Functionary Manual - Vol. III

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DR. MCR HUMAN RESOURCE DEVELOPMENT INSTITUTE OF ANDHRA PRADESH HYDERABAD

FOREST DEPARTMENT

GOVERNMENT OF ANDHRA PRADESH

DR. MCR HRD INSTITUTE Of Andhra Pradesh

Dear Reader,

As part of its endeavor to provide a SMART (Simple, Moral, Accountable, Responsive and Transparent) administration, the State Government of Andhra Pradesh has launched a major Human Resource Development and Training initiative aimed at developing a large human resource base of well informed and responsive functionaries and officials.

The successful and effective implementation of any initiative or programmed in government is largely the result of the involvement and efforts put in by its functionaries at all levels. Obviously, the most fruitful way in which to bring this about is to make individual functionaries aware of their role functions and responsibilities. To achieve this, the Human Resource Development Institute of A.P., as the apex training institution of the State Government responsible for the overall implementation and co ordination of the state training initiative, has proposed to bring out department wise Manuals two parts.

namely

1. Departmental Manual **2. Functionary Manual**

The Departmental Manual would indicate the role, responsibilities and functions of the department. The Functionary Manual will detail, as the nomenclature indicates, the functions and responsibilities of the functionaries within the department, at all levels. While doing so, the evolving role of governmental functionaries in being effective managers of change in a welfare state has been delineated. The Departmental Manual also details the department's organizational chart, the rules, regulations, legislations and enactments which govern its functioning and direct its activities and the various interdepartmental interactions it has to perform. The Manual also facilitates a definition of the Department's role in serving the general public as customer while drawing up a vision for its future development in the coming decades in line with the vision 2020 of the state.

The manuals developed by the Forest Department are in two parts. As in evident these publications are the out come of thorough study and analysis of the Departments role, functions and procedures. They are intended to serve as useful aid to each every employee of the Department in the effective discharge of his / her functions. It may be noted, however that these two manuals do not replace the codes and orders of Government on the subject but are at best, meant to guide and assistance of functionaries in the effective discharge of their duties.

Any suggestions for the improvement of these Manuals may be sent directly to the Director General, Dr. MCR HRD Institute of Andhra Pradesh, Road No : 25, Jubilee Hills, Hyderabad – 500 033, for consideration and incorporation in subsequent updations and revisions of the manuals.

P V R K PRASAD IAS
Director General
Dr. MCR Human Resource Development Institute of A.P.
&
Ex officio Spl. Chief Secretary to Government (HRD)

FUNCTIONARY MANUAL - Vol. III

FOREST DEPARTMENT

GOVERNMENT OF ANDHRA PRADESH

CONTENTS

CONSERVATOR OF FORESTS
(RESEARCH AND DEVELOPMENT)

1. GENERAL :

The post of Conservator of Forests (Research and Development) was created vide G.O.Ms.No.996, F&RD (For.II) Department, dated 17-7-71.The Research & Development Circle, Hyderabad is functioning with effect from 16.8.1971 Headed by Conservator of Forests, with jurisdiction of entire State with head-quarters at Hyderabad. As per the G.O.Ms.No.675 GAD (SPFA) Deptt. Dt 20.10.75, the Conservator of Forests, (R&D), Hyderabad is the State Level Officer.

The following divisions are under the administrative control of Conservator of Forests, Research & Development Circle, Hyderabad.

1.Forest Utilisation Officer, Hyderabad, State level office

2.Forest Geneticist, Warangal,
3.State Silviculturist, Hyderabad,
4.State Silviculturist, Tirupati,
5.State Silviculturist, RaJahmundry.
} Special offices

2. HIERARCHICAL POSITION IN THE DEPARTMENT :

The Conservator of Forests, Research & Development Circle is immediate subordinate to the Chief Conservator of Forests incharge of research and Principal Chief Conservator of Forests and he will follow instructions issued by them on all professional matters, research activities and such other related issues.

The Conservator of Forests, Research & Development Circle is the Controlling Officer of the Divisions which are under the jurisdiction of Research and Development Circle.

The Conservator of Forests, Research & Development is the over all incharge of various research works in the Circle, control of establishment and regulation of expenditure.

3. OPERATIONAL JURISDICTION :

The Conservator of Forests, Research & Development will regulate the budget allotment, exercise control over the expenditure. He will tour the research stations m the State and inspect the research works being taken up by the Forest Geneticist and State

Silviculturists. He will also undertake tour in various divisions in the State in coordination with territorial and Planning and Extension Conservator of Forests and guide the Divisional Forest Officers on technology transfer. He will also guide the Forest Utilization Officer, Hyderabad. He will also assess the working abilities of Forest Utilization Officer, Forest Geneticist and State Sivliculturists and Research Range Officers.

4. POWERS:

I. Administration:

(a) Transfers, postings:

The Conservator of Forests, Research & Development is empowered to Issue posting orders to the staff allotted to Research & Development Circle on tenure basis from territorial circles by Prl. Chief Conservator of Forests.

(b) Increments:

The Conservator of Forests, Research & Development is competent to release the increments of the Deputy Conservators of Forests and Assistant Conservators of Forests working in his Circle other than I.F.S. Officers.

The Conservator of Forests, (R&D) is competent to sanction additional pay to Non-Gazetted staff for whom the Conservator of Forests (Territorial) is the Appointing Authority.

(c) Sanction of leave:

The Conservator of Forests, (R&D) is competent to sanction leave to Range Officers, Deputy Range Officers, Managers, Superintendents, Draughtsman Gr.I & II not exceeding one month.

(d) Inspection of Offices:

He will take up Annual Office Inspection of each Division under his control and assess the performance of the Division Offices.

It is the responsibility of the Conservator of Forests, (R&D) to verify whether all the works sanctioned by the Forest Utilization Officer, Forest Geneticist and State Silviculturists are within their powers during the Annual Office Inspection.

(e) Annual Confidential Reports:

It is the responsibility of the Conservator of Forests, (R&D) to countersign the Confidential Reports of the Research Range Officers received from the Forest Utilization Officer, Forest Geneticist and State Silviculturists and keep them in his custody.

The Conservator of Forests, R&D will also initiate the Annual Confidential Reports of the Deputy Conservator of Forests and Assistant Conservator of Forests who are holding Independent charge under his administrative control.

II. Disciplinary Powers:

(i) The Conservator of Forests, R&D, Hyderabad can take action against the subordinates who are working under his control for Imposition of such penalties as specified under Rule (10) (1) and Clause (i) & (iv) of rule (9) of A.P.C.S. (CCA)Rules, 1991.

(II) In respect of imposition of penalties in Clause (iv) (a) and (vi) to (ix) of rule (9) the Conservator of Forests, (R&D) under whom a subordinate is working, can initiate disciplinary proceedings under rule (19) (2) of C.C.A Rules 1991, but on completion of enquiry he has to send the entire case to the appointing authority i.e., territorial Conservator of Forests or Divisional Forest Officer who will take action as per powers vested in them as disciplinary authority and as per provisions laid down under Rule (16) of CCA Rules, 1991.

III. Duties & Powers related with execution of works and implementation of research schemes:

It is the responsibility of the Conservator of Forests, R&D, to obtain Annual Plan of Operations relating to various works from the Forest Utilization Officer, Forest Geneticist & State Silviculturists scrutinise them with reference to the schemes being implemented in the Circle.

He is responsible for the administration of all the divisions under his control and undertaking the works allotted to them. He will frequently coordinate with Forest Utilization Officer, Forest Geneticist and State Silviculturists in execution of works.

The Conservator of Forests, (R&D), will keep himself abreast with the latest trends in forestry research and development. He will guide the Forest Geneticist and State Silviculturists in designing, various research experiments and coordinate the research works in the State. He will also keep close contact with institutions conducting forestry research. It is the duty of Conservator of Forests, (R&D) to guide the Forest Geneticist and State Silviculturists to analyse the data from research experiments, interpret the results and publish the findings. He will document and store the research findings. He will transfer the technology to the field on applied forestry research through Seminars, demonstrations, visits to the various forest nurseries, plantations, natural forests and publications in the shape of books, booklets, brochures, manuals, leaflets etc. He will Interact with Conservators of Forests and Divisional Forest Officers in the entire State on application of research findings on tree improvement raising of superior planting stock, collection, processing, testing and supply of Improved see, improved nursery practices, effective silvicultural practices, afforestation techniques, harvesting, value addition, marketing and utilization of forest produce etc. He will also guide the Forest Utilization Officer in undertaking various publicity works and utilisation of forest produce.

The Conservator of Forests, (R&D) will keep the Chief Conservator of Forests incharge of research and Principal Chief Conservator of Forests informed about the development of various research works, research findings and matters pertaining to transfer of technology to the field. He will also seek their guidance in conducting various research trials.

The Conservator of Forests, (R&D) will prepare annual research report enlisting all the research experiments conducted during that particular year and submit to Principal Chief Conservator of Forests duly communicating a copy to all the Conservator of Forests and Divisional Forest Officers in the State.

The guidelines for Research on Tree Improvement are given in appendix.

IV. Duties and Powers related with Accounts :

It is the responsibility of the Conservator of Forests, (R&D) to see that all the Drawing and Disbursing Officers in his Circle render their monthly accounts within the time limit. It is the responsibility of the Conservator of Forests, (R&D) to scrutinise and countersign the T.A. bills of the Forest Utilization Officer, Forest Geneticist and State Silviculturists working under his control.

The Conservator of Forests, (R&D) is competent to accord permission to enhance A.R advance beyond the limits prescribed to the Drawing and Disbursement Officers (DDOs), in his Circle.

The Conservator of Forests (Research and Development) can authorise the Research Range Officers to draw cheques against the drawing account of the Forest Geneticist and State Silviculturists.

V. Forest Schedule of Rates :

The team of Conservators of Forests, headed by the Senior most Conservator of Forests in the F.S.R. Zone is competent to fix up the Forest Schedule of Rates for various forestry and related works to be executed in the department. There are 4 FSR zones in the State. The Conservator of Forests, (R&D) will attend all the 4 Zonal committee meetings and proprose new works based on the research findings for their practical application in the field.

VI. Sanction of work estimates:

The Conservator of Forests, (R&D) is competent to sanction work estimates which are more than Rs.3.00 lakhs in value and upto Rs.5.00 lakhs both for Plan and Non-Plan works.

VII. OTHER POWERS :

The Conservator of Forests, (R&D) is competent to sanction G.P.F., H.BA., Marriage, Motor Cycle and Cycle advance to the subordinates working in the Circle.

The Conservator of Forests, (R&D) is competent to purchase books and periodicals to a limit of Rs. 1500/- per year.

The Conservator of Forests, (R&D) is competent to purchase steel and wooden furniture to a tune of Rs.10,000/- per annum and also competent to incur an amount of Rs.3,000/-towards repairs of furniture and purchase of racks, table cloths and office scales and weights.

The Conservator of Forests, (R&D) is competent to sanction Lawyer's fees to private counsel upto Rs.300/- in each case.

There is no restriction for the Conservator of Forests, (R&D) for purchase of copying stamps required in connection with suits.

The Conservator of Forests, (R&D) is competent to sanction an expenditure of Rs.200/-at a time upto a limit of Rs.2,500/- per annum on photography charges.

The Conservator of Forests, (R&D) Is competent to Incur an expenditure of Rs.8,000/-per annum towards supply of press clippings.

The Conservator of Forests, (R&D) is competent to sanction an expenditure of Rs.16,000/- per month towards rent of private lands and buildings for offices.

For purchase and repairs to stores, tools and plants the Conservator of Forests (Research and Development) is competent to sanction upto Rs.25,000/- and for purchase of bulbs, lamps the Conservator Is competent to sanction Rs.1,000/-. per annum.

The Conservator of Forests, (R&D) is competent to sanction Rs.5,000/- per annum towards local purchase of stationery articles.

The Conservator of Forests, (R&D) is competent to sanction Rs.600/- towards purchase of sports material.

The Conservator of Forests, (R&D) is competent to incur an expenditure of Rs.16,000/-towards repairs and replacements to light motor vehicles.

The Conservator of Forests, (R&D) is competent to accord permission of deviation upto 10% in cases of the approved estimates on schedule of rates.

VIII. Powers of Write off:

The Conservator of Forests, (R&D) is competent to write off upto Rs.2,500/- towards driage and wastage and upto Rs.1,000/- for other than deficits due to driage and wastage.

The Conservator of Forests, (R&D) is competent to write off unsalable produce upto Rs.500/-.

The Conservator of Forests, (R&D) is competent to write off unserviceable stores, tools, plants except those missing upto Rs.500/-.

The Conservator of Forests, (R&D) is competent to write off Irrecoverable value of stores or public money loss through fraud, negligence or other cases upto Rs.2,500/-.

The Conservator of Forests, (R&D) is competent to write off irrecoverable Items of departmental revenue upto Rs.1,000/-.

The Conservator of Forests, (R&D) Is empowered to remit or write off irrecoverable forest advance of Rs.200/-.

The Conservator of Forests, (R&D) is competent to write off irrecoverable value of stationery articles upto Rs.1,000/-.

FOREST UTILISATION OFFICER

1. CREATION OF POST :

The post of Forest Utilisation Officer (Andhra Pradesh), Hyderabad was created with the intention of carrying out the following works vide G.O.Ms.No.307 F&A Department, Dated 7-2-1964.

i) The FUO is the nodal officer for all matters of Forest Utilization, Logging, Marketing, Publicity etc.

ii) The FUO should encourage the people for effective utilisation of Forest produce in trade, industries etc. by having a register of inventories on available Forest resources and formulating strategies for minimising wastages of forest produce.

iii) He will study the trends in the market for timber and other Forest produce and work in collaboration with territorial Divisional Forest Officers to secure the best price for the timber and other Forest produce sold by them for every quarter.

iv) He should supply information to general public and Industries regularly about the availability and utilisation of tree species.

v) He will pool the information on the development in the utilisation of Forest products in the country and outside and document the information to the field officers. He will organise the exhibitions and make publicity to Inform the developments in Forestry and effective utilisation of Forest produce.

vi) He will give expert opinion after examining the cases referred to him to examine any samples of wood or Forest produce in any legal proceedings.

vii) He will attend to any special work that may be entrusted to him by the superior officers.

viii) He will prepare the Tableau on Independence day (15th August) and Republic day (26th January) every year on behalf of Andhra Pradesh Forest Department showing activities of Forest Department.

The Forest Utilisation Officer was brought under the control of Conservator of Forests Research and Development since 1965. The Forest Utilisation Division is headed by a Deputy Conservator of Forests and is assisted by one Range Officer, two Deputy Range Officers, one Forester and one Forest Beat Officer along with an office staff of one Superintendent, 3 Junior Assistants and one Typist.

The Statistical Cell is also attached to Forest Utilisation Officer.

2. POSITION WITHIN THE ORGANISATION AND INTERACTION WITHIN THE FOREST DEPARTMENT:

The Forest Utilization Officer (Andhra Pradesh), Hyderabad is an independent post with the overall charge of functionary division. He will work under the direction of Conservator of Forests, Research and Development Circle, Hyderabad. He will compile the data given by different Conservators' of Forests and furnish to central statistical organisation, News Delhi, ICFRE, Dehradun and Director of the Economics and Statistics, Hyderabad. He will also prepare Annual Administration Report and Facts and Figures of the Forest Department. He will correspond with his immediate superior officer i.e., Conservator of Forests, Research and Development Circle for guidance and instructions.

3. GENERAL FUNCTIONS OF FOREST UTILIZATION OFFICER:

- ❖ To conduct studies on different forest produce to cover it's demand, supply position, projection of demand and supply for future.
- ❖ To determine rotation age for plantations of new species for maximum yield
- ❖ To study economics of preservation and treatment of timber and it's popularization
- ❖ To study and fix number and location of timber depots keeping In view, production areas, consumption centres etc.
- ❖ To identify species not fetching proper prices when compared with extraction costs and finding alternative use for the same
- ❖ Evaluation and popularization of alternate renewable energy source like high efficiency fire wood hearths, Solar cookers/ heaters, wind mill pumps etc.
- ❖ Preparation of Annual Administration Report of Andhra Pradesh Forest Department.
- ❖ Preparation of Annual Facts and Figures showing the entire department statistical figures.
- ❖ Updating and preparation of Andhra Pradesh Forest Department Telephone Directory every year.
- ❖ Submitting annual statistical returns to central statistical organisation, New Delhi; ICFRE Dehradun, and Director of Economics and Statistics, Hyderabad.
- ❖ He will organise Exhibitions showing activities of Forest Department for bringing awareness about the importance of Forests.

- He will arrange tableau on 26th January and 15th August showing the latest activities of the Forest Department
- He is a liaison officer of Forest Department with general public and industries.
- He will organise the Forest Department stall at exhibition grounds, Hyderabad every year.
- He will arrange the Forest stall showing Departmental activities from time to time during various functions as per the instructions of the superior officers.

He will attend to the works entrusted to him on various publicity and extension activities including JFM, Wildlife, Social Forestry etc. by Conservator of Forests (Research and Development) and Chief Conservator of Forests (Development).

4. DESK FUNCTIONS:

i) He will maintain the office in a befitting manner and submit reports to his higher officers and maintain files and records neatly.

ii) He will maintain the data relating to sale of Timber in Government Depots.

iii) He will obtain the information from all circles for preparation of Annual Administration Report and Facts and Figures of Andhra Pradesh Forest Department.

iv) He will maintain all the Registers connected with the Administration and Statistics.

5. STATUTORY FUNCTIONS:

i) He will issue A.R. advance to Range Officer for execution of work

ii) He will obtain cash accounts from Range Officer and forward the accounts to A.G.(AP), Hyderabad by 15th of every month

iii) He will prepare and submit F.A.VII and progress report of Revenue and Expenditure to Conservator of Forests, Research and Development Circle, Hyderabad every month.

iv) He is responsible for claiming pay and allowances of the staff with the division and maintain proper records.

STATISTICAL CELL :

Statistical Cell was formed in the year 1976 and assisted by three Senior Investigators deputed by Bureau of Economics and Statistics.

The Statistical Cell should assist the FUO on the following :

1. Preparation of Annual Administration Reports
2. Preparation of Book on Facts and Figures of the forests of Andhra Pradesh
3. Preparation of Producers' prices
4. Preparation of Catalogue of books, Central Library
5. Preparation of Forest Department Telephone Directory
6. Annual Forest Statistics to be furnished to Director of Economics and Statistics and Central Statistical Organisation, Government of India
7. Forest Statistics to be furnished annually to Central Forestry Commission, Government of India.

6. OPERATIONAL JURISDICTION :

The Forest Utilization Officer can exercise his own decisions in respect of compiling the data received from different circles and releasing in the form of a Book and sending information on Forestry Statistics to Director of Statistics and Economics, Hyderabad. In case of arranging tableaus on 15th August and 26th January and organising exhibition at A.I.I.E., Hyderabad, Science Congress, World Environment day etc. requires the permission of Conservator of Forests, Research and Development and Chief Conservator of Forests (Development).

7. ENACTMENT OF RULES AND REGULATIONS REQUIRED :

The present rules existing to the post of FUO are sufficient. No fresh rules for enactment are necessary.

8&9 : In case of any help required, he will approach his immediate superior officer i.e., the Conservator of Forests, Research and Development Circle. In the absence of Conservator of Forests (Research and Development) he will approach the Chief Conservator of Forests (Dev.).

10 : The administration accountability to be approached in case of Omissions or Commissions is the Conservator of Forests, Research and Development Circle and the Chief Conservator of Forests (Development).

11. PERIODICAL RETURNS:

ANNUAL REPORTS:

1) Supply of out turn on Major and Minor Forest Produce and its average prices and total value to central statistical organisation New Delhi.

2) Annual Administration Report to Government showing the highlights of various activities of Forest Department.

3) Information on statistical abstract pertaining to Forestry statistics to Director of Economics and Statistics.

MONTHLY REPORTS :

1) Monthly progress report of expenditure

2) Monthly performance appraisal report

FOREST RANGE OFFICER WORKING IN FOREST UTILIZATION OFFICER'S OFFICE

1. a) **Origin :** The post of Forest Range Officer is created vide G.O.Ms.No.70, E,F,S&T (For.II) Department, dated 4-5-96 and allotted to Forest Utilization Officer in Principal Chief Conservator of Forests, Andhra Pradesh, Hyderabad Ref.No.8305/ 99/ AI, Dated : 23-2-1999 (S.O. No.8/ 99/ AI). The post is filled by allotting a person to Research and Development Circle by Principal Chief Conservator of Forests.

   b) **Reasons for Creation :** The Range Officer post is required to assist FUO in execution of various works connected with efficient utilization of forest produce and publicity.

2. GENERAL FUNCTIONS:

- He Is responsible for execution of all works entrusted to him with the help of Deputy Range Officer, Forest Section Officers and Forest Beat Officer according to the instructions and orders of the Forest Utilization Officer.
- He is responsible for prompt and correct payment of all sums due for the works executed.
- He must carryout his Inspections in detail and see that all his subordinates do their work properly. In the event of serious misconduct of any subordinate, the Range officer should report the matter to the Forest Utilization Officer for further action.
- He should maintain all accounts relating to Revenue and Expenditure and submit his reports, accounts punctually to the Forest Utilization Officer.
- He will execute the sanctioned works at the rates not exceeding the sanctioned rates and record measurements and quantities of work done.

3. DESK FUNCTIONS:

1. The Range Officer is responsible for keeping his office neat and clean with upto date correspondence.
2. He is responsible for rendering cash accounts to the Forest Utilization Officer on time for the A.R. advance received by him and maintain cash book and related records.

3. He shall promptly attend to the various references received from superior officers.
4. Posting and maintenance of various registers should be prompt.

4. STATUTORY FUNCTIONS:

1. Rendering of cash accounts to the Forest Utilisation Officer, Hyderabad

5. AREAS OF JURISDICTION FOR INDEPENDENT DECISION :

i) a) Allotment of works in his range among the subordinates
   b) Advancing of funds to the subordinates for execution of works
   c) Making payment to the petty contractors as per works executed.

ii) In all other areas of operations the Range Officer is required to submit reports to higher authorities as called for.

6. RULES AND REGULATIONS :

Since this is a functional division, no special enactment's and rules and regulations are necessary. It is enough if the existing forest code account code and forest manual are followed.

7. CRITICAL PROVISIONS OF RULES DO NOT RELATE TO THE FUNCTIONAL RANGE :

8. WHOM TO APPROACH IN NEED OF HELP :

In case of requirement of any help, the Range Officer can approach his immediate superior that is the Forest Utilization Officer, Hyderabad.

9. ACCOUNTABILITY :

In case of omissions and commissions noticed, he is directly accountable to the Forest Utilization Officer. He is required to bring all such matters to the notice of the Forest Utilization Officer immediately and act promptly under his directions.

10. QUANTIFICATION OF WORK :

As per the system of monthly appraisal report, he is required to submit every month, a report to the Forest Utilization Officer on monthly performance showing the physical and financial targets fixed and achieved every month. The Range Officer shall submit these monthly reports promptly.

11. PERIODICAL REPORTS:

The following periodical reports are to be submitted by the range officer to his superiors.

i) Monthly cash accounts.

ii) Monthly progress reports on various schemes under implementation.

12. THE FOLLOWING REGISTERS ARE REQUIRED TO BE MAINTAINED AT RANGE LEVEL:

1. Cash book
2. Register of S.Os.
3. Store register
4. Stationery register

STATE SILVICULTURIST / FOREST GENETICIST

POSITION AND INTERACTION WITHIN THE DEPARTMENT :

The State Silviculturist/ Forest Geneticist Is an independent post with the overall charge of Functionary Division. He will work under the directions of the Conservator of Forests, Research and Development Circle and in collaboration with the territorial forest officers. He will conduct research and experiments Into problems confronting the forestry practices in the region of the state where his office is located. He can make direct correspondence with the local territorial forest officers, on issues confronting the forestry practices, but policy decisions will be taken by the Conservator of Forests, Research and Development Circle, according to which the State Silviculturist is required to function in his official capacity.

The State Silviculturist/ Forest Geneticist is assisted by Research Range Officers in discharging his functions in his official capacity.

GENERAL FUNCTIONS :

He will evolve plantation and regeneration techniques of various species, introduce exotic species of economic value, Investigate methods for improvement of growing stock and soil fertility, find out suitable species for afforestation to denuded and arid tracts, cultivation of medicinal plants and other plants of economic importance. He will also investigate measures for the conservation of soil and moisture and measures for controlling and preventing diseases concerning plant species and attend to weed problems. However, these functions will be carried out basing on the local factors and on the directions of the Conservator of Forests, Research and Development circle.

He will compile statistical data regarding the rate of increment and prepare volume and yield tables for important species.

He will conduct experiments in forest genetics, hybridisation of different species and seed origin.

He will maintain necessary experimental, research and demonstration plots.

He will be a co-ordinating agency for the supply and distribution of seed and other planting material both within and outside the state.

He will keep contact with the silviculturist in the F.R.I, Dehradun and other Silviculturists within the state and other states, exchange notes with them and conduct and guide the silvicultural research in the region of the state.

He will also do any special work that may be entrusted to him by his superior officers.

DESK FUNCTIONS :

i. He will maintain his office in a befitting manner, submit reports to his higher authorities and to maintain files and records neatly.

ii. All data relating to Research plots to be maintained correctly and analysis of data submitted to higher authorities for taking decisions.

iii. He will maintain all registers connected with the administration

iv. He will submit fortnightly diaries to the Conservator of Forests, Research and Development Circle.

v. He will obtain weekly diaries from the Research Range Officers and file in his office.

STATUTORY FUNCTIONS :

i. He will Issue A.R. advances to the Research Range Officers for the execution of works.

ii. He will obtain cash accounts from the Research Range Officers in two batches for each fortnight separately. He shall forward monthly accounts along with documents, appendices etc., as laid down in local rulings under articles 280 to 297 of the A.P.Account code Vol-III direct to the Accountant General.

iii. After despatch of cash accounts to the Accountant General, Andhra Pradesh, the progressive statements of Revenue and expenditure shall be despatched to the . Conservator of Forests, Research and Development Circle.

iv. He is responsible for claiming pay and allowance of the staff in the Division and for proper accounting and maintenance of connected records.

OPERATIONAL JURISDICTION :

The areas where the State Silviculturist/ Forest Geneticist can take independent decision are the same as that of all Deputy Conservator of Forests. (State cadre DCF) and Deputy Conservator of Forests (IFS cadre) as the case may be. However some salient points are mentioned below:

1. The State Silviculturist/ Forest Geneticist can exercise his own decisions in respect of Research and experimental plots so far as it relates to raising and maintenance of nurseries and plantations and collect data and submit analysis to the Conservator of Forests (Research and Development). But for standardisation of technologies and transfer of technology to the field, the approval of the Conservator of Forests (Research and Development) is necessary.

ENACTMENT OF RULES AND REGULATIONS REQUIRED :

The present rules as are applicable to the post of Deputy Conservator of Forests or Assistant Conservator of Forests as the case may be, are sufficient. No fresh rules are necessary.

In case of any help required he can approach his Immediate superior i.e. the Conservator of Forests, Research and Development Circle. Next to have the approachable authorities are the local Conservator of Forests and other territorial forest officers.

The administration accountability to be approached in case of omissions and corrections is the Conservator of Forests, Research and Development Circle and the Principal Chief Conservator of Forests, Andhra Pradesh, Hyderabad.

