation and purification, strains are screened for their infectivity (ability to

form nodules) and effectivity (ability to fix N). Strains that are both infective and effective are then mass-produced in large fermentors. Fast growing tree legumes commonly used in reforestation are *Acacia mangium*, *A. auriculiformis*, *Paraserianthes falcataria*, etc. which are in nature become nodulated after some time in the field. Inoculation with the right strain of *Rhizobium* should be done in the nursery. In Bukidnon Forest Industries, *A. mangium* are usually inoculated with an effective strain of *Rhizobium* collected in their plantations. These *A. mangium* plantations were inoculated previously with effective strains from Australia. The nodules are collected, crushed, and inoculated into seedlings as suspension. An effective strain has pinkish color inside the nodule.

Interest in the use of microbes as one of the promising alternatives in developing low-cost substitute and complementary inputs instead of commercial inorganic fertilizers has grown significantly over the last decades because of the latter's escalating cost and harmful effects in the environment.

Since not all soils contain sufficient rhizobia to infect leguminous species, it is advisable to ensure effective nodulation in the nursery before the seedlings are sent in the field for planting. Healthy nodules should be visible upon inspection of the root system after removing the plastic bag.

A crude but practical method of inoculating nursery soils is to add some surface soil and leaf litter collected from beneath the healthy, nodulated trees of the same species.

An alternative is to dig up roots of healthy trees and remove some plump, firm nodules (Effective nodules are pale pink in color when cut with a sharp knife). Immerse the nodules in 70% ethanol for 5–10 seconds to minimize the risk of contamination from foreign microbes. Rinse in rainwater or good quality tap water. Crush the nodules in water, using a ratio of about 1 part nodules to 10 parts of water. Allow the coarser particles to settle, and decant the rhizobial suspension; dilute until faintly turbid. Use a clean medicine dropper or syringe to place 1–2 ml of this suspension onto the soil beside the base of each seedling; inoculate when germination is complete or preferably at the time of pricking out into containers.

About 10 g of nodules will be adequate to nodulate at least 1,000 plants as long as the nodules have been well ground and thoroughly dispersed in water. Nodulated plants will grow well, and

will appear green and healthy. Non-nodulated plants often exhibit stunted growth, and will tend to have a brownish or yellowish coloration (Williamson, 1993).

*Rhizobium* inoculants for ipil-ipil, kakawate, and pasture legumes have been developed during the early years of BIOTECH. However, inoculants developed have not been commercialized. At present, there is an initiative, through the Forest Biotechnology Program of the College of Forestry and Natural Resources, UPLB to study the combined effects of the soil-based biofertilizer and a commercialized N-fixing inoculant on the growth and survival of forest trees.

## Applications of Biofertilizers in Forest Plantation Establishment

**Ectomycorrhizal tablets.** The ectomycorrhizal tablets (Fig. 31) have been found to effectively increase growth of *Pinus kesiya, P. caribaea, Eucalyptus camaldulensis*, and *E. deglupta* in the nursery and in the field. In all trials, height, diameter growth, and survival of *Eucalyptus* and *Pinus* species inoculated with ectomycorrhizal tablets were significantly greater than their uninoculated counterparts (De la Cruz and Aggangan, 1990; Aggangan et al. 1999).

Ectomycorrhizal tablet can reduce the amount of chemical fertilizer needed by the plant. In Surigao Sur, inoculated seedlings required only 10 g of fertilizer to attain a height of 153 cm in 10 months, while uninoculated seedlings needed 72 g to attain the same height. The difference (62 g or 86%) is the amount of savings generated from mycorrhiza. In a degraded grassland in Nueva Ecija, ectomycorrhiza inoculated and uninoculated *P. kesiya* were fertilized with varying levels of complete fertilizer. To attain a height of 77 cm in 15 months, inoculated plants required 17 g of fertilizer, while uninoculated

**Fig.31.C ommercialized ectomycorrhizal tablets** ***(BIOTECH)*****.**

seedlings needed 68 g (De la Cruz et al. 1988). The difference is the amount being replaced by mycorrhiza.

The ectomycorrhizal tablet can replace from 60% to 85% of fertilizers required for the growth of our test plants in marginal grasslands (De la Cruz et al. 1988, 1989, 1990a). Inoculation with ectomycorrhizal tablet also increased the growth of other reforestation trees.

**Mycelia in alginate bead.** For mycelia in alginate bead (Fig. 32), trials have been established in nursery and grasslands in Pangasinan; Malaybalay; Bukidnon; and in Bislig, Surigao Sur (Aggangan et al. 1997, 1998). In Pangasinan, the growth of *E. urophylla* inoculated with a *Pisolithus* isolate from Australia outgrew those trees inoculated with the Philippine *Pisolithus* isolate. Using DNA analysis, it was found that the Philippine *Pisolithus* is more related to the pine *Pisolithus*. Accordingly, ectomycorrhizal fungi associated with pines are more hosts specific than those associated with eucalypts. Although root colonization by the Philippine isolate was observed, longitudinal and cross sections of the infected roots revealed incompatibility between the fungus and *E. urophylla*. Similar results were obtained in Bukidnon and in Surigao Sur. The Australian *Pisolithus* was consistent in promoting better growth of *E. urophylla* than the Philippine isolate in spite of the presence of high concentration of nickel and chromium in the experimental area in Bukidnon (Aggangan et al. 1997, 1998, 1999).

**Soil-based biofertilizer.** For endomycorrhiza, significant growth promotion in both nursery and field trials has been observed. It was demonstrated that some VAM fungi are more effective than others in promoting growth of agricultural and reforestation species

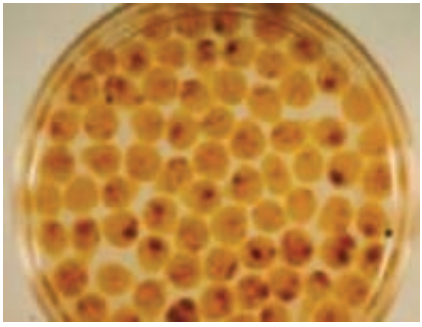


**Fig.32.M ycelia in alginate bead** *(BIOTECH)***.**

(Aggangan 2001, De la Cruz et al. 1988, 1989,1990b). The effective strains of VAM fungi promoted better than the uninoculated seedlings (Fig. 33).

The soil-based biofertilizer was pilot tested in different regions of the country by DENR in early 90's. Results from these pilot trials indicate that the site affected the success of inoculation. There were field sites that inoculation did not benefit the trees in the nursery and in the field. It should be noted that the performance of any organism is affected by the environment, the plant/host and the cultural practices employed during the raising of seedlings in the nursery. It is very important that, before outplanting, the seedlings should be colonized by the introduced mycorrhizal fungi so that it can compete with the indigenous or native mycorrhizal fungi.

Dual inoculation with a soil-based biofertilizer and *Rhizobium* has been done in the nursery and on field trials to determine their effect on the growth of various legume trees. Generally, dual inoculation of a soil-based biofertilizer and *Rhizobium* promoted the growth of *Acacias* (*A. mangium, A. auriculiformis*, *P. falcataria*, ipil-ipil, and other legume trees) (Aggangan et al. 1991, De la Cruz et al. 1990b). However, there were some experiments where the growth of the seedlings was lower than those obtained from single inoculated treatment. This indicated that the two microorganisms had antagonistic interaction to each other. There were also times that their presence does not have any beneficial effect on inoculated seedlings. It is very important to select the best growth-promoting mycorrhizal fungi and *Rhizobium* isolate for a specific tree legume.


**Fig.33.C ommercial soil-based biofertilizer** *(BIOTECH)***.**

## Mycorrhizal Fungi as Biological Control Against Root Pathogens

Mycorrhizal fungi provide an effective alternative method of disease control against root pathogens. Root diseases are one of the most difficult to manage and lead to great losses. Ectomycorrhiza are known to prevent growth of pathogenic fungi on the root surface of host plant, thereby protecting the plants from the harmful effect of pathogens. Ectomycorrhizal fungi release volatile substances that are lethal to pathogenic microorganisms (Schisler and Linderman 1987), but harbor the population of beneficial bacteria and fluorescent pseudomonads that are known to produce plant growth promoting substances (Linderman 1988). Some ectomycorrhizal fungi produce antibiotics in pure culture that are lethal to root pathogens (Kope and Fortin 1990).

At BIOTECH, studies under laboratory and nursery conditions have shown the biocontrol capabilities of both ectomycorrhizal and AMF fungi on pathogenic fungi such as *Fusarium* spp. *Verticillium*, *Rhizoctonia*, *Phytopthora*, *Pythium* spp. and other root pathogens infecting fast-growing trees such as *Pinus*, *Eucalyptus*, *Acacia* and *Casuarina*.

The biological control capability of a soil-based biofertilizer against *Fusarium* wilt and *Rhizoctonia* has been observed in tomato and eggplant (Aggangan et al. 2000a). Likewise, the soil-based biofertilizer can be a biological control against root knot nematodes (Aggangan et al. 2000b). Genetic engineering of mycorrhizal fungi offers the potential to increase the efficiency of these microbes as biological control agents.

## Plant Tissue Culture

Tissue culture is one of the several advanced techniques being used in biotechnology in forestry today. This technique uses parts of plants cut out and grown aseptically in artificial (culture) medium. Numerous seedlings can be produced from a very small tissue of individually selected plants. Today, this technique is viewed as a valuable tool for mass propagation of certain plant species where seed propagation is a problem or where the conventional methods of vegetative propagation have proven impractical.

In the Philippines, biotechnological studies on tissue culture have been done on some forest tree species. So far, bagras (*Eucalyptus deglupta*), moluccan sau (*Paraserianthes falcataria*), gubas (*Endospermum peltatum*), mangium (*Acacia mangium*), red gum (*Eucalyptus camaldulensis*), and narra (*Pterocarpus indicus*) have been successfully produced in test tubes in the laboratory (Crizaldo 1980; Calinawan 1981; Calinawan et al.1988; Capuli and Calinawan 2002; De la Cruz 2003)

Significant impacts of tissue culture on forest productivity are well documented throughout the world (Cheliak 1991). The use of tissue culture in forest trees can increase growth rates of plantations and reduce rotation age (De la Cruz 1998). This can be achieved by mass-producing genetically superior stocks selected for faster growth rates, uniformity and better quality timber.

Tissue culture affords precise site-genotype matching. Clones produced by tissue culture can be matched to the site more precisely than those from seeds, which exhibit large genetic variation for growth response. And therefore it will be difficult to make precise estimates of suitability for a specific location for seedling from seeds.

Tissue culture allows also for the mass propagation of disease-free plants (Dela Cruz 1998). Some of the limitations to growing valuable hardwoods that are sensitive to high soil temperature may be overcome by selection and tissue culture of desirable phenotypes.

Continuous work on tissue culture in the Philippines may lead to an adequate and reliable source of supply of high-quality planting stocks any time of the year. Hence, this biotechnology offers a lot of promise for accelerating reforestation and plantation development in the country.

ERDB has successfully developed protocols for plantlet production of *Acacia mangium, Eucalyptus deglupta,* and *E. pellita-urophylla* using the tissue culture method (Fig. 34). Samples of tissue-cultured seedlings of these species have been planted in the ERDB Experiment Station in Mount Makiling, Los Baños, Laguna, and in Llavac, Quezon.

## Biological Control of Forest Pests and Diseases

Pests and diseases are among the major factors contributory to the rapid depletion of our forest resources. One example is the *Ipscalligaphus* infestation of the pine forest, which almost wiped out

**Fig. 34. (L to R). Six-week old plantlets of** *E. pellita x urophylla* **in tube, two-month- old shoots of** *Acacia mangium*, **and three-year-old** *Eucalyptus deglupta* **tissue-cultured trees in Llavac, Quezon** *(ERDB)*.

the Benguet pine (*Pinus kesiya*) stands in Baguio and other parts of the Cordillera Region. Not only that pests and diseases deplete our resources, they also have negative environmental impacts on the forest ecosystem.

Conventional means of controlling pests and diseases in our forests include the use of toxic chemicals, either imported or locally produced. This method, however, greatly affects both the forest and the wildlife within.

An appropriate alternative to chemical control is the so-called biological control. Biological control is biology-based technology that is a natural or applied regulation of populations of pest organisms, through the role or use of natural enemies (i.e., predators, parasites, fungi, bacteria, or virus, against an insect pest or a pathogenic agent and/or use of resistant host/species). Biological control is very promising, especially for developing countries like the Philippines as chemical pesticides are exorbitantly priced and hazardous to the environment.

Researchers of ERDB have conducted a survey and identification of entomogenous microorganisms associated with insect pests of forest trees. The common entomogenous microorganisms isolated from *Ips calligraphus* attacking Benguet pine were: *Serratia, Bacillus* sp., *Aspergillus flavus*, and *Fusarium moniliforme*. In shoot moth of Benguet pine in Abra, they were: *Bacillus* sp., *A. flavus, Pseudomonas* sp., and *Serratia* sp. except *A. flavus*. These microorganisms showed to be promising agents in biological control of the abovementioned insect pests (Lapis, 1995).

Results of a field trial experiment in Abra regarding the control of shoot moth-attacking *Pinus caribaea* showed that a pure culture of

bacteria, *Bacillus thuringensis* as a form of biological insecticide could control the infestation by 93-95% if properly applied.

This biological means of controlling pests and diseases, as a natural method, could provide protection for large-scale forest plantations at reasonable cost without much environmental stress.