He shall submit the monthly performance appraisal reports to the Conservator of Forests, Research and Development Circle.

PERIODICAL RETURNS:

Annual reports :

Administration Report

Annual Research Report

Monthly Reports :

Seed Collection and Supply Report

Report on production and distribution of high yielding clones

Monthly P.R. on various plan and non plan schemes

Fortnightly :

Tour diaries of State Silviculturist/ Forest Geneticist

REGISTERS :

The following registers shall be maintained.

1. Register of Research Experimental Plots
2. Register of Candidate Plus Trees
3. Register of Seed Production Areas and Seed Orchards
4. Register of Seed collection
5. Register of Production of high yielding clonal plants
6. Register of Stores
7. Register of Buildings
8. Register of Roads
9. Register of wells
10. Register of lands
11. Register of Stationery
12. Register of Diaries
13. Personal Registers
14. Cash book
15. Work Register
16. Sanction Order register
17. Register of cheques issued

FIELD & LABORATORY FUNCTIONS OF STATE SILVICULTURISTS & FOREST GENETICIST

I. TREE IMPROVEMENT RESEARCH :

A) TREE IMPROVEMENT :

1 Selection of CPTs by continuous inventory of natural forests and plantations and proper documentation - Development of selection criteria of different species.

2 Conducting the progeny trial and assessment of the progeny trial plots at different stages and registering of the CPTs as plus trees Recurrent selection and selection and establishment of progeny trial In order to improve the quality of seeds progressively.

3 Controlled pollinatiön between selected plus trees in the progeny plot and laying down full-sib progeny trial and establishing advance generation orchards.

4 Establishment of multilocational clonal trial plots of various selected CPTs and screening the clones for arriving at the site and stress specific clones of individual species

5 Integration of vegetative propagation and breeding and development of a clonal deployment strategy

6 Establishment of SPAs, CSOs and SSOs for meeting the demands of genetically Improved varieties of seeds

7 Domestication of lesser known species - surveying the population status of various local species used for economical activity and popularization of their planting.

8 Introduction of exotic species, provenance trial of major economic species which can be further converted in to seed stands.

B) SEED RESEARCH :

1 Seed morphology, polymorphism and ecological significance of various forest seeds including the periodicity of flowering and seed setting of different agro-climatic regions.

2 To standardize the various processing mechanisms, drying intensity for prolonged storage and grading methods of various major forest species.

3 Determination of extent of purity of the seeds of different agroclimatic regions.

4 Standardization of appropriate time of seed collection of various species keeping in view the colour, hardness and other Phenotypic parameters.

5 Germination studies of different forestry seeds including seed dormancy; germination behaviour and quantification of germination, physiological and biochemical changes during germination; bio-regulators on germination mechanism; and seed pathology Including the control studies.

6 Developing the quick methods of determing seed viability for different species.

7 Standardization of storage environment' for both orthodax and recalcitrant seeds including the studies of the types of containers in which seeds to be stored. The study should also include the factors responsible for the longevity of seeds by subjecting the seeds to a gradient of temperature and humidity and periodically doing the germination test till the seeds completely fail to germinate.

8 Standardization of pretreatment and germination protocol.

9 Development of correlation between the germination under controlled conditions i.e.mside the germination cabinet, inside the room temperature and germination under nursery conditions.

10 Establishment of a seed herbarium.

11 Establishment of seed certification unit and supplying the certified seeds to the user agency.

12 Establishment of Seed Production Areas (SPA) to meet Immediate demand of the seeds as an interim method and establishment of seed Orchad (CSO & SSO) as a permanent source of supply of genetically improved seeds.

C) VEGETATIVE PROPAGATION :

1. Macropropagation studies like grafting and rooting of juvenile cuttings :

a) Standardization of grafting technology of fruit bearing economical forest species like *Embika officinalis, Tamarindus indica, Syzygium cumini, Sapindus emarginatus, Limonia acidissima, Semecarpus anacardium, Terminalia chebula, T.bellerica, Strychnos nux-vonica, S.potatorum, Madhuca indica, Buchanania lanzan* etc.

b) Standardization of production of true-to-type planting stock by rooting of Juvenile cuttings of coppicable important timber species for Increasing yield, diseases resistance and stress tolerance.

c) Creation of Clonal Multiplication Areas (CMA) or cutting orchard of selected species from which vegetative propagules can be produced on large scale by macro propagation methods.

d) Study of the cutting cycle, method of coppicing, time of coppicing and harvesting methods of different species.

e) Improvement of the propagation unit.

f) The development of management packages for clonal plantations of different species.

2. Micropropagation studies through tissue culture technique and development of protocols for the mass propagation of selected forest species. Economics of production should be taken into consideration :

II. Research on Forest Microbiology :

- Survey of forest soil and assessment of distribution of VAM fungi and correlation studies with the growth of VAM in natural stands.
- Isolation and culturing of VAM and maintenance and production of VAM inoculum.
- Nursery evaluation of VAM association with tree seedlings.
- VAM interaction with micro-flora and with tree seedlings.
- Isolation and culturini of *Frankia* strains.

III. Conservation and Exploration of Genetic Resources of indigenous Trees:

1 *In-situ* conservation: establishment and maintenance of permanent preservation Plots, ecosystem studies, habitat evaluation studies, regeneration studies etc.,

2 *Ex-situ* conservation: arboretum establishment, clonal orchards and germplasm/ gene banks.

3 Identification and conservation of endemic, threatened and endangered species.

4 Introduction of species to enhance genetic diversity.

IV. Research related to Plantation Forestry :

1 Soil - moisture conservation devices- in situ moisture conservation techniques.

2 Watershed treatment technique including gully plugging, check dams, vegetative barriers etc.

3 Treatment packages to sites subjected to various stresses like salinity, alkalinity etc; greening of mined area OB dumps, coal, barite mines etc.

4 Determination of the combinations of rates and frequency of application of fertilisers to maximise the economic return of species suitable for commercial as well as social and agro forestry plantations. Developing the techniques capable of accurately predicting quantitative response of forest stands to specific fertiliser treatment.

V. Nursery Technology :

1 Development of suitable containers and potting mixtures for raising seedlings of various species of different age class (duration).

2 Correlation studies on seedling vigour and field performance by physical and physiological attributes.

3 Nursery cultural operations like root culturing, top pruning, grading, fortification of seedlings with mycorrhiza and rhizobium and evaluation studies for their performance

4 To determine the type and dosage of chemical/biological fertilizer application to the nursery seedlings and their performance in the field.

5 To standardise the optimum size of seedlings to be transplanted in the field for sure establishment and best performance.

6 To determine pre-sprouted technique of stumpable species for planting/ replacements in the plantations.

7 Grafting experiments of important species, whose seed is not easily available or whose viability is less.

8 Tall plant raising techniques and planting techniques for fully grown trees.

VI. Research on J.F.M :

1 Habitat evaluation studies to determine the degree of silvicultural and social interventions and maintenance of sustainability.

2 Evaluation of the response of people living around the forest towards the usage pattern of the usufructs (non wood forest produce, fuel wood etc).

3 Development of JFM models.

VII. Natural vegetation management technologies :

1) **Vegetation identification and inventory :** Inventory of natural forest to find out the species diversification, association of species etc should be carried out. Region wise flora should be prepared covering not only the species distribution but also the density.

2) **Ecology and Climate :** Phonological studies of different species in different agro-climatic regions should be taken up.

3) **Degradation rates :** A comprehensive study should be taken up covering the threat status of different species in different areas.

4) **Soil Loss Rates :** In view of the various SMC works carried out in all the VSS of the State, sample studies can be initiated in different areas to assess the extent of prevention of soil loss and consequent improvement of vegetative cover

5) **Human/ animal demands :** Keeping in view the demands on the forest, the quantification of human/ animal demands on the forest is necessary.

6) Yield at different seasons and animal densities and the yield of different fodder species in various seasons can be worked and a correlation study can be taken up vis-a-vis the animal densities

7) A data base regarding the incidence of fires In different areas of Andhra Pradesh and a comprehensive action plan detailing the suitable methods to control fire can be prepared.

8) NTFP yield from the forest, standardization of processing and value addition and market analysis can be taken up.

9) Yield determination and incremental growth of various types of plots taken up for improvement by the VSS members under JFM can be taken up. An assessment method should be developed giving a true picture of the quantitative and qualitative change of the forest cover status managed under JFM.

VIII. Development of suitable agro-forestry model to increase the productivity of the land :

IX. Natural forest oriented research :

Natural Forests are expected to regenerate themselves, but with Increased pressures off grazing, fires, hacking etc, the forests may fail to deliver goods and services, as are expected from them. Hence, the need to study the problems of natural regeneration and to find solutions the following are suggested,

1. Study the problem of natural regeneration of important species in degraded/ dry evergreen /dry deciduous forests.
2. Study the impact of soil and moisture conservation works on the natural regeneration.
3. Study the impact of site preparation like ploughing/hoeing on natural regeneration.
4. Study the application of low dosages of fertilisers, especially Phosphorous and its impact on natural regeneration.
5. Study the effect of proper coppicing of important timber species in natural forests
6. Assessment of availability of fodder grasses/medicinal plants
7. Phonological studies and seed directors in different agro-climatic zones.
8. Maintenance of old preservation plots/laying new observation plots in different ecotypes.

X. Afforestation oriented research :

Massive afforestation of degraded/denuded forests has come to stay, but the problems a forester is facing in the field are many. Initiate action to find solutions, in the following manner.

1. Study the nutrient status of different degraded forest types.
2. Study relative advantages of different soil preparation techniques like pitting, trenching, ploughing, ripping, etc, for the establishment of a good plantation.
3. Developing planting models for barren hill afforestation,
4. Study the methods of soil preparation for successful afforestation of grassy blanks, mined areas, water logged areas, saline and acidic areas.
5. Species performance trials in different soil types,
6. Species trials under different irrigated conditions, hormonal treatments and rood promoters.
7. Provenance trials of common species in different climatic zones,

8. Coppicing studies in Social forestry plantations for Subabul, Sissoo, Eucalyptus, Casuarina etc.

XI. Ethnobotanical Studies :

1) The floristics of medicinal plant rich areas should be taken up and a comprehensive database should be prepared enlisting the distribution, abundance and local use of the various species

2) A market analysis regarding the demand and supply position of the different medicinal plants should be carried out

3) The standardization of farming technologies of medicinal plants should be taken up and the information package can be disseminated to the farmers

4) The harvesting, processing, value addition methods and storage of different medicinal plants can be worked out.

5) The species recovery plan should be prepared and in collaboration with VSS attempt should be made to plant the particular species which have become rare in that area.

XII. Basic Research Facilities :

1) Establish the laboratory facility for soil analysis from different parts of the state

2) Establish the laboratory facility for plant analysis from different experimental plots

3) A statistical analysis cell should be developed to analyse the experimental results of the various experiments using the modern computer software packages.

4) Analyse the data and determine the usability of experiments,

5) Document the results in a retrievable manner for easy reference and application,

6) Publicise the successful experiments, in more effective manner, to take the technology from LAB TO LAND

PLANS FOR PROGENY TEST :

Trees can look very different when grown in different areas. When trees are selected for superior performance, the initial criterion for selection is the original phenotype. But this may not be a good indication of the true worth of the tree. A way of overcoming this problem is to test the progeny of the selected trees in a controlled manner to see whether or not they perform upto expectation. The higher the proportion of the total variability due to genetic variation rather than environmental variation, the more the progeny resemble their parents. In other words after the selection of superior phenotypes they are tested for their genetic worth whether they are capable of transmitting their good traits to their progeny or not. This enables to estimate the amount of gain we can expect from selection. Such a test of progeny is called a progeny test.

There are basically two types of progeny tests:

i. Open - pollinated (often wrongly called half-sib) tests.

ii. Control - pollinated tests.

2. Questions which can be answered in the progeny test are:

a) How good is this plus tree in relation to the others in the collection?

How this question is to be answered depends on the form in which the plus tree is held. If the only material available is the tree itself in the forests, then the quickest and the cheapest form of progeny test to answer this question is the open-pollinated progeny tests. Seed is collected from the plus trees in the forest, and is grown in the some appropriate design. The progeny performance will give an indication of the worth of the plus tree when it Is included in a seed orchard.

b) Another question commonly asked, and which can often be answered by progeny tests is:

If it is selected from this group of plus trees, or from this population, how much gain will be achieved. Open pollinated progeny tests can only satisfactorily answer this question If the progeny are truly half-sibs. In this case, an estimate of heritability can be made.

3. Design of progeny test :

The question that the progeny trial will answer should be borne in mind when designing the trial. If the question is only concerned with the ranking of progeny by their arithmetic mean, then almost any sort of design will do. Randomised blocks or wholly randomised designs are suitable, but incomplete block designs are better since they allow for site variation (if it exists in the test site).

Similarly, for the estimation of variances, single-tree plots or non-continuous plots should be used, unless plot means are to be considered as the basic unit for analysis. This Is because the environmental variance between plots is greater than the environmental variance within plots. When the within family variance is compared with the between family component, the environmental part is not the same and the comparison is invalid.

When designing the progeny tests, it is necessary to consider the number and positioning of replications. Material which is extremely variable required more replication than fairly uniform material. If the breeding programme covers a variety of sites, then each of these should be used for a repetition of the experiment since ranking of families may not be the same on different sites. Within a site, variability of soil or other environmental variable should be observed and noted so that each kind of area can be accounted for by a block. In this way, within-site, variation can be taken into account and is not confounded with the differences between families.

While doing the designs for the progeny test trial, following technical points can be taken care of:

a) The very best field design or the very best mating design is entirely useless If proper care is not taken at every stage to ensure that the trees are correctly identified. Adequate and correct labelling is a paramount importance and needs careful supervision by the person responsible for the experiment.

b) When the seeds are first sown, the seed lots should be properly randomised and replicated so that the nursery effects are random. No nursery Is uniform enough to obviate the need for either randomisation or replication. Where there are large differences between replicates in the nursery, the nursery replicates should become part of the design for the field experiments so that proper account can be taken of the nursery effects. In any case, the plants should be given as uniform conditions of growing as possible (particularly fertilizer and watering) because nursery effects complicate the field design.

c) It is very important, particularly for single-tree plots, that each tree receives equal treatment as far as possible. Differences in treatment may be random, and will probably not alter rankings, but they will inflate the error variance of the experiment and may lead to rejection an otherwise significant result.

d) Assessment of the trail should be carefully planned along with the rest of the experiment at the start. The timing, and the characters assessed depend on the species and the nature of the breeding programme.

3. INTERPRETATION:

The Interpretation of the data from progeny tests usually follows some statistical analysis. The original plan must start with correct presumptions. Crosses must be properly carried out, and seed adequately and correctly labelled. Variation in nursery and field plots be adequately assessed and covered by blocks. Trees must be correctly labelled at every stage. Data must be checked to eliminate the possibility of mistakes in assessment and finally, the calculations must be correct. If all of these are properly carried out, the process of interpretation can begin.

Ranking of progenies probably does not mean much if the differences between progenies are not statistically significant i.e., the differences in rank could be due to chance. ' Duncan's multiple range test's is a good way of seeing at a glance which progenies are significantly different.

In Andhra Pradesh, progeny testing studies have been carried out and heritability estimates for. some characters have been reported for teak, sandal and red sanders. However, the progeny trial for the following species hold a lot of promise in tree Improvement programme.

a) Tectona grandis
b) Pterocarpus marsupium
c) Santalum album
d) Gmelina arborea
e) Terminalia alata
f) Anogeissus latifolia
g) Dalbergia latifolia
h) Eucalyptus spp.
i) Casuarina equisetifolia
j) Pterocarpus santalinus
k) Albizia odortissima
l) Adina cordifolia

PROGRAMME FOR PROVENANCE TEST :

1. Each species has got a natural range of its geographic distribution and in the course of its evolution it develops into natural and clearly discernible land-race or provenance. Provenance trials assume that important genetic differences do exist through out the distribution range of the species. Exploitation of the natural variation existing in the species by selection breeding is the first step in the improvement of the species and provenance trials take care of this principle. The species and provenance trials are intended to identify and determine the best suited species and provenances for a particular site (Eco-climatic zone). Genetically there may be small or large differences in allele-frequency at different geographical locations. All provenance trials are half-sib progeny trials. The best way to find out as to whether these variations are due to genetic or environmental differences is by bringing the various populations (provenances) together in a common environment by collecting seed, raising seedlings and planting provenance trial. The trial will define the genetic and environmental components of phenotypic variation associated with geographic region. With the increasing pressure on land, it has become essential to choose particular provenance which suits best to a particular environmental condition to obtain higher yield per unit area.

2. In a provenance-trial, seeds are collected from a large number of seed sources throughout the genetic spectrum and geographical distribution of the species and are tested over a range of planting environments. Different provenances are tested against uniform environments and site factors, so as to determine the response and behaviour of different provenances; and thus determine the best suited provenance for the test-site. The planting site variables determine the phenotypic variables of original environmentally induced variations, while the genotype, is determined by the source-induced genetic variations. An uniform response of a provenance in different environments indicates the degree of stability of the provenance and the provenance trials undertaken in different test sites indicate the extent of stability of the populations tested.

In view of the multi-gene, control of traits of tree species (particularly woody species) provenance testing is concerned with more than one trait at a time.

In a provenance trial it is necessary to ensure the following:

- ❐ Objectives clearly tested.
- ❐ Seeds collected by investigator personally, if possible.
- ❐ Seedlings grown in the nursery under uniform conditions and with suitable replication.
- ❐ A sound statistical design
- ❐ Plot size determined by the expected variation in the material and by the anticipated age of final assessment
- ❐ Planting sites representative of future planting areas, are as uniform as possible.
- ❐ Great care in labelling and recording of data at all stages.

Already much work has been carried out for provenance trial of Tectona grandis in Andhra Pradesh. However, other spp. like *Terminalia alata, Eucalyptus, Casuarina equisetifolia, Pterocarpus marsupium Albizia odoratissima, Azadirachta indica, Anogeisus latifolia* etc. are to be taken up. While doing so, It Is worth while to take the other seed zones of the country into consideration wherever the spp. finds its distribution to a fair extent.

3. Assessment is a time consuming and potentially extremely lengthy process. The characters assessed, and the frequency of assessment will depend upon the objectives of the trial and should be clearly determined at the time of designing the trial.

The following assessment schedule is recommended as the minimum requirement in a provenance trial.

CHARACTER	FREQUENCY OF ASSESSMENT
Height	1) 6 months
	2) 12 months.
	3) Annual thereafter, upto about 7 meters.
	4) Then every 2-5 years.
Survival	1) 6 months.
	2) 12 months
	3) Annual thereafter, in conjunction with height assessment.
Height	Continuous, but score health when conducting height Measurement.
Diameter at breast height	1) When tree height average 2-3 meter.
	2) Annually thereafter, upto about 7 meters.
	3) Then every 2-5 years.
Stem form and number of stems	1) When tree height average 3 meter.
	2) Thereafter at 3-5 year interval.
Branching habit	1) When tree height average 3 meter.
	2) Thereafter at 3-5 year interval.

The frequency of assessment is given as a guide only; it may be necessary to tailor the schedule of assessments to local climatic conditions, both for ease of working, and in order to coincide with the growing season. It may also be necessary to measure other characters, depending upon trial objectives. Multipurpose trees, particularly ones being tested for bio-mass production (such as fuel wood and fodder) may be difficult to measure accurately without destructive sampling.

4. It is essential that throughout the life span of the trial, regular written reports are made giving details of current progress. Each report should serve as a summary of the current progress on the trial, giving details of any measurements taken and any analysis of the data obtained

The guidelines for Tree improvement are given in detail in Appendix

RESEARCH RANGE OFFICERS

1. a) **Origin :** The post of Research Range Officer takes its origin from the post of Forest Range Officer. The post is filled by allotment of Forest Range Officer to Research and Development Circle by Principal Chief Conservator of Forests from the concerned Zone in which the research division is located.

b) **Reasons for creation :** The Research Range Officer is required to assist the Forest Geneticist/ State Silviculturist in executing works connected with the Research experiments in a systematic manner on sound Silvicultural lines and to collect data from the experimental plots.

c) **Role played by the functionary :** Research Range Officer is the officer in executive charge of the Range (here the range implies the specified area where works are located) without territorial charge and he is responsible for the efficient execution of research works and for safe custody of all Government property in his charge.

2. a) **Position in the organisation :** This post is an important post as grounding of various schemes and plans start here only. He occupies the place of an executor with all his range staff like Research Forest Section Officers and Research Forest Beat Officers.

b) **Span of interaction :** This post being purely functionary for execution of departmental research works has no public relations. He can interact with the public only to the extent of labour deployment and guidance to the interested parties like farmers, VSS members etc., on transfer of technology. He will freely correspond with his immediate superior, the State Silviculturist or Forest Geneticist as the case may be for solving problems connected with execution of various research works and Interact with the Forest Officers of the other departmental units such as territorial, Planning and Extension etc. located in his jurisdiction.

3. a) **Listing out functions to be discharged :**

1. He is responsible for execution of all works in the Range with the help of Forest Section Officers and Forest Beat Officers according to the instructions and orders of the State Silviculturist/ Forest Geneticist.

2. He Is responsible for prompt and correct payment of all sums due for the works executed,

3. He must carry out his inspections in detail and see that all his subordinates do their work properly. In the event of serious misconduct of any subordinate of the Research Range Officer he should report the matter to the State Silviculturist/ Forest Geneticist for further action.

4. He should maintain all accounts relating to Revenue and Expenditure and submit his reports, accounts punctually to the State Silviculturist/ Forest Geneticist.

5. He should take effective measures to protect the Research and experimental plots in his custody.

6. He will execute the sanctioned works at the rates not exceeding the sanctioned rates and record measurements and quantities of work done.

7. He is responsible for correct posting of work registers, ledgers, Journals, plantation registers and other registers maintained in the range.

8. He should always wear the prescribed uniform, whenever he is on duty and he should see that all Section Officers, Forest Beat Officers and Assistant Forest Beat Officers wear the uniform when on duty.

9. He should submit his weekly diaries with details of work allotted, their progress during the week, status of protection of research plots etc., to give a comprehensive picture of the range.

10. All correspondence connected with the Range should pass through the Range Officers. Any subordinate wishing to submit representation to the State Silviculturist/Forest Geneticist or other superior officer, he may do so, only through the Research Range Officers. Court summons issued to any subordinate should similarly be served through the Forest Range Officer, who has to arrange for the duties of subordinates being carried out during his absence.

11. He is responsible to prepare annual plan of operations for the Range based upon the sanctioned working schemes or executive Instructions and prepare necessary estimates and execute the works after obtaining sanctions and budget.

12. He shall obtain weekly diaries from his executive subordinates (FSOs and FBOs), scrutinize them and file in his office.

DESK FUNCTIONS :

1. The Range Officer is responsible for keeping his office neat and clean with up to date correspondence.

2. He is responsible for rendering cash accounts to the State Silviculturist/Forest Geneticist on time for the AR advances received by him and maintain cash book and related records.
3. Promptly attend to the various references received from superior officers.
4. Posting and maintenance of various registers.
5. Submission of weekly diaries, monthly performance appraisal reports and other periodicals as prescribed by the superior officers from time to time.
6. Receiving and scrutiny of weekly diaries of subordinates

STATUTORY FUNCTIONS:

I. Rendering of cash accounts to the State Silviculturist/ Forest Geneticist.

4. Areas of jurisdiction for independent decision :

I. a. Whenever superior trees of any species are selected the Range Officer may Include the same in the list of Candidate Plus Trees.

b. Allotment of works in his range among the subordinates

c. Advancing of funds to the subordinates for execution of works

d. Sanction of casual leave to the subordinates

e. Making payments to the petty contractors as per works executed.

II. In all other areas of operations the Range Officer is required to submit reports to higher authorities as called for.

5. Rules and Regulations :

Since the Research Range Officer's duties are functional in nature, no special enactment and rules and regulations are necessary. It is enough if the existing forest code, financial code, Account code and Forest manual are followed.

6. Critical provisions of rules does not relate to the functional Range.

7. To whom to approach in case of help required :

In case of requirement of any help, the Range Officer can approach his immediate superior i.e., the State Silviculturist/ Forest Geneticist. He can also approach the Forest Range Officers in territorial units existing in his jurisdiction.

8. Accountability:

In case of omissions and commissions noticed he is directly accountable to the State Silviculturist/ Forest Geneticist. He is required to bring all such matters to the notice of the State Silviculturist/ Forest Geneticist immediately and act promptly under his directions.

9. Quantification of work :

As per the system of monthly appraisal report, he is required to submit every month, a report to the State Silviculturist/ Forest Geneticist on monthly performance showing the physical and financial targets fixed and achieved every month. The Range Officers shall submit these monthly reports promptly.

10. Periodical Reports:

i. monthly cash accounts
ii. monthly progress reports on all the ongoing schemes
iii. monthly seed collection and supply report
iv. monthly reports on production and supply of high yielding clonal plants.
v. weekly diaries
vi. annual research reports
vii. annual administration reports

11. The following registers are required to be maintained at Range level:

a) Cash book
b) Work register
c) Measurement books
d) AR advance register
e) register of S.Os
f) seed collection register
g) register of high yielding clonal planting stock produced
h) register of experimental/ research plots
i) register of Candidate Plus Trees

j) register of Seed Production Areas and Seed Orchards

k) store register

i) stationery register

m) register of buildings

n) register of roads

o) register of lands

p) register of wells

q) register of diaries

APPENDIX

WHAT IS TREE IMPROVEMENT ?

In order to understand what tree improvement is it is necessary to know three terms and their development and relationship to each other. They are forest tree breeding, forest genetics and forest tree improvement. Activities that are restricted to genetic studies of forest trees are termed **forest genetics**, here, the objective Is to determine the genetic relationships among trees and species. An example of a forest genetic activity is the attempt to determine crossability patterns among species within a genus. The crosses are made to determine relationships, but otherwise they have no special breeding, in which activities are geared to solve some specific problem or to produce a specially desired product. An example of such directed **breeding** is the development of pest-resistant strains of trees or breeding trees that possess specially desired wood. The third term, **forest tree improvement**, is applied when control of parentage is combined with other forest management activities, such as site preparation or fertilization, to improve the overall yields and quality of products from forest lands.

Tree improvement Is effective only when it consists of the combination of all silvicultural and tree-breeding skills of the forester to grow the most valuable forest products as quickly as possible and as Inexpensively as possible. It consists of a marriage of silviculture and tree parentage to obtain the greatest overall returns. Stated, simply **tree improvement is an additional tool of silviculture that deals with the kind and genetic make up of the trees used in forest operations.**

In the beginning tree improvement programme consists the following:

1. Determination of the species, or geographic sources within a species, that should be used in a given area for tree improvement works.
2. Determination of the amount, kind, and causes of variability within the species.
3. Packaging of the desired qualities into improved individuals, such as to develop trees with combinations of desired characteristics.
4. Mass producing improved individuals for reforestation purposes either through vegetative propagation or seeds. The integration of breeding should be made with the vegetative propagation.
5. Developing and maintaining a genetic base population broad enough for needs in advanced generations.

In some instances, step 1 may have been completed before intensive tree improvement programs are initiated. In others, considerable time, money and skill may be required to complete step 1. This first step must be done well before steps 2 to 5.

In tree improvement programs using hybridization and or vegetative propagation, the principles previously listed will still hold, although their order or Importance may vary. In truth, all methods of tree improvement require that all five steps must be followed. The special advantage with a vegetative propagation program is that once a suitable "package" has been located, or developed through breeding, It can be reproduced rapidly many times, and the propagules are essentially the same genetically as the desired parent tree. Vegetative propagation allows quick and large gains because all types of genetic variation can be captured. Hybridization has an advantage because it enables the creation of something entirely different by recombining the variability produced in nature into a new "package", the hybrid tree. Thus, it may be possible through hybridization to create a plant with characteristics for difficult environments, pest resistance, or specially desired products.

WHERE AND WHEN SHOULD TREE IMPROVEMENT BE USED?

The contributions that tree improvement can make to growth, quality, pest resistance, and adaptability of forest stands are greater under some conditions than under others. Obviously, large-scale, aggressive planting programs are most conducive to the use of genetic improvement. Tree improvement is more difficult to justify economically when forests are regenerated naturally. The basic fact remains, though, that all forest management activities can profit from using tree improvement concepts. If this is not done, forest managers can only partially achieve their objectives. Forest trees are plants with responses controlled by the environment and by genetics, like all other organisms. The results obtained from any forest management operations will be determined both by the genetic makeup of the tree and by its interaction with the environment in which it grows. Tree improvement should play a significant role in forest management any time the production of high volumes of good quality timber is the principal management objective. The most intensive tree improvement efforts will be made where stands are regenerated artificially at least once every few rotations. It is in these cases that the greatest gains can be obtained from tree improvement.

The objective of Intensive tree farming can be stated simply as the production of the desired quality timber in maximum amounts in the shortest period of time at a reasonable cost. This objective is simpler to state that it is to achieve, of course, but in the recent past three decades tree improvement has played an increasingly important role in helping to achieve it by increasing forest productivity and reducing the time needed to harvest. Tree improvement can be used to help accomplish many management objectives to over come problems, but this will not be done without some adverse reactions. For example, the harvest age of trees can be reduced through genetic selection for growth rate, but the reduction may lead to significant changes in wood quality, harvesting costs, and regeneration costs. A major job of the tree breeder is also to help overcome problems that arise from Intensive forest management. There are essentially three lines of attack that the tree improved can use to increase timber production: 1) Breeding can be accomplished for improved yields and quality on the more productive forested areas; (2) trees can be developed that will grow satisfactorily on land that is currently sub-marginal and non-economic for timber production; and (3) strains of forest trees can be developed that are more suitable for specialized products or uses. The first approach has been widely utilized for several tree species, and dramatic results have been obtained. Many persons only associate tree Improvement and the use of genetics with yield and quality improvement.

The development of trees especially suitable for marginal sites is long term in nature, but it will result in substantial benefits as pressures for forestland use Intensify. Competition for land is increasing, which Is forcing forestry operations from the more productive sites to areas that were previously considered to be marginal or useless for timber production. As a result, large amounts of genetically improved seeds are needed quickly that are specifically developed to grow on the vast forest areas that are currently marginal or sub-marginal for economic forest or agricultural production. The current emphasis in tree improvement is toward breeding for adaptability to marginal sites, in addition to improving trees for better products or better growth on forest sites that are suitable for forest production potential gains from breeding for adaptability to marginal sites are great and huge areas of such land are available for forestry use. However, forest managers and tree breeders must be constantly alert to the basic biological constrains to the productive potential on a given area of land. High production will not be obtained from deficient soils, no matter how good the trees are genetically.

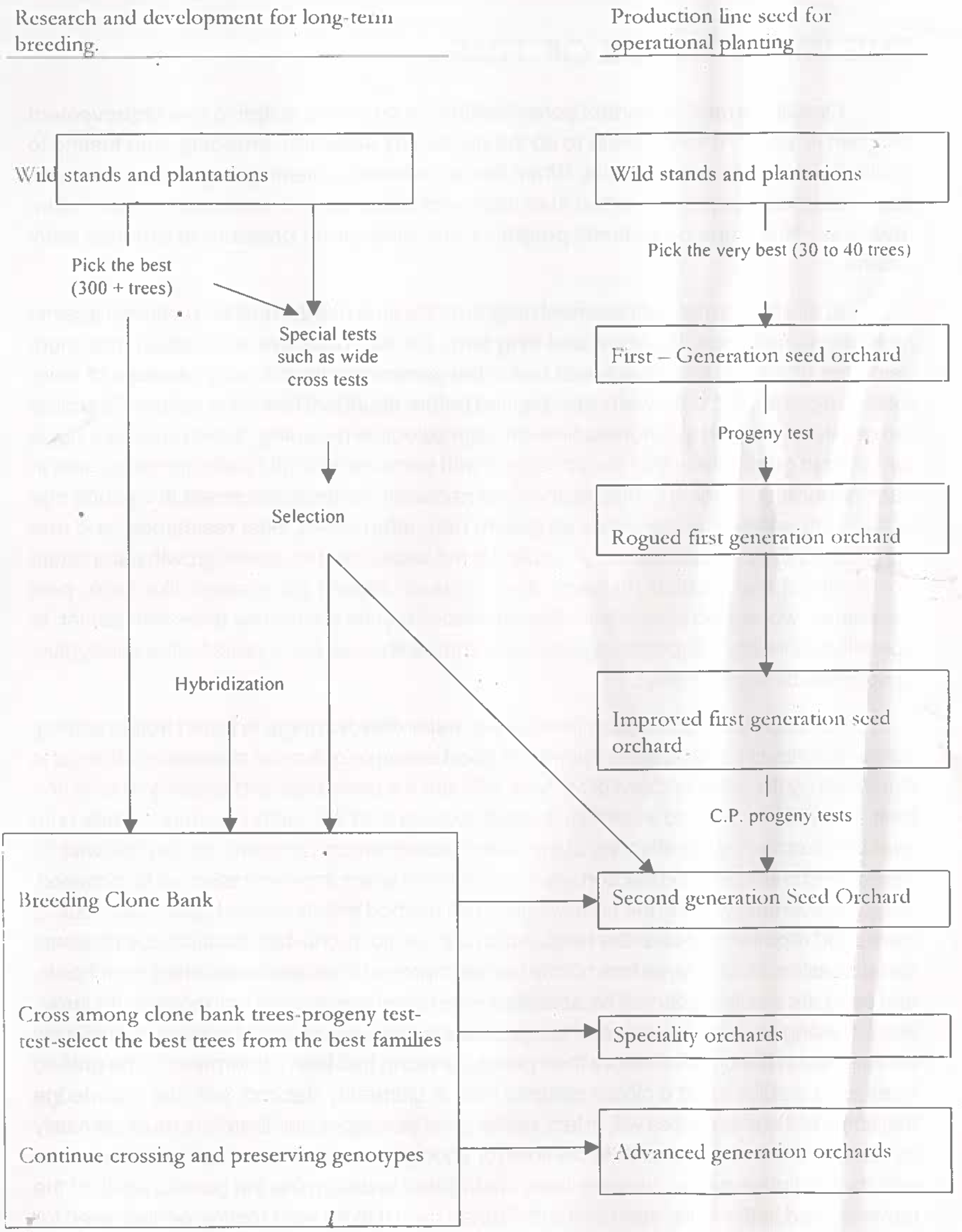
Tree improvement without commensurate intensive forestry is generally of marginal value, and there must be a union between the two if maximum gains from either are to be achieved. The total genetic potential can only be exploited if the trees are grown in the best environments.

ESSENTIALS OF A TREE IMPROVEMENT PROGRAM:

There are two aspects to any successful tree Improvement program. The first relates to obtaining an immediate gain of desired products as rapidly and as efficiently as possible. This is achieved by Intensively applying genetic principles to operational forestry programmes that will result in better-quality, better-adapted, and higher-yielding tree crops. Maximum gains are achieved by the use of a few of the very best genetic parents to supply planting stock for operational programs. A benefit of a tree improvement program that is often not recognised is the production of large and regular seed crops that are suitable for the forest operations since lack of suitable seed is one of the greatest deterrents to forestry. Immediate gains after selecting through clonal forestry. But in order to consistently improve the genetic-quality and maintain the broad genetic spectrum in the planting stock, long term tree improvement programme is necessary.

All tree Improvement programs must have an operational (production) and a developmental (research) phase. The two are closely linked, yet they require different approaches and philosophies. The developmental, or research, phases are necessary for a successful long range program. As the programs mature, the operational activities become increasingly dependent on continued progress in the developmental area. Therefore, to be successful, a tree improvement program must have the developmental aspects Initiated at an early stage in the program, along with the operational activities.

The main objective of the developmental phase is to obtain and retain a broad genetic base and to combine desired characteristics into suitable trees that will be valuable for future generations. No program can be better than the base of genetic material upon which it is founded, and although the developmental phase takes considerable time to yield useful results, the provision of the skill and money required to maintain it is mandatory.


Research and development for long-term breeding.
Production line seed for operational planting
Wild stands and plantations
Wild stands and plantations
Pick the best (300 + trees)
Pick the very best (30 to 40 trees)
Special tests such as wide cross tests
First – Generation seed orchard
Progeny test
Selection
Rogued first generation orchard
Hybridization
Improved first generation seed orchard
C.P. progeny tests
Breeding Clone Bank
Second generation Seed Orchard
Cross among clone bank trees-progeny test-test-select the best trees from the best families
Speciality orchards
Continue crossing and preserving genotypes
Advanced generation orchards

THE IMPORTANCE OF TIME :

One of the most important considerations in an active, ongoing tree improvement program is TIME . It takes years to do the necessary selection, breeding, and testing to obtain the desired improvements. When the department is planting large areas annually, each year that unimproved, rather than Improved, stock is used represent a loss in future revenues. Therefore, operational programs are under great pressure to produce early returns.

In all applied tree improvement programs the time needs must be balanced against possible gains in both the short and long term; the key objective is to obtain maximum gains per unit time. For most forest trees, the generation time is long because of long-rotation ages and 10 to 20 years are required before abundant flowering occurs. To accrue the greatest gains in the shortest time through selective breeding, there must be a quick turn over of generations that are combined with some meaningful selection pressures in each generation. A most critical factor is the necessity for an assessment at a young age of such Important characteristics as growth rate, adaptability, pest resistance, and tree form. Currently, for most species generally it is not satisfactory to assess growth parameters before about half-rotation (harvest) age, although certain parameters like form, pest resistance, wood, and adaptability characteristics can be accurately assessed earlier. In operational forestry, the rotation age can vary from as short as 6 to 8 years for the eucalyptus, to 80 years or more for teak.

Although long-generation times are a major disadvantage in forest tree breeding, certain shortcuts have been developed. A good example of a most successful shortcut is illustrated by the seed orchard programs. Without the pressures and urgency of time, the best scientific method to establish a seed orchard that will yield maximum gains is to evaluate thoroughly the offspring of the select parent through progeny testing followed by the establishment of the production seed orchard from which improved seed will be obtained. Although eventually giving the greatest gain, this method entails several years delay during the period required to make the tests, which can be up to one-half rotation age for some characteristics. Such a large loss of time before improved trees are established In orchards, and seed are available cannot be accepted when seed are needed immediately for large-scale planting programs is one in which good phenotypes are selected and are immediately established in the orchard before their genotype worth has been determined. The grafted trees are established at a closer spacing than is ultimately desired, with the knowledge that some of the phenotypes will, in fact, not be good genotypes and therefore must ultimately be removed from the orchard. At the time (or shortly thereafter) of orchard establishment with the best phenotypes, progeny tests are initiated to determine the genetic worth of the parents used In the initial seed orchard. During the 10 to 20 year testing period, seed for planting have been obtained from the orchard that are considerably improved over wild seed, although they are not as good as those from proven parents. However, the added value of the partially improved seed to the forest management operation is large.

The concept of the value of time is indicated in Figure 1. Note that smaller but earlier gains are obtained when the orchard is established with parents chosen only on their appearance than when the parental genetic quality is known. These gains will increase as progeny test data are obtained, and rogueing is done in the seed orchard. If the testing properly designed, the genetic gain from both types of programs will be about the same following progeny assessment. In programs in which there are small pressures for immediate planting on a large scale, the prospective parents should be tested with respect to their genetic worth before the production orchards are established.

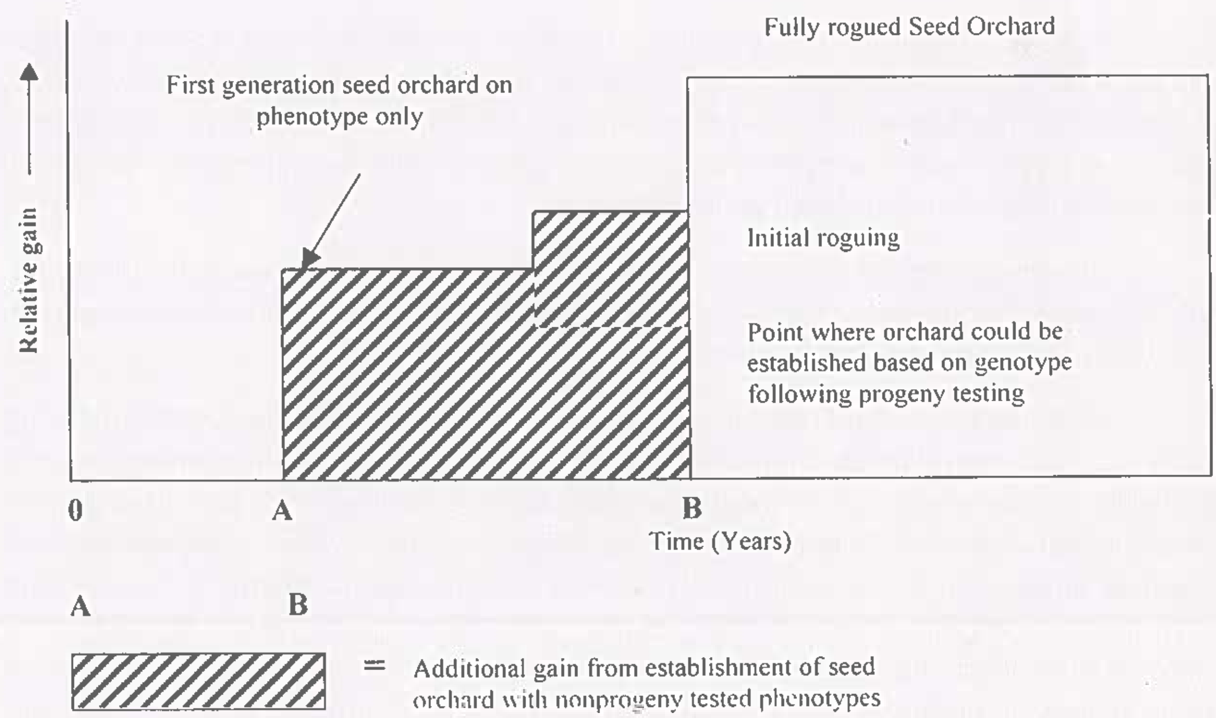


Figure-1

Time is all important in an operational tree improvement program associated with a large planting program. Shortcuts, such as establishing untested phenotypes in the seed orchard, may be taken to give early gains (AS) These are an addition to greater gains that are obtained after progeny test data are available immediate planting on a large scale, the prospective parents should be tested with respect to their genetic worth before the production orchards are established.

A current major feature of tree improvement programs is to produce the same amount and quality of production in less time at a reasonable cost rather than to produce more at a given time. This objective of reducing time to harvest is now of prime importance in many tree improvement programs, and it will result in large monetary gains to the forest manager.

BREEDING OBJECTIVES :

The tree improver can capture more of the genetic variation that is present in a population by suitable manipulation of the environment. The tree improver's best tool to increase gains is to use the existing variation to its fullest and to help develop additional variability when needed.

In order to obtain the best possible gains from tree improvement, it is necessary to understand the nature of wild populations, how they have developed, and how their variability can be used. The important item to remember is that forest trees are mostly wild populations that are not yet greatly changed by the action of people. This gives the tree improver an outstanding opportunity to make improvements.

The differences within and among wild tree populations have developed naturally. With proper management, intensity of selection, and suitable breeding systems people can bring about desired changes very rapidly.

Methods that can be used to change trees and the realized improvement arising from them vary with different characteristics. Because of the nature of the genetic patterns that influence the inheritance for most characteristics of forest trees, only part of the genetic variation that exists within a population can be utilised, especially when' regeneration using seed is employed. Thus progenies obtained for operational planting from a tree improvement program are only partially as good on the average as the combination of the parents from which they came. When vegetative propagation is feasible, gains that are realized may be greater, but even then, some of the desired parental characteristics are not obtained in the progenies because of the interaction of genotypes with the environment. The practical approach is to come as close to the ideal as possible with a reasonable and justifiable expenditure of time and energy.

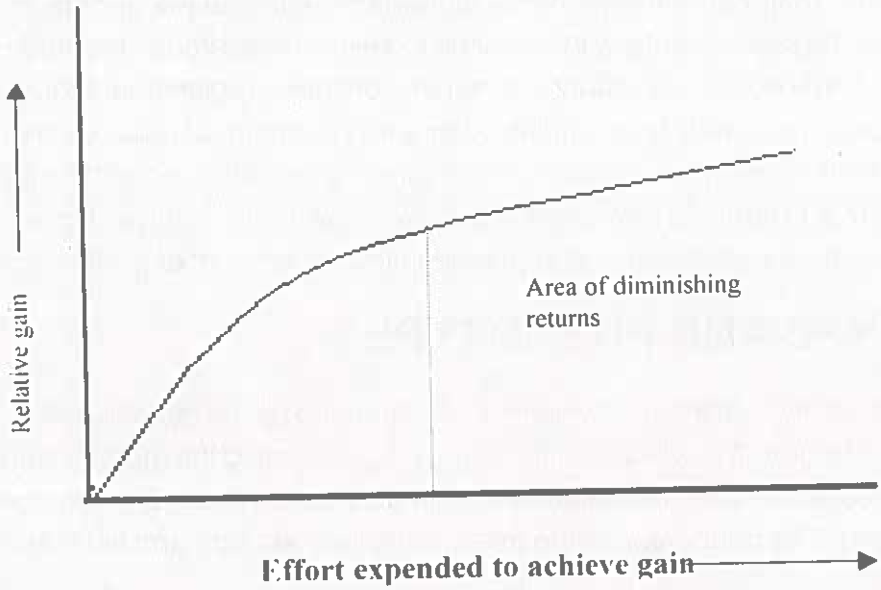


FIGURE 2

The law of diminishing returns is fundamental in tree improvement. As one gets closer and closer to the ideal, the cost and effort becomes greater for each added unit of gain. There comes the time when breeding for additional gains is not warranted by the time and effort involved.

The most important and exciting part of tree improvement is that it is usually possible to breed for improved economic characteristics while at the same time to maintain or broaden the genetic base for adaptability and pest resistance. This is also true for changing product requirements. This is possible because very few of the important characteristics of forest trees are strongly correlated genetically. For example, one can develop disease resistance in either straight trees or crooked trees. Drought-resistant trees can have high-or-low specific-gravity wood.

ADVANTAGES AND LIMITATIONS OF TREE IMPROVEMENT :

One major advantage, of genetic improvements in forest trees is that once a change is obtained, it can be kept over a number of generations. This quality of the "permanence" of genetic improvements over several rotations makes them very appealing economically, even though the initial cost of developing desired trees may be considerable. The advantage will be somewhat reduced when environments, pests, or markets change, so that the genetic material is no longer suitable.

Another major advantage of tree management Is that the genetic material that is developed can be kept essentially intact for an indefinite time through methods of vegetative propagation. Many out crossing annuals require continued replacement through producing new seeds because seeds lose viability after a few years in storage. Every new crop will differ somewhat from that of the parents because of genetic re-combinations. Also, the cost and effort of producing new seed crops every few years is large. However, for forest trees, the desired genotype can be kept indefinitely in the form of grafts or cuttings.

GENOTYPE AND PHENOTYPE :

The phenotype is the tree we see. It Is influenced by the genetic potential of the tree and by the environment in which the tree is growing, including the managerial history of the site. The phenotype is often Indicated by the simple formula P=G+E (phenotype=genotype + environment). The phenotype of the tree is what we measure and what we work with.

The genotype is the genetic potential of the tree. It cannot be seen directly, and it can only be determined through well-designed tests. The genotype is determined by the genes that reside in chromosomes in the nucleus of every cell in the tree. The sum total of non-genetic factors that affect the growth and reproduction of trees is called the environment. It is a very general term and includes the influence of soils, moisture, weather, and often also the Influence of pests and sometimes to the Interference of people.

The basic fact is that one cannot say anything definite about the genetic worth of a tree just by looking at it, that Is, from its phenotype. One is never sure whether the characteristics observed are primarily determined by the environment in which the tree is growing or by the genetic control from the genotype of the tree. Both will interact to affect the tree's phenotype. The objective of the tree improver is to package the better genes into improved genotypes and then to manipulate the environment so that this genotype will react in a positive way to produce the most desirable phenotype.

If we can say nothing definite about the genetics of a tree from its phenotype, how then does one proceed to determine genetic superiority in a tree Improvement program? Because the genotype is a component of the phenotype, It Is related to the genetic potential of the tree; therefore, If good phenotypes are selected, Improved genotypes will often result. Once the general relationship between the phenotype and genotype Is known, it will then be possible to make some assumptions about the genetic value of a tree, just from observing its phenotype. For example, since it is known that the straightness of the tree (phenotype) and its genetic potential for straightness are correlated, the predictions can be made with some confidence that straighter trees will be obtained if straight trees are used as parents.

STARTING A TREE IMPROVEMENT PROGRAM :

The basic requirement for starting a tree improvement program is to determine whether or not one Is really needed. Planning requires projection into the future as well as an estimation of current needs. In addition to the biological factors, assessments of the need for a potential tree improvement program require estimates of future markets, economic climates, utilization practices, and political conditions

The following basic principles must be Incorporated if a tree improvement program is to be successful.

1. What is the objective? The products needed and the urgency to produce them must be determined. Will solid-wood products be a major part of the forest production or are fibre products the primary end goal? Will forest uses such as energy or chemicals from wood be of primary concern? Answers to these questions will determine the species or seed sources as well as the emphasis and methodology best suited for the program. The most serious error made in starting a tree improvement program is to organize and to become committed to specific goals before the objectives of the program have been determined.

2. What basic biological facts are needed? The biology of certain species Is so poorly known that intensive studies are required before a program can proceed. Such simple things as how to collect and store seed and pollen, how to grow seedlings in the nursery, and how to outplant the trees and care for the plantations must sometimes be determined. This need Is especially critical for the lesser known tropical species. Foresters in the tropics often choose to work with pines and eucalyptus because they know the silviculture of those species, whereas such information is often lacking for the indigenous species. Very large programs have proven to be unsuccessful because the basic information about how to grow seedlings in the nursery or how best to establish and care for plantations was not known: therefore, all the potential advantage from a tree improvement program could not be realized.

3. Always have at least one secondary species or source along with the primary one. The secondary species or sources should be sufficiently tested so they can be used in the event that something unforeseen happens to the primary species and source. At least some commercial plantings should be made with secondary species or sources to provide the necessary experience about how to grow them and the opportunity to develop the needed land races if catastrophe should strike to the primary species.

4. Establish the necessary seed production capacity (or facilities for vegetative propagation) in seed orchards or clonal "nurseries". Selecting and breeding the genetically improved material is only a first step; it must be possible to produce the improved trees in mass quantities at a reasonable cost.
5. Do the testing necessary for the determination of the genetic worth of the selected trees and to form a base for long term, advanced-generation improvement. Tests should be made in an area and under conditions that are typical of those used for commercial planting; there should be progeny tests to determine the value of the parents and genetic tests to develop populations that can be used for advanced-generation breeding. Accomplishing both objectives simultaneously is possible only with considerable planning.
6. The tree improvement program must have both an operational (applied) and developmental (research) function. For a successful tree improvement program, the operational phases must be associated with the equally important developmental phases so that long-term as well as short-germ objectives are required if a program is to be successful. It is easy to become so involved in the day to day chores of conducting an operational tree improvement program that new ideas are not pursued or that a reassessment is not made of the current operational program. New possibilities and technologies need to be explored.
7. Make certain that there is sufficient commitment to support and finance the project over the long term, with capable people to carry on the program so that its objectives can be fulfilled.
8. Combine breeding for improvement economic characteristics with breeding for broad genetic base for adaptability and to develop trees suitable for new products. Because most economically important traits are usually genetically Independent, it is possible to develop them simultaneously. One of the greatest needs in forestry is to have trees that will grow on marginal sites. The genetic base that is necessary to develop trees for shorter rotations and wood for non-conventional products such as energy or chemicals must also maintained.

METHODS TO BE USED :

Has it been tried before? If it has, making a decision is simple. Existing programs should be studied and analysed, always with the question in mind, "will It work for us ? The tendency to copy ongoing successful programs without analysing the parts can result in costly failures. A small tree improvement program cannot operate in the same way as a large one; therefore, methodologies must often be altered. In large programs, such as one established through a co-operative, partial results can be obtained by each member and pooled for the benefit of all., An organization with a small program has to be more self sufficient and have a broader testing and crossing program than does each individual member of co-operative.

"What are the advantages and problems of the proposed program?" Some program approaches should be automatically rejected as being too expensive or too difficult for the objectives and resources available. A programme must be suitable biologically, or it will not result in optimal returns. No program is perfect, but the. pros and cons must be considered before a decision is made. The decision with respect to the best program must take into consideration both the long term and short term criteria. Shortcut analyses of program alternatives can be dangerous and misleading. In the final analysis, the program must be viewed with respect to what is essential, and the other factors should be given a lower priority or deleted.

Should a new method be used?" New and sometimes quite different ideas are constantly being proposed for development of tree improvement programs. Those that sound promising in theory must be evaluated for operational conditions. New methods sometimes are based on the concept of quick returns combined with minimal costs; they may even be a version of get-rich-quick schemes. New ideas should never be rejected until well-designed and well-executed studies have shown their true worth. However, a full fledged program should never be developed on theoretical or unproven methods. Always make the intended program flexible enough so that new ideas can be incorporated into with no interruption of the ongoing work.

Accelerated breeding plans should be incorporated into all tree improvement programs. A quick turnover of generations is very Important m obtaining genetic gain through a breeding program. The objective is not to see how much total gain can be obtained per generation but how much gain can be achieved per unit of time. Although the total gain from the conventional and accelerated programs may be the same, obtaining the gain several years earlier results in planting improved trees that would not have been available otherwise during the interim period while a conventional program was being developed.

One must estimate future methodologies, such as vegetative propagation, and include the ability to Incorporate new methods into the program so that advantage can be taken of advancements. In addition, the following must all be considered: changes related to non-conventional forest products, how much uniformity will be needed, how much will quality needs change with improved technology, and how important will coppice regeneration become.

THE CO-OPERATIVE APPROACH :

Tree improvement requires a large expenditure of effort and money, trained people, and suitable facilities. Because of this, it is usually not economical to undertake tree Improvement on a small scale. It is an activity that is best suited for forest departments to undertake, especially in situations where the forestland base is extensive enough to obtain a good pay back. This restriction does not mean that smaller organizations cannot share in Its benefits. The way to obtain more general application of tree improvement is to establish co-operatives. Tree improvement is well suited to a co-operative effort in which the members share costs and returns as well as equipment, plant material and information.