**Advantages of Biological Control**

- It is an environment-friendly approach, nontoxic to human and animals.
- Target organisms do not develop resistance.
- Cheap and readily available
- Easy to mass produce

**Biological Control Agents**

Types of biological control agents (Tables 18 and 19) based on the mechanism of action or mode of attack on the target organisms are:

1) *Predatory arthropods* – organisms that prey on other individuals during their development. Examples: Coleoptera (lady beetles), Hymeroptera (ants, wasps and bees), Neuroptera (lacewings and ant lions), and spiders

2) *Parasitic insects* – insects that feed on other destructive insects. Many are endoparasites. The ovipositor serves as the organ for injecting venom that paralyzes the host.

3) *Entomopathogens* – disease-causing organism on insects that belong to the following groups: virus, bacteria, fungi, and nematodes.

4) *Antagonists* – organisms that produce toxins or antibiotics that suppress the growth of plant pathogens. Such group is also competitive for space and nutrients.

Nematode trapping fungi with specialized hyphal structures can be used to control root knot nematode (*Meloidogyne incognita*):

**Table 18. Summary list of biological control agents of some insect pests.**[a]

| Insect Pests | Biological Control Agent |
|---|---|
| Varicose borer: (*Agrilus sexsignatus*) on *Eucalyptus deglupta* | Parasitoids: *Ocencyrtus erionotae*<br>*Tetrastichnus* sp. |
| Mealy bugs (*Ferrisiana virgata*) on mango and other host trees | Parasite: *Gyranosoidea tebygi* |
| Psyllid (*Heteropsylla cubana*) on Ipil-ipil and other host trees | Parasites: *Conidiobolus coronatus*<br>*Hirsutella citriformis*<br>*Curinus ceruleus*<br>Entomopathogens: *Paecilomyce farinoses*<br>*Fusarium* sp.<br>*Entomophthora* sp.<br>*Aspergillus* sp. |
| Teak defoliator (*Hyblaea puera*) | Entomopathogen: *Bacillus thuringensis*<br>Planting of mixed species that harbor predators and parasites of Teak defoliator |
| Teak skeletonizer (*Eutectona machaeralis*) | Parasite: Spider |
| Aphids, white flies, mites, scale insects and mealy bugs on many host plants | Parasite: Lace wings and Ant lions |
| Pine shoot borer (*Dioryctria subella*) and Pine tip moth (*Petrova cristata*) | Parasite: *Eriborus* sp.<br>Entomopathogen: *Bacillus thuringensis* |
| Mahogany shoot borer (*Hypsipyla robusta*) | Entomopathogen: *Beauveria* sp.<br>*Trichoderma* sp.<br>*Aspergillus* sp. |

[a]Balatibat, 2002.

**Table 19. Summary list of biological control agents of some tree pathogens.**[a]

| Antagonists | Pathogens | Diseases |
|---|---|---|
| 1. *Acremonium recifii* | *Uromycladium tepperianum* | Gall rust |
| 2. *Agrobacterium radiobacter* strain (K-84) | *Agrobacterium tumefasciens* | Crown gall |
| 3. *Aspergillus niger* | *Macrophomina phaseolina* | Root rot/Seed decay |
| 4. *Bacillus penetrans* | *Meloidogyne incognita* | Root Knot |
| 5. *Bacillus subtilis* | *Rhizoctonia solani* | Damping-off; Root rot |
| | *Fusarium roseum* f.sp. dianthi | Root rot |
| 6 *Gliocladium virens* | *Pythium ultimum* | Damping-off |
| 7. *Gliocladium roseum* | *Botrytis dinerea* | Graymold; Blight |
| 8. *Paecilomyces lilacinus* | *Meloidogyne incognita* | Root knot |
| | *Pratylenchus* spp. | Root lesion |

**Table 19. (Continued).**

| Antagonists | Pathogens | Diseases |
|---|---|---|
| | *Tylenchorynchus* spp. | Stunt |
| | *Tylenchulus semiperitrans* | Citrus decline |
| | *Trichodorus* sp. | Stubby root |
| | *Sclerotium rolfsii* | Root rot |
| | *Rhizoctonia solani* | Damping-off; Root rot |
| 9. *Penicillium italicum* | *Uromycladium tepperianum* | Gall rust |
| 10. *Pseudomonas flourescens* (Pf-5) | *Pythium ultimum* | Damping-off |
| 11. *Penicillium vermiculatum* | *Rhizoctonia solani* | Damping-off; Root rot |
| 12. *Peniophora gigantea* | *Coniophora puteana* | Wood decay |
| 13. Scytalidium aurantiacum | *Fomes annosus* | Root and Butt rot |
| *S. album* | *Polyporus versicolor* | Wood decay |
| | *Lentinus lepidus* | Wood decay |
| 14. *Streptomyces lavendulae* | *Pythium aphanidermatum* | Damping-off |
| 15. *Trichoderma harzianum* | *Sclerotium rolfsii* | Damping-off; Root rot |
| | *Rhizoctonia solani* | Damping-off; Root rot |
| 16. *Trichoderma lignorum* | *Phytophthora parasitica* | Root rot |
| | *Rhizoctonia solani* | Damping-off; Root rot |
| | *Sclerotium rolfsii* | Root rot |
| 17. *Trichoderma viride* | *Poria placenta* | Wood decay |
| | *P. carbonica* | Wood decay |
| | *Rhizoctonia solani* | Damping-off, Root rot |
| | *Phellinus noxious* | Root and Butt rot |

[a]Militante, E.P., 2002.

- *Arthrobotrys oligospora* – produce sticky branches
- *Catenaria anguilulae* – produce sticky branches
- *Dactylaria sclerohyphae* – with sticky knobs

Marigold plant (*Tagetes* sp.) roots secrete chemicals toxic to nematodes.

With the new advances in biotechnology, other biological control strategies were developed. These include:

1. Application of mycorrhizae

   Ectomycorrhiza forms a mantle on the feeder roots that acts as physical barrier to root pathogens. Some mycorrhizal fungi produce antibiotics and volatile substances that are lethal to root pathogens.

Examples:

- *Scleroderma bovista* produces antibiotics potent to *Pythium* spp.
- *Boletus variegates* produces volatile substances such as terpenes and sesquiterpenes that inhibit growth of pathogens.
- *Leucopaxillus cerealis* var. *piceina* produces diatrytene nitrite that suppresses spore germination of *Phytophthora cinnamomi* causing little leaf disease.

2. Use of compost tea

   This also known as compost or dung extracts. Applied on leaves to control foliar diseases.

   Examples:

   - Horse compost extract on *Phytopthora infestans*
   - Cattle compost extract on *Botrytis cinerea*
   - Bark compost extract on *Fusarium oxysporum*
   - Animal manure – straw compost extract for powdery mildew disease.

3. Use of plant extracts

   Extracts from *Pongamia pinnata* and *Azidarachta indica* have fungitoxic properties that can control *Fusarium* spp.

4. Use of antifungal products from mushroom

   "Azoxystrobin" is a natural product from mushroom that can control pathogens of the group, Ascomycetes, Basidiomycetes, Deuteromycetes, and Oomycetes.

5. Use of pest and disease resistant trees

   Trees in the field with potential for resistance are selected and tested. With new developed biotechnologies, such as tissue culture and genetic engineering shortcuts to breeding for the desired trait can be done.

6. Application of plant growth promoting rhizobacteria (PGPR)

   The PGPR induce systemic resistance (ISR) on pine seedlings against needle blight.

# Harvesting and Transport

As stipulated under PD 705, as amended, otherwise known as the Revised Forestry Reform Code of the Philippines, the cutting, gathering, collecting, and/or removal of timber or other forest products from any forest land or timber from alienable and disposable (A&D) public lands need prior authority or permit from the agency concerned which is the DENR. With regards to the harvesting of planted trees within forest lands and tax declared A&D lands, cutting permit is no longer required from plantation owners to harvest their mature plantation as these planted trees has been already deregulated but prior to transport of these forest products, a Certificate of Verification is to be issued by the DENR (DMC 99-20). However, for planted narra that is a premium species, a Special Private Land Timber Permit (SPLTP) shall be required pursuant to Section 4 of DENR Administrative Order No. 58 issued in 1993. For the maximum allowable cut, the PENRO may grant to the permitee up to 5 $m^3$, while the Regional Executive Director (RED) is authorized for volume not exceeding 10 $m^3$.

All timber and other forest products coming from forest lands to be transported from their point of origin to any point of destination shall be accompanied by a transport permit. However, the plantation owner should secure and accomplish a "Self-Monitoring Form" (SMF) from the CENRO office concerned indicating all the required therein.

### Harvesting Policies

Harvesting of trees within the planted areas should be in accordance with the following requirements incorporated in each tenurial instrument.

a) IFMA – approved Comprehensive Development and Management Plan (CDMP) and Integrated Annual Operations Plan (IAOP), subject to 100% inventory. For timber license holders (TLA) and IFMA holders, the harvesting or cutting of timber and other forest products is normally governed by an approved 25-year Timber Management Plan for TLA or CDMP for IFMA.

b) PFDA – 100% inventory upon the request of the PFDA holder. For PFDA holders, an approved Private Forest Development Plan as well as an approved Annual Plan is required when harvesting (DAO 96-16).

c) CBFMA – Affirmed five (5) Year Workplan based on the ratified Community Resource Management Framework (CRMF) as indicated under DAO 2004-09 dated August 25, 2007. Under DAO 2004-29, harvesting and transporting of forest products from CBFM areas should be in accordance with existing rules and regulations.

For PFDA, DENR Memo Order No. 99-20 dated July 29, 1999 stipulates among others the registration of private plantations within titled or tax-declared A&D lands in the community environment and natural resources office (CENRO) having jurisdiction over the area, including all information about the plantation. Upon registration and ground validation by a registered forester, the CENRO concerned shall issue to the plantation owner a Private Tree Plantation Ownership Certificate (PTPOC). A cutting permit shall no longer be required from the plantation owner in harvesting his mature plantation. It is further stated that there shall be no restriction on the disposition/marketing of plantation species, provided, it is delivered/supplied to legitimate buyers.

As part of the deregulation process on planted trees in private lands covered by original certificate of titles (OCTs), transfer certificate of titles (TCTs) including certificate of lumber origin (CLOs), and tax-declared A&D lands, DENR Administrative Order No. 2004-04 was issued on March 16, 2004, providing among others the following guidelines:

- Transport of plantation-grown wood in whatever form (e.g., logs, sawnwood, poles and piles; pulpwood; fuelwood; wood chips; and the semifinished or finished wood products derived therefrom), regardless of volume, shall be accompanied by a certification from the local tree farmers association or by the individual tree farmer, duly authenticated and affirmed under oath by a private registered forester, with the information on ownership of planted trees, tree species, tally sheets, and

delivery receipts. Certification is not necessary if the wood/ wood product is not transported out of the private land; and

- Certified copy of the original certification shall be filed at the CENRO of origin and the original Certification, duly acknowledged by the buyer/recipient of the shipment, shall be submitted to the CENRO at destination.

Properly disseminated and discussed with concerned LGUs, tree farmers, registered foresters, and other stakeholders, these measures could pave way for the establishment of more private tree plantations for income generation and ecological restoration.

## Harvesting Technologies

The harvesting of plantation wood is usually subdivided into four main phases namely: felling and bucking, extraction, loading, and major transportation. Prior activities are being taken up before harvesting such as perimeter survey of the intended areas for operations, blocking survey, preparation of set-ups or blocks, and tree marking.

PICOP Resources, Incorporated is adopting systems in its plantation, such as skidding, yarding and skylining.

### Skidding

This system describes the movement of logs along the ground in segments from the stump site or a landing area. Skidding can operate successfully on downgrade of up to 30–40%. The equipment or animal in this system is mobile, which drag the logs from cutting area to the landing.

- *Tractor* - 50.75 HP equipped with winch and when needed antiskid device (chains, halflacks). Auxillary equipment includes skidding tongue, pan, trailer, sled, and crane as suitable (Fig. 35).
- *FMC roller-skidder* - a skidder machine with higher horsepower with similar operation to tractor. This machine can be used on areas with downgrade of up to 40% (Fig. 36).

**Fig.35. Tractor** *(D.R. Tumambing)* **.**

**Fig.36. F MC roller-skidder** *(D.R. Tumambing)* **.**

- *Manimal* - movement or minor transport of logs employs the combination of men (manual) and carabao through skidding system (Fig. 37).

**Fig.37. M animal** *(D.R. Tumambing)* **.**

## Yarding

This system moves logs to the landing point from stumpsite, while the machine is stationary.

- *Wrecker* - a 30 HP small track type machine with a single down powered by the truck engine. During extraction the propeller shaft is transferred to the differential where the drum is also connected. A recovery block is installed at a standing tree along the road about 2 m above the ground. This system is a ground lead yarder (Fig. 38).

- *Stump puller* - a Filipino innovation of a sledge type yarder with a single drum powered by a 9.5 HP YANMAR air-cooled diesel engine. This system is also a ground lead yarder.

## Skylining

This extraction system involves a carriage that moves logs laterally to and longitudinally along the suspended cable. The logs being

**Fig.38 Wrecker** *(D.R. Tumambing)* **.**

transported are fully suspended in comparison to yarding in which the logs are partially suspended and dragged.

- *Thunderbird* - a 350 HP drum skyline yarder using a clamping carriage. The photo shows the skyline operation that allows lateral skylining and full suspension of logs (Fig. 39).