A co-operative effort becomes especially valuable when advanced generations are developed. A few trained professionals with proper technical support can direct a very large program. Each member cannot afford its own specialists, but it can share them by means of a co-operative. There are many rules and methods necessary to make a co-operative successful. A few of the more important ones have been outlined as follows:

1. Enthusiasm Is needed. The supporters must be told on the need and value of a tree Improvement program. Half hearted support will doom co-operative.

2. All members must make a full commitment. Nothing will ruin a co-operative quicker than having a member or members who fail to give their share fully. This includes not only financial support but also technical support and action in field operations. A minimum contribution of time and action is expected from each member. Also every member must make a contribution that is a value to the other members.

3. Development and tests of Improved materials should be on the lands of the co-operators. Contributions of money are not enough. Each member must feel that "this is my opinion". There must be pride in what the co-operative achieves, both for the overall membership and for each member. Without such pride, a co-operative will not be effective nor will it survive.

4. Information and ideas must be fully exchanged among members; a proprietary attitude cannot prevail. Exchanges should take place in written reports but also in meetings within the co-operative in which members can compare ideas and see what others are doing. In forest biology, it is not the obtaining of information that will give an orgnization an economic advantage; rather, it is the using of available knowledge that enables on organisation to forge ahead of another.

5. The membership has common objectives for all members, although there many be specific ones for individual members. For example, developing seed orchards is a common objective, whereas developing a strain of trees that is especially adaptable to an unusual adverse environment may be of interest to only one or to a few of the members.

6. Strong leadership is needed to bring the members together and to keep them all headed in the same direction. This cannot be over emphasised. A co-operative will fail unless it has as its head a person who is respected by the members, one they will follow to get the job done, and one who has the authority to get necessary

action. Such a director needs to have rather broad decision making powers. There should be responsibility to a membership, but the director is the one who has the authority over the operation of the co-operative and who directs action to achieve its objectives. Occasionally, co-operatives have been administered by committee, but this system often is less than successful.

7. Each member should have equal authority and responsibility and receive equal benefits. Co-operatives in which the larger organisations pay more and thus also have more Influence frequently develop political problems. The co-operative must be large enough to Justify its activities economically; this is also true for the operations of each member. It is important that each potential new member be carefully assessed to determine his or her sincere Interest, commitment, and ability to make the need contribution to the co-operative before he or she is accepted into It.

8. Both short and long term objectives are needed. No matter what the attitude is at the beginning of a program, there always comes a time within a few years when the question will be asked, "What are we getting for our money", The program must be so designed that a continuous feed back of results to the program supporters is possible so that they can see the worth of effort. Some short-term projects serve this purpose well.

9. Good communication is necessary. This is achieved by using the "language" that the programme supporters understand. Highly scientific or complex reporting of results to co-operative administrators is self defeating .One can not teach the supporters a new "language", the co-operative staff and associated scientists must learn method of expressions, that is best understood by the administrators and present results in such a way that they are understandable to the administrators. This Is particularly necessary with respect to the people who control finance.

10. The terms basic or fundable research are often viewed unfavourably by forestry administrators. Yet, both types of studies are needed if programs are to be efficient and continue to make progress. Use of the word 'supportive' research rather than basic research has been most successful in enabling the administrators to appreciate the need for basic studies and accept them in the applied programme.

The success of the co-operatives that are already established in several countries on several continents has been outstanding. Most applied tree improvement programmes would just now be in the establishment phases if co-operatives had not been organized and functioning at the time when the need for tree improvement was recognized.

TYPES OF GENETIC VARIATION

Variation in tree populations can be partitioned into genetic and environmental components. The simple model described previously for individual tree values can be extended to apply to variation encountered in a population of Individuals. If an individual phenotype is described as.

$$P = G + E$$

Then variation can be stated as

Phenotypic variation = genetic variation + environmental variation.

$$\text{or } d^2P = d^2G + d^2E$$

Genetic values ($\bullet^2G$) are influenced by both additive and non additive effects. Genetic variation can therefore be partitioned into additive and non-additive components. Symbolically

$$d^2G = d^2A + d^2NA$$

The model phenotypic variation can therefore be extended to read.

$$d^2P = d^2A + d^2A + d^2E$$

The additive genetic variance (d^2A) arises from differences among parents in general combining ability and is simply the variance of breeding values (breeding value = 2 GCA) in the population. Non additive variance (d^2NA) is the result of specific combining ability effects. The variance of specific combining abilities in a non-inbred population can be shown equal to $1/40^2_{NA}$

Most tree improvement programs are aimed at selecting parents with high general combining abilities or high breeding values. In these instances, the additive variance is the "type" of genetic variation that is utilized to produce improved propagules. Successful use of non-additive variance depends upon vegetative propagation or using specific crosses.

HERITABILITY :

The concept of heritability is one of the most important and most used in quantitative genetics. Heritability values express the proportion of variation in the population that is attributable to genetic differences among Individuals. It is therefore a ratio indicating the degree to which parents pass on their characteristic to their offspring. Heritability is of key importance in estimating gains that can be obtained from selection programs. The discussion here will focus on individual tree hertiability.

Two types of individual tree heritabilities are important in applied tree improvement. Broad sense heritability (H^2) is defined as the ratio of total genetic variation in a population to the phenotypic variation, or

$$H^2 = \frac{d^2G}{d^2P} = \frac{d^2A + d^2NA}{d^2A + d^2NA + d^2E}$$

Broad sense hertiability can range from 0 to 1. A lower limit of 0 would occur if none of the variation in a population was attributable to genetics. If all variation was due to genetics, then broad sense heritability would be equal to 1. Broad sense heritability has a limited application in tree improvement. And is of primary use when both the additive and non-additive variation can be transferred from parent to offspring, such as when vegetative propagation is used.

Narrow sense heritability is the ratio of additive genetic variance to total variance. Symbolically,

$$h^2 = \frac{d^2A}{d^2P} = \frac{d^2A}{d^2A + d^2NA + d^2E}$$

The lower limit for narrow sense hefitability is also 0 (no additive variance), and the upper limit is 1 (non environmental or non-additive variance). Narrow- sense heritability is never greater than broad sense heritability; if all the genetic variance is of the additive type, narrow and broad sense heritabilities are equal. Most heritability estimates given in the forest genetics literature are for narrow sense heritability, because most tree improvement programs today are aimed at improving general combining ability and thus utilize only the additive portion of the genetic variance. This will undoubtedly change as vegetative propagation methods and economical methods of producing specific crosses, such as supplemental mass pollination, become available, but as of today, narrow sense heritabilities are of the most use to tree breeders.

An important but often overlooked aspect of heritability estimates is that they apply only to a particular population growing in a particular environment at a particular point in time. For example, estimates of heritability for a group of trees grown in a green house would not be appropriate for the same trees growing in a field environment. Height in the green house may not be influenced by exactly the same genes as height in the field. Even if the two traits were the same, though estimates of h^2 obtained in the green house will usually be higher than those from the field, because there is less environmental variation in the green house. As can be seen in the formula for h^2, changes in the environmental variance component ($\bullet^2$) in the denominator will have a effect on the h^2 ratio. Because of the influence of the environment on the heritability ratio, the h^2 estimates for a given characteristic in a species in one geographic area probably will not be the same as those found in another region. The heitability values of a given characteristic in a population often change with age when the environment changes and when the genetic control of the characteristic, changes as the trees mature. The degree of change with age has been debated, but there is now an accumulating body of evidence that suggests that heritabilities do change markedly, and perhaps in a predictable fashion, as test plantations grow and develop.

The most widely used technique in forest genetics to estimate heritability is to grow progeny from group of parents or crosses together in the same generic test plantation. Heritability estimates are then derived from the relative performance of the progenies, within and between parent trees. Another method of estimating heritabilities is through parent offspring regression techniques.

The basic and key point about heritability is that it is a ratio between genetic and phenotypic variances; thus, it is not a fixed value for a given characteristic of given species. Estimates of heritability are not estimated without error; therefore the ratios obtained are only a relative indication of genetic control and should not be interpreted as absolute or invarient values.

QUANTITATIVE GENETICS AND SELECTION :

INTRODUCTION :

The primary objective of an applied tree improvement program to is change the frequency of desired alleles that influence important tree characteristics in such a way that the improved plants are superior in performance to unimproved material. The way of accomplishing this Is through the process of selection, which can be defined as "choosing individuals with desired qualities to serve as parents for the next generation". Although selection can be a major tool for studying the way traits are inherited, in applied tree improvement programs selection is primarily used for the Improvement of economically important characteristics.

If selection is to be effective, there must be a genetic variation in the population. As shown before, for most tree improvement activities it is the additive portion of the genetic variation that is readily usable for manipulation by the tree breeder. Selection that is based on utilization of the additive variance works by increasing the frequencies of favourable alleles. The additive effects of these alleles are observed in the improved performance of progeny produced by the breeding program or in seed orchards.

The practice of selection in tree improvement is both a science and an artistic skill that must be developed by the tree improver. The following paragraphs will introduce the genetic principles associated with selection activities.

SELECTION AND GENETIC GAIN :

Selection is based upon the principle that the average genetic value of selected individuals will be better than the average value of individuals in the population as a whole. For metric or quantitative traits, gain from selection is usually measured as a change in the population mean. The improvement that can potentially be made from selection for a characteristic is a function of the heritability of the trait, and the variation for the trait that exists in the population.

The importance of heritability in determining the response to selection was stressed earlier. A higher heritability indicates that much of the variation for a given characteristic observed in the population is genetic in origin, and that the breeder has a high probability to choose parents that are good genetically by selecting those that have desirable phenotypes.

The total amount of variation for a trait is equally as important as heritability in determining gain that can be made from selection, but it is often overlooked by persons involved in tree improvement activities. The total, or phenotypic, variation is important because of its influence on the selection differential. Symbolized by S, selection differential is defined as " the average phenotype value of the selected individuals, expressed as a deviation from the population mean". If there is much phenotypic variation for a given characteristic, then the selection differential can be large, whereas if the total variation is minimal, then the selection differential must be small.

The selection differential, or S, is the difference between the mean of the selected individuals (Xs) and the population mean (X). Symbolically.

$\underline{X} \quad {}^{s}\underline{X} = S$

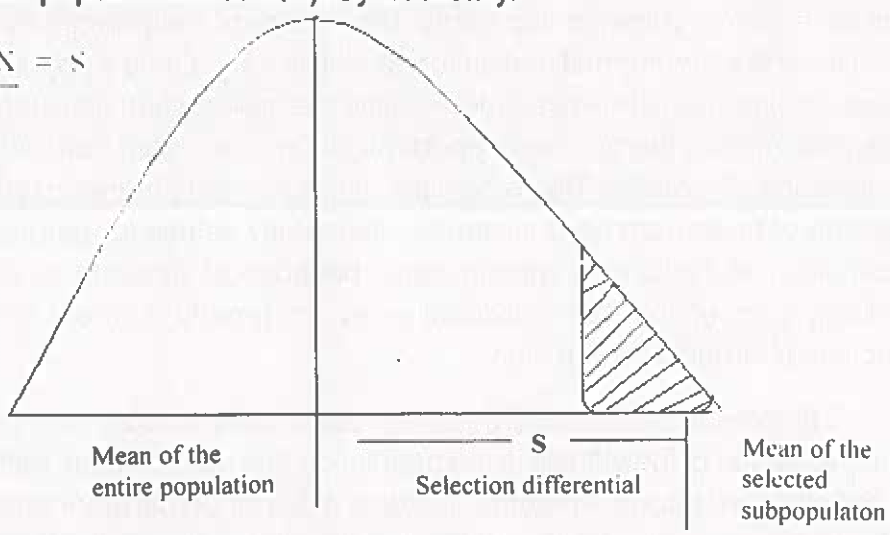


Figure - 3

The selection differential is indicated as the difference between the mean of the entire population and the mean of the selected subpopulation.

When Individuals are selected based only on their phenotypic values without information on relatives, response to selection can be estimated by the following formula

Genetic gain = narrow sense heritability X selection differential

Or

$$G = h^2S$$

From the preceding formula, it is obvious that the progenies from selected parents can be no better than the mean of the selected parents and are usually much less. There are two reasons for this.

1. Usually, only a portion of the superiority of selected parents Is due to genetics. The remainder is due to the environment. Superiority caused by environment cannot be passed on from parent to offspring. For example, a selected parent may have been superior to its neighbours because it was growing in a slightly better microhabitat.
2. In population improvement programs where many selected parents are mated together, only the additive genetic variance can be utilised. This is the reason why the narrow-sense heritablity is utilized in the preceding equation. Even if all the variation observed was genetic in origin (no environmental variance), gain would be equal to selection differential only if all the variation was additive and none was of the non additive type; that is $h^2 = 1$.

The tree breeder can influence gain from selection In essentially two ways. First, the base population can be managed so as to maximise heritability by the use of uniform sites and control of the environment. This Is one of the primary factors involved in site selection and experimental design for genetic testing. Once a population is established in a given environment, however, there is little the breeder can do to increase heritability. As a practical matter, the greatest opportunity to Improve gain from selection is to Increase the selection differential. This is how tree improvement programs have obtained gains by selection of trees from natural stands. Heritability values for natural stands of trees are usually low, especially for growth traits, because of extreme environmental variation, including competition, but individual trees are greatly different from one another and selection differential can be high.

The selection differential that the breeder uses is dependent upon two factors. One is the proportion of individuals in the population that are selected; that Is, the Intensity with which selection is done. The other factor is the phenotypic standard deviation, which, as we have seen, is a description of the variation in the population and is expressed in the same units as the population mean. Many breeders prefer to express response to selection or gain by the formula.

$G = ih^2 \bullet p$

Where

i	=	intensity of selection
h2	=	heritability
• P	=	phenotypic standard deviation

This formula indicates that both selection intensity and phenotypic variation influence gains that can be made.

A comparison of the two formulas for selection response shows that

$$G = h^2 S = ih^2 \bullet p$$

$$\bullet s = i \bullet p, \text{ and } i = S/\bullet p$$

The selection intensity, or i measure how many standard deviations the mean of the individuals that were selected exceeds the mean of the base population. For example, a selection differential (S) of 10 indicates that the mean of the selected population is 10 units better than the mean of the whole population. If the phenotypic standard deviation (•P) is equal to 5, then i=S/• p = 2, and the mean of the selected population is two phenotypic standard deviations better than the mean of the whole population. Because of the characteristics of the normal distribution, the equation $G = ih\bullet^2 P$ is a convenient way to calculate genetic gain. If the breeder knows the phenotypic standard deviation and the intended selection intensity, a response to selection can be predicted before selections are even made. Alternatively, selection intensity can be varied to determine how many individuals must be chosen to obtain a certain desired gain. Selection intensity related to the proportion of individuals in the population that are selected. If the proportion is known, it can be calculated directly from that value. Calculation of selection intensity involves a more in depth knowledge of statistics.

In summary, response to selection for a given trait is determined by two factors the heritability of the trait and the selection differential that is used. The tree improvement specialist must manage his or her population in such a way that both of these are large enough to give a useful gain from selection.

Selection Methods :

There are several different selection methods available to the breeder, depending upon the types of information available.

Approximate Selection Intensities (i) for Populations of Various Sizes and Proportions Selected

Proportion Selected	*Population Size*				
	20	50	200	200	Infinite
0.01	-	-	2.51	2.58	2.66
0.05	1.80	1.99	2.02	2.04	2.06
0.10	1.64	1.70	1.73	1.74	1.76
0.20	1.33	1.37	1.39	1.39	1.40
0.30	1.11	1.142	1.15	1.15	1.16
0.40	0.93	0.95	0.96	0.96	0.97
0.50	0.77	0.79	0.79	0.79	0.80
0.60	0.62	0.63	0.64	0.64	0.64
0.70	0.48	0.49	0.49	0.50	0.50
0.80	0.33	0.34	0.35	0.35	0.35
0.90	0.18	0.19	0.19	0.19	0.20

Note: For a given proportion selected, selection intensity increases with population size.

Mass Selection: Mass selection involves choosing individuals solely on the basis of their phenotypes, without regard to any information about performance of ancestors, siblings, offspring, or other relatives. Mass selection works best for highly heritable traits, where the phenotype is a good reflection of the genotype. It Is the only type of selection that can be used in natural stands or in plantations where tree parentage is unknown. Mass selection is rarely used when pedigrees are known, as in advanced-generation genetic tests, because more gain can be obtained using other methods. The terms mass selection and individual selection are genetically used synonymously.

Family Selection : Family selection involves the choice of entire families on the basis of their average phenotypic values. There Is no selection of individuals within families, and individuals tree values are used only to compute family means. Family selection works best with traits of low heritability, where individual phenotypes are not a good reflection of genotypes. When family averages are based upon large numbers of Individuals, environmental variance tends to be reduced, and family averages become good estimates of average genetic values. Family selection by itself is rarely used in forestry, even with traits of low heritability because more gain can be obtained from other methods that include family selection as a part of the method. Family selection may also lead to Increased rates of Inbreeding because entire families are discarded, thus reducing the genetic base of the population.

Sib selection : This is a form of selection in which individuals are chosen on the basis of the performance of their siblings and not on their own performance. When family sizes are large, it is very similar to family selection. Sib selection is rarely used in forestry but may be applicable when destructive sampling must be used to make measurements, and it is not feasible to preserve genotypes by grafting or other techniques before sampling begins.

Progeny Testing: Progeny testing involves selection of parent trees based upon the performance of their progeny. It can be a very precise selection method, because it allows direct estimation of breeding values to use in the selection process. This is what occurs when parents from a seed orchard are progeny tested, and orchards are then rouged of parents that prove to be poor genetically. Progeny testing is not generally the initial form of selection for most breeding programs. Initial selection by progeny testing considerably lengthens the generation interval, which means a critical loss In time.

Within-Family Selection : Here individuals are chosen on the basis of the deviation from the family mean, and family values per se are given no weight when selections are made. Of all the selections methods, this one gives rise to the slow rate of inbreeding, which Is a major problem in most programs. In practice, family selection is rarely used in tree improvement because large increments of gain are obtained from selection on family selection on family values. Thus, the family and within-family methods are almost always combined.

Family Plus Within-Family Selection : This two stage method Involves selection on families followed by selection of individuals within families. It works well with low heritabilities, and is a predominant form of selection used in most advanced generation tree improvement programs. It consists of choosing the best family along with the best individuals in them. A refinement of this method is combined selection where an index is computed that rates all individuals based upon the family value combined with their individual phenotypic values. Coefficients of weights used in the index equation depend upon the heritability of the trait with more weight given to the family average for traits with low heritabilities, and with more weight given to the individual when heritability of the trait is high.

SELECTION FOR SEVERAL TRAITS :

Most tree improvement programs are geared toward the improvement of several traits at the same time. This requires that information developed on several characteristics be included in the selection procedure. How best to do this is one of the major areas of research in tree improvement today. Any of the methods discussed previously could be utilised to develop information on individual traits, but that information must be manipulated to develop a multitrait selection scheme. Essentially three systems have been developed that pertain to multitraits selection.

Tandem selection: When tandem selection is used, breeding is for one trait at a time until a desired level of improvement is made for that trait. After the desired improvement has been obtained in the first, and usually most important, trait (this may take more than one generation), selection and breeding efforts are then concentrated on other traits. This method of improving several traits in tandem is rarely used because of the pressure of time and the need to improve several traits simultaneously. The primary use of tandem selection is when one trait is of over riding importance, such as disease resistance.

Independent Culling : Independent culling is a method of multitrait selection that involves setting minimum values for each trait of interest. Individuals must this meet minimum criteria if they are to be retained. Independent culling is shown graphically in Figure. It is a very widely used form of multitrait selection in forest tree improvement.

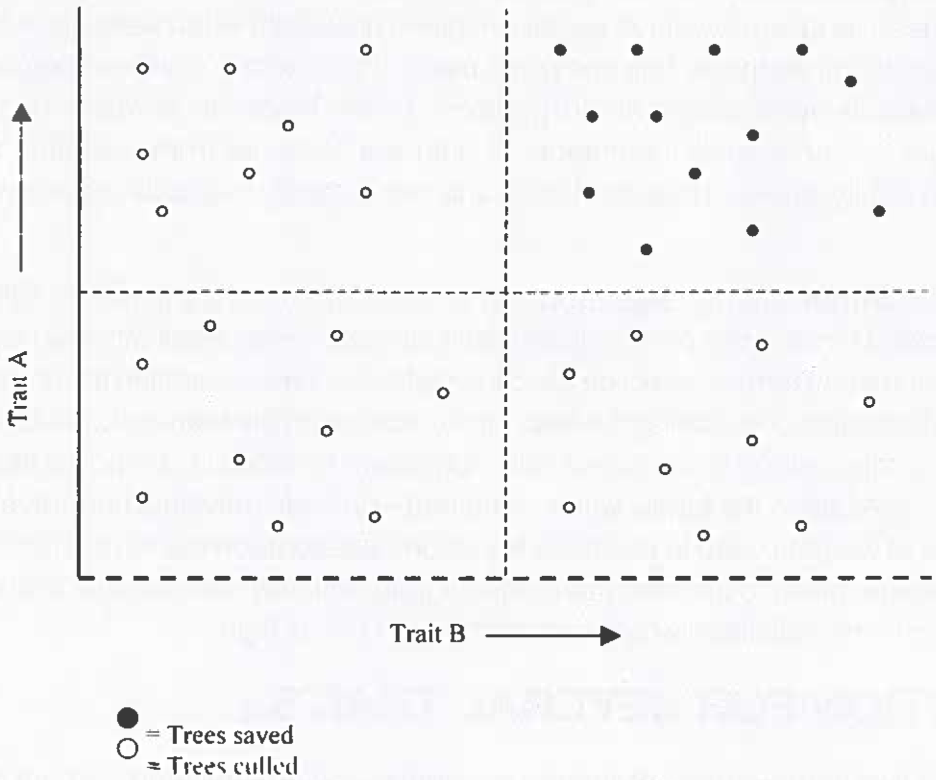


Figure 4

The independent culling method of selection is illustrated as it would be applied for two traits. Only those individuals that meet minimum standards for both traits are saved.

Selection Index : The selection index is a form of multitrait selection that combines information on all traits of interest Into a single index. This enables the breeder to assign a total score to each individual. In addition to genetic information, it attaches economic weight to each of the characteristics under consideration. In its most complete and complex form, a selection index combines family plus individual information for all traits into cone idex. Index values for Individuals are derived through a multiple regression equation in which the coefficients depend on the heritabilities, the correlation among traits, and the economic weights of each trait. Theoretically, the selection index method of multitrait selection can be shown to give the greatest total genetic gain for all traits combined. A major problem, however, is to have or to determine the appropriate economic weights. Derivation of the correct economic weights is still a major stumbling block to a more widespread application of this most useful form of multitrait selection in forest tree improvement. Use of selection indexes where economic weights are grossly incorrect can lead to very Inefficient selection programs.

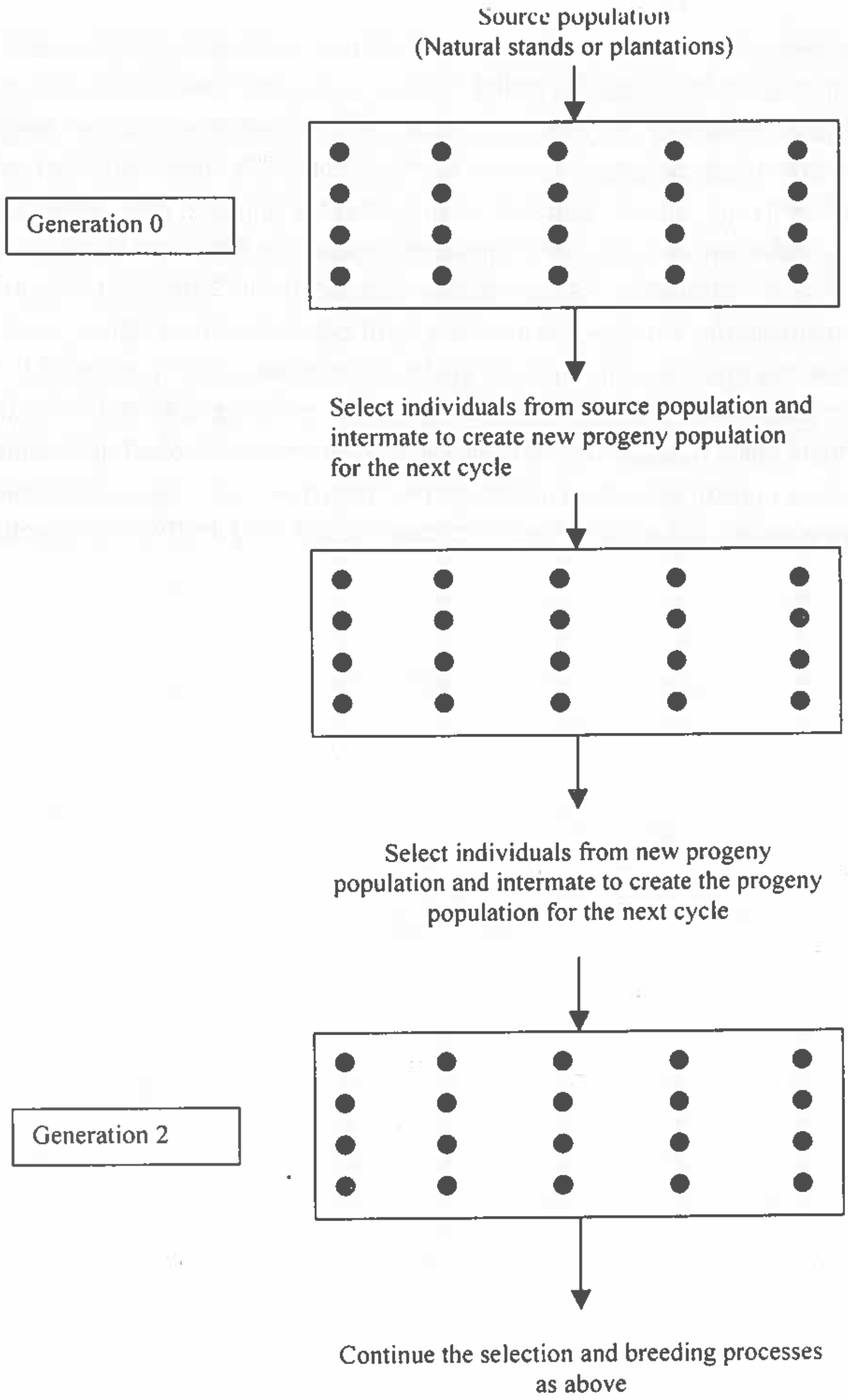


figure 5

Illustrated is simple recurrent selection that forms the basis for many tree improvement programs. A successful recurrent selection system will result in genetic gain for many generations of improvement.

RECURRENT SELECTION :

Most tree improvement programs are designed to provide continued gain through each of many cycles of improvement. The selection methods discussed before have centred on improvement that can be obtained in one generation, but they are also applicable to programs that Involve many generations. The selection procedure that involves many cycles of selection and breeding is known as recurrent selection. A number of recurrent selection schemes have been devised by plant and animal breeders in order to utilize variation in general combining ability, and, in some cases, specific combining ability. The system most often used in forest tree improvement is known as simple recurrent selection, which is shown diagramatically in Figure. With this system improvement programs begin by selecting trees in natural stands or in unimproved plantations based upon their phenotypic values. Selected trees are then mated, and their progenies are established in such a way that they can be used as a source of selection for the second generation of improvement. In most instances, second-generation selections are made on the basis of family and individual values. These selections are then mated, creating a new progeny generation that can be used as a source of selections for the next generation. The system Is one that repeats Itself. Selections are made in a base population, mated in some fashion, and the resultant progenies serve as a population for the next generation of improvement.

For now, it Is important for the reader to realize that when many cycles of improvement are envisioned, extreme care must be taken at the outset of the program to ensure that genetic resources are available to make the recurrent selection program successful. The tree improver must have the following two goals in mind when beginning an applied tree improvement program.

1. Obtaining as much gain as possible as quickly as possible through selection and production of improved seed.
2. Maintaining a genetic base that is large and diverse enough to allow successful improvement programs to continue for many generations.

SELECTION IN NATURAL STANDS AND UNIMPROVED PLANTATIONS :

The objective of a selection program is to obtain significant amounts of genetic gain as quickly and Inexpensively as possible, while at the same time maintaining broad genetic base to ensure future gains. All methods of selection in an applied tree improvement program are based on the same general principle; that is choose the most desirable individuals for use as parents in breeding and production programs. As was discussed in the previous chapter, the selection method that is used will depend on the information and plant materials that are available and on the goals of the program. The testing is done as soon as possible but is often still underway when the first use is made of the improved material.

Selection is a key part of all applied tree improvement programs. The gains can be no greater than the quality of the parents used, and the way to obtain the best parents is through intensive selection. Selection costs may appear to be large, but they generally account for a minor part of the total costs of tree improvement. Estimates from various programs range from 5% to 11% to 30%. Selection is normally the first step in a tree improvement program and will determine how much gain will be obtained, both in the first and succeeding generations. Doing a poor job of selection to reduce initial costs certainly cannot be justified.

A number of selection methods are available to the tree improver. The one chosen for any particular program depends upon the types of genetic variations in the population, whether pedigree information exists, and the degree of urgency in establishing production seed orchards. Selection methods used for trees from stands where there is no pedigree information are almost always different than those from genetic tests where parentages are known.

The great variation within the important traits of most forest trees and their reasonably strong general combining ability allows a good chance for gain by selecting desired phenotypes. The best selections are then used in seed orchards, allowing favourable genic combinations to interact and produce progeny with a larger proportion of the desired characteristics. In most species, a considerable improvement in bole straightness, disease resistance, wood quality, and adaptability to adverse environments or tolerance to pests can be rapidly obtained by selecting and allowing cross-fertilization among the very best trees.

Of the several methods available to make gains quickly and inexpensively in a beginning tree improvement program, individual (mass) selection of trees is the most used and is generally the most satisfactory. It Is widely applied in the initial stages of tree improvement programs and is suitable for many species. Occasionally, where there is little urgency for production of improved propagules for reforestation, and when time permits establishment of genetic tests, such methods as progeny test selection or family and within family selection may be used to establish initial seed orchards. Because of its overwhelming importance in most beginning tree improvement programs, mass selection assumes significance in tree improvement programmes.

WHEN SHOULD INDIVIDUAL SELECTION BE USED :

Individual or mass selection works best for those characteristics that have a high narrow-sense heritability. Obviously, it Is the only method that can be used to select trees in stands where pedigree are unknown. To be most successful, mass selection should be used in stands that have a large proportion of good trees and that have not been subjected to logging operations in which the best trees have been removed. Examples of characteristics showing relatively high heritabilities are wood specific gravity, and most adaptability characteristics. Straightness of tree bole and disease resistance are intermediate, whereas for most characteristics related to growth , individual selection is less effective because of low heritability. For some characters with very low narrow-sense heritability Individual, selection may not be a suitable method to make gains.

Gain from an individual tree selection program can be indicated as G == heritability x selection differential, or $G=h^2 S$. Heritability is generally quite constant for a given characteristic at a given age in a given environment, and the tree breeder can not do much to improve it other than to create an environment that is more suitable for the tree to express its genetic potential. However, the selection differential can be manipulated (within limits) by the tree breeder by varying the intensity with which selection is applied. A major objective is to increase the selection differential that, in turn, increases genetic gain.

As selection intensity is increased, a point of diminishing returns is reached when gains become less per unit increase in selection intensity. However, the Intensity of selections used in operational programs is usually less than optimal.

It is essential to reemphasise that an Individual selection program is based solely on the phenotype of the tree. For most characteristics, individual selection should be followed by progeny testing to determine If the selected trees is in fact genetically superior; this is especially true for traits with low heritabilities. Individual selection was very effective to the extent that the greatest value of the genetic tests was to serve as a source from which to select for advanced generations. For characteristics that have a high heritability and large amounts of variations, one can be sure that gains from a careful selection program will be reasonable. Although the trees could be straightened more by additional selection, the Increased economic value from this small improvement would be minimal; this enabled placing more emphasis on other characteristics.

SELECTING SUPERIOR TREES :

The techniques used in tree improvement to find and select superior trees depend on the types of stands in which selections are to be made. A determination of the best selection techniques depends on several factors, including species characteristics, past history, the present condition of the forest, variability and inheritance pattern of important characteristics, and objectives of the particular tree improvement program. There are two major kinds of forest stands, each of which require differing first-generation selection systems.

1. Even-aged wild stands or plantations from unimproved seed where the parentage of the trees is unknown.

2. Uneven-aged, scattered, or sprouting species where the parentage is not known. These include stands with species growing intermixed where check trees are not available.

SELECTING FROM EVEN-AGED STANDS :

Individual selection works best when good even-aged stands of the proper age are available. This allows efficient comparisons to be made among selected trees and checks. Individual tree selection is best in even aged natural stands composed primarily of one species or In plantations. This is by far the most common method of first-generation selection and has been applied world wide.

There are several advantages to selecting in even-aged stands rather than in uneven-aged or mixed stands when practising individual tree selection. First, the breeder can be sure that age will not differ greatly among trees, and that relative expressions of growth, form, disease tolerance, and adaptability will not be confounded with age effects. Second, trees are growing under competitive situations similar to those that will be encountered when improved trees are established in commercial plantations. Also, it is in these types of stands where the "comparison tree" system of selection can be used that trees considered for selection are graded against the best trees in the stand. All of these factors work to increase selection differential, and this results in greater gain.

Generally, plantations are preferable to natural stands in selection efforts if plantations of suitable seed source are available. In plantations, all trees are exactly the same age. In natural stands, even slight differences in age cause differential competition that can result in large differences in volume and form within the stand. It is known, for instance, that in densely stocked teak stands, a difference of one or two years in age among neighbouring trees will usually result in the younger tree's never becoming dominant or codominant trees in the stand. An additional advantage of selection in populations is that spacing among trees is more uniform. Competition is in essence an environmental force that affects the tree's phenotype. When competition is equalized, heritabilities are raised.

General guides for locating select individuals in even-aged natural stands and plantations follow., These guides have been very useful in choosing superior trees in first-generation tree improvement programs.

1. The search should be concentrated on stands and plantations that are average or better In growth, pruning, straightness, branch angle, and other characteristics of interest. An occasionally acceptable tree may be found in a poor stand but this is rare, and search efforts are more efficient when they are carried out in good stands. Outstanding stands of trees are sometimes referred to as *plus stands.*

2. Stands and plantations in which candidate trees are sought should be located on the same variety of sites where plantations from improved seed will ultimately be established. This is true unless there is evidence that sites have no effect on the performance of the genotype. If the majority of an organisation's landholding are on average sites, then the majority of selections should come from such sites. *There should never be a concentration of selections from the very highest site lands*, if the plantations are to be established on average or poor sites.

3. When selections are made from plantations, information about the suitability of the seed source used in the planting, should be obtained. Selections should not be made from stands planted with seeds from areas known to be poorly adapted to the area where planting will be done.

4. In older stands, the search efforts should be confined to trees that have an age range of no more than 10 to 15 years younger or older than the projected rotation age of the plantations that are to be established. For species that are harvested at an early age, the trees must be old enough to have shown their potential. In some eucalyptus as young as 3 years of age can be easily selected if very short rotations are used.

5. Selections should be made from stands that are as pure in species composition as possible. Differential growth rates among species can severely complicate selection through differential competition If the stand has a sizable component of two or more species.

6. Stands must be avoided that have been logged for poles or piling or that have been otherwise high graded or thinned from above. If the stand has been thinned from below, or if it has suffered fire damage, allow crown competition to be re-established before selections are made. Stands that are mechanically thinned or thinned in a truly silvicultural manner are suitable for an individual selection program.

7. The minimum size of a stand or plantation in which a candidate can be located is immaterial. If the stand is large enough to locate a good candidate tree and to allow choosing comparison trees, then it is large enough to search for select trees.

8. Preferably only one select tree should be accepted from any one small natural stand to reduce the possibility of obtaining candidate trees that are close relatives. This restriction does not apply to selecting in plantations.

9. Although it is highly desirable for candidate trees to exhibit a heavy flower or cone crop, these characteristics are generally not given much emphasis. This is

particularly true in young and dense stands where many trees show no sign of flowering because of insufficient light on their crowns to stimulate flower production. Usually, these will heavily in the seed orchard environment.

10. Once the decision has been made to look over an area for candidate trees, a thorough, systematic search should be made. Experience has shown that excellent trees are often missed when a stand is searched haphazardly. Experience has also shown that select trees are generally found only by people who are specifically looking for them. Although an occasionally acceptable tree Is located during routine woods work, this is the exception. The only efficient way to locate candidate trees is to be specifically on a selection mission.

11. A comparison or check tree selection system should be used when feasible. This helps to account for environmental differences within stands and permits more efficient and objective selection of superior trees.

SELECTION IN UNEVEN-AGED, MIXED SPECIES, OR STANDS OF SPROUT ORIGIN :

Forest stands are quite frequently not of types allowing use of the individual selection program that was just described for even-aged stands. There are several reasons for this: (1) stands may be truly uneven aged; (2) the desired species may be so scattered that comparison (check) trees are not available; (3) the species may be a vigorous sprouter and trees growing near the candidate tree can be on a common root system and have the same genotype; and (4) the stand is composed of mixed species.

The comparison tree system does not work when trees are growing in all-aged stands. Since growth curves within a species vary with age, it is not suitable to use ratios such as height or diameter growth per unit time for comparison purposes. In addition, the form of the tree often changes, drastically with age. Therefore, even quality characteristics cannot be compared among trees of different ages from uneven-aged stands. Many foresters make the mistake of assuming that stands containing trees of varied sizes, are all aged. The major exception to this generlization that forests are usually even-aged is when stands have been manipulated by humans into an all-aged condition by selective cutting. Even within the true uneven-aged stands, there is tendency for a storied age class to be present.

Trees sometimes grow in *mixed stands* with relatively few individuals of a given species found in a specific area. This condition is most common for hardwoods. A comparison tree selection system will not work in this case because the scattered Individuals of a species are growing under different environments. This is by far the most common situation that requires a grading system other than the standard comparison tree method.

The Importance and frequency of relatedness among trees from stands of *sprout* origin is often not understood. Usually, sprouts from a single tree are limited to those individuals that are adjacent to the tree, but sometimes, sprouts from a common root system can be quite extensive. When stands of sprout origin are large enough and of sufficient genetic diversity to enable use of a comparison tree system, the check trees must be carefully chosen so they will not be related to the candidate tree. This is sometimes difficult to do accurately.

Stands composed partially of sprouts and partially of seedlings also pose the problem of growth differential between trees from sprout and seedlings origin. Initially, sprouts usually grow much faster than seedlings because of the established root system and stored food., However, sprouts often culminate growth at a younger age than do seedlings. After a few years, it commonly becomes impossible to distinguish sprouts from seedlings, but selection results will not be good if the two types of trees are mixed.

Although they are not sprout stands, occasionally trees form root grafts that can also make tree selection difficult. The result of root grafting usually Is that the large tree benefits at the expense of the small tree by taking nutrients from the small tree with which it shares a common root system. This serves to inflate the superiority of the larger tree and is an environmental effect that cannot be captured through selection.

THE REGRESSION SELECTION SYSTEM :

The most useful method of tree grading for the uneven-aged or mixed-species-type stands described previously is the regression system. This requires the development of tables relating the characteristic of interest to true age. The regression method is of particular value for growth characteristics because quality characteristics can often be determined on the basis of the phenotype of the candidate tree alone without need for comparison trees.

A regression selection system is built by sampling a number of trees for a desired characteristic, such as volume growth on a given site, and then plotting them against age (Figure). It is of key importance that different regressions are developed for different sites. A reliable regression curve for height or volume can be made with about 50 trees if there is a reasonable age-class for height distribution. Once the curve has been developed, the regression is used as follows:

1. A candidate tree is chosen, based on the judgement of the selector and measured for the characteristics desired, such as height or volume.

2. The trait is plotted on the regression graph using the proper age and site. If the candidate tree falls at some defined distance above the regression line, it is acceptable and the higher above, the more desirable it becomes (figure). When the value of the characteristic falls below the acceptable level, the tree is rejected.

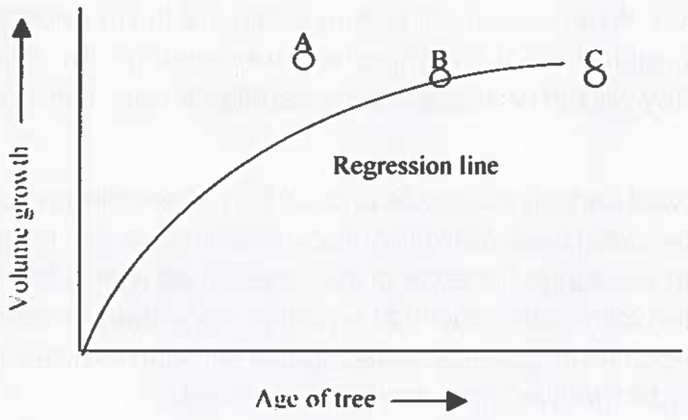


Figure 6

The regression system of selection is particularly suitable for all aged-or-mixed-species stands. It consists of developing a curve of production (growth is illustrated) for different ages of trees on a given site. Candidate Tree A falls above the curve, therefore, it has the desired growth for its age. Tree B is average, therefore its use depends on other characteristics, whereas Tree C has inferior growth for its age and should not be used. The regression line should be based on at least 50 trees if the age spread is considerable.

The regression system is more difficult to use than the comparison tree method, but there is no doubt that it will become more commonly employed as hardwood tree improvement becomes more widely practised.

THE MOTHER TREE SYSTEM :

When there is no immediate urgency to obtain large amounts of improved seed the mother tree system of selection may be best. It consists of locating "good" trees that are usually not as good as select trees in the comparison tree or regression systems. Then, one must obtain seed from these and establish seedlings in genetic tests. After this, either the best parent trees or the best trees of the best families can be used in a vegetative orchard. If suitably laid out. The progeny test may be thinned to create a seedling seed orchard.

The main disadvantage of the mother tree system is that time is lost before commercial quantities of seed are needed for planting programs. The testing must be carried on for a long period, approaching at least one-half rotation age if growth is to be

reasonably assessed before the seed orchard can be established. This method has been used extensively for hardwords for which planting programs are small and seed are not immediately needed. It also works verywell for species that are grown on very short rotations, such as the eucalyptus. If the interim seedling *orchard* concept Is used, time to seed production can be shortened, but potential gain will be reduced because of the smaller selection differential from the seedling orchard as compared with the vegetative orchard. The mother tree system may also be best in seriously high-grade stands where few good phenotypes are available. It may also be best for characteristics such as discase resistance that often can only be determined through testing.

THE SUBJECTIVE GRADING SYSTEM :

Some persons who are familiar with a species feel that an acceptable job of selection be done based only on the judgement of the grader about what constitutes a good tree. This certainly possible, but the grader must *know the species* immediately and must be as unbiased as possible. This system is used successfully but has also failed. The tendency, when the subjective system is used, is to spend less time seeking the candidate trees, thus choosing less outstanding trees with smaller selection differentials. This results in less gain. The subjective grading system frequently used for hardwoods but is successful only If the grader is experienced and dedicated to finding the best trees possible.

TRAITS DESIRED FOR SELECTION DEVELOPING A GRADING SYSTEM :

Two factors are of paramount importance when developing a grading scheme for the selection of superior trees. First, the trait under consideration should be under at least *moderately strong genetic control.* Second, the trait *must have considerable economic value.* Regardless of the magnitude of either of these factors, a characteristic is of little use in a selection program whem either the genetic control or economic value is too low. For example, if a characteristic such as leaf size were under strong genetic control, It would have little value in a commercial tree improvement program. This would be the case if trees with large leaves yielded no greater amount of the desired products than did those with small leaves. The numerical value allocated to each characteristic in a tree grading process is determined by weighting the heritability or the characteristic against its economic worth. For example, bole straightness usually is considered more Important than limb size because of its stronger genetic control as well as its greater economic worth.

Growth rate is nearly always the key characteristic in a selection program but other characteristics are usually also important. This priority of quality characteristics over volume should be used when selections are from wild, unmanaged stands where heritability for growth is low. In advanced-generation tree improvement or in plantations where selections come from more uniform stands of the same age and equal spacing, the heritability for growth rate will be larger, and a greater concentration on improvement of volume growth should e made.

Most first-generation selection programs have a "threshold" value for each characteristic, below which no tree is accepted for an operational orchard no matter how excellent the rest of the tree's characteristic might be. Trees that have one marginally acceptable characteristic are often held in breeding clone banks for possible later use.

The general tendency is to *include too many characteristics* in a selection system. The more things that must be graded, the more difficult it becomes to find suitable trees. The objective of tree selection and grading is to emphasise the few most important characteristics, such as volume production, bole quality, adaptability, and pest resistance. The lesser characteristics that are assessed should be kept above an acceptable level, but selection Intensities need not be as great. The objective is to give the greatest weight to characteristics that have the best combination of economic importance and heritability and to give less weight to other characteristics. No tree Is used that has a characteristic that falls below the level of acceptability.

The main objective of a grading system is to force the grader to look critically at the tree. The grade given does not represent the final decision about whether a tree will be used forever in the improved seed orchard. This decision is finally arrived at after progeny testing. All efforts to obtain the best phenotypes should be taken, but some mistakes will be made. This was followed by progeny testing and rouging of the undesirable genotypes to upgrade the genetic quality of the first-generation orchards.

The grading system is relatively simple to use and is one version of the comparison tree system discussed earlier. It works as follows:

1. Once the decision has been made to grade a tee, the five best crop trees in the stand in which the candidate tree is located are chosen as comparison or check trees. They, like the candidate tree, must have a dominant or co-dominant crown position and must be growing under conditions of competition that are similar to the candidate tree. The comparison trees are chosen for desirable characteristics in much the same way as the candidate tree. It is helpful to consider the checks as crop trees that would be retained if the grader could leave the five best trees in the stand and not including the candidate tree. Comparison trees can occur at varying distances from the candidate tree, but they are selected on site and under an environment similar to that of the candidate tree. If the candidate tree is located on a relatively uniform site, an attempt is made to locate the comparison trees in a circle around it. If suitable trees are not available in a circle, one or all of the

comparison trees can be chosen in any sector of the circle. When the candidate tree is located on sloping terrain, the comparison trees should be selected on approximately, the same contour as the candidate. In cases where this is not possible, the comparison trees should be located on the downhill or better side of the candidate to ensure that it is never compared to trees growing on a poorer site.

The candidate tree is awarded points for each characteristic shown on the grading form, based on the importance of the character and relationship of the candidate tree to the five comparison, or check trees. Height and diameter are actually measured for the candidate and the comparison trees. Crown formation, pruning ability, branch angle, and branch diameter are subjectively scored by visually comparing the characteristics of the candidate and the comparison trees. Straightness and disease or insect infection are subjectively scored on the candidate tree only and are not judged in relation to the comparison trees. Thus, a tree must meet a given level of straightness if it is to be graded, no matter how crooked or straight the check trees may be. In even-aged natural stands, the candidate tree is automatically rejected if it is more than three years older than the average of the five comparison trees; conversely, it is a warded points if it is more than 2 years younger than the average of the comparison trees.

2. No tree is accepted if it is infected by serious diseases or insects. The disease is genetically controlled strongly enough to make good gains by selecting only non-diseased trees for use in seed orchards, if Infection levels are high.

3. An 11mm bark-to-bark Increment core is extracted from the candidate tree at the time of grading to be used for wood analysis.

INDIRECT SELECTION :

For some characteristics, it has been found that It Is easier to use indirect selection rather than selecting directly for a specific character. This approach is especially valuable for forest trees because of their long life span and large size. Development of techniques to select at very young ages for performance at rotation age would result in a much shorter generation Interval and greater genetic gain per unit of time and would speed up the tree improvement efforts greatly.

SELECTION OF CANDIDATE PLUS TREES-eg.

1) Casuarina :

In the selection process of plus trees grading system Is to be adopted. In the grading system a number of traits are assessed. The grading system usually contains both exact measurements and subjective assessments of traits. These are compared to comparison / check trees in the stand / area. Each candidate tree is to be evaluated on the tree grading sheet (enclosed). After processing of the assessment, the trees with the highest score may be selected as plus trees.

Plus trees are individual trees of outstanding merit initially selected on the basis of superior phenotypical characters like height, diametre, clear bole, disease resistance etc. The selection of plus trees Is to be done as given below :

- Preliminary reporting of the outstanding trees called candidate trees.
- Final phenotypical appraisal and approval as plus trees.

PRELIMINARY REPORTING :

The preliminary reporting of the candidate plus trees is to serve the purpose of screening as large areas as possible. This is carried out at Research Forester's level and below, who are more familiar with the occurrence of trees within their jurisdiction.

The region is to be divided into 5 convenient units. Each Research Forester is to carryout preliminary reporting of 25 screened trees for each of the units species, to a total of 125 trees in his Jurisdiction.

2) Criteria for screening the trees:

1. Age	:	More than half the rotation.
2. Growth	:	Vigorous, healthy and superior in height and diameter. Dominant or Co-dominant.
3. Stem Form	:	Straight, cylindrical, clear bole free from pronounced buttress, fluting and forking.
4. Crown	:	Narrow, light and spreading branches, good natural pruning, Few epicormic branches, dense and healthy foliage.

5. Free from insect and pest attack

6. Moderate to good flowering and fruiting

3) Grading of the trees:

The candidate trees are measured and graded against comparison / check trees.

a) **Height :** The height of the Candidate Plus Trees and comparison / check trees are measured with clinometer and recorded in the grading sheet (check list).

b) **DBG (Diameter at Breast Height) :** Diameter at breast height is measured with tape or caliber and recorded.

c) **Crown diameter:** The diameter of the crown is estimated by projecting the outermost branches to the ground and the tree with narrow crown is selected over the trees with large crown.

d) **Bole Form :** Deviation from the desired Ideal straight, cylindrical bole is evaluated. Following observations are recorded.

1. Basal Sweep
2. Bends and twists
3. Trunk curves
4. Bole swelling
5. Leaning
6. Circularity

e) **The Branch Angle :** The third branch from below is specified and estimated for wide angle. Wide angle is preferred.

f) **Branch diameter :** Small branch diameters as compared to other trees and relative to the size of the tree are desired and selected.

g) **Self pruning ability :** A long clear bole is preferred. The presence of old branches or epicormic branches are assessed and recorded.

h) **Forking or Apical dominance :** A non-forking clear bole is desired. The height to the first fork or the first live branch is measured to evaluate percentage of apical dominance.

i) **Resistance to diseases :** Signs of attack from insects, fungi and other pests is recorded. The disease is genetically controlled, strongly enough to make good gains by selecting only non-diseased trees for use in seed orchards, if infection levels are high.

j) **Wood properties :** Specific gravity and fibre length of wood are evaluated in the laboratory and tree with wood having high specific gravity and long tracheid fibres are selected. An 11mm bark-to-bark increment core is extracted from the cPT at the time of grading to be used for wood analysis.

The Research Range Officer on receiving the filled in Grading Sheets of Candidate Plus Trees from the Research Forester, will personally inspect, verify and satisfy himself to the correctness of the report and send report to the State Silviculturist, for visual appraisal, after screening the 125 CPTs of each unit to 25 i.e. 5 trees for each species.

4) Final phenotypic appraisal :

The Final phenotypic appraisal Is done by the State Silviculturist, by critically analysing and discussing without any bias going in favour or against the superiority or phenotypic expression of the Candidate plus trees as per tree grading sheet scoring. The final number of the screened and selected CPTs will be 20 i.e. 5 trees from each unit and 1 tree of each species in one unit.

The trees are evaluated depending on location of whether in plantation or in natural stand. There are basically two methods applied for the selection.

- Comparison tree selection.
- Base line selection.

The comparison tree selection or check tree selection is used in even aged stands of a species. The candidate plus trees (CPTs) are screened for traits of interest in relation to few surrounding trees called comparison trees or check tree. If the candidate plus tree exceeds comparison tree, it is selected as candidate plus tree. After selection of candidate plus tree an average for the desired traits is arrived at and screened to select above average candidate plus trees. A progeny trial will be conducted to study the performance of candidate plus trees in field experiments. Observations of Candidate Plus Trees will be recorded and superior trees or plus tree are selected after first generation trials.

In an uneven aged stand with mixed species growing plus trees are screened by Baseline selection method. This method is adopted for the miscellaneous species identified for selection of plus trees. In this method individuals are located, their value for traits of interest is compared to the average of the region in which selections are made. The average is a "baseline" giving the system its name the baseline selection. If the Candidate Plus Tree exceeds the baseline by a considerable amount, it is selected as PLUS TREE.

CHECK LIST FOR INDEX METHOD OF SELECTION

LOCATION: NO

FOREST DIVISION : .... NAME OF

THE FOREST : ....

SPECIES : .... DATE OF ASSESSMENT : ....

AGE : .... DISTINCT MARKS : ....