- *Urus* - a low powered (150 HP) mobile spar machine with a nonclamping carriage and three drums. The skyline, mainline headsper is installed to improve the lifting capacity for extracting logs. This system is a north bend skyline (Fig. 40).

## Transport System

In a recently concluded study in the country's "Timber corridor," both the minor and major log transport methods were documented. Minor log transport methods are hauling activities of logs from the stump site to roadside, landing, deck, and to the pond. Activities in a minor log transport are hauling by either people or animal, and transporting by either motorcycle, small trucks, modified trailer, and/or

**Fig.39 S kyline** *(D.R. Tumambing)*.

**Fig.40U rus** *(D.R. Tumambing)*.

rafting. Major log transport methods, on the other hand, are hauling activities of large log volume from log landing, roadside, and/or log pond to the mill or market. These are done through rafting and use of 10-wheeler trucks (Dela Cruz et al. 2006).

The choice in the use of available transport system depends on the length of haul, size of load, types and quality of road where trees are to be harvested and transported. As reported in the study, rafting is a cheaper method than use of motorcycle in the minor log transport system, while in the major log transport system, rafting again is cheaper than using trucks.

It was noted that the costs of transporting depended on factors such as terrain, accessibility, and climatic conditions, among others. As such, there was no explicit recommendation made for an effective and efficient log transport method since factors differ from one area to another.

# Growth, Yield, and Economic Rotation

Tree plantations may be established for production, protection, or other uses. Various products like sawtimber or solidwood, pulpwood or fuelwood may be derived from tree plantations. The kind of product that the owner wants to produce affects the rotation, which can be defined as the age at which timber is harvested (Klemperer 1996). Some owners base this solely on biological rotation, which considers a biological criterion like the maximum mean annual increment. However, a tree grower also has to consider the profitability of the harvest, which is why the financial rotation should also be considered. Financial rotation can be defined as the age that maximizes the financial objective of the tree grower, which can be to maximize the net present value (NPV), soil expectation value (SEV), or internal rate of return (IRR) (Cruz and Calderon 2000).

In determining a plantation's rotation, growth and yield information are very important. These allow the tree grower to estimate the rate at which the trees can grow, and what the expected volume can be for different dbh, height, site class, and/or age. In a more general sense, growth and yield information are important to strike a balance between the demand for and supply of wood. They can enable a tree grower to make a deliberate decision as to when a plantation should be harvested so that the owner's objectives are met and market requirements are addressed.

Many growth and yield studies have been undertaken in the Philippines. Aside from modeling the growth and yield of a particular species, the studies were also able to come up with recommended economic rotations based on the products

to be derived. Table 20 shows the growth, yield, and economic rotations of some species that are suitable for plantation establishment. On the other hand, Table 21 provides the growth and yield models that were developed for various species, from which the growth, yield, and rotation estimates were derived.

For example, Moluccan sau or falcata can be harvested at 7–9 years for pulpwood and 10–15 years for solidwood. Before, Moluccan sau was mainly used as pulpwood, but it is now popularly used for corestock (for plywood manufacture) and furniture, among others. The expected yield ranges from 25 m/ha per year to 35 m/ha per year, depending on the site.

**Table 20. Growth, yields, and economic rotations of suitable species for plantation establishment and their end products.**

| Species | Optimum Growth | | Yield ($m^3$/ha/yr) | Economic Rotation (yr) | End Products |
|---|---|---|---|---|---|
| | Height (m) | Diameter (m) | | | |
| Mangium (*Acacia mangium*) | 15–30 | 0.5–0.9 | Dry site: 20–25<br>Good site: 40 | Pulp: 6–8<br>Solidwood: 14–16<br>Pole: 6–8 | Pulp, pallets, furniture, boxes, poles, corestock, mine timber, and fuelwood |
| Kaatoan bangkal (*Anthocephalus chinensis)* | 25–30 | 0.5–1.0 | 10–20 | Pulp: 6–8<br>Solidwood: 10–20 | Pulp, pencil slats, matches, corestock veneer, particle board and chopsticks |
| Bagras (*Eucalyptus deglupta)* | 30– 40 | 0.5–1.0 | 18–25 | Pulp: 6–10<br>Solidwood: 14–16<br>Poles: 12–15 | Pulp, lumber, poles, construction lumber, boxes, furniture, mine timber, door skin, fuelwood, veneer, pallets, particleboard |
| Agoho (*Casuarina equisetifolia)* | 15–25 | 0.5–1.0 | 20–30 | 7–10 | Firewood, windbreak, erosion control, tannin and pulp |
| Gubas (*Endospermum peltatum)* | 10–15 | 0.6–0.8 | 10–20 | Solidwood: 20–25 | Matchsticks, tongue depressor, chopsticks, ice cream sticks, and door curls |
| Japanese acacia or auri or wattle (*Acacia auriculiformis*) | 8–15 | 0.4–0.6 | 10–25 | Fuelwood: 3–5<br>Pulp and paper: 8–10<br>Solidwood: 15–25 | Pulp and fuelwood |
| Large leaf mahogany (*Swietenia macrophylla*) | 30–40 | 1.0–1.5 | 10–20 | Solidwood: 20–50 | Veneer, door skin, lumber, millwork, moulding and furniture |

**Table 21. Growth and yield models for forest plantation species in the Philippines.**

| | Equations | $R^2$ | Authors | Year |
|---|---|---|---|---|
| Moluccan sau (*Paraserianthes falcataria*) | Site Index Guide Equation: log H = 1.72056 - $0.9632/A^{0.7}$ | | Appleton | 1980 |
| | Stand Site Index Model (BAGE = 10): log S = -0.1928 + log H + $0.9632/A^{0.7}$ | | | |
| | Total tree timber yield model: log $Y_{10}$ = 3.21336 - 1.61865/A - 0.20522 log (SP) - 16.23671/S | 0.69 | | |
| | Pulp timber yield model: log $Y_{15}$ = 3.3313 - 2.03505/A - 0.20365 log (SP) - 20.74576/S | 0.72 | | |
| | Sawtimber Yield Model: log $Y_{20}$ = 3.59971 - 3.3790/A - 0.15278 log (SP) - 31.11963/S | 0.72 | | |
| | Site Index Guide Equation: log H = 1.0455 + 0.41834 log A | 0.85 | Revilla | 1974 |
| | Stand Site Index Model (BAGE≠ 0): log S = 0.41834 + log H - 0.41834 log A | | | |
| | Pulp timber yield model: log $Y_{10}$ = -1.53657 + 0.20085 log A + 1.46447 log S + 0.63247 log (A*S) | 0.81 | | |
| | Pulp timber yield model: log $Y_{15}$ = -1.87195 + 0.79250 log A + 1.8803 log S + 0.25167 log (A*S) | 0.71 | | |
| | Sawtimber Yield Model: log $Y_{20}$ = -2.34183 + 1.31168 log A + 2.07938 log S + 0.0646 log (A*S) | 0.66 | | |
| Bagras | Site Index Guide Equation: H = -18.176946 + 50.47292 log A | 0.97 | Tomboc | 1976 |
| | Stand Site Index Model (BAGE = 6): S = H + 50.47292 (log BAGE – log A) | | | |
| | Pulptimber Yield Model: log (Y + 1) = 3.538342 – 14.021407/A + 0.2314196 S/A | 0.88 | | |
| Kaatoan bangkal | Site Index Guide Equation: H = 0.932333 + 0.32407 log A | 0.86 | Cacanindin | 1982 |
| | Stand Site Index Model (BAGE = 10): S = H + 0.32407 (log BAGE – log A) | | | |
| | Total Yield Model: log $Y_{10}$ = 1.607298 + 0.1672299/A + 0.0389856 S - 0.108905 S/A | 0.60 | | |

**Table 21. (Continued).**

| | Equations | $R^2$ | Authors | Year |
|---|---|---|---|---|
| | Sawtimber Yield Model: log $Y_{20}$ = 5.439887 + 1.333439 log A * log S + 2.794613 log S + 0.8185465 log Y-10¯ | 0.64 | | |
| Yemane | Site Index Guide Equation: log H = 1.47463 – 0.92094/A | 0.86 | Lingan | 1980 |
| | Stand Site Index Model (BAGE = 15): log S = -0.06139 + log H + 0.92094/A | | | |
| | Total Pulp Timber Yield Model: log ($Y_p$ + 1) = -0.02915 – 5.34794/A + 0.08893 S/A + 1.75964 log S | 0.89 | | |
| | Sawtimber Yield Model: log ($Y_s$ + 1) = 3.07179 + 3.10405/log A – 6.29913/ (log S * log A) | 0.73 | | |
| Benguet Pine | Site Index Guide Equation: log H = 0.46369 + 0.84555 log A | 0.92 | Revilla | 1976 |
| | Stand Site Index Model (BAGE 4 0): log S = log H + 0.84555 log (BAGE – log A) | | | |
| | Basal Area Equation: log (BA + 4)/4 = -0.92419 + 1.2249 log A * log S – 0.00875354 log A – 0.012331 log S | 0.84 | | |
| | Yield Model: log Y = -9.1992 + 3.7725 log A + 4.6798 log S – 0.015521 PBA – 0.048355/RD | 0.94 | | |
| Gubas | Site Index Guide Equation: log H = 0.693041 + 0.59416 log A | | Ramos | 1977 |
| | Stand Site Index Model (BAGE = 15): log S = 0.69879 – 0.59416 log A + log H | | | |
| | Pulp Timber Yield Model: log ($Y_{10}$ + 1) = -11.157879 + 9.488114 log S – 4.2273 log A * log S – 1.013591 (log S)2 + 7.65447 log A | 0.90 | | |
| | Sawtimber Yield Model: log ($Y_{20}$ + 1) = -6.396101 + 1.87902 log S – 3.943808 log A * log S + 1.878074 (log S)2 + 7.33411 log A | 0.81 | | |
| Giant ipil-ipil | Site Index Guide Equation: ln H = 1.7795 + 0.4881 ln A | 0.89 | Monoy | 1981 |
| | Stand Site Index Model (BAGE = 6): ln S = 0.87456 + ln H – 0.4881 ln A | | | |

**Table 21. (Continued).**

| | Equations | $R^2$ | Authors | Year |
|---|---|---|---|---|
| | Yield Model: ln Y = 2.1077 – 5.0730/A + 0.2276 S + 1.9353/SP – 0.1386 S/SP | 0.70 | | |
| Teak | Site Index Guide Equation: log H = -0.04077 + 1.06566 log A | 0.85 | Gonzales | 1985 |
| | Stand Site Index Model (BAGE = 40): log S = 1.70725 + log H - 1.06566 log A | | | |
| | Total Yield Model: $Y_{10}$ = 421.8274 - 6434.7581/A - 2746.6466/S - 0.04872 $(SP)^2$ | 0.74 | | |
| | Sawtimber Yield Model: $Y_{20}$ = 217.3958 - 4317.4929/A -1503.24763/ S + 27.7399 log SP | 0.76 | | |
| Mahogany | Site Index Guide Equation: log H = 0.17336 + 0.76605 log A | 0.74 | Revilla et. al. | 1976 |
| | Stand Site Index Model (BAGE = 40): log S = log H + 1.22726 - 0.76605 log A | | | |
| | Yield Model: log Y = 1.7348 -6.6721/A + 0.053801 S - 0.78406 S/A | 0.88 | | |

where:

H = stand height in meters (average of at least 5 dominant and co-dominant trees)
S = site index at a given base age
A = stand age in years
SP = spacing in square meters
$Y_{10}$ = stand yield in cubic meters/ha of materials up to 10 cm top diameter
$Y_{15}$ = stand yield in cubic meters/ha of materials up to 15 cm top diameter
$Y_{20}$ = stand yield in cubic meters/ha of materials up to 20 cm top diameter
$R^2$ = coefficient of determination
BA = basal area in square meters
PBA = predicted basal area
RD = relative density
BAGE = base age in years
Y = yield in cubic meters per ha

On the other hand, narra takes longer to mature (i.e., 25–50 years) because it is slow growing compared to Moluccan sau. The expected yield ranges from 10 m/ha per year to 15 m/ha per year. Because it is a premium species, narra is used mostly for veneer, lumber, furniture, and millwork.

The more popular fast-growing plantation species are mangium, bagras, auri, and yemane, with economic rotations ranging from 3–5 years for fuelwood, 6–10 years for pulpwood, and 15–20 years for solidwood.

One of the questions that a tree farmer would like to know is what the expected volume of a tree would be at a given age, or when the dbh and height are known. The growth and yield models given above require information like height, age, spacing, and basal area. Those who are interested in the details of these models can consult the references given.

Tables 21, 22, and 23 provide examples of the estimated volumes of trees at different dbh and heights of Moluccan sau for pulptimber and solidwood. The dbh ranges from 10 cm to 80 cm, while the merchantable height ranges from 5 m to 40 m. Appleton (1980) determined the economic rotation of Moluccan sau for pulptimber to be six years, based on NPV and using interest rates of 12%, 14%, and 16%. For saw timber, the economic rotation is eight years for interest rates of 12% and 14%, and seven years for 16%. The same rotations are recommended for spacings (in m) of 2x3, 3x3, 4x4 and 6x6.