CHARACTERS	INDEX	SCORE
1. Height 2.GBH 3.GGL	i. Trees with more than average Height, GBH, GGL	[ ] 7
	ii. Trees with average Ht. GBH, GGL	[ ] 4
	iii. Trees with less than average Ht., GBH, GGL	[ ] 1
4. Leader shoot presence	i. Presence of leader shoot	[ ] 6
	ii. evidence of leader shoot	[ ] 4
	iii. absence of leader shoot	[ ] 2
5. Straiehtness	i. clear straight long bole without knots	[ ] 6
	ii. less knots with or without knots	[ ] 4
	iii. large knots	[ ] 2
6. Self pruning	i. excellent pruning	[ ] 3
	ii. partly pruning	[ ] 2
	iii. poor pruning	[ ] 1
7. Branching	i. branches found in upper 1/3 stem	[ ] 6
	ii. branches found in half stem	[ ] 4
	iii. branches found in lower 1/3 stem	[ ] 2
8. Branch angle	i. branches with less than 45 degrees	[ ] 6
	ii. branches with 60 degrees	[ ] 4
	iii. branches more than 60 degrees	[ ] 2
9. Crown architecture	i. plants with conical crown	[ ] 6
	ii. plants with cylindrical crown	[ ] 4
	iii. plants with globular crown	[ ] 2
10. Disease incidence	i. no pathogenic incidence	[ ] 3
	ii. slight pathogenic incidence	[ ] 2
	iii. moderate pathogenic incidence	[ ] 1
11. Insect incidence	i. no pest infestation	[ ] 3
	ii. controlled pest infestation	[ ] 2
	iii. severely infested	[ ] 1

THE BREEDING AND PROPAGATION CYCLES

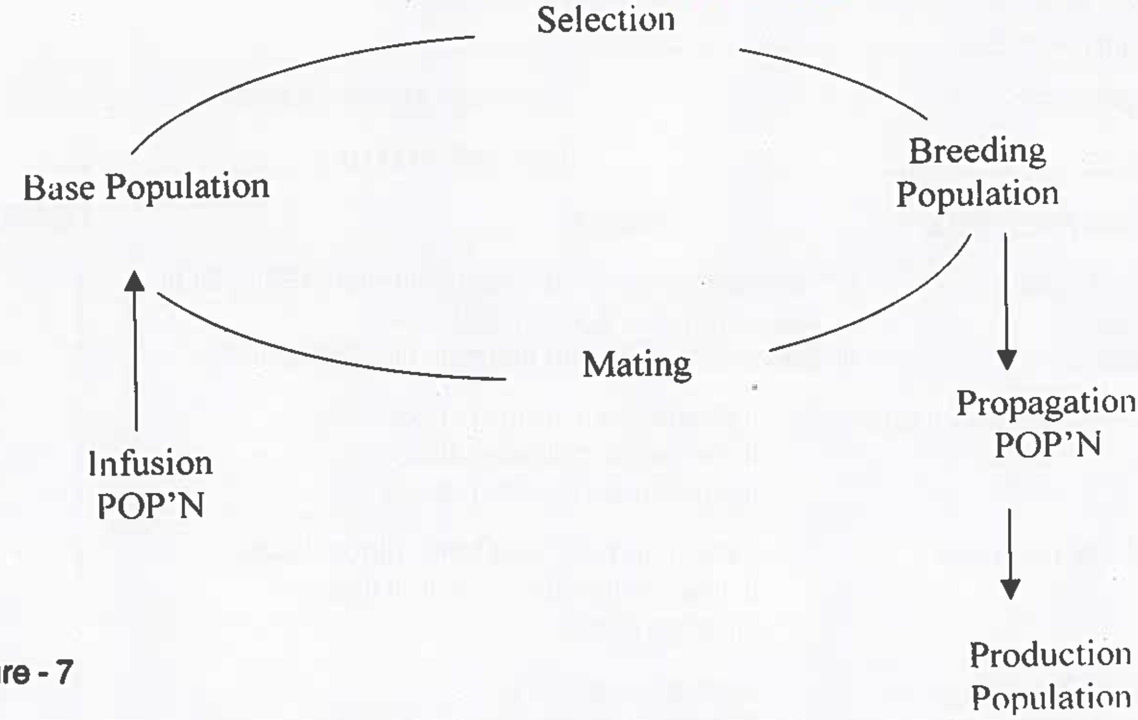


Figure - 7

Over time genetic material is progressed through the populations by cycles of selection and mating.

Options for managing the breeding population

- **Single Population breeding** - simple, but ultimately has problems of coancestry
- **Subline breeding** - more complicated but copes better with build-up of coancestry. Well suited to regional co-operative breeding. Should be started early in a program.
- **Multiple population breeding** - specially relevant where:
  - Genoptype-by-environment interaction is large
  - Different products required in different regions
  - Means are required to cope with build-up of coancestry.

Options available for utilising the propagation population include :

- Seedlings seed orchard
- Clonal seed orchard
- Control-pollinated seed orchard
- Stool plants as a basis for mass vegetative propagation of superior families or clones.

Methods of population improvement available range from :

- Simple e.g. Mass selection, i.e., no controlled crossing; no testing to
- Complex e.g. full-sib family recurrent selection i.e. fully controlled

One of many possible methods is illustrated in Figure 8.

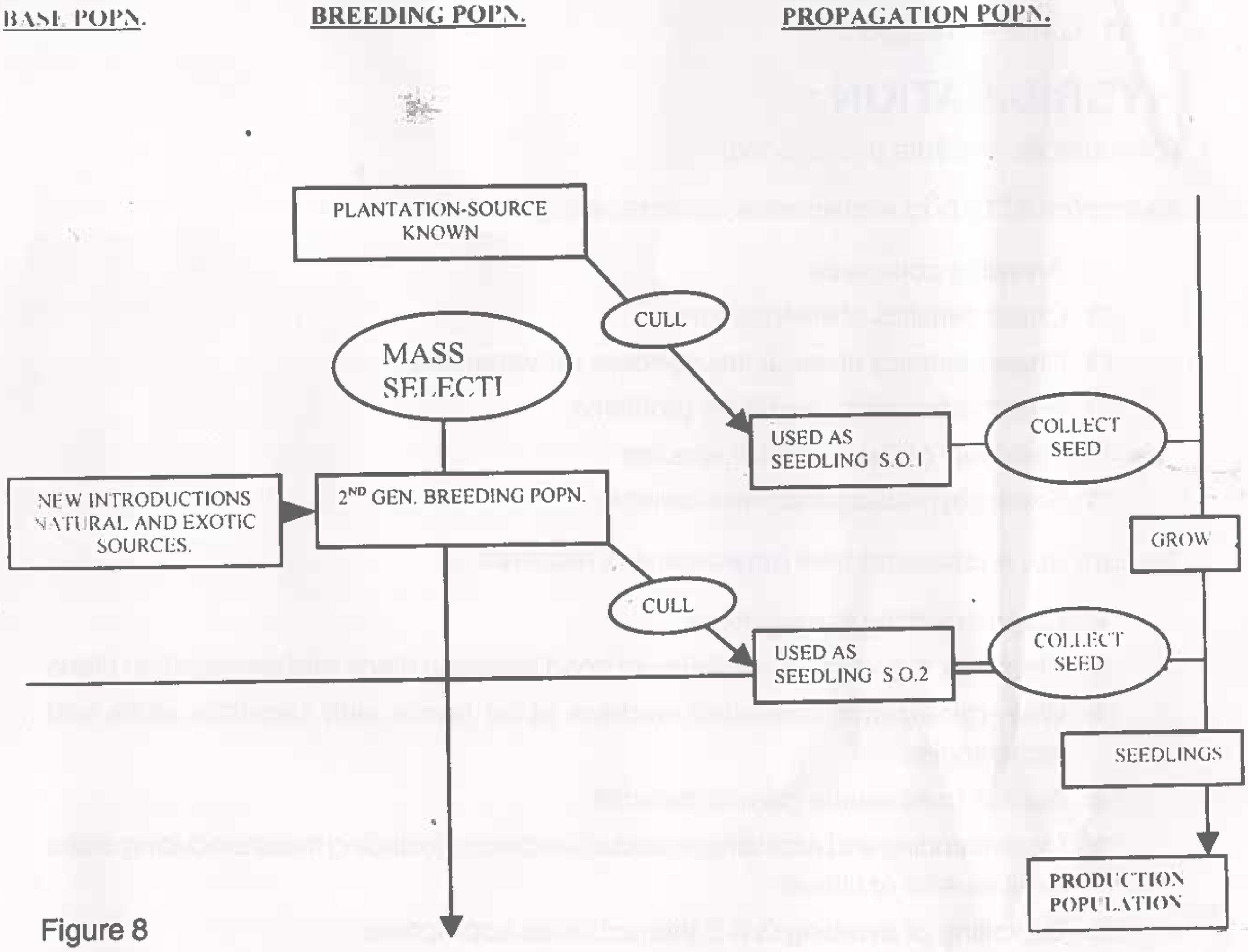


Figure 8

Flow chart showing a recurrent selection scheme of intermediate complexity

Efficient population improvement requires :

1. Knowledge of the reproductive biology of the species
2. Adequate base populations
3. Knowledge of genetic parameters
4. Means for accurate selection and regeneration of breeding populations
5. Appropriate and few selection criteria

6. Choice of good breeding method
7. Short generation Interval
8. Assessment of gain
9. Transfer of gain - via CSOs, clones, etc.
10. Good, documented plan
11. Long-term support.

HYBRIDISATION :

(Inter specific and inter provenance)

Examples of hybrid vigour now numerous e.g.

- Breeding objectives
- Characteristics of environments
- Characteristics of candidate species/ provenances
- Possible benefits - and likely problems
- Variability of the best pure species
- Testing hybrids against valid controls

To sum up, successful tree improvement requires :

- Commitment by management
- Preparation and Implementation of good breeding plans and propagation plans
- Well-trained and dedicated workers at all levels with requisite skills and technologies
- Access to adequate genetic material
- Understanding and exploiting reproductive biology including mass producing super families and/ or clones
- Exploiting or avoiding G X E interaction as appropriate
- Adequate in-house or commissioned research
- Appropriate collaboration and communication with client and other relevant organisations
- Adequate monitoring and demonstration of gains
- Rapid transfer of gains developed in breeding populations to operational planting stock.

BREEDING STRATEGY :

The general aims of a tree improvement programme are: to BREED progressively **better genetic base populations and breeding populations;** to PROPAGATE the best of the genetically improved material to develop superior **production population;** to MAINTAIN variability and population size in the base and breeding populations and to ACHIEVE all this economically. Greatest long term gains are achieved through **effective selection in high performance, large and variable populations in which co-ancestry is controlled over generations.** Selection and mating accumulates genes which influence yield and adaptation, gradually increasing the maximum phenotype and frequency of superior individuals. The cyclic nature of the selecting, testing and mating processes involved is well Illustrated in Figures 7 and 8

Key components of tree improvement are BREEDING and PROPAGATION strategies. Their formulation requires an understanding of variation, genetic gain and method of realising genetic gain. An appropriate breeding strategy in particular circumstances will be influenced by factors such the reproductive biology of the species, the time schedules and costs of breeding and testing operations, rotation length, stumpage prices and overall resources available.

Definition of a breeding strategy

- A plan for achieving the goals set for a tree improvement program
- Determinants of a breeding strategy
  - Objectives
  - Reproductive biology and time schedules
  - Gene action
  - Additive
  - Non-additive

- G X E Interaction - very strong or not?
- Potential of hybrids
- Propagation cost.
- Breeding population
- Production population

- **Resources**
- Genetic material
- Human resources
- Information
- Infrastructure
- Technologies

The plus Objectives determine intensity of breeding management: low-intermediate-, high - intensity.

Elements of a breeding strategy :

- Objectives
- Base population, breeding populations
- Selection.
- Genetic testing
- Mating design
- Inbreeding effects, management of coancestry
- Resources, responsibilities, flexibility

Objectives :

- ❒ Define improvements required
- ❒ Choose selection criteria
- ❒ Identify traits for which to select

Base population, breeding population :

- ❒ Start with best provenance as far as possible.
- ❒ Accumulate large area (over 100 ha) of each provenance with known broad genetic base.
- ❒ Mass selection in base populations.
- ❒ As soon as possible develop pedigreed stands of large numbers of open-pollinated families of the mass selected trees of best sources (including improved)
- ❒ Develop and maintain a large breeding population (over 300)

Selection :

- ❒ Use "comparison tree" method in **unpedigreed** base plantations.
- ❒ Use "plot adjustment" methods in **trails of families** from natural stands/plantations. Use "combined index" selection in family trials.

Genetic testing :

- ❒ Progeny /clonal trials:
- ❒ Increase gains by controlling environmental variation thus allowing more accurate selection
- ❒ Allow pedigree control

Mating design :

- ❒ Determines the kind of generic information:

- General combining ability (GCA) from half sib family means
- Specific combining ability (SCA) from full sib family means
- Determine whether you can keep pedigrees.

Comparison of mating designs can be on the basis of :

- Cost effectiveness (pollination method, need for pedigree control, complexity)
- How well they estimate GCA, SCA and other parameters.
- How well they evaluate parents.
- How well selection is facilitated in progeny (how rapidly coancestry builds up)

Management of coancestry. Aims are to :

- Avoid Inbreeding depression in the **production** population.
- Avoid the loss of alleles that may be useful in the future.

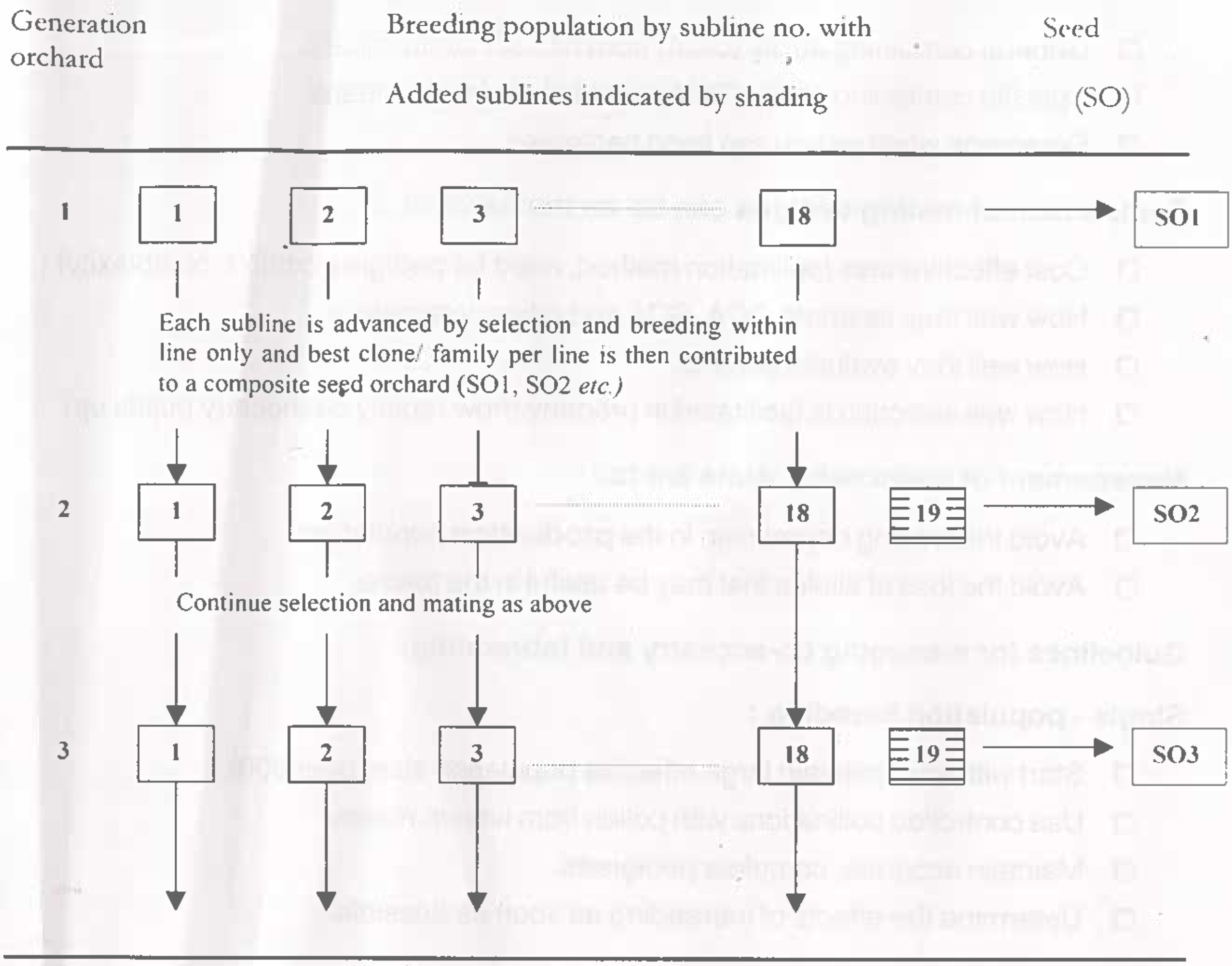
Guidelines for managing co-ancestry and inbreeding:

Single - population breeding :

- Start with and maintain large effective population size (over 300)
- Use controlled pollinations with pollen from known males
- Maintain accurate, complete pedigrees.
- Determine the effects of inbreeding as soon as possible.

Sub-line breeding

- Form 15-20 or more unrelated sublines each of 20+ individuals.
- Breed only **within** each subline
- Crossing between sublines occurs in the propagation population only.



Note: sublines 19 and 20 exemplify the addition of sublines required after program initiation.

Figure 9:

Diagrammatic representation of sublined breeding population and its improvement by selection and mating within sublines and its extension over generations as well as relationship to seed orchard development.

Mode of reproduction and ease of crossing:

- ❒ Vegetative - if asexual propagation of mature individuals practical operationally.
- ❒ Vegetative - if asexual propagation of juvenile individuals practical operatinally.
- ❒ Sexual - if abundant seeds produced at relatively early age
- ❒ Sexual — if vegetative propagation not feasible opertionally.
- ❒ Open pollinated if control of pollination very difficult as in *Acacia*
- ❒ Control pollinated if crossing is easy. However, choice can also depend on intensity or breeding that is economical.

Resources, responsibilities and organisation :

- Resources available and scale of planting determine intensity of breeding.
- Best to define responsibilities of each participant in program.
- Co-operative breeding programs can be very cost effective and dynamic.

Breeding strategy includes:

- Specifying objectives
- Considering all resources
- Maintaining flexibility
- Developing options and choosing best
- Acquiring genetic material and information on biology
- Estimating parameters
- Defining selection criteria
- Controlling inbreeding and maintaining variability
- Developing technologies
- Assigning responsibilities
- Specifying schedule of activities
- Achieving genetic gain efficiently per time and cost.

PROPAGATION STRATEGY :

Breeding and propagation strategies should be well integrated. The aim of a propagation strategy is to ensure rapid and effective transfer of gains achieved in the breeding population to the operational planting stock.

Definition :

A plan for producing and deploying genetically improved propagules (seedlings and/or clones.)

Determinants of propagation strategy :

- Kind of gene action
- Additive
- Non-additive.
- Mode of reproduction
  - Seeds
  - Vegetative propagules

- Cost of propagation
  - Biological costs
  - Production costs.
- Value/Cost of hybrids

Gene action :

- Additive
  - ✓ Any mode of reproduction
- Non-additive
  - Asexual propagation or
  - Recreate specific crosses (which may be hybrids)

Mode of reproduction" SEEDS :

- When vegetative propagation is not practical but seed production is good.
  - Seed production area.
  - Seedling seed orchard
  - Clonal seed orchard (conventional or control pollinated).

Seed production area (SPA) :

- Characteristics:
  - Unpedigreed stand
  - Good provenance important
  - Broad base important
  - Open pollinated.
- Advantages :
  - Cheap
  - Early production of slightly improved seed
- Disadvantages :
  - Subject to contamination
  - Low intensity and accuracy of culling limits gain.
  - Very limited control of build up of co-ancestry
  - Relatively low gain.

Seedling seed orchard (SSO)

- Characteristics:
  - ✓ Multiple families arranged to promote random mating after culling
  - ✓ Open pollinated
  - ✓ Half pedigrees maintained.
- **Advantages**
  - Relatively cheap
  - Relatively low technology
  - Substantial gains feasible
  - May be managed for multiple purposes, e.g. including breeding.
- Disadvantages:
  - Captures only GCA gains
  - Gains usually low than those of clonal seed orchard
  - May be subject to contamination.
  - Must be located for favourable seed production, so G x E interaction may be a problem.

Clonal seed orchard (CSO) - conventional

- Characteristics:
  - Multiple clones arranged to promote random mating.
  - Open-pollinated
  - Half-pedigrees can be maintained.
- Advantages:
  - Relatively cheap
  - Fairly flexible
  - Substantial gains feasible.
- Disadvantages:
  - Captures only GCA gains
  - Contaminating pollen reduces GCA gains
  - Stock-scion incompatibility may be problem.

Control pollinated CSO :

- Characteristics:
  - ✓ Clones may be in clonal blocks
  - ✓ Pollination controlled
  - ✓ Full pedigrees may be maintained
- Advantages:
  - ✡ Great flexibility
  - ✡ Very high gains especially if SCA effects large
- Disadvantages ;
  - Þ Cost

Mode of reproduction - CLONES (can deliver a greater proportion of the breeding population gains to production population faster than via seed)

Juvenile clones are used

- When vegetative propagation of juvenile material is practical
- "Bulking up" to:
- Circumvent poor seed production
- Utilize good GCA combinations
- Utilize non-additive genetic variation (SCA).

II. Mature clones are used :

- When vegetative propagation of mature trees is easy via sprouts e.g .poplars of some eucalyptus and acacias
- Capitalizes on additive and non-additive genetic variances
- Deployment method may be critical

Breeding program is still required in clonal propagation programs. Cost of propagation :

- Biological costs, e.g. cloning, may include penalties such as loss of "poor rooters", loss of growth etc.
- Production costs, e.g. may be too expensive to produce clones or hybrids.

Value/cost of hybrids :

- Superiority of hybrids (growth and/or other traits) needs to be substantial - because of extra costs of production.

- Cost of production including usually higher **breeding** costs (of **two** populations) may be high but collaboration may offset this.
- Ease of mass propagation a necessity e.g. rooted cuttings.

Assessment and demonstration of gains.

- Periodic "Genetic gain trials" (well-replicated)
- Demonstration plots (easily accessible)

EXPERIMENTAL DESIGNS

The following information provides a brief guide to the establishment and management of simple but effective forestry experiments. The guide covers the selection of site and treatments and the statistical aspects of experimental design such as randomisation, replication, and blocking. Practical aspects of trial management and assessment are also discussed.

INTRODUCTION :

A forestry trial is an expensive and generally long term exercise; therefore, it must be conducted properly and must be justified by the potential worth of the results.

A well-designed experiment should provide accurate estimates of the effects of different Treatments or management regimes on important traits such as height and diameter growth. The results should be as widely applicable as possible, within the terms of reference of the experiment, and should not depend on unjustifiable assumptions, e.g., it cannot be assumed that pruning, thinning, or fertilising have no effect on height growth: recent work suggests all three factors can have an effect that varies according to the combination of treatments applied. Good statistical design helps to reduce the possibility that experimental results will be biased by extraneous factors.

Although the requirements of accuracy and validity are paramount, experimental design should be as simple as possible. Simple experiments are easier to establish, manage, and assess; there is generally less that can go wrong; and analysis and interpretation of the results are often easier and more reliable.

Cost is also an important criterion. Larger and more complex experiments are more expensive than smaller, less complex ones. The are also more prone to mistakes during establishment, management, and assessment. The precision with which treatment effects are estimated is partly a function of size; trials should not be larger than they need to be in order to detect differences that would have a practical impact.

In summary then, an experiment must be **statistically sound** and should be kept as **simple** and as **cost effective** as possible.

OBJECTIVES OF EXPERIMENT :

Before any experiment is undertaken the objectives must be clearly described. The officer proposing the trial must define what he or she is trying to find out in terms of precise questions, e.g., "what is the effect of early thinning on diameter growth?". The timing and intensity of thinning must be specified; parameters of growth and the period over which they will be measured must be defined; the species, site and other relevant conditions under which the trial will be conducted must be clearly stated.

It is pointless to carry out expensive, lengthy experiments if the answers to the problems are already available. Duplication should be avoided by checking published reports of similar work; similar experiments may be in progress or completed elsewhere in the countly and should not be repeated unless results are likely to differ because of local factors.

An unfinished experiment may be a complete waste of time and money; the Initiator must ensure that sufficient resources are available to enable the experiment to be carried through to completion, including proper reporting of the results. In particular, it is essential to ensure that there is someone else to take responsibility for the experiment if the initiator Is transferred.

WORK PLAN :

A work plan (also termed a control plan) Is absolutely essential and should cover all aspects of the experiment including the following:

- It should clearly summarise the objectives of the experiment.
- Resource requirements should be estimated and responsibilities for establishment, management assessment, analysis, interpretation, and reporting should be clearly allocated.
- The work plan should enable the experiment to be successfully completed even after the departure of its originator or any key collaborators.
- It should provide sufficient detail about the project to enable others to provide useful assistance or device.

PRINCIPLES OF EXPERIMENTAL DESIGN :

Most experiments are analysed by techniques that compare induced systematic variation between treatments with the residual or background variation within the trial. The treatments should form a logical grouping, as few in number as possible, chosen either to reveal differences of practical importance or, sometimes, to confirm that there are no such differences. The accuracy of measured treatment differences depends directly on the level of residual or unexplained variation, which includes site variability, genetic differences between trees, and errors in management and assessment of the trial.

Residual variation must be minimised and this is achieved by:

- Careful selection of a uniform experimental area.
- Restricting experiment size to increase site uniformity.
- Groping of trial plots into blocks to further control site variability.
- Replacing treatments to obtain precise estimates of residual variation.
- Randomising treatment plots to minimise the possibility that treatment differences will be biased by site variation.
- Managing and assessing the trial carefully.

CHOICE OF TREATMENTS :

In experimental jargon the "treatments" refers to the different effects that are to be compared. Thus, depending on the type of experiment, a treatment may be a species, a seed source, a micro site class, an establishment technique, or a pruning regime. There must be at least two alternative treatments and the effect of one treatment relative to another is usually expressed as the difference between, or ratio of, the measured responses (growth, survival, etc) associated with each treatment.

The choice of treatments will depend first of all on the type of experiment, e.g., a fertiliser trial will have treatments corresponding to different rates and/or types of fertiliser, and an establishment trial may Incorporate different methods of site preparation planting techniques, or planting stock. More complex silvicultural trials may compare differential spacing, and thinning and pruning regimes. Whenever there are two or more treatment factors, there can be substantial advantage in choosing combinations that together form a full factorial set.

The set of treatments must cover the range of conditions specified in the experimental objectives; they should include appropriate comparisons and provide precise information in the areas of main interest. The temptation to "add on" extra treatment not directly related to the experimental objectives must always be resisted.

The experiment should include **all** treatments to be compared. Comparison of results from one experiment with those for different treatments in other experiments should be avoided as It is very likely that such comparisons will be biased because of different experimental circumstances. However, there should not be more treatments than necessary.

Most experiments should include a **control** treatment. That is usually an existing standard method or regime, i.e. normal management prescription. It does not necessarily mean that nothing is to be done (e.g., no fertiliser, no pruning, no thinning).

Many trials are designed to measure the effects of two or more related treatment "factors" e.g., thinning and pruning, or site cultivation and fertilisation. These are **factorial** experiments and typically the treatment .set includes all possible combinations of the levels or amounts of each factors. A full factorial experiment is a highly efficient way of obtaining information on each of the treatment factors and on the extent to which they Interact with each others. However, the total number of treatments in a full factorial experiment can easily become very large, e.g., four methods of cultivation, three rates of nitrogen, and four rates of phosphate together give a full factorial set of 48 treatments. If possible, keep the total number of treatment combinations to 12 or less for simple experiments. Typically, this means no more than three factors and only two to four levels of each factors. If the levels of a factor are quantitative (e.g., rates of fertiliser or of herbicide application), there should be at least three levels in order to estimate a quadratic response function. Specialised response surface designs may be useful when there are three or more quantitative factors.

Aspects of management of a trail that are not part of the experimental objectives, e.g., plant spacing in a fertiliser trials, should generally conform to standard practice; this will help ensure general applicability of experimental results.

CHOICE OF SITE :

The experimental site should be as uniform as possible in terms of aspect, slope, soil, etc., and also with respect to tree stock and other vegetation, trash, stumps, etc., except when any of these form part of the experimental treatment. It Is possible, by means of blocking, to reduce site variability effectively by arranging the experimental plots within two or more internally uniform blocks. In forestry field trials uniformity should be aimed for although it is difficult to achieve. The work plan should contain a full site description including details of all non-uniform features.