Table 24 shows the estimated volume of bagras for dbh ranging from 10 to 35 cm and heights ranging from 5 m to 20 m. The economic rotations based on net present value (NPV) and soil expectation value (SEV) and using an interest rate of 18% are 10 years for site indices[1] 22, 24, and 26, and 11 years for site indices 16, 18, and 20. It is worth mentioning that the volume estimates were developed for PICOP plantations.

[1]In this case, a site index shows the expected mean total height of the dominant and co-dominant trees given the age of the stand using a bass age of 6 years.

**Table 22. Estimated tree volume of falcata (*Paraserianthes falcataria)* for pulptimber based on dbh (cm) and merchantable height (m)[a].**

| DBH (cm) | Merchantable Height (m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
| 10 | .04 | | | | | | | |
| 15 | .08 | .14 | | | | | | |
| 20 | .14 | .24 | .34 | | | | | |
| 25 | .21 | .37 | .51 | .64 | | | | |
| 30 | .29 | .52 | .72 | .91 | 1.09 | | | |
| 35 | .39 | .69 | .96 | 1.21 | 1.45 | 1.69 | | |
| 40 | .50 | .88 | 1.23 | 1.55 | 1.87 | 2.16 | 2.46 | |
| 45 | .62 | 1.10 | 1.53 | 1.94 | 2.33 | 2.70 | 3.06 | |
| 50 | .76 | 1.34 | 1.87 | 2.36 | 2.83 | 3.29 | 3.73 | 4.16 |
| 55 | .91 | 1.60 | 2.23 | 2.82 | 3.39 | 3.93 | 4.46 | 4.97 |
| 60 | 1.07 | 1.89 | 2.63 | 3.18 | 3.99 | 4.63 | 5.25 | 5.85 |
| 65 | 1.24 | 2.19 | 3.05 | 3.86 | 4.63 | 5.37 | 6.09 | 6.80 |
| 70 | 1.43 | 2.52 | 3.50 | | | 6.17 | 7.00 | 7.81 |
| 75 | 1.63 | 2.86 | 2.99 | 5.04 | 6.05 | 7.02 | 7.78 | 8.88 |
| 80 | 1.83 | 3.23 | 4.50 | 5.69 | 6.83 | 7.93 | 8.99 | 10.02 |

[a]Appleton, 1980.

**Table 23. Estimated tree volume of falcata (*Paraserianthes falcataria*) for sawtimber based on dbh (cm) and merchantable height (m)[a].**

| DBH (cm) | Merchantable Height (m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
| 10 | .05 | | | | | | | |
| 15 | .09 | .17 | | | | | | |
| 20 | .14 | .27 | .39 | | | | | |
| 25 | .21 | .39 | .56 | .72 | | | | |
| 30 | .28 | .52 | .75 | .97 | 1.19 | | | |
| 35 | .35 | .66 | .96 | 1.24 | 1.52 | 1.79 | | |
| 40 | .44 | .82 | 1.18 | 1.53 | 1.88 | 2.21 | 2.55 | |
| 45 | .53 | .99 | 1.42 | 1.85 | 2.27 | 2.67 | 3.07 | |
| 50 | .63 | 1.17 | 1.69 | 2.19 | 2.68 | 3.16 | 3.64 | |
| 55 | .73 | 1.36 | 1.97 | 2.55 | 3.12 | 3.68 | 4.23 | 4.78 |
| 60 | .84 | 1.57 | 2.26 | 2.93 | 3.59 | 4.23 | 4.87 | 5.49 |
| 65 | .95 | 1.78 | 2.57 | 3.33 | 4.08 | 4.81 | 5.53 | 6.24 |
| 70 | 1.07 | 2.00 | 2.89 | 3.75 | 4.59 | 5.41 | 6.22 | 7.02 |
| 75 | 1.19 | 2.24 | 3.23 | 4.19 | 5.12 | 6.04 | 6.95 | 7.84 |
| 80 | 1.32 | 2.48 | 3.58 | 4.64 | 5.68 | 6.70 | 7.70 | 8.69 |

[a]Appleton, 1980.

**Table 24. Estimated tree volume of bagras (*Eucalyptus deglupta*) in PICOP plantations based on dbh (cm) and merchantable height (m)[a].**

| DBH (cm) | Merchantable Height (m) | | | |
|---|---|---|---|---|
| | 5 | 10 | 15 | 20 |
| 10 | .05 | | | |
| 15 | .09 | .17 | | |
| 20 | .14 | .27 | .39 | |
| 25 | .21 | .39 | .56 | .72 |
| 30 | .28 | .52 | .75 | .97 |
| 35 | .35 | .66 | .96 | 1.24 |

[a]Tomboc, 1976.

## Growth and Yield Monitoring

The objective of monitoring the growth of trees in the plantation is to provide the resource data needed to develop economically sound timber management plans and action programs to meet present and anticipated future demands of timber. Achieving this objective requires collecting and recording field data to determine current growth and yield of a specific unit of area (i.e., quadrant, section, and block, among others).

Growth and yield monitoring activity involves the charting of trees to determine total living trees count for the area, each tree's crown classification (i.e., dominant, intermediate, or suppressed), and the density classification of the area (i.e., high, medium, or low). It also includes the measurement of diameter and height of sample trees in each crown class to determine volume and average or total height of trees in the area.

The monitoring activity will be done every other year starting right after turn over of an established area until the cutting cycle.

The guidelines, procedures, and forms contained in this portion of the manual were designed to have a set of standards to be followed and capture the necessary data and store it in the computer files to facilitate fast and easy retrieval. This has been the practice in PICOP.

**Procedure Guidelines**

1) Plantation growth and yield monitoring shall be made upon turnover of established blocks and every two years thereafter until harvest time. It shall cover the following major activities:

   - Tree charting

     Charting activity shall determine the following:
     - Total tree count of the block
     - Crown class of each tree in the block
     - Density class (high, medium, low) of the block
     - Block site description (topography, vegetation, etc.)

   - Tree measurement
     - Average tree diameter and height by crown class for the block.
     - Average tree volume by crown class per block.

2) Fieldwork shall be directed by a section head with the assistance of foreman. He shall be responsible for the coordination of effort of all teams and assigns work areas and shifts crews between teams as necessary to meet work schedule.
3) The foreman shall direct the day-to-day activities of a team of 4 two-man crews working in the same area or block. He shall be responsible for the efficient operation of the crews as a team.
4) The block to be cruised shall be established first on the field by locating its four corner posts with the aid of a map and survey control points previously laid out on the ground. Its four sides or boundary lines shall be cleared of weed vegetation.
5) All trees of the planted species within the planted area of the block shall be charted.

6) A strip method shall be followed when charting the trees in the block, each strip covering three rows of planted trees to be charted.
7) Charting shall start from the east side of the block going to the west side covering three rows for the strip, west to east for the next strip covering another three rows, east to west again for the next, charting all the rows under his area of responsibility.
8) Plantation forest maintenance chart map shall be used as the final report for the tree charting activity. The chart map shall also be used as the input document for computer processing.
9) A field worksheet chart shall be used by the charters when charting the trees in the field. Each worksheet shall contain only the number of rows assigned to each charter as shown below:

| Charter/ Worksheet | | Row Numbers |
|---|---|---|
| #1 | - | 1–31 |
| #2 | - | 32–62 |
| #3 | - | 63–93 |
| #4 | - | 94–124 |

The accomplished worksheet shall be consolidated and summarized by the foreman into the plantation maintenance chart map as final report.

10) Each charter on the following assigned row number:

Charter # 1 – Row # 2
" # 2 – Row # 33
" # 3 – Row # 64
" # 4 – Row # 95

11) Land features and other information describing the block such as topography, soil class, etc., shall also be gathered and indicated/outlined on the chart map to determine their extent.

12) The following crown class code shall be used:

D - For Dominants
I - For Intermediates
S - For Suppressed

Crown class for each tree shall be judged in the context of its immediate environment, those trees affecting it or trees being affected by it in terms of crown competition.

13) Sampling intensity for the measurement by crown class classification shall be as follows:

20% of the Ds
15% of the Is
10% of the S

14) Diameter shall be measured with a tape at a point 1.3 m above the ground level. If slope, measurement shall be on the uphill side of the tree.
15) Merchantable height shall be measured with a clinometer at a point 1.3 m above the ground level up to 10 cm from the top end of the tree. Measurement of total height shall be up to the top end of the tree.
16) If the tree forks at or above 1.3 m (i.e., open crotch of fork is at or above 1.3 m), the tree shall be considered as one tree and the diameter shall be measured below the swell but as near as possible to 1.3 m above the ground level.
17) If the stem forks below 1.3 m, the tree shall be considered as two trees and the diameter shall be measured above the crotch.

18) Sampling intensity shall be 20% of the total number of blocks in a quadrant.
19) An average yield of 0.60 $m^3$/tree and 75% survival/block shall be attained upon reaching the cutting cycle.

Work performance on each block shall be properly and careful done, for errors introduced by careless charting and measurement of trees and areas will be magnified many fold in the end total, resulting to a misleading report.

# Economics and Marketing

One of the first things a prospective investor in tree farming will ask is whether the venture will bring financial rewards or profit. There may also be several options available to the investor as far as investments are concerned. For tree farming to be chosen over other possible alternatives, it should prove to be superior. Thus, there is a need to analyze the profitability of various options.

## Profitability of Tree Plantations

Profitability analysis involves the comparison of revenues and costs that occur at different times during the entire cycle of the stand, and the determination of the effect of time on these revenues and costs. It is basic for the tree grower to know that tree farming will yield the highest returns from the alternatives available to him. He would also want to be able to harvest the stand at the best time. Time is of particular importance in timber production because timber is a long gestation crop. This best time is called financial rotation, which refers to the rotation where the tree grower's financial objective is maximized.

In both cases, financial indicators of profitability have to be determined. These indicators include:

**Net Present Value (NPV)** – considered the most straightforward discounted cash flow measure of project worth; it gives the difference between the present value of revenues and the present value of costs. The formula for NPV is:

$$NPV = \frac{\Sigma R_t}{(1+i)^t} - \frac{\Sigma C_t}{(1+i)^t}$$

where: $R_t$ is the revenue in year t; $C_t$ is the cost in year t; i is the interest rate; and t is any year within the rotation.

**Internal Rate of Return (IRR)** – the discount rate that makes NPV equal to zero, or the interest rate that equates the present values of project benefits and costs. This may be estimated using the following formula:

$$IRR = i^{+} - NPV^{+} \quad \frac{i^{-} - i^{+}}{NPV^{-} - NPV^{+}}$$

where: $NPV^{+}$ is the positive NPV computed using the lower interest rate ($i^{+}$); and $NPV^{-}$ is the negative NPV computed using the higher interest rate ($i^{-}$).

Both NPV and IRR can easily be computed using spreadsheet software.

The interest rate may represent the investor's opportunity cost of capital (for equity capital) or the cost of borrowing (if capital is borrowed). At the given interest rate, a project will be considered feasible if NPV is positive, and IRR is greater than the interest rate.

To be able to compute the indicators, the tree grower needs information about the costs that will be incurred in the establishment, management and/or harvesting of the stand, as well as the revenues that will be generated from its products, throughout the rotation.

Let us look at the profitability of developing bagras, falcata, and mangium plantations. The per hectare costs of developing these plantations are summarized in Table 25. Most of the activities are similar for the three species, but bagras requires form pruning, which is not necessary for falcata and mangium.

The major products that can be obtained from a plantation depend on the species and the rotation. Bagras is commonly used for pole, sawtimber, and pulpwood; falcata for pulpwood and sawtimber; and mangium for pulpwood. The rotations of these species are commonly 12, 8, and 7 years, respectively. The mean annual increment (MAI) varies, and falcata has been reported to have the highest MAI.

At 15% interest rate, the NPV and IRR of a one-hectare falcata plantation are highest at ₱25,475/ha and 22%, respectively. The profitability indicators for the three plantation species show that all of them are financially feasible (Table 26). The NPV and IRR for these species were computed using the above cost information, and using the assumptions on products and prices given in Tables 27–29.

**Table 25. Activities and costs of developing bagras, falcata and mangium plantations[a].**

| Activity | Bagras | | | Falcata | | | Mangium | | |
|---|---|---|---|---|---|---|---|---|---|
| | Unit Cost (P/ha) | Mandays | Nature of Labor | Unit Cost (P/ha) | Mandays | Nature of Labor | Unit Cost (P/ha) | Mandays | Nature of Labor |
| A. Site Preparation | | | | | | | | | |
| 1. Site clearing | 453.60 | 2.40 | Manual | 453.60 | 2.40 | Manual | 453.60 | 2.40 | |
| 2. Tree tops clearing | 249.00 | 1.40 | Manual with chainsaw | 264.60 | 1.40 | Manual with chainsaw | 264.60 | 1.40 | |
| 3. Strip zero weeding | 3,137.40 | 16.60 | Manual | 3,137.40 | 16.60 | Manual | 3,137.40 | 16.60 | |
| B. Planting | 321.30 | 1.70 | Manual | 321.30 | 1.70 | Manual | 321.30 | 1.70 | |
| C. Seedlings | 1,374.00 | | Manual | 1,374.00 | | Manual | 1,374.00 | | |
| D. Maintenance | | | | | | | | | |
| 1. Strip zero weeding | 2,003.40 | 10.60 | Manual | 2,003.40 | 10.60 | Manual | 2,003.40 | 10.60 | |
| 2. Replanting | 94.50 | 0.50 | Manual | 94.50 | 0.50 | Manual | 94.50 | 0.50 | |
| 3. Strip zero weeding 2 | 2,003.40 | 10.60 | Manual | 2,003.40 | 10.60 | Manual | 2,003.40 | 10.60 | |
| 4. Strip zero weeding 3 | 2,003.40 | 10.60 | Manual | 2,003.40 | 10.60 | Manual | 2,003.40 | 10.60 | |
| 5. Form pruning | 945.00 | 5.00 | Manual | | | | | | |
| 6. Zero weeding 4 | 2,003.40 | 10.60 | Manual | 2,003.40 | 10.60 | Manual | 2,003.40 | 10.60 | |
| 7. Form pruning 2 | 1,323.00 | 7.00 | Manual | | | | | | |
| 8. Form pruning 3 | 2,268.00 | 12.00 | Manual | | | | | | |
| 9. Protection/maintenance | 2,721.60 | 14.40 | Manual | 5,443.20 | 14.40 | Manual | 2,721.60 | 28.80 | |
| E. Plantation inspection | 302.40 | 1.60 | Manual | 189.00 | 1.00 | Manual | 189.00 | 1.00 | |
| F. Other costs | 6,000.00 | | | 6,000.00 | | | 6,000.00 | | |
| **TOTAL** | **27,203.40** | **105.06** | | **22,667.00** | **80.46** | | **20,769.60** | **94.80** | |

[a]PICOP, 2006.

**Table 26. NPV and IRR of bagras, falcata and mangium plantations, one-hectare model.**

| Plantation | Rotation (years) | MAI ($m^3$/ha/year) | NPV (P/ha) | IRR (%) |
|---|---|---|---|---|
| Bagras | 12 | 21 | 25,475 | 22 |
| Falcata | 8 | 31 | 39,830 | 31 |
| Mangium | 7 | 23 | 15,678 | 25 |

## Marketing of Tree Plantation Products

Marketing may be defined as a human activity that aims to satisfy needs and wants through exchange processes (Kotler and Armstrong 1987). Marketing is important in timber production. From the start, when the tree grower decides on the species to plant, he must already have his target market in mind. What does my target market want in terms of species, volume, quality, and price? Considering the target market at the start becomes even more important because of the long period of timber production. Going back on decisions made in the past (e.g., choice of species) may have serious implications in terms of time and monetary costs.

The following guidelines (adapted from Brinker and Bliss 1996) may be useful in marketing timber:

1) *Know your objectives for your plantation.* If your main objective for plantation establishment is to produce timber, you still need to define what your intended products are – are you producing pulpwood, poles, fuelwood, or sawtimber? The intended products will affect your choice of species, rotation, and silvicultural practices, among others.

2) *Know your products*. The products that can be obtained from trees change with time. At a young age, the wood may be used for fuelwood, posts, and similar uses. High-value uses like sawtimber and veneer logs require longer time. You will also need to estimate the volumes of your products, which will require an inventory.

3) *Know the value of your products.* One of the peculiarities of timber production is the immobility of timber, that is, timber as

**Table 27. Cashflow of bagras plantation, 4m x 3m spacing, one-hectare model.**

| | Y0 | Y1 | Y2 | Y3 | Y4 | Y5 | Y6 | Y7 | Y8 | Y9 | Y10 | Y11 | Y12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SALES** | | | | | | | | | | | | | |
| Poles | | | | | | | | | | | | | 131,040 |
| Sawtimber (46–58 cm) | | | | | | | | | | | | | 8,920 |
| Sawtimber (36–44 cm) | | | | | | | | | | | | | 101,520 |
| Sawtimber (26–34 cm) | | | | | | | | | | | | | 238,786 |
| Pulpwood (18–24 cm) | | | | | | | | | | | | | 17,280 |
| Pulpwood (7–24 cm) | | | | | | | | | | | | | 73,467 |
| **Total Sales** | | | | | | | | | | | | | **571,013** |
| **COSTS** | | | | | | | | | | | | | |
| Development cost | 16,187 | 6,525 | 1,323 | | 3,169 | | | | | | | | |
| Selling expenses | | | | | | | | | | | | | 44,400 |
| Extraction/loading | | | | | | | | | | | | | 12,137 |
| Road cost | | | | | | | | | | | | | 85,201 |
| Overhead | | | | | | | | | | | | | 9,937 |
| Handling | | | | | | | | | | | | | 6,562 |
| **Total Costs** | **16,187** | **6,525** | **1,323** | **-** | **3,169** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **158,237** |
| **Net Income** | **(16,187)** | **(6,525)** | **(1,323)** | **-** | **(3,169)** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **412,776** |
| **Net Income after Tax (35%)** | **(16,187)** | **(6,525)** | **(1,323)** | **-** | **(3,169)** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **268,304** |
| **NPV (15%)** | **25,475** | | | | | | | | | | | | |
| **IRR** | **22%** | | | | | | | | | | | | |

**Assumptions:**

| Product | % of Total | Volume | Price/ $m^3$ |
|---|---|---|---|
| Poles | 13.00 | 31.20 | 4,200 |
| Sawtimber (46–58 cm) | 0.93 | 2.23 | 4,000 |
| Sawtimber (36–44 cm) | 11.75 | 28.20 | 3,600 |
| Sawtimber (26–34 cm) | 34.31 | 82.34 | 2,900 |
| Pulpwood (18–24 cm) | 6.00 | 14.40 | 1,200 |
| Pulpwood (7–24 cm) | 34.01 | 81.63 | 900 |
| | 100.00 | 240.00 | |

**Table 28. Cash flow of falcata plantation, 4m x 3m spacing, one-hectare model.**

| | Y0 | Y1 | Y2 | Y3 | Y4 | Y5 | Y6 | Y7 | Y8 |
|---|---|---|---|---|---|---|---|---|---|
| **SALES** | | | | | | | | | |
| Peelable | | | | | | | | | 28,800 |
| Sawmill grade | | | | | | | | | 172,800 |
| Pulpwood | | | | | | | | | 164,256 |
| **Total Sales** | | | | | | | | | **365,856** |
| | | | | | | | | | |
| **COSTS** | | | | | | | | | |
| Development cost | 15,782 | 3,035 | 6,474 | | | | | | |
| Selling expenses | | | | | | | | | 44,436 |
| Road cost/loading | | | | | | | | | 10,080 |
| Overhead | | | | | | | | | 10,560 |
| Handling | | | | | | | | | 3,600 |
| **Total Costs** | 15,782 | 3,035 | 6,474 | - | - | - | - | - | **68,676** |
| | | | | | | | | | |
| **Net Income** | **(15,782)** | **(3,035)** | **(6,474)** | **-** | **-** | **-** | **-** | **-** | **297,180** |
| **Net Income After Tax (35%)** | **(15,782)** | **(3,035)** | **(6,474)** | **-** | **-** | **-** | **-** | **-** | **193,167** |
| **NPV (15%)** | **39,830** | | | | | | | | |
| **IRR** | **31%** | | | | **ar** | | | | |

**Assumptions:**

| Product | % of total | Volume | Price/$m^3$ |
|---|---|---|---|
| Peelable | 5.00 | 12.00 | 2,400 |
| Sawmill grade | 35.83 | 86.00 | 2,000 |
| Pulpwood | 59.17 | 142.00 | 1,160 |
| | 100.00 | 240.00 | |

**Table 29. Cash flow of mangium plantation, 4 m x 3 m spacing, one-hectare model.**

| | Y0 | Y1 | Y2 | Y3 | Y4 | Y5 | Y6 | Y7 |
|---|---|---|---|---|---|---|---|---|
| **SALES** | | | | | | | | |
| Pulpwood | | | | | | | | 190,400 |
| **Total Sales** | | | | | | | | **190,400** |
| | | | | | | | | |
| **Operating Cost** | | | | | | | | |
| Development cost | 15,782 | 3,035 | 3,753 | | | | | |
| Selling expenses | | | | | | | | 29,600 |
| Road cost/loading | | | | | | | | 202 |
| Overhead | | | | | | | | 7,040 |
| Handling | | | | | | | | 2,400 |
| **Total Costs** | 15,782 | 3,035 | 3,753 | - | - | - | - | **39,242** |
| | | | | | | | | |
| **Net Income** | (15,782) | (3,035) | (3,753) | - | - | - | - | 151,158 |
| **Net Income After Tax (35%)** | (15,782) | (3,035) | (3,753) | - | - | - | - | 98,253 |
| **NPV (15%)** | 15,678 | | | | | | | |
| **IRR** | 25% | | | | | | | |

**Assumptions:**

| Product | % of Total | Volume | Price/$m^3$ |
|---|---|---|---|
| Pulpwood | 100 | 160 | 1,190 |

a product is usually sold where it stands. It is common for the buyer, and not the tree grower, to harvest the trees. In this case, the tree grower's product is stumpage, and the stumpage price is the price of the standing merchantable tree that excludes harvesting costs.

Some of the factors that affect the price of stumpage are (Leblanc n.d.):

a) **Species.** Among the commonly used plantation species in the Philippines, for example, mahogany enjoys higher prices compared to yemane.
b) **Size and quality.** In general, bigger (and older) trees produce bigger logs with higher quality. However, the biological rotations of different species vary. Upon reaching a certain age, some species deteriorate, which means that it will not make sense to grow them for a longer period.
c) **Location and accessibility.** Harvesting costs are a major determinant of the price of timber. While stumpage price excludes costs, they will definitely affect the final price of the product.
d) **Harvestable volume.** Highly mechanized logging operations require substantial investments, which may be recovered only with big areas and high harvestable volumes. On the other hand, timber harvesting from small holdings can be feasible, but may be less mechanized.
e) **Competition.** The tree grower has to be conscious of the competition (i.e. sellers who offer the same or similar products to the same buyers). Buyers will always compare the prices, products and terms of sale of different sellers. As such, you will have to be competitive.

The value should reflect the costs of producing the timber (including the cost of self-owned resources), quality, and the distance of the plantation to the market or mill, among others. You will also have to know the prevailing market prices for your products.

4) *Determine how you will sell your products.* The most common practice in the Philippines is through a negotiated sale. This

involves face-to-face bargaining between the buyer and the tree grower. It is common for the buyer to have the upper hand because they know the market, are skilled in sales negotiations and in striking a bargain price. To improve your bargaining position, you will need to gather market information about product prices and other prospective buyers, among others.

5) *Market your timber.* You will have to inform your prospective buyers about your intention to sell, what you have to sell, when, and how you intend to sell and other information.

6) *Select a buyer.* It is very important for you to know your buyer – you have to check his background.

7) *Protect your interests.* You will also need to protect your interest by entering into a contract with the buyer or ask for advanced payment to avoid the experience of some tree growers in Compostella Valley, Mindanao. A buyer promised the tree growers good prices if they delivered their logs to Davao. However, they did not enter into a formal log purchase agreement nor did they ask for advanced payment. When they reached Davao, the buyer was nowhere to be found, and they had to sell their logs at very low prices.

8) *Practice good forestry.* Sound forestry practices are required not only during tree growing, but also during harvesting and regeneration.

## Entrepreneurial Opportunities

### Seedling Growers

In Diadi, Nueva Vizcaya the San Luis Seedling Growers Association has embarked on seedling production and sales of assorted tree and fruit seedlings (Fig. 41). The village-level entrepreneurs are producing mainly the most common exotic tree plantation species (e.g., gmelina, mahogany, acacia). In addition, they also produce and sell rare and indigenous species like dipterocarps, tindalo, dao, molave, and almaciga, among others. In other parts of the Philippines small nurseries have cropped out along the major highways to offer seedlings

**Fig. 41. Potted seedlings** *(E.L. Tolentino,J r.)*.

of fast-growing species to a variety of customers. Unfortunately, seedling quality (both physiological and genetic) from these nurseries is usually poor.

## Tree Production Training Center

On an eight-hectare farm, Henry and Perla Binahon have developed what could be the envy of fellow farmers like him (Fig. 42). Sprawling in this private land overlooking Mt. Kitanglad in Malaybalay, Bukidnon are assorted timber intercropped with agricultural plants and trees. The farm also raises livestock like swine and some *carabaos*.


**Fig. 42. The Binahon Agroforestry Farm and Resource Center** *(E.L. Tolentino,J r.)*.

They have developed an extensive nursery of an assorted tree and fruit species for the growing seedling market. Formerly working for the DENR, the couple found fulfillment in tree planting and tree domestication. Imbued with a natural passion for farming, Landcare Philippines has also complemented it by providing the Binahons with soil and water conservation technologies like contour farming and the natural vegetation strips. Henry does not keep his secret to himself so he is frequently invited by fellow farmers or formal training courses as resource person. The couple is also managing a Farmers Training Center in the Songco, Lantapan, Bukidnon (Paelmo & Binahon, no date; Razal & Paelmo, 2004; Metcalfe, 2004).

## Plantation Log Marketing

### Pricing System

The system of log pricing depends on the prevailing market conditions. If prices of end-products are high, the demand therefore is also high. Once the demand is high, then we can also increase our price. In fact, existing timber license holders can even dictate its price especially now that there are only few legitimate logging operators in the country today.

But the price of logs nowadays is being affected by the proliferation of cheaper imported logs. This is the very reason why lumber and plywood products cannot compete head-on with other competitors in terms of pricing. These operators substitute log species from other countries like Papua New Guinea, Indonesia, Malaysia, Sabah, etc., at a very low price.