The trial site should also be representative of plantation areas; atypical sites will not produce results that are widely applicable. In order to select a site that is both uniform and representative, it may be necessary to arrange experimental plots or blocks across a whole age class or other region of Interest within a forest.

Care should be taken to ensure that the trial will not be affected by management of its surroundings (e.g., top dressed with fertiliser, affected by spray drift, pruned or thinned by mistake, or grazed by animals). In general, the experimental area should be clearly marked and, if necessary, fenced.

PLOT SIZE AND SHAPE :

There are statistical advantages in using small plots: there is greater uniformity among neighbouring plots and more plots can be established within the same experimental area, thereby increasing precision of treatment comparisons. In established stands, where mortality is not expected to be a problem and where thinning is not scheduled during the life of a trial, singletree or two-tree plots can be highly effective, particularly if there is likely to be little or no Interaction between one tree and its treatment, and the next. Very small plot are most commonly used in tree Improvement trails and they may also be used in fertiliser trials in which low mortality and minimal edge effects are expected.

Larger plots are frequently necessary, particularly if attributes such as tree mortality or infection are to be assessed, when at least 10 and preferably 20 measured trees per plot are desirable. Longer-term experiments require more trees per plot to ensure that an adequate number remain after thinning or natural mortality. Plot size will have to be increased if there are likely to be edge effects between plots,.e.g., in fertiliser trials the threes near the edge of one plot may be affected by fertiliser applied to the neighbouring plot; similarly in spacing or thinning experiments, trees at the edge of close-spaced plot will be relatively open space if the next plot is open-spaced. If edge effects are expected, it will be necessary for each plot to have a surround of one or two "guard rows" of trees that receive the same treatment as the rest of the plots but which are not assessed. Systematic designs may be used in appropriate circumstances to avoid the need for an excessive area of guard rows.

For most silvicultural trials square plots or rectangular plots (including row plots) are preferred. They are easier to lay out than most other shapes, fit well together to form a relatively compact experiment, and generally facilitate simple and precise estimation of basal area and volume per hectare.

In most trials plot dimension should be constant, or as nearly so as possible. Statistical problems may be encountered when plot size varies substantially since smaller plots tend to be inherently more variable than larger ones. A special difficulty can arise with spacing and thinning trials: it Is usually better to maintain constant plot area (and variable number of trees per plot) than constant number of trees (with variable plot area), but the latter strategy is virtually impossible with differential thinning regimes. Note that as far as possible analysis of experimental results should be based on a constant number of trees per plot. These may be the crop element (defined from constant final stocking per hectare), or they may be selected from each plot either randomly or e.g., as then largest stems in the plot where n is the smallest number of tress in any plot.

REPLICATION :

There must be at least two plots of each treatment because no field trial site is completely uniform and because there is also genetic variation between trees as well as differences In the way that each plot is managed. All these sources of variation are together termed residual (or error) variation. By having repeats or replicates of each treatment the amount of residual variation (variation not the result of experimental treatment differences) can be estimated and that estimate provides a measure of the precision of the experiment. Replication also helps remove bias from treatment comparisons, e.g., it is relatively unlikely that several plots of a treatment in a well-designed trial should all have above-average natural fertility.

Increasing the number of replications - the number of plots per treatment - improves the estimate of residual variation and thereby the precision with which treatment differences are estimated. It increases the probability that a given difference between treatment means will be Judged statistically significant. However, it also makes the experiment larger and more costly.

To estimate the number of replications a trial will need it is necessary first to decide what smallest difference, between treatment means is practically meaningful in terms of management (e.g., 1mm in height; 20 mm in diameter), and second to have some idea of the likely amount of residual variation between plots. This is usually expressed as s, the residual standard deviation of plot mean values, and it can be estimated in various ways. It may be roughly estimated by r/ 4 where r is the expected range between the estimate of the extreme mean values of similarly treated plots. Given some estimate of the residual standard deviation, s, then In order to estimate a difference, d, which is statistically significant at the 5% level, the number of replicates should be approximately $n = 9 s^2/ d^2$. This rule should only be used with moderate-sized experiments (i.e., those with 4 to 12 treatments). It can be applied to each measured trait (such as height, d.b.h., survival, etc.) and in general this will produce different values of n for different traits. Select a value of n appropriate to most traits of Interest.

In some cases the different values of n generated may be too contradictory, or it may be impossible to provide a sensible estimate of s. In such cases, a very rough rule of thumb is to aim for at least 20 plots altogether. Thus, if there are five treatments, there should ideally be four replicates or plots of each treatment. This rule is based on ensuring a minimum of about 12 degrees of freedom for estimating the residual variance in an analysis of variance.

Lack of resources may make it impossible to achieve a required level of precision with a given type of design, plot size, and number of treatments. In this case it may be possible to achieve a worthwhile experiment by reducing the number of treatments or by using smaller plots, thereby increasing the number of replicates. A more complex type of design, e.g., fractional replication, may provide a means of increasing the accuracy of an experiment. Alternatively, it may be feasible to accept a lower level of precision. However, there are limits to this sort or compromise; there Is no point in proceeding with an experiment that is unlikely to provide any useful information: a worthwhile experiment, if only half-completed, is worthless.

RANDOMISATION :

An Important feature of most of the commonly used types of experimental design is the random allocation of treatments to plots. Since some plots will be inherently better than others, random allocation of treatments is generally the best way to avoid bias in the estimates of treatment differences (e.g., through one treatment being assigned to predominantly "good" plots). In addition, random allocation ensures an unbiased estimate of residual variation, thereby providing theoretical justification for the use of common significance tests and calculation of confidence limits. However, it should be noted that randomisation is not always appropriate and there are circumstances under which systematic designs may be useful, e.g., "Nelder" variable spacing designs.

Randomisation should be done with tables of random number printed in some statistical textbooks, or by using some acceptably "fair" mechanical process, e.g., drawing numbers from a hat. Most computers and some calculators have random number generators built in that may be used. To use random numbers simply give each treatment a unique number and assign the treatments to plots according to the corresponding order in the random sequence.

Where there is substantial variation within the experimental site a block design should be used. In this case each block should be randomised separately.

If a randomisation is obviously exceptional having e.g., an apparently systematic look to it, then the design should be re-randomised. There are some theoretical objections to re-randomisation. It may be that the chosen type of design is inappropriate, in which case the design should be changed. In general, however, it is more Important to avoid bias by ensuring a really random appearance to the treatment allocation than to hold on to a design that may be the product of genuine randomisation but that looks likely to give spurious experimental results. It Is much easier to spot and avoid this sort of problem when randomisation is carefully planned in the office.

If new information on site variation is revealed as the trial Is being established it may be necessary to re-randomise, possibly after revised blocking.

BLOCKING :

Trials with forest trees may cover large areas within which there is often variation in soil quality, natural fertility, slope, aspect, and other factors. The precision of experimental results is lowered by site variation, which can introduce bias into estimates of treatment differences. These problems may be minimised by dividing the experimental site into blocks so that the plots within each "block are more-uniform, e.g., if the trial site occupies a slope with uniform aspect, each block should run across rather than down the slope. Variations in growth, etc., resulting from position on the slope are then incorporated with inter-block differences and are excluded from comparisons of treatments. Differences in aspect, fertility or any other site factor can also be assigned to blocks. If site variation is large and likely to have a substantial effect on treatment differences, the trial should be split evenly with at least two blocks at each major site type to allow estimation of treatment by site interaction effects. Blocks need not be continuous, but it may be necessary to stratify blocks throughout a forest or region in order to cover a representative range of sites.

For most common and simple types of experimental design the trial site is subdivided by Just one system of blocks and each block has the same number of plots. In the most common type of design, randomised complete blocks, every block contains one plot of each treatment. More complex designs may have blocks with fewer plots than the number of treatments or there may be two or more blocking systems.

Although it is usual for each block to occupy a single, contiguous area, It is not essential. If the required total number of plots (number of treatments multiplied by number of replicates) is marked out on the experimental site, blocks may be defined, e.g., by soil quality or, if an experiment is imposed on an existing stand of trees, by initial (pre-treatment) mean diameter, height, or stocking. Allocation of treatments to plots within each block must still be done randomly and any site quality assessment on which the blocking is based must be recorded In the work plan.

If a trial is blocked, all management and assessment should be done block by block. In this way any systematic differences between operators, between machines, or between times (because of changes in the weather, or because techniques are modified with practice) will be assigned to block differences and will not bias comparisons of treatments.

Sometimes there may be few or no existing features on which to base blocks. The site should be blocked any way because differences are likely to emerge as the trial proceeds. No penalty can be incurred through blocking even if there turns out to be no block effect. In that case, block structure can be ignored during statistical analysis.

TYPE OF DESIGN :

The type of design to be used depends on the nature of the experimental treatments, site characteristics, and block size. So far as is possible, the simpler the design, the better it is. Simpler designs are not only easier to lay out, but also the results will be easier to analyse and interpret. Several types of design are described briefly below.

RANDOMISED COMPLETE BLOCKS (RCB):

This is the most widely used design in forest experimentation and should be used for most simple trials. Each block must be large enough to include one plot of each of the experimental treatments (hence the name "complete block"). The number of blocks is then the same as the number of replicates. Sometimes a treatment of special interest (e.g., the control) is replicated twice in every block. This provides greater precision for the estimated treatment mean and comparisons of that mean with others, with only a small loss in analytical simplicity. Within each block the treatments are assigned at random to the plots; a separate randomisation should be done for each block.

RCB designs are suitable for a wide variety of experimental situations; here statistical analysis is simple and easily done on a calculator, and interpretation of the results is usually straightforward. The designs are also statistically robust, i.e., the analysis does not depend on very stringent assumptions and there are simple techniques for dealing with a moderate number of missing plot values. However, RCB designs are much less suitable when there are many treatments (since block size will then be large and blocks will generally be less uniform), or where natural site variation is complex and cannot be adequately controlled with a single, simple blocking system. RCB designs should not be used for forestry field trials when there are many more than about 12 treatments.

FULLY RANDOMISED DESIGNS:

This is the simplest type of experimental design because individual plots are assigned to treatments completely at random with no blocking. The treatments need not be equally replicated; consequently, there may be more plots of treatments in which there is greater interest. The analysts is very simple, but residual variation will often be Inflated, relative to an RCB design, by inherent site variation. Consequently, a fully randomised design will generally give poorer precision than an RCB design of the same size. Systematic variation within the trial site may also bias treatment comparisons If, for example most of the plots of a given treatment are located at the fertile end of the experimental site. Fully randomised designs are not recommended for forestry field trials, especially when there will be only limited replication.

LATIN SQUARES:

A Latin square design has two superimposed blocking systems called, by convention, rows and columns. The Number of rows and the number of columns must both be equal to the number of treatments and each treatment occurs once in each row and once in each column. An experiment may consist of one or more Latin squares, e.g., two squares double the replication. Latin square designs are very restrictive In the number of treatments that can be accommodated in a given experimental site, although other, more complex, row and column designs, which are less restrictive in this sense, do exist. The analysis of any row and column design is more complicated than that of an RCB design, although a Latin square analysis may still be done on a calculator. The designs are also less robust and are particularly use of Latin squares in forestry research is in nursery and glasshouse experiments in which rows and columns are readily identified with the natural layout. Latin squares and other row and column designs should only be used with expert guidance.

FACTORIAL DESIGNS :

In factorial experiments the treatments consist of combinations of different levels of two or more treatment factors. In a two-factor experiment two different types of treatment effect are investigated, e.g., levels of N and levels of P. Suppose that there are three levels of N (called N1,N2, N3) and two levels of P (Pl & P2); then a full factorial design will have six treatments corresponding to all possible N and P combinations: N1P1, N1P2, N2P1, and so on. The advantage of factorial designs is that they provide estimates of **main effects** (i.e., the overall differences between levels of one factor, averaged over all the levels of all other factors) and **interaction effects** (which measure the different responses to one factor at varying combinations of levels of other factors).

Simple factorial experiments are usually laid down as RCB designs but, if the number of treatments in a full factorial is larger than can be accommodated within a reasonably uniform block, then more complex designs may be used to reduce block size these include confounding, fractional replication and response surface designs, but they should not be attempted without statistical guidance.

SPLIT PLOT DESIGNS :

A split plot design may be useful in factorial experiments, e.g., when there are two treatment factor are likely to be substantially larger than the other (and so require less precise estimation to attain statistical significance) or one factor involves operations such as mechanical cultivation that cannot easily applied to small plot. Let A denote the factor that requires larger plots or less precision, and let B be the factor that can be applied to smaller plots or for which greater precision is required. A split plot experiment is usually a modified RCB design: the levels of Factor A are each assigned randomly to large **main plots** within each block and then the levels of Factor B are assigned randomly to smaller **subplots** within each main plot.

The analysis of a split plot experiment is fairly straight-forward but involves separating the estimated residual variation Into two parts, one for testing main plot treatment effects, and the other for testing subplot treatment and Interaction effects.

INCOMPLETE BLOCK DESIGNS:

These are used when there are more treatments (but not forming a factorial set) than can be accommodated in a uniform block. Strictly specified subsets of the treatments are each assigned randomly to plots within blocks. The blocks are called incomplete because they each contain less (usually considerably less) than the full set of treatments. These designs are complex to lay out and analyse and should not be attempted without appropriate statistical expertise.

SYSTEMATIC DESIGNS:

These have been devised particularly for use in spacing trials. In order to avoid the need for guard rows between plots with widely different spacing, the distance between trees is increased gradually and systematically. The best-known of these designs are the "Nelder" designs. Other systematic layouts for spacing designs exist, and a similar technique can be used for fertiliser trials: the rate of fertiliser is gradually increased across the experiment. Site uniformity is essential with systematic designs. Analysis of results is more complicated than for randomised plot designs in that it involves the fitting of a regression function to the response pattern. .

ESTABLISHMENT OF THE TRIAL :

Surveying the experimental site will be an essential part of deciding on the type of design to be used for the trial. Once a suitable design exists on paper it must be translated into a field layout, making due allowance for roads, streams, and other obstructions within the trial site, and also for irregularities such as missing rows.

There must be accurate demarcation of plots on the ground as plot area must be known in order to estimate basal area or volume per hectare. In practice, it is easiest to lay out one baseline down the length of the site and then offset by compass at right angles. In the initial layout stage errors on the closing (fourth) side up to 5% of the plot edge (i.e.,1.5 m in 30m) may be accepted provided that no trees could be marginal (i.e., judged to be in or out of a plot). If dimensional errors exceed 5%, or if there are marginal trees, plot layout must be corrected.

Each plot should be clearly marked with permanent materials. Metal dymo tape labels should be fixed to treated timber pegs sited consistently at one corner of each plot. The label coding and pegsiting should be clearly described in the work plan, which should also contain an accurate map of the site location and plot layout. Tees of appropriate height must be permanently marked by a painted band at breast height to avoid errors between measurements through misidentification of this point. Numbers should be painted on or attached to each tree so that comparisons between successive measurements can be made in the field, thereby avoiding errors.

Management schedules must be clearly defined and correctly followed as mistakes may invalidate the whole experiment. Responsibilities must be assigned and accepted. Site establishment, planting and other management operations that are not part of the experimental treatments should conform as closely as possible to normal practice. In blocked designs all such operations should be done block by block to avoid possible systematic bias of results.

TREATMENT AND ASSESSEMENT SCHEDULE :

The trial should last no longer than Is necessary to obtain the required results; the work plan should contain a clear statement of the trial's planned duration and schedules for treatment and assessment. Times at which the trial is to be assessed will often be related to management operations such as thinning. It is important to specify whether an initial or pre-treatment assessment is to be done; this may be invaluable later in improving the accuracy of results by covariance analysis.

At the very least, diameter and stocking should be measured at trial establishment and at prescribed times thereafter, in particular whenever silvicultural operations or other treatments are carried out.

The work plan should also define what traits are to be assessed, how they should be measured (e.g., whether tree height is to be measured by poles or using an optical device), and which trees should be assessed. With small plots and whole-tree characteristics such as breast-height diameter and survival, it is normal to assess all trees within a plot. Height might be measured only on dominant trees. If guard rows are to be left, the inner assessment plot must be defined. When complex or within tree traits such as branch size or wood density are to be assessed, the method of selecting representative samples must be specified. Measurement devices should be described (height poles, optical instruments, tapes, etc.) and should be appropriate to the task and to the precision required.

It is generally best for assessments to be done by a team of two or may be three people, e.g., one measuring and another recording . If the trial has a blocked design, assessment should be done block by block; assessors may exchange roles at the end of each block, or two or more teams of assessors may each measure a block at a time. Then any systematic difference between individuals will be included with inter-block variation and not with treatment differences.

RECORDING DATA :

Appropriate forms should be available for recording data in the field. PSP (pemanent Sample Plot) forms may be used wherever appropriate, but it may be necessary to design forms for a particular trial or type of measurement. The form should allow the assessor to record measurements clearly and unambiguously. Each item of data must be clearly identified according to date measurement, block, plot, treatment, tree and, when appropriate, position within tree. Comparison of successive measurement is aided If each form has space for several assessments -even if this is achieved only at the expense of having each form represent just one plot or part of plot.

Data on a recording form should not be crammed in. Figures should be recorded clearly, distinguished m particular between ones and sevens, and between sixes, noughts, and nines. Wrong digits should not be changed; they should be crossed through and the correct number written nearby. There should be space to enter brief notes, e.g., when a tree has lost its leader or when there is evidence of disease or damage not otherwise assessed if no space on the form for essential notes, they should be written on the back of the form.

The record forms should be designed to facilitate analysis: it should be easy to transfer the data, with minimal chance of error, to calculator or computer

PLANNING FOR ANALYSIS :

Detailed description of analytical methods Is outside the scope of this guide. Descriptions for standard techniques are found in many widely available textbooks. It is important to determine what statistical tests should be used to analyse trial data and for this information to be presented in the work plan. Data should not be collected unless the experimenter knows how they will be analysed and what questions the analysis might answer.

For measured characteristics such as height, diameter and basal area the fundamental techniques for analysing data from a designed experiment is the **analysis of variance**. This technique gives estimates of variations for making F-tests of treatment differences and also for comparing pairs of treatment means by **least significant difference tests or by multiple range tests. Analysis of covariance** may be used to eliminate initial (non treatment) effects from estimated treatment variation.

Attributes such as mortality may also be compared by analysis of variance of the proportion or percentage of trees with the attribute. Comparison between treatments may also be made by chi-squared tests when there are relatively small plots and little difference between replicates.

Relationships among measured traits, and between those traits and quantitative site and treatment data, may be tested by **correlation and regression analysis**.

Data should be analysed promptly and not allowed to accumulate in files. Analysis may reveal apparent errors or anomalies in the data; prompt analysis may enable correcting checks to be made and it will reveal trends in experimental results that may profoundly affect further management of the trial.

REPORTING RESULTS :

Experimental results should always be written up in a report and circulated to other workers for their information and to help avoid unnecessary duplication. Negative results (no apparent difference between treatments) are as important as positive ones.

The reasons for carrying out the experiment and the conditions under which it was conducted should be fully described. There should be summaries of all data collected and analysed. If the trial is a small one, the raw data may be included in the report; otherwise, they should be preserved in a form that is easily understood and accessible to other workers.

Analytical results should be presented in tables and/or diagrams, whichever seems clearer or more meaningful. A measure of error variation such as the residual standard deviation should be given. This measure of error will assist In interpretation of treatment differences and their statistical significance, e.g., a difference may be large but not significant when precision is poor (large residual standard deviation). In addition, publication of the residual standard deviation will assist designers of future, similar experiments.

Discussion of results should include all major treatment responses and notable non-responses along with possible explanations.

SELECTION OF METHODS FOR DETERMINING THE NUMBER OF REPLICATIONS REQUIRED

Determination of the number of replications required in a trial using a RCB design.

The number of replications needed may differ markedly for different parameters, and it is therefore essential to select the most important parameter for calculation. A rule of thumb in the planning of the analysis of variance is never to have less than 10 degrees of freedom for residual error, and preferably about 15 or more. Thus with four species or provenances one would need about 6 or more replications, thus,

Anovar 1.	No.	Source	Number	d.f.	Number	d.f.	Number	d.f.
	4	Species	4	3	10	9	20	19
	6	Replications	6	5	3	2	2	1
		Residual		15		18		19
	24	Total	24		30		40	

The effect of increasing the number of species or provenances is to decrease the number of replication required, thus

Anovar 2.	No.	Source	d.f.	No.	Source	d.f.
	10	Species	9	20	Species	19
	3	Replications	2	2	Replications	1
		Residual	18		Residual	19
	30	Total	29	40	Total	39

This rule of thumb is based on the fact that table "F" values change comparatively little for a residual 12 degrees of freedom and above.

The number of replications required to achieve a certain probability of obtaining a significant result can also be calculated. This gives a difference number of replications from the rule of thumb above, because it takes account both of the variability of the material, and the size of difference that the experiment is required to detect. Clearly, If the coefficient of variation percent Is greater than the percentage difference it is desired to detect, no amount of replication can enable this to be done. The ratio of the variation (standard error or coefficient of variation CV%) to the difference required (actual value, or percentage difference) must therefore be less than 1. The following procedures may be used.

ESTIMATION OF VARIATION :

An estimate of the standard deviation (SD) of the plot mean values Is required which may be available from other trials as the square root of the residual mean square in the analysis of variance. If there is no previous information, an estimate can be derived from the expected range of the treatment means within a single block:"

SD = f x range

"f" is a factor dependent on the number of treatments, and obtained from the following table.

No. of treatments	f	No. of treatments	f
2	0886	9	0.337
3	0.591	10	0.325
4	0.486	12	0.307
5	0.430	14	0.294
6	0.395	16	0.283
7	0.370	18	0.275
8	0.351	20	0.268

Having obtained an estimated standard deviation it is necessary to decide the difference (D) to be detected using the same units (or percentages) for both values.

The ratio SD/D is then calculated. From the following table is obtained the number of replications required for a difference of the magnitude chosen to be detected as significant at the p = 0.05 level. This gives a probability of 95% of the result being significant.

Ratio SD/ D	umber of treatments		
	4	12	20
	umber of replications		
0.2	2	2	2
0.3	3	3	2
0.4	5	4	4
0.5	7	6	6
0.6	9	8	8
0.7	12	11	10
0.8	15	13	13

It will be noted that the number of replicates required varies very little with the number of treatments, but considerably with the SD/D ratio. This illustrates the extreme importance of keeping the unexplained variation in the experiment to a minimum, by making all non experimental factors as uniform as possible. This method is of little value If the ratio SD/D is greater than 0.5 because it suggests impracticably high numbers or replications. A modified direct formula for estimating the number of replications required (r) is given by

$$r = \frac{t^2 \times \text{range}}{8 \times LSD^2}$$

Where LSD is least significant difference

DETERMINATION OF THE NUMBER OF REPLICATIONS REQUIRED IN A FULLY RANDOMISED TRIAL :

The number of replications for a completely randomised trial can be obtained from the table below. This table is similar to the one above in its probability and significance levels.

Ratio SD/D	Number of treatments	
	4	12+
	Number of replications	
0.2	2	2
0.3	3	2
0.4	4	3
0.5	5	5
0.6	7	6
0.7	9	8
0.8	11	11
0.9	13	13

In this it is assumed that there are equal numbers of replications per treatment. It will noted that fewer replications are needed for a given SD/D ratio and number of treatments than for an RCB design. This is because of the larger number of degrees of freedom available in a completely randomised design. However this advantage could be offset by an increase in the expected standard deviation.

DETERMINATION OF SAMPLE SIZE :

In order to ensure an adequate sample but at the same time to avoid wasted efforts, the size of sample should be linked to the variability of the characteristic to be measured. This may be done as follows :-

1. Obtain an estimate of the population standard deviation (S) from previous work, a preliminary sample, or by crude estimation from

— Where R = estimated range from the smallest to the largest value likely to be encountered in sampling.

The variation is usually expressed as the percentage coefficient of variation.

— N.B. ean is that of the sample and may have to be estimated If no measurements are available

2. The desired precision of the mean value must be stated, and is best expressed as ±E% at a given level of probability.

3. The sample size n may be determined from

$$n = \frac{CV)^2}{(E)^2}$$

Where t - value of Student's for n degrees of freedom and for given level of probability. Because the value of t depends on the value on n, the above formula must be solved by tial and error. However, once n becomes greater than 50, t may be assumed to have a constant value of 2 at the 95% level.

e.g. let CV = 50%

E = 10%

assume n will be around 60 therefore t = 2

$$n = \frac{(2 \times 50)^2}{(10)^2} = 100$$

t for n = 100 is 1.99 instead of the assumed 2, but this will make very little difference, so take n as 100.

If the sampling fraction f (i.e. the sample size over the total population) is not negligible, i.e., greater than 0.05, then n must

RECORDING OF INVESTIGATIONS :

REQUIREMENTS

1. An investigation record in required to :

(1) promote sound design and analysis, followed by inference and criticism:

(2) permit continuity;

(3) facilitate dissemination.

2. To achieve these objectives the record must contain all the following categories of information:

Origin : why the investigation was started, preceding history and background.

Origin : the plan, how the Job is to be done and by whom, resources to be used, observations to be made, expected duration.

Events : the course of the experiment and results obtained.

Conclusion : discussion of results, inferences, recommendations, suggested action.

OR, in short:

WHY?
HOW, WHEN & WHEREF?
WHAT HAPPENED?
SO WHAT?

3. The record of an investigation may be judged sufficient if a newcomer can successfully

(1) find the plot (if any) and locate its blocks or treatment subdivisions;

(2) discover why it was laid out and what it was intended to show;

(3) follow its history and understand how and when the observations were taken;

(4) read what was inferred, what practical conclusions were drawn, whether the experiment was closed or abandoned, and the reasons for doing so.

THE PLAN :

(commonly called the Investigation Plan, Experiment Plan, Research Plot Plan, etc.)

4. The Plan must cover **Origin** and **Intentions** only. In the case of the cheap-and short-term experiment, a single sentence may suffice. The long-term or-quantitative category needs more Information, with the following minimum requirements:

Divisions of an Investigation Plan

(1) Reasons for the investigation; background, previous work and publications, if any.

(2) Its objects, precisely what it is intended to discover, preferably in statistical terms.

(3) Intended situation, design, layout, methods of observation and analysis and recording, periodicity of review and duration.

(4) Resources required; equipment, staff and land.

(5) Name of originator, executor and date.

5. An Investigation Plan should make it possible for:

(1) a supervisor or administrator to assess its value and allocate the necessary resources;

(2) an adviser or critic to follow the method and check Its validity.

(3) A technically competent newcomer to carry the whole job through;

(4) A future investigator to re-interpret work long since closed. Note that results alone, without their plan and history, are often valueless.

THE RECORD OF EVENTS :

6. This covers only the third of the minimum requirements, namely the EVENTUALITY or "WHAT HAPPENED" section. Three stages are necessary : state of affairs at the start, what happened during the work, and its physical result, (not the scientific or practical inferences).

7. Initial description Whatever the intentions of the plan, there will be some differences when it comes to be physically set up, which may affect results and interpretation. The following are essential:

(1) Location: sufficient information to allow a newcomer to find the plot or place of mvestigation e.g., situation and plot maps, description of the access route.

(2) initial condition: applies mainly to studies in the forest or nursery; may vary from a detailed ecological or silvicultural description to a brief definition of seed-bed type or laboratory material.