Pricing will depend on the kind of species, grade, diameter ranges and oftentimes, will also depend on its length (the longer, the more expensive). Log cost component on a per cubic meter basis are the following:

- wood cost (planting/maintenance, extraction/harvesting, and hauling costs);
- processing cost (processing in the camp plus the equipment cost);
- forest charges;
- stevedoring (FOB Bislig);

- cost of sales (marketing cost);
- overhead/Incidental expenses; and
- Margin for profit (at least 30%).

The future in this business will then again depend on the availability of logs. Right now, natural forest species are getting scarce in terms of volume. What happened is that most of these building construction companies are shifting to Bagras and Gmelina species for construction materials. There are also furniture makers who are now utilizing Mangium as their materials, and our electric companies likewise, are using plantation species as electric poles instead of Lauan or Apitong.

# Policies and Programs Related to Reforestation, Tree Farming, and Plantation Development

The management of the country's forest resources is the primary responsibility of the Department of Environment and Natural Resources (DENR). In the past decades, however, DENR shared both macro- and micro-scale forestland management with the private sector, local government units (LGUs), and other government agencies, as well as with nongovernment organizations (NGO) thru executive fiat, administrative issuance, or memoranda of agreement. Tenurial arrangements have been put in place for the security of tenure of the partners for putting up long-term investments, such as forest plantations, infrastructure, and facilities. In addition, private landowners were encouraged to develop their lands into tree plantations.

## Forest Laws, Rules, Policies, and Proclamations on Forest Management

Laws, rules, policies, and proclamations regulate reforestation, tree farming, and plantation development activities. These are in the forms of republic acts (RA), presidential decrees (PD), executive orders (EO), implementing rules and regulations (IRR), administrative orders (AO), and local government (LGU) ordinances. All of these provide the parameters on which activity is permissible and not, and to some extent, provide incentives and other support.

DENR is authorized to issue policies, rules, and regulations to ensure the protection and sustainable use of the natural resources thru AOs, memorandum orders, and/or circulars. The President may issue proclamations and EOs to govern reforestation, tree farming, and plantation development activities. The Congress (House of Representatives and the Senate) enact laws in the form of RAs. DENR, in this case, may issue implementing guidelines to the RAs known as IRRs. The provincial, municipal/city, and barangay policymakers may similarly issue specific reforestation, tree farming, and plantation development regulations within their area of jurisdiction

thru ordinances or resolutions. In all cases, the basic law and hierarchy of laws are respected.

The policy issuances and pertinent Philippine Laws related to reforestation, tree farming and plantation establishment are in Appendix 1 and 2.

## Programs on Reforestation, Tree Farming, and Plantation Development

The government is implementing various tree production programs and policies that are designed to meet specific objectives. Most of them are relevant to the needs of the various wood-based industries, such as furniture, gifts, toys, handicrafts, building construction and housing components, poles and piles, veneer, wood processing plants/lumber and plywood, plyboard, blockboard, and pulp and paper.

### Private Forest Development Agreement (PFDA)

Private landowners are granted PFDA for the establishment and development of forest plantations within their private lands for the duration of 25 years. This encourages them to develop their lands into private plantations and allow the harvesting of natural forest; if there is any, provided that proceeds therefrom shall be plowed back to plantation development.

For private lands that are not covered by PFDA, owners or developers are enjoined to register their plantations at the nearest DENR Office.

The PFDA holder shall plow back at least 30% of the proceeds resulting from the sale of timber and other forest products in further developing his property.

### Socialized Industrial Forest Management Program (SIFMP)

DENR ensures the equitable access and sharing of rights to natural resources development and utilization by providing opportunities to the people to participate actively in forest plantation development. DENR provides security of tenure to the participant through the issuance of Socialized Industrial Forest Management Agreement (SIFMA), which is a 25-year agreement renewable for another 25 years.

This is an agreement by and between a natural or juridical person and DENR, wherein the latter grants the former the right to develop, utilize, and manage a small tract of forestlands, consistent with the principle of sustainable development. As an incentive for the participation of qualified tree planters, they are granted the privilege to benefit from their crops, which shall consist primarily of trees for wood production, nontimber species, and other cash crops that may be interplanted.

Areas available under the program are grasslands, brushlands, and open and denuded forest lands under the jurisdiction of the DENR, including those within government reforestation projects that are not otherwise to be classified under the National Integrated Protected Areas System (NIPAS), Certificate of Ancestral Land Title (CALT), Certificate of Ancestral Land Claim (CALC), vested rights, license, and permits or management agreements. The areas available vary from 1 ha to 10 ha for individual/single family and up to 500 ha for associations or cooperatives.

**Community-Based Forest Management (CBFM) Program**

This program addresses the continuing destruction of our remaining natural forests and responds to the issue of upland poverty considered as the root cause of the country's deforestation problem. It is based on the concept of "*People first and sustainable forestry will follow*". It gives organized and empowered communities the right and responsibility to directly manage and benefit from forestland resources.

Aside from the management of the natural forest, another important aspect of the CBFM is the management of timber plantation. With the incorporation of the Forest Land Management Program in this program, plantation management is a component of the CBFM. Likewise, these CBFM beneficiaries have developed plantations as part of their developmental activities. Some of these plantations were developed when the area is still under Forest Occupancy Management, Family Approach to Reforestation, and Communal Tree Farm, which were lumped into Integrated Social Forestry Program.

**Industrial Forest Management Program (IFMP)**

The IFMP started in 1975 as Industrial Tree Plantation (ITP) Program. The areas available then were the open, denuded, and inadequately stocked residual natural forest within concessions. It was later renamed as IFP since its coverage has been expanded to allow the planting of non-timber products like bamboo, rattan, and rubber. Likewise, its activities were expanded to include not just the development of industrial plantation and related activities but the management and protection of the natural forest. The tenurial instrument issued is Industrial Forest Management Agreement (IFMA).

IFMA combines natural forest management and industrial forest management establishment and relegates to the private sector the responsibility for managing and protecting remaining residual forested and for converting degraded areas into forest plantations within the Agreement.

This agreement is granted to qualified applicants/investors who are given the right to manage and develop forest areas ranging from 500 ha to 40,000 ha for a duration of 25 years renewable for another 25 years.

# Recommendations

The country has sufficient policies to govern and further enhance reforestation, tree farming, and plantation development. However, there is the need to harmonize policies such that all policies will be aligned to the basic stipulation of the Constitution, not in conflict between or among different policies, extension of security of tenure, and provision of sufficient resources to implement these policies.

Contracts should not be impaired by enactment of policies such as executive and administrative orders of the President of the country, administrative orders issued by head of departments, and ordinances enacted by LGUs. This recommendation supports the 1987 Constitution Article III, Section 10 "No law impairing the obligation of contracts shall be passed." This warrants contracts to be executed or implemented unhindered to what was previously made in good faith and in accordance to the law. This ensures contracts to be safeguarded from sweeping pronouncements and to undergo due process.

Similarly, licenses should not expire prematurely. The Revised Administrative Code states that license made timely and sufficient for the renewal of license with reference to any activity of a continuing nature shall not expire until the application shall have been finally determined by the agency. Needless to say, a license should allow operation within its legal limits unobstructed by any policy and only cease upon the end of its duration.

An adjustment of the security of tenure from 25 years to 60 years renewable for another 60 years will encourage investments from the private sector. Furthermore, single proprietorship goes against the principle of social equity, thus, should be disqualified to be awarded an IFMA. Moreover, a longer timeframe for the conversion of Timber License Agreement (TLA) holders to IFMA should be considered in order for the TLA holders to do due diligence study whether to continue or not.

Government agencies should provide support/assistance for possible loans and financial assistance/grants, whether domestic or internationally funded, to plantations development/reforestation, and capital investments on forestry operations. Support to professional foresters as stewards of the forest and other natural resources are

needed. They should be provided with basic necessities, moral motivations, proper incentives, physical protection, and modern equipment to perform their duties and responsibilities (PWPA, 2006).

Finally, sufficient resources should be provided to agencies to implement the policies such as to identify and delineate on the ground forestland boundaries, closely monitor and protect the forest resources, and to manage the forest in a sustainable manner.

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# Appendix 1

## Policy Issuances Related to Reforestation, Tree Farming, and Plantation Establishment

| Policy Issuances | Subject | Salient Features |
|---|---|---|
| **Presidential Decree No. 705 May 19, 1975, as amended** | Revised Forestry Code of the Philippines | Sec. 33. This section indicates forest lands to be reforested and/ or afforested, to wit:<br>• Bare or grass-covered tracts of forestlands;<br>• Brushlands or tracts of forest lands generally covered with brush, which need to be developed to increase their productivity;<br>• Open tracts of forest lands interspersed with patches of forest;<br>• Denuded or inadequately timbered areas proclaimed by the President as forest reserves and reservations as critical watersheds, national parks, game refuge, bird sanctuaries, national shrines, national parks, game refuge, bird sanctuaries, national shrines, national historic sites;<br>• Inadequately stocked forest lands within forest concessions;<br>• Portions of areas covered by pasture leases or permits needing immediate reforestation; and<br>• Riverbanks, easements, road-right-of-way, deltas, swamps, former river beds and beaches.<br>• Portions of private lands required to be reforested or planted to trees for environmental protection. |
| **Presidential Decree No. 953 July 6, 1976** | Requiring the planting of trees in certain places and penalizing unauthorized cutting, destruction, damaging and injuring of certain trees, plants and vegetation | The decree requires every person (e.g., owner of the subdivision; holder of license agreement and owns land adjoining a river or creek) to plant trees and take good care of them.<br>Any person who cuts, destroys, damages or injures, naturally growing or planted trees of any kind shall be punished with imprisonment. |
| **Letter of Instructions No. 818 February 24, 1979** | | This requires all holders of existing timber licenses, leases or permits to reforest denuded and/or brushland forest areas, for every hectare logged-over. |

**Appendix 1. (Continued).**

| Policy Issuances | Subject | Salient Features |
|---|---|---|
| **Ministry Administrative Order (MAO) No. 4 Series of 1980 MAO No. 5, S. 1981 DAO No. 42, S. 1991 DAO No. 60, S. 1992 DAO No. 97-04 DAO No. 99-53** | Rules and Regulations governing the Industrial Forest Management Program | This includes the development, utilization and management of specified area, consistent with the principle of sustainable development. This covers all grasslands, brushlands, and open and denuded forestlands under the jurisdiction of DENR. |
| **DAO No. 79, Series of 1987** | Amendment of certain provision of Wood Industry Development Authority (WIDA) Circular No. 1–85, S. 1985 re: Prescribing guidelines in the preparation, submission and appraisal of the IAOP for holders of Timber Licenses | Requires timber licensees/permittees to make deposit for reforestation at ₱10,000/ha for CY 1988. Thereafter, the amount shall be determined by DENR Secretary.<br>Require reforestation of 1 ha for every hectare logged. |
| **DAO No. 32, Series of 1988** | Prescribing Guidelines for the Payment, Disbursement and Use of Reforestation Deposit required under DAO 87–79 | Timber licensees/permittees required to make a deposit for reforestation shall, for the year 1988, put up the amount of ₱10,000/ha based on the equivalent area programmed for reforestation of the open and denuded areas for the year. DENR with option to change the amount based on current average reforestation cost. |
| **DAO No. 01, Series of 1991** | Increasing the Reforestation Deposit paid by logging concessionaires to include maintenance costs and further amending DAO 32, Series of 1988 | Increases the reforestation deposit imposed on logging concessions to include maintenance costs of plantations<br>• ₱10,000/ha of reforestation goal for current year<br>• ₱1,500/ha of one-year old plantation<br>• ₱1,000/ha of two-year old plantation<br>TLAs without open and denuded areas are allowed to conduct TSI, which shall be twice the area approved for logging and deposit an amount equivalent to ₱3,500/ha. |
| **DAO No. 16 Series of 1992** | Addendum to DAO No. 42 which provides the regulations and guidelines governing the establishment and development of | This regulation governs the development of forest plantations in private lands. The Private Forest Development Agreement (PFDA) is an agreement entered into by and between the DENR and a private land owner or his duly |

**Appendix 1. (Continued).**

| Policy Issuances | Subject | Salient Features |
|---|---|---|
| | Industrial Forest Plantations (IFPs) | authorized representative for the establishment and development of forest plantation within his private property. |
| **Republic Act No. 7942 March 3, 1995** | An Act Instituting a New System of Mineral Resources Exploration, Development, Utilization and Conservation | Sec. 69. Environmental Protection. The contractor is required to rehabilitate, regenerate, revegetate and reforest the mineralized areas. |
| **Executive Order No. 263 July 19, 1995** | Adopting Community-based Forest Management as the National Strategy to ensure the sustainable development of the country's forestlands resources and providing mechanisms for its implementation | Entrusting the responsibility for forest rehabilitation, protection, and conservation to the community and affording them equitable access to the forest. |
| **Department Administrative Order (DAO) No. 21 Series of 1996** | Guidelines for the establishment of Pilot Dipterocarp Plantation | In support to the intensified reforestation efforts under the National Forestation Program<br><br>At least 10 ha dipterocarp plantations is required to be established in every provinces. |
| **DAO No. 24 Series of 1996** | Rules and Regulations Governing the Socialized Industrial Forest Management Program (SIFMA) | SIFMA is an agreement entered into by and between a natural or juridical person and the DENR wherein the latter grants to the former the right to develop, utilize and manage a small tract of forest land, consistent with the principle of Sustainable Development |
| **DAO 97-34** | Tree Planting Near Electric Power Line Systems | Promote an organized and systematic tree planting activity within the electric power line system areas to reduce power distribution losses particularly non-technical losses.<br><br>Established active linkages and proper coordination among agencies involved in tree planting and electric power distribution to ensure public safety and continuous electric services. |
| **DAO 99-36** | Revised Rules and Regulations Governing the Administration, Management, Development, and Disposition of Lands Used for Grazing Purposes | The nongrazeable area shall be reforested at the rate of 10% of the area per year, which shall be a primary condition for the renewal of the Forest Land Grazing Lease Agreement (FLGLA). |

**Appendix 1. (Continued).**

| Policy Issuances | Subject | Salient Features |
|---|---|---|
| **DAO 2000-12** | Requiring the Planting of of Permanent Trees on Portion of Alienable and Disposable Areas Susceptible to Soil Erosion | A portion of applied lots susceptible to erosion, such as those demarcated and preserved for forest purposes in accordance with Section 1, DAO No. 99–21 along or near the banks of creeks, rivers, or any bodies of water, and those with steep slopes (15%-up). These portions shall be the subject of tree planting of permanent trees with known economic values by the applicant and on patent shall be issued until said. |
| **DAO 2000-19** | Guidelines Governing the Updating of Cost Estimates and Intensi-fication of Plantation, Maintenance and Protection Activities for DENR-FSP Watershed Sub-Projects Under JBIC Funding | Update the cost estimates and intensify plantation maintenance and protection activities to improve project implementation. |
| **DAO 2004-59** | Rules and Regulations Governing the Special Uses of Forest Lands | Forest Land Agreement (FLAg) may cover all forest lands which are found are found suitable and available for FLAg sites within the CENRO areas of responsibility using DENR control maps and which are not otherwise classified as protected areas or are subject to vested rights, licenses/leases, permits or other instruments. |
| **Executive Order No. 318 June 9, 2004** | Promoting Sustainable Forest Management in the Philippines | Declared the policy of government to pursue the sustainable management of forests and forestlands in watersheds. Watersheds shall be deemed as ecosystem management units and shall be managed in a holistic, scientific, rights-based manner and observing the principles of multiple-use, decentralization and devolution, and active participation of Local Government Units (LGUs), synergism of economic, ecological, social, cultural objectives, and the rational utilization of all resources found therein. |
| **DENR Memorandum Circular 2004-06** | Guidelines in the Integration of Rainforestation Farming Strategy in the Development of Open and Denuded Areas within Protected Areas and other Appropriate Forest Lands | The Rainforestation farming strategy is an approach in restoring the original vegetation stand and at the same time promoting and conserving the biological diversity in the area by facilitating the natural process of succession. |

# Appendix 2

## Pertinent Philippine Laws that Serve as Guide to Various Stakeholders and those Responsible in the Management of the Philippine Forestlands

| Date of Issuance | Highlights |
|---|---|
| 1931 February 27 | Gov. Gen. Dwight Davis issued Proclamation No. 369 establishing the Davao-Agusan-Surigao Forest Reserve of 1,927,000 ha. |
| 1961 June 17 | R.A. 3092 (The Permanent Forest Act) was approved, amending Section 1826 of the Revised Administrative Code making forest reserves permanent unless reclassified by law passed by Congress. |
| 1975 May 19 | President Ferdinand Marcos issued P.D. 705 under Section18, the President can modify boundaries of forest reserves and reservations. |
| 1987 February 26 | The 1987 Constitution was ratified whereby under Section 4, Article XII, "forest lands and national parks, shall be conserved and may not be increased nor diminished except by law." |
| 1987 June 10 | President Corazon Aquino signed E.O. 192 renaming into and reorganizing DENR to be responsible for the conservation, management, development, and proper use of the country's forest, among others. |
| 1987 July 25 | Pres. Aquino signed the 1987 Administrative Code (EO 292). Under Book III Title I, Section 14, the power of the President to reserve lands of the public and private domain of the government was limited to areas where "the use of which is not otherwise directed by law." |
| 1988 June 10 | R.A. 6657, known as the Comprehensive Agrarian Reform Law of 1988,states in Section 49, Chapter II as to coverage that "No reclassification of forest or mineral lands to agricultural lands shall be undertaken unless through Act of Congress." |
| 2004 June 9 | Pres. Macapagal-Arroyo signed E.O. 318 that promotes sustainable forest management. |

# Appendix 3

## Selected Seed Source Directory in the Philippines

| Location/Contact Address | Contact Person/Telephone |
|---|---|
| Manila Seedling Bank Foundation, Inc. (MBSFI)<br>EDSA cor. Quezon Avenue<br>Quezon City | **Mr. Lucito M. Bertol**, President/General Manager, Tel. No. (02)924-7001;<br>Fax No. (02)924-0166<br>Email: mbsfi@biznas.com<br>Web site: www.biznasweb.com/MSBFI |
| Bukidnon Forest Industries, Inc. (BFI)<br>Abyawan, Dalirig<br>Manolo Fortich, Bukidnon | **Engr. Manny Casiño**, Project Manager or<br>For. Gomer Sindo/ SPA In-Charge and Leadman<br>Tel. No. (088)813-2654; (088)813-2037 |
| BFI<br>Malaybalay City, Bukidnon | **Engr. Manny Casiño**, Project Manager or<br>For. Gomer Sindo/ SPA In-Charge and Leadman<br>Tel. No. (088)813-2654; (088)813-2037 |
| Provident Tree Farms, Inc. (PTFI)<br>Talacogon, Agusan del Norte | **Mr. Roberto Justo**, Resident Manager/<br>Tel. No. (02) 532-3071; (02)532-1562 |
| PICOP Resources, Inc. (PRI)<br>Mangagoy, Bislig City<br>Surigao del Sur | **Mr. Wilfredo Fuentes**, Resident Manager<br>or **For. Domingo R. Tumambing**, Operations Manager/Cell No. (0917)824-9440;<br>Tel. No.(086)853-3251 or 49<br>Telefax No. (086)628-2161 |

# Appendix 4

## Calculation of Seeds per Unit Weight

- Eight (8) random replicates of 100 pure seeds are obtained from the pure seed fraction of the purity analysis.
- The 8 reps are weighed individually.
- The number of seed per kilogram is calculated as follows:

    - Compute for the standard deviation of the 8 reps as follows:

$$SD = \sqrt{\frac{n(\sum X^2) - (\sum X)^2}{n(n-1)}}$$

where x = weight of each replicate in grams
n = number of replicates
S = sum of

    - Compute for the coefficient of variation as:

$$CV = \frac{\text{Standard deviation x 100}}{\text{Mean}}$$

If CV is less than 4%, the sample is considered as homogenous, if not another 8 samples should be taken. The SD of the 16 samples is computed. Any sample deviating by more than 2 SD units are discarded. Use the remaining values for computing the average seeds for kilogram.

- Compute for the weight of 1000 seeds as:
= (Mean weight of 100 seeds) X 10

- Compute for the number of seeds per gram
= 1000/(Weight of 1000 seeds)

- Compute for the number of seeds per kilogram:
= (Number of seeds per gram) X 1000 g/kg

Examples for calculating the number of seeds per kg

Seeds of bagalunga (*Melia dubia)*

| Replicate Number | Weight of 100 seeds (g) |
|---|---|
| 1 | 35.03 |
| 2 | 35.73 |
| 3 | 34.97 |
| 4 | 34.47 |
| 5 | 37.31 |
| 6 | 36.23 |
| 7 | 36.72 |
| 8 | 36.77 |
| Mean | 35.90 |
| STD | 1.02 |
| CV | 2.83 |

Since the coefficient of variation is less than 4%, the sample is considered homogenous and the weight of seed per kilogram can be calculated from the data as follows:

$$\text{Weight of 1000 seeds} = 35.90 \times 10 = 359 \text{ g}$$

$$\text{Number of seeds per g} = \frac{1000 \text{ seeds}}{359 \text{ g}}$$

$$= 2.785 \text{ seeds/g}$$

Number of seeds per kg = 2.785 x 1000 = 2,785 seeds/kg

Calculation of seeds to be sown (Modified from Jaenicke, 1999)[1]

| | |
|---|---|
| Spacing | 3 x 2 m |
| Seedlings required per ha (S) | 1,667 seedlings per ha |
| % Germination (G) | 97.5 % |
| Culling percent[2] (C) | 5 % |
| Replacement percent[3] (R) | 10% |
| % Purity (% P) | 90% |

Add for germination failure (GF):
S x 100/G = 1,667 x 100/97.5 = 1,709.74
Add for culling at transplanting (CT):
GF x (100+C)/100 =1,709.74 x (100+5)/100 = 1,795.23

Add for replacing at outplanting (RO):
CT x (100+R)/100 = 1,795.23 x (100 +10)/100 = 1,974.75

Total number of seeds needed is H" 1,975.

The weight of the seed to be sown is calculated in the table below:

| Species | Average Number of Seeds/kg | Weight of Seed to be Sown (in grams)[a] [Total seeds needed/ ave. number of seeds/kg] X 1000 | Weight of Seed to be Sown (in grams)[a] [Total seeds needed/ ave. number of seeds/kg X 90%] X 1000 |
|---|---|---|---|
| *L. leucocephala* | 20,000 | 35.45 | 39.39 |
| *L. trichandra* | 26,000 | 27.27 | 30.30 |
| *L. diversifolia* | 34,000 | 20.85 | 23.17 |

[a]100 % pure seeds

[b] 90% is the percent purity

[1] Values have been rounded to 2 decimals places, differences in calculations are due to rounding off of numbers.
[2] Culling percent is the number of seedlings discarded due to grading from the germination box or bed to the transplant beds, pots or any container. This will include unhealthy or poor seedlings, odd-sized seedlings.
[3] Replacement percent refers to the number of seedlings lost due to mortality during the nursery propagation stage, i.e. from transplanting to outplanting.

# Appendix 5

## Responsibilities and Actions Done in Plantation Maintenance[a]

| Responsibility | Action |
|---|---|
| Manager – ITP Maintenance | 1. Based on an incident report on a recommendation, issues instructions to the Section Head concerned to implement the necessary action to be taken. |
| Section Head | 2. Mobilizes a team and equips themselves with the necessary tools, materials or equipment.<br>3. Gives instructions to the foreman and the crew on the things to do. |
| Foreman | 4. Supervises the crews on the activity being done.<br>– The Section Head shall make frequent inspections of the work of the crews and assists to see that instructions are uniformly and consistently interpreted and followed by all crews.<br>5. Upon completion of the activities, makes a written report of accomplishment and indicates all pertinent data/information on the report.<br>6. Signs report and submits it to the Section Head for notation. |
| Section Head | 7. Checks completeness and consistency of the report.<br>8. Affixes signature on the report certifying its validity and submits report to the ITP Maintenance Manager. |
| Manager – ITP Maintenance | 9. Goes over to the report and makes the necessary things to do like going to the field to check things out, etc.<br>10. Gives the report to the Technical Planner for the preparation of the input document. |
| Technical Planner | 11. Based on the report, prepares a Maintenance Activity Update Slip (MAUS) indicating all the pertinent information on it.<br>12. Forwards the update slip to the Forestry Statistics and Systems for input processing and files the report. |
| Data Processor FSS | 13. Acknowledges receipt by stamping "RECEIVED" on the Update Slip and affixes signature and date on it.<br>14. Checks correctness of coding and completeness of data/information.<br>15. Validate the Block ID Numbers indicated on the Update Slip and stamps "VALIDATED" on the slip if all are valid.<br>If there's an invalid block or there are other inconsistencies, inquires from sources and effects the necessary correction.<br>16. Performs documents control and transmittal procedure. |

[a]PICOP, 2006.

# Appendix 6

## Detailed Procedure in Handling Detected Violations or Adverse in PICOP Plantations[a]

| Responsibility | Action |
|---|---|
| Workers/Personnel/ Forest Rangers/Section Heads | 1. Reports immediately any violation (s) or occurring adverse/unfavorable condition (s) detected. |
| Section Head | 2. Conducts inspection of the affected area and assess the situation, together with the one (s) who made the report.<br><br>Conditions:<br>a) If the unfavorable condition was caused by people i.e., kaingin, illegal logging, etc. proceed to step # 3.<br>b) If the unfavorable condition was caused by grazing animals, proceed to step # 11.<br>c) If the unfavorable condition was caused by fire, proceed to step # 16.<br>d) If the unfavorable condition was caused by adverse effect of climate, i.e., floods, droughts, etc., proceed to step # 20.<br>e) If the unfavorable condition was caused by insects/ disease, proceed to step # 22. |
| | Condition A – Caused by Man |
| | 3. Coordinates with Forest Protection Department.<br>4. Ascertains the identity of the violator (s) and the permit to enter and cut trees in the area.<br>5. Confiscates tools, equipments or any equipment used by the violator (s).<br>6. Survey the actual location and extent of kaingin or logging operation and conducts an inventory and scaling of logs.<br>7. Confiscates and impounds logs cut by the violator (s).<br>8. Brings violators to the nearest law enforcement office for formal investigation.<br>9. Coordinates with the Company Legal Office, Forest Management Bureau and the Law Enforcement Agency in filing the case in court.<br>10. Prepared a Plantation Incident Report (PIR) filling up the necessary information and submits report to the ITP Maintenance Manager. Proceed to step # 24. |
| | Condition B – Caused by Animal (s) |
| | 11. Identifies the animal (s), if possible, that has caused damage to the plantation.<br>12. If it's a domestic animal, identifies the owner. |

**Appendix 6. (Continued).**

| Responsibility | Action |
|---|---|
| | Note: If wildlife, the only recourse is to put up necessary fences or barriers around the perimeter of the plantation and ensures that no animal will be left inside the perimeter that might cause damage again. |
| | 13. Upon identification of the owner, determines if a violation was made. |
| | 14. If a violation was made, informs the owner of the animal that he has violated certain rules and the fines/ penalties for these violations. Gathers witnesses for support, if necessary. |
| | Note: If no violation was made, informs the owner on the things to do to prevent future occurrence of the incident. |
| | 15. Prepares a Plantation Incident Report (PIR) filling up the necessary information and submits report to the ITP Maintenance Manager. Proceed to step # 24. |
| | Condition C – Caused by Fire |
| | 16. Promptly report the occurrence of fire to the LT Control first, then to the ITP Maintenance Manager or to the Safety Dept. to get all the necessary help. |
| | Note: The LT Control Center shall notify the camp fire fighting crews, forest crash fire fighting units and all responsible staffs concerned upon notification. |
| | 17. In the meantime, supervises the suppression of the fire with any available means until assistance arrives. |
| | 18. After the fire is extinguished, makes some investigation such as the cause of the fire, etc. |
| | 19. Prepares a Plantation Incident Report (PIR) filling up the necessary information and submits report to the ITP Maintenance Manager. Proceed to step # 24. |
| | Condition C – Caused by Adverse Effect of Climate |
| | 20. Determines the extent of damage. |
| | 21. Prepares a Plantation Incident Report (PIR) filling up the necessary information and submits report to the ITP Maintenance Manager. Proceed to step # 24. |
| | Condition D – Caused by Insect Pest/ Disease |
| | 22. Determines kind of insect / disease, causes and extent of damage done. |
| | 23. Prepares a Plantation Incident Report (PIR) filling up the necessary information and submits report to the ITP Maintenance Manager. Proceed to step # 24. |

**Appendix 6. (Continued).**

| Responsibility | Action |
|---|---|
| ITP Maintenance Manager | 24. Reviews incident report and consults with the Forestry Division Manager on matters requiring his comments/ approval. If necessary, goes to the field/area f incident.<br>25. Coordinates with the following company offices and government agencies on matters that may require their assistance:<br>– Forest Protection Department<br>– Legal Department<br>– Forest Management Bureau (FMB)<br>– Law Enforcement Agencies<br>– Forest Research Department<br>– Electronic Data Processing<br>26. Issues necessary instructions to concerned personnel to implement recommended remedial or protective measures.<br>27. Gives the PIR to the Technical Planner for the preparation of input document. |
| Technical Planner | 28. Prepares a Maintenance Activity Update Slip (MAUS) based on the incident report (PIR) submitted.<br>29. Forwards update slip to the Forestry Systems and Statistics Section for input processing and files the incident report. |
| Data Processor FSS | 30. Checks correctness / completeness of information and appropriate coding on the update slip and validate blocks ID numbers indicated on it.<br>– If block ID is invalid, inquires from sources for the valid Block ID.<br>31. Stumps validated on the update slip and performs documents control and transmittal procedures. |

[a]PICOP, 2006.

# Appendix 7

## Potential Seed Production Areas (SPAs) in the Philippines[a]

| Region | Location | Species | No. of Trees | Area (ha) | Type of Stand |
|---|---|---|---|---|---|
| | **GRAND-TOTAL - 61** | | **8,967** | **368** | |
| **CAR** | **Sub-Total - 6** | | **849** | **22.4** | |
| | Camp John Hay, Loakan, Baguio City | Benguet pine (*Pinus kesiya*) | 400 | 4 | Natural |
| | UABAC Plantation, Bun-ayan, Sabangan, Mt. Province | Benguet pine (*Pinus kesiya*) | 40 | 1.2 | Plantation |
| | Cabunagan Gate Ref. Project, Km. 407, Sabangan, Mt. Province | Benguet pine (*Pinus kesiya*) | 200 | 2 | Plantation |
| | Binga, Itogon, Benguet | Murray red gum (*E. camaldulensis*) | 49 | 1.2 | Plantation |
| | Busol Watershed Baguio City | Benguet pine | 80 | 12 | Natural |
| | South Drive (Forbes 1 & 2), Baguio City | Benguet pine | 80 | 2 | Natural |
| **I** | **Sub-Total - 3** | | **462** | **36.8** | |
| | PFDPIN Project Ilocos Norte | *Eucalyptus camaldulensis* | 204 | 4.8 | Plantation |
| | Caniaw Reforestation Project, Ilocos Sur | Narra | 100 | 17 | Plantation |
| | Marcos Nueva Era Ilocos Norte | Yemane Agoho | 158 | 15 | Plantation |
| **II** | **Sub-Total - 9** | | **2,322** | **33** | |
| | Claveria Experimental Forest, Claveria, Cagayan | Dipterocarps | 800 | 5 | Plantation |
| | Taggat Industries, Inc. Aparri, Cagayan | Dipterocarps | 300 | 5 | Plantation |
| | North Luzon Timber, Inc. Sanchez Mira, Cagayan | Dipterocarps | 150 | 2 | Plantation |
| | Salinas Reforestation Project, Bambang, Nueva Vizcaya | Mahogany | 205 | 3 | Plantation |
| | Consuelo Reforestation Project Consuelo, Sta. Fe, Nueva Vizcaya | Mahogany (Large leaf) | 108 | 2.8 | Plantation |
| | Magat Experimental Forest Diadi, Nueva Vizcaya | Mahogany (Large leaf) Gmelina, Teak | 500 | 9.7 | Plantation |

**Appendix 7. (Continued).**

| Region | Location | Species | No. of Trees | Area (ha) | Type of Stand |
|---|---|---|---|---|---|
| | Callao Reforestation Project<br>Callao, Peñablanca, Cagayan | Mahogany (Large leaf) | 75 | 1.6 | Plantation |
| | Nagtipunan Reforestation Project<br>Nagtipunan, Quirino | Yemane | 129 | 2.5 | Plantation |
| | Solana Reforestation Project<br>Maguirig, Solana, Cagayan | Yemane | 55 | 1.5 | Plantation |
| **III** | **Sub-Total - 7** | | **743** | **123.5** | |
| | Labney Reforestation Project<br>Mayantoc, Tarlac | Mahogany | 80 | 2 | Plantation |
| | ANZAP, Bigbiga, Tarlac | *E. deglupta* | 200 | 22.5 | Plantation |
| | Mariveles Reforestation Project<br>Mariveles, Bataan | *A. auriculiformis* | 80 | 2 | Plantation |
| | Brgy. Alas-asin Refo. Project<br>Mariveles, Bataan | Yemane | 107 | 2 | Plantation |
| | Carranglan Reforestation Project<br>Nueva Ecija | Mahogany<br>Agoho<br>Teak<br>Narra | 73 | 50 | Plantation |
| | Roosevelt National Park, Dinalupihan, Bataan | Narra<br>Mahogany | 80 | 5 | Plantation |
| | RP-Japan Carranglan Refo. Project<br>Nueva Ecija | Narra<br>Mahogany | 123 | 40 | Plantation |
| **IV-A** | **Sub-Total - 4** | | **406** | **8** | |
| | Quezon National Park<br>Atimonan, Quezon | Mahogany | 95 | 2 | Plantation |
| | Kinabuhayan, Dolores, Quezon | Mahogany | 211 | 2 | Plantation |
| | Upper Kitingan, Antipolo, Rizal | Yemane | 20 | 2 | Plantation |
| | Mt. Palay-palay Reforestation Project<br>Cavite | Gmelina<br>Narra | 80 | 2 | Plantation |
| **IV-B** | **Sub-Total - 6** | | **372** | **35.75** | |
| | Sibuyan Island, Brgy. Agtiva<br>San Fernando, Romblon | Narra | 10 | 0.25 | Natural |
| | Roxas, Palawan | Ipil | 22 | 1 | Natural |
| | Dampulan, Torrijos, Marinduque | Molave | 100 | 2.5 | Plantation |

**Appendix 7. (Continued).**

| Region | Location | Species | No. of Trees | Area (ha) | Type of Stand |
|---|---|---|---|---|---|
| | Brgy. Maranatha/Rizal San Jose, Occ. Mindoro | Narra | 80 | 15 | Natural |
| | Brgy. San Rafael Puerto Princesa, Palawan | Almaciga | 80 | 15 | Natural |
| | San Jose Refo. Project Occidental Mindoro | Yemane | 80 | 2 | Plantation |
| **V** | **Sub-Total - 4** | | **248** | **14** | |
| | Catanduanes | Narra | 38 | 5 | Natural |
| | Napulidan Reforestation Project Sooc, Lupi, Camarines Sur | *Acacia auriculiformis* | 100 | 1 | Plantation |
| | Balatan, Camarines Sur | Mahogany<br>Narra | 80 | 6 | Plantation |
| | Progreso Reforestation Project | Narra | 30 | 2 | Plantation |
| **VI** | **Sub-Total - 3** | | **585** | **19** | |
| | Jawili, Tangalan, Aklan Beach Agoho | Mountain Agoho | 350 | 14 | Plantation |
| | Mt. Tag-ao Integrated Ref. Project Brgy. Tumalulod, Dumarao, Capiz | Mahogany | 155 | 1 | Plantation |
| | WVSU, College of Agriculture Lambunao, Iloilo | Narra | 80 | 4 | Plantation |
| **VII** | **Sub-Total - 2** | | **160** | **25** | |
| | Osmeña Reforestation Project | Mahogany<br>Teak<br>Yemane | 120 | 10 | Natural / Plantation |
| | Central Cebu Reforestation Project, Cebu City | Teak<br>Gmelina<br>*A. mangium*<br>Moluccan sau | 40 | 15 | Natural / Plantation |
| **VIII** | **Sub-Total - 1** | | **80** | **2** | |
| | Tacloban Coop. Forest Nursery Tacloban City | | 80 | 2 | Plantation |
| **IX** | **Sub-Total - 4** | | **1,090** | | **17** |
| | Baluno Ref. Project, Zamboanga City | *E. deglupta*<br>Falcata<br>Mahogany<br><br>Dipterocarp | 360 | 10 | Plantation<br>Plantation<br>Natural/ Plantation<br>Natural/ Plantation |

**Appendix 7. (Continued).**

| Region | Location | Species | No. of Trees | Area (ha) | Type of Stand |
|---|---|---|---|---|---|
| | | White lauan | | | Natural/ Plantation |
| | | Mayapis | | | Natural/ Plantation |
| | | Bagtikan | | | Natural/ Plantation |
| | | Tangile | | | Natural/ Plantation |
| | | Almon | | | Natural/ Plantation |
| | | Yemane | | | Natural/ Plantation |
| | Upper Palanas | Giant Ipil-ipil | 20 | 1 | Natural/ Plantation |
| | Baluno, Zamboanga City | Teak | | | |
| | Baclay Pulacan Ref. Project | Dipterocarp | 200 | 2 | Natural/ Plantation |
| | Cogon Ref. Project Dipolog | Yemane | 510 | 4 | |
| | Zamboanga del Norte | Mahogany | | | Natural/ Plantation |
| **X** | **Sub-Total - 8** | | **800** | **15.5** | |
| | Impalutao, Impasugong, Bukidnon | Mahogany | 250 | 5 | Plantation |
| | Camansi, F. S. Catanico Malasag Cagayan de Oro City | Mahogany | 100 | 2 | Plantation |
| | Camansi, F. S. Catanico Malasag Cagayan de Oro City | Teak | 100 | 2 | Plantation |
| | Kaatoan, Lantapan, Bukidnon | *Cinchona* spp. | 100 | 2 | Plantation |
| | Impalutao, Impasugong, Bukidnon | White lauan | 50 | 0.5 | Plantation |
| | Kaatoan, Lantapan, Bukidnon | Igem | 100 | 1 | Natural |
| | Malaybalay, Bukidnon | Gmelina | 50 | 1 | Plantation |
| | Kitaotao, Bukidnon | Molave | 50 | 2 | Natural/ Plantation |
| **XI** | **Sub-Total - 2** | | **400** | **9** | |
| | Sto. Tomas, Davao del Norte | Yemane | 320 | 8 | Plantation |
| | | *Acacia mangium* | | | Plantation |
| | | Mahogany | | | Plantation |
| | | Palasan | | | Plantation |
| | Nabunturan, Davao del Norte | Yemane | 80 | 1 | Plantation |
| **XII** | **Sub-Total - 1** | | **100** | **2** | |
| | Amas Refo. Project Kidapawan | Mahogany | 100 | 2 | Plantation |

**Appendix 7. (Continued).**

| Region | Location | Species | No. of Trees | Area (ha) | Type of Stand |
|---|---|---|---|---|---|
| **XIII** | **Sub-Total - 1** | | **350** | **5** | |
| | Bislig, Surigao del Sur | Dipterocarp, Red lauan | 350 | 5 | Natural/ Plantation |
| | | White lauan | | | Natural/ Plantation |
| | | Almon | | | Natural/ Plantation |
| | | Mayapis | | | Natural/ Plantation |
| | | Bagtikan | | | Natural/ Plantation |
| | | Tangile | | | Natural/ Plantation |
| | | Apitong | | | Natural/ Plantation |

[a]FMB-DENR Records, 2004.