(3) initial operations: what was actually done, noting especially any deviations form the investigation plan. If the latter was followed precisely, it is merely necessary to state the fact.

8. Subsequent events; i.e. what happened during the course of the work. This item may continue for many years. Three types of record are necessary:

(1) textural record of inspections, observations, treatments and other works. Each entry must be dated and the observer's name noted.

(2) tabulated or diagrammatic record of measurements counts, analyses, etc. A common fault in this section is failure to note dates, operators and units.

(3) periodic summaries. Section (1) and (2) become bulky over the years, and even this . section must be closely watched for brevity. Often the appropriate paragraph from the research officer's annual report is sufficient.

9 Results This section should always be brief. It may consist only of the final periodic summary. It should summarise only the physical results of the investigation, if possible unclouded by the Judgement of the researcher and without any recommendations.

THE CONCLUSIONS :

10. In this scheme, "conclusions" must be kept quite clear from the "results". The latter are purely physical, the former discuss the importance of the results to theory and practice and make suggestions as to how may be used.

The concluding section must include:

(1) Interpretation and inference: translating the results into theoretical and practical terms. It is here that statistical safeguards and the weight of evidence may need discussion.

(2) Recommendations: usually this will be very brief, but must include suggestions:

- for the investigation itself; close? continue? extend further? local dissemination or publication?
- for field practice - nil or limited or widespread action?

PRESENTATION OF RESULTS OF EXPERIMENTS :

The analysis of an experiment cannot be considered complete until the results have been described in a report. This should be done while the details are fresh in the mind of the experimenter. Actual headings will depend on the nature of the experiment but the following headings are usually considered to be the most important.

1) Objects of the experiment

A clear statement of the objectives, together with definitions of the treatments and the limitations within which inference from results can be made. The particular hypothesis or hypotheses to be tested are given.

2) Design of the experiment

Description of the type of design and number of replications plus an actual plan of the layout. Details of blocking and what sources of variation are accounted for. Analysis of variance table; details of any partitioning; analysis of covariance.

3) **List of variables assessed**

List all variables measured and If necessary define the method used.

4) **Practical considerations and difficulties**

Describe any practical difficulties, mistakes; any other factors which are not allowed for in the design and which may have affected the results, e.g. bird damage, effect of unexpected drought etc.

Missing plots - reasons for and method used to overcome in the analysis. The use of transformations e.g. angular transformation for data as percentages.

5) **Results of the experiment in detail**

Main body of the report. Full discussion of the results. Summarisation of the data in simple tables is the basis of the discussion. These tables give the treatment means, together with standard errors and the differences for significance between pairs of values. Interactions can be shown by two or three-way tables.

Graphs may aid presentation especially for experiments involving regression or correlation.

Results should also be given in words.

6) **Criticisms of experiments and suggestions for improvement**

Has experiment fulfilled the objectives? Should treatments be modified or more suitable factorial combinations used? Was design suitable: any variation left uncentrolled? Was the number of replications too few or too many?

7) **Summary of data**

Useful to give the basic data as an appendix if analysis is for someone who will not have access to the working file.

8) **Methods used in the analysis**

Calculations should not be given but left in the working file. If the method of analysis was unusual it may be of value to include a short description as an appendix.

NOTE :

If an experiment plan (control plan) exists then this can replace the first two headings.

THE CHECKLIST FOR INTERPRETATION AND PRESENTATION OF RESULTS :

CLARITY :

1. Choose the most appropriate technique to Illustrate each result.
2. Use established, familiar methods unless a new or unfamiliar method has clear superiority.
3. Avoid jargon wherever possible.
4. Exclude extraneous information from tables and figures.
5. Do not present too much information at once. Keep tables as small as possible and figures simple.
6. Use two (or at most three) significant digits when presenting numerical results.
7. Arrange information in tables so that the most Important comparisons are made between adjacent or nearly adjacent values in columns.
8. Use clear, informative titles and labels for tables and figures.
9. Use standard notation wherever possible. Define all notations. Give variables meaningful names or symbols.
10. Include appropriate estimates of experimental error to assist interpretation of your results.
11. Give significance probability values, rather than asterisks.

VALIDITY :

12. Choose methods so as to provide answers to appropriate questions, as directly as possible.
13. Intrinsic assumptions of the methods must be satisfied and they should be reasonably based.
14. The data must support conclusions drawn from them.
15. Avoid invalid or dubious extrapolation to circumstances outside the range or vicinity of experimental conditions.
16. Use appropriate statistical tests.
17. Be consistent in the choice of methods.
18. Do not omit or select data without a valid reason. Explain why.

19. Evidence is not proof.
20. Statistical referencing is essential.

RELEVANCE :

21. Present only those statistical results that are relevant to the theme and conclusions of the report.
22. Describe relevant background, including experimental conditions and design.
23. Avoid duplication.
24. Use the appropriate analytical approach, especially in the choice between estimation and significance testing.
25. Do not present raw data unless they are very brief and essential to the reader.
26. Think twice before presenting analysis of variance tables or tables of correlation coefficients.
27. Discuss all important results, including any unexpected non-responses.
28. Distinguish between statistical significance and practical significance.

AN EXAMPLE ON FORESTRY RESEARCH TRIAL DESIGN AND MANAGEMENT :

1. **RESEARCH PROGRAMMING :** The need for a good research plan, setting out priorities and projects, together with allocation of responsibilities. Continuity is important as forestry research is long-term, and others will have to follow. Simple designs and excellent records are therefore essential

2. **THE WORK PLAN :** It is the most important part of research. Gathering the thoughts. Discussing ideas, researching the literature. Planning the work. Why a work plan is necessary: so that Research Director has input, and work is approved; to ensure the methods are appropriate. Chapters should be Rationale (Justification for the work), Background (any past work, what prompted the work), Materials, Methods, Design, Costs, Collaborators. It is a good idea for all those taking part to sign the work plan.

3. **TRIAL DESIGN :** The fundamentals of good trial design and management. Work Plan should cover all the aspects.

   - Choice of entries (treatment). What to include in the trial, what to leave out. Importance of controls (e.g., genetic checks). Anticipate and look ahead the types of answers you will want. Importance of local controls. But do not try to answer all questions in one trial. Try also not to proliferate trials unnecessarily. Think out each trial carefully. Number of entries is important, as it effect precision, land area, maintenance costs.

- Experimental design. Statistical aspects. Randomisation and replication. Degrees of freedom. Design option. Type of analysis. RCB as the standard. How many reps? Plot size? Plot shape? Should thinning be allowed for? How many sites? Replication over sites for security and G x E interaction. Single tree plot: precise and unbiased. Robustness of designs. The need for valid comparisons e.g. tissue culture vs seedlings should be of the same genetic material, and equivalent planting stock quality.

- Selection of sites. A very Important aspect. General experience is that good growth sites give the bet results. Extreme sites can be useful for screening (disease resistance, drought resistance).

- Trial establishment and maintenance. Quality of planting stock very important. Good seedlings or cuttings, even size. Accuracy. Careful planting. Records, maps. Regular inspection. Maintenance and protection (fire, animals) Trial diary. Photographs. Management prescription. At what age are results meaningful?

- Recording and application of results: should be considered during trial initiation and design, at time of design of assessments, and during interpretation of results. Layout and contents of the report. Who will read the results, who will use the results.

- Assessment. When, how often, what traits. Organisation of the field crews. Data recording. Comparability between crews. Each crew to do a rep? Observer effects. Measurement traits. Score traits (yes/ no, or scales 1-9). Routine traits: height, diameter, stem form, health. Specialised assessment: wood properties, nutrient contents, oleoresin content.

4. DATA MANAGEMENT AND ANALYSIS :

- Data capture: emphasise again the importance of accurate measurement, scoring, and recording. Fool-roof method required. Fundamentals are accurate navigation of field crews and accurate recording. Field assessment sheets should be designed for easy recording in the field, avoiding transcription, and rapid entry into the computer. It is important that the data entry system be customised for the particular analyses to be performed. Single-tree plot layouts: field map entered into the computer.

- Statistical analysis: planning the analysis: what analyses are required. Can take much more time than the measurement. Important that data is promptly analysed and results used. Preliminary cleaning of data, trimming of outliers. Transformations for normalisation of data, homogeneity of variances (Bartlett's Test) purpose of assessment: estimating and comparing means, with multiple comparison tests. First step is ranked list of means with general mean, F-test for treatments, and LSD (.05). This enables winners to be picked for each trait at each site, and over all sites combined. These will be the main results of interest. Graphic presentation of results. Mathematical linear model of the data. Random, mixed, and fixed-effects models. Supplementary quadratic analyses can be numerous and time-consuming, but are an Important part of interpreting the data. This includes estimation of variance and covariance components, genetic parameters, and genotype X environment interaction, and juvenile-mature correlations. Expectation of mean squares. Selection indices. Importance of getting a measure of precision (standard error of estimates).

- Analytical and computing methods. The handling of missing data, and imbalance generally. "Messy" data is normal. Computer programme to be used: SAS, GENSTAT, SPSS, SISS, etc. Select a basic approach for handling the trial analyses, e.g. Henderson Method I, Henderson Method 3 (least squares). Important that the algebra of the method be understood. -In tree improvement, range in complexity: RCB balanced clonal test on one site to unbalanced disconnected dialled on several sites, with multiple traits and different years of measurement. The only way to learn is to get plenty of experience, and to become thoroughly familiar with the computer.

5. PRACTICAL EXAMPLE :

A clonal test of 5 Eucalyptus clones.

Planning

- Work Plan
- Choice of clones
- Design
- Sites
- Reps
- Plot size, shape

Plant propagation

- Propagation : number of plants required
- Propagation : quality of planting stock
- Propagation : accuracy of labelling and Identity

Establishment

- ❐ Field site selection
- ❐ Site preparation
- ❐ Layout of trial: survey, pegs
- ❐ Planting, weed control, fertilising
- ❐ Records, maps, field file.

Maintenance

- ❐ Regular inspection
- ❐ Protection and maintenance

Assessment

- ❐ Purpose of assessment (e.g. choose best clones to multiply up in clonal multiplication garden)
- ❐ What and when to assess (height, diameter, etc.)
- ❐ Need for accuracy of measurement and recording
- ❐ How soon can conclusive measurements be obtained (half-rotation)

Analysis

- ❐ Decide on the analysis to be done, and statistical programme
- ❐ Enter the data into the computer
- ❐ Analyse the data (analysis of variance, ranking of means, range test of least significant difference)
- ❐ Genetic gain: 5% superiority of best clones over average of all clones and/ or a seedling control

Application of Results

- ❐ Choose the best clones
- ❐ **Future Management**
- ❐ Thinning of trial
- ❐ Felling of trees for coppicing and/ or wood testing
- ❐ Future assessment

Writing up the Results

- ❐ Internal report (Department records). Introduction, Method and Materials (site description, propagation of plants, planting, trial design, list of clones, assessment traits), Results, Discussion, Conclusions, Applications, References, Annexes (data, analyses of variance, location map of trial)
- ❐ Publication.

ANALYSIS OF A CLONAL TEST

Number of clones	:	5
Number of reps	:	3
Plot size	:	3 trees
Trait	:	diameter (cm)

RAW DATA

CLONE	REP 1	REP 2	REP 3
1	47 52 44	67 70 61	69 69 60
2	59 55 60	77 80 77	52 69 56
3	39 44 41	55 57 66	49 51 55
4	515252	68 55 61	42 52 53
5	70 65 69	73 66 71	69 71 67

VIEW DATA

Case	*Clone*	*Diameter*	*Height*	*New*	*Number*	*Rep*	*Tree*
1.	1.0000	47.000	6.7000	47.000	47.000	1.0000	1.0000
2.	1.0000	52.000	6.9000	52.000	52.000	1.0000	2.0000
3.	1.0000	44.000	6.3000	44.000	44.000	1.0000	3.0000
4.	2.0000	59.000	8.3000	59.000	59.000	1.0000	1.0000
5.	2.0000	55.000	7.7000	55.000	55.000	1.0000	2.0000
6.	2.0000	60.000	9.1000	60.000	60.000	1.0000	3.0000
7.	3.0000	39.000	4.5000	39.000	39.000	1.0000	1.0000
8.	3.0000	44.000	5.2000.	44.000	44.000	1.0000	2.0000
9.	3.0000	41.000	5.0000	41.000	41.000	1.0000	3.0000
10.	4.0000	51.000	6.5000	51.000	51.000	1.0000	1.0000
11.	4.0000	52.000	7.0000	52.000	52.000	1.0000	2.0000
12.	4.0000	52.000	6.9000	52.000	52.000	1.0000	3.0000
13.	5.0000	70.000	8.8000	70.000	70.000	1.0000	1.0000
14.	5.0000	65.000	7.0000	65.000	65.000	1.0000	2.0000
15.	5.0000	69.000	8.6000	69.000	69.000	1.0000	3.0000
16.	1.0000	67.000	7.2000	67.000	67.000	2.0000	1.0000
17.	1.0000	70.000	7.5000	70.000	70.000	2,0000	2.0000
18.	1.0000	61.000	6.5000	61.000	61.000	2.0000	3.0000
19.	2.0000	77.000	9.6000	77.000	77.000	2.0000	1.0000

20.	2.0000	80.000	9.1000	80.000	80.000	2.0000	2.0000
21.	2.0000	77.000	8.8000	77.000	77.000	2.0000	3.0000
22.	3.0000	55.000	6.1000	55.000	55.000	2.0000	1.0000
23.	3.0000	57.000	5.7000	57.000	57.000	2.0000	2.0000
24.	3.0000	66.000	7.3000	66.000	66.000	2.0000	3.0000
25.	4.0000	68.000	6.9000	68.000	68.000	2.0000	1.0000
26.	4.0000	55.000	5.3000	55.000	55.000	2.0000	2.0000
27.	4.0000	61.000	6.5000	61.000	61.000	2.0000	3.0000
28.	5.0000	73.000	9.9000	73.000	73.000	2.0000	1.0000
29.	5.0000	66.000	7.8000	66.000	66.000	2.0000	2.0000
30.	5.0000	71.000	8.8000	71.000	71.000	2.0000	3.0000
31.	1.0000	69.000	8.5000	69.000	69.000	3.0000	1.0000
32.	1.0000	69.000	8.0000	69.000	69.000	3.0000	2.0000
33.	1.0000	60.000	7.8000	60.000	60.000	3.0000	3.0000
34.	2.0000	52.000	6.5000	52.000	52.000	3.0000	1.0000
35.	2.0000	69.000	7.6000	69.000	69.000	3.0000	2.0000
36.	2.0000	56.000	7.0000	56.000	56.000	3.0000	3.0000
37.	3.0000	49.000	5.2000	49.000	49.000	3.0000	1.0000
38.	3.0000	51.000	6.7000	51.000	51.000	3.0000	2.0000
39.	3.0000	55.000	6.0000	55.000	55.000	3.0000	3.0000
40.	4.0000	45.000	5.7000	45.000	45.000	3.0000	1.0000
41.	4.0000	52.000	6.0000	52.000	52.000	3.0000	2.0000
42.	4.0000	53.000	6.2000	53.000	53.000	3.0000	3.0000
43.	5.0000	69.000	9.8000	69.000	69.000	3.0000	1.0000
44.	5.0000	71.000	9.7000	71.000	71.000	3.0000	2.0000
45.	5.0000	67.000	8.9000	67.000	67.000	3.0000	3.0000

ANALYSIS OF VARIANCE TABLE FOR DIAMETER

SOURCE	DF	SS	MS	F	P
CLONE (A)	4	2006.80	501.69	5.30	0.0220
REP(B)	2	1397.20	698.60	7.38	0.0153
A*B	8	757.24	94.656		
TREE (C)		0			
A*B*C	30	578.00	19.267		
TOTAL	44	4739.24			
GRAND AVERAGE	1	1.6092E+05			

LEAST SIGNIFICANT DIFFERENCE PAIRWISE COMPARISONS OF DIAMETER BY CLONE

Clone	Mean	Homogeneous Groups
5	69.00	I
2	65.00	I
1	59.89	I
4	54.33	..I
3	50.78	..I

THERE ARE 2 GROUPS IN WHICH THE MEANS ARE NOT SIGNIFICANTLY DIFFERENT FROM ONE ANOTHER

CRITICAL 'T' VALUE 2.306, REJECTION LEVEL 0.050

CRITICAL VALUE FOR COMPARISON 10.576

STANDARD ERROR FOR COMPARISON 4.5863

ERROR TERM USED : CLONE REP, 8 DF

SEED TECHNOLOGY

INTRODUCTION :

In consonance with the recognition of the fact that improved planting stock may increase the productivity of the planted crop, it is increasingly felt that use of genetically improve reproduction propagules by the nursery manager is an important factor for the production of improved planting stock. Specialised seed organisation is required not only to ensure that seed is available where, when and in the quantities required, but also because the seed procurement is complicated by a number of factors affecting physiological quality and genetic characteristics.

The standard of seed handling, at all stages from collection to sowing is an important factor affecting physiological quality, while genetic characteristics are affected by choice of seed source and in the long term, by the breeding of the improved genotypes and at the same time by the conservation of the maximum possible diversity of genetic resources.

In the past not much attention has been paid for strengthening the seed certification although there was a serious effort to improve the seed source particularly in case of teak. Many Seed Collection Areas (Seed stands, and Seed Production Areas (SPA)) for teak were identified and maintained for collection of improved quality of seed.

Keeping in view the importance of procuring the seeds of improved physiological and genetic quality, APFD has to focus its attention towards all practices designed to produce seeds of high genetic quality such as species priorities and seed procurement strategies, identification and development of seeds, seed technology, collection, processing, testing, storage and pretreatment of seeds.

The immediate priorities of seed research are as follows:

- Organisational structure of the Seed Unit has to be strengthened technically by exposing the staff to training in seed handling.
- Infrastructure of seed collection, seed processing, seed cleaning, seed testing and certification has to be improved. The storage of short-viable seeds should be given importance.
- Management of seed production areas requires constant attention. It is essential to ensure that identified and marked SPAs are rouged immediately.
- As a long term objective, more Clonal Seed Orchards (CSOs), Seedling Seed Orchards (SSOs) and Provenance conservation stands are established for abundant supply of genetically improved seeds.

- Exploration, testing, evaluation and utilisation of superior seed sources and recommendation for choice of provenance.

SEED SOURCES :

When planning the seed programme, it is important to have clear objectives. These can be outlined as follows:

- The immediate objectives are to prepare strategies for seed procurement and tree Improvement (unselected natural stands, plantations, import of seeds) which will make it possible to cover the immediate seed demand appropriately. At the same time, long term measures such as selection, conservation and establishment of seeds sources and breeding population to include plus tree selection and introduced superior genetic germplasm should be incorporated.
- The long-term objective is to ensure the provision of a sustained supply of seed of high genetic and physiological quality for afforestation and tree breeding schemes aimed at the creation of well-adapted populations of woody species.

Both these objectives require to run in parallel and to be supported by well documented seed information together with laboratory and filed testing.

ASSESSMENT OF PRIORITIES:

Establishment of improved seed sources is time consuming and expensive. It is therefore essential at the planning stage to limit the scale of the work by carefully assessing the priorities of each species for inclusion In the programme, in the State's planting requirements. Following are the priority species for which seed source improvement works are to be taken up.

1. TECTONIA GRANDIS
2. EUCALTYPES
3. CASUARINA EQUISETIFOLIA
4. GMELINA ARBOREA
5. ALBIZZIA ODORATISSIMA
6. DALBERGIA LATIFOLIA
7. TERMINALIA ALATA
8. PTEROCARPUS MARSUPIUM
9. P.SANTALINUS
10. ADINA CORDIFOLIA
11. A NOGEISSUS LATIFOLIA
12. ACACIA NILOTICA
13. DALBERGIA SISSOO
14. AZADIRACHTA INDICA

Objective of seed unit is to collect genetically superior varieties of seeds from recognised, identified, selected and certified sources followed by seed testing and supply to the different planting agencies. Seed sources can be classified into a number categories based on the germplasm used for establishment which in turn is related to genetic potential. The following categories demonstrate the range of seed sources which have different genetic potential. These range from routine seed sources where there has been no genetic improvement to seed orchards where the best tree breeding principles and genetic material has been used. For a more scientific evaluation of the genetic potential of seed sources, the problem would have to be addressed through field trials.

The demand of teak and miscellaneous seeds is very high, and therefore all the seeds can not be supplied from the clonal seed orchards or seedling seed orchards. As a short term strategy for the collection of genetically better seeds, number of seed production areas and seed stands to be identified and maintained. The following paragraphs indicate the various genetic improvement gradients of seed sources.

a) Routine seed sources from seed stand:

Stand of trees originating from either a natural source or planted using indigenous or exotic species for which there has been no selection or thinning to retain the bet trees forms the seed stand. Most of such seed collection areas are plantation crops. Generally in the case of a stand being established from seed of single tree, this may be regarded as the worst possible seed source with subsequent seed being a result of inbreeding and should be avoided. Conversely, seed collected from natural stand is likely to consist of a broad genetic base and therefore be more desirable to collect from them.

Keeping in view the Increase in the demand of the seed, attempt has to be made to identify more number of such stands as seed collection areas or stands and then convert such seed collection areas or seed stands to seed production areas (SPA) by culling down the phenotypically inferior trees and Intensively managing the retained trees for the production of more quantity of seeds. It has been considered the first level of improvement of seed source because the seeds from these areas are better than the seeds collected from an unidentified source.

However, till adequate quantity of seeds are available from the established SPA or provenance stands, the procedure of seed collection from seed stand will have to be continued. However the Research Wing requires to have the sole responsibility for monitoring collections from routine seed sources like the seed stands. Routine seed sources should be identified and registered with information on species, location, area, number of trees, age where known, natural or planted. Wherever trees are veiy close reducing the yield, arrangements for rouging the seed stands should be made.

The first and foremost important job of the Research Wing, incharge of the seed collection is to accelerate the activities related to the survey of stands of different species available for seed collection classified according to seed zone (agro-climate) and quality. The best available local stands, sufficiently isolated from inferior sources of the same species and from hybridising species should be thinned and managed as "Seed Production Areas" (SPA). Seed from these improved collections of different agro-climatic seed zones should be used to establish **ex situ** seed production stands under broad provenance groupings. This work can also solve the purpose of establishing ex situ conservation stands. Seed yields from these stands would provide genetically superior seeds than from a SPA.

SEED PRODUCTION AREAS (SPA) :

SPA is phenotypically a superior stand resulting from the selection of better than average trees and treated to Improve seed production. It provides genetically superior quality seeds over routine seed sources.

ESTABLISHMENT OF SEED STANDS/SEED PRODUCTION AREAS :

Converting a stand into a seed stand implies following actions:

1. Delineation of the area.

The minimum area for practical management is about 4 ha. The borders are clearly demarcated in the area with poles and signboards, and indicated in the forest map.

2. Selection and demarcation of seed trees and trees to be removed

The selection criteria have been established like fast growth, stem straightness etc. and those trees that do not meet a minimum standard are demarcated for roguing. The individual trees to be retained in the seed production area are demarcated and sometimes numbered. It is easier if both the trees to be retained and the trees to be cut are demarcated, e.g., the former with a ring and the latter with a cross. When crossing trees for cutting, it is advisable to cross at two sides, so that the mark is easily discovered by the forest labourers.

Importance should be given to both functions of the seed stand, viz., the production of abundant seed and the production of Improved seed. Although all inferior phenotypes should be rogued no matter whether it will leave some gaps without trees, there should still be enough trees left for seed production. There are generally two ways of selecting.

a) The seed trees are selected as the best trees in the stand no matter their distribution. This method will leave an uneven distribution of seed trees in the stand. The selection differential is higher but the seed production is likely to be lower.

b) The area is subdivided into smaller plots in which the best trees are selected as seed trees. In case two trees are equal the selection should be according to proper spacing. This method leaves a more even distribution of seed trees in the stand. The selection differential is lower but the seed production is likely to be higher.

Selection of trees on an exposed border is usually difficult since these trees have favourable growth conditions and often exhibit a peculiar growth form (e.g. wide asymetric crown) which is not desired for plantation trees. The selection criteria should hence be less rigid for those trees.

In case of dioecious species, care should be taken so that sufficient male trees are left behind for pollination.

3. Rogueing of inferior phenotypes.

The inferior phenotypes are cut and removed. That holds for all inferior phenotypes no matter whether it implies large openings.

4. Additional thinning of the stand

If rogueing leaves too many trees in the stand in total or in certain parts, some additional trees are thinned out. These trees may be acceptable for seed production and the operation is purely silvicultural in order to improve the spacing and consequently promote flowering of the remaining trees. However, when thinning is carried out it should still leave the best material behind. The line stand should leave about 100-200 trees per hectare. It is important that the first thinning is done early.

Rogueing and thinnings should be done carefully in order to avoid or minimise damage to the remaining seed trees in the stand. Trees with partly damaged crowns are not good seed producers and broken branches and other damages may serve as entry points for fungal diseases.

Opening a stand by rogueing and thinning implies some risks by leaving the remaining trees exposed to adverse weather conditions. There are two main risks.

1. In hot humid climates and especially for climax forest species vulnerable to desiccation.

2. In areas exposed to heavy wind and for species prone to windthrow.

The problems may be overcome by rogueing and thinning in several steps - not the total operation at one time. This will allow the remaining trees to adjust and adapt to the new conditions.

3. The time of cutting should be chosen such as to minimise the negative effects. For example If desiccation is the major risk, just before the onset of the rainy season.

4. In certain areas a method is applied in which the trees to be cut are girdled, causing a slow die back of the trees and allowing the remaining trees to adapt to more open exposure. Poisoning tree prior to cutting may be applicable, but implies a risk of killing or damaging trees to be retained since the root systems are connected.

Using this method implies, however, a risk that dying trees may attract pest diseases. If the method is applied, the trees should be cut and removed soon after they have lost their leaves.

5. Removal of debris and cut material.

The rogued and thinned material should be removed in order to avoid attracting diseases, being a fire hazard or impede traffic in the area.

6. Establishment of a pollen dilution zone (PDZ) around the SPA.

The PDZ may be open (grass or other low vegetation) or have trees that are different from the species of the SPA and which do not hybridize with that species. If the stand is part of a larger stand, it should be selected so that it is surrounded by a zone of good phenotypes.

*Note: A seed stand is likely to produce an abundant fruit trees crop only after full crown development of the remaining trees which Is likely to take 1-3 years after thinning, dependent on species, location, etc.,

The following management principles have to be adopted in the existing and proposed SPAs in future:

- The site quality for the proposed SPA should not be less than All India Site Quality-IV and in natural stands the SPA should comprise an area of uniform environment.
- Age of stands selected for SPA should not be less than (30- to 50 yearly)vigorously growing stand, but not too old. Generally It should be half the rotation age. Trees should be sufficiently old enough to be able to assessed their phenotypic potential. It is generally seen that good parent trees can be selected at an early age in a very young plantation based on superior height growth. Teak stands should be rogued for SPA before they attain 20 to 30 years. This would allow the crowns to develop into a large open

- habit, shorter bole length for ease of climbing, reduced damage to tree crown and flowering/fruit development, earlier flowering and over-all easier management of SPAs. In general, it should be said that there needs to be some assurance of the likelihood of flowering of the trees remaining when the selection of relatively earlier age plantation to be converted to SPA is made on the basis of superior height growth.
- Areas of SPAs should be between 2-5 Ha. wherever there is an area exceeding 5 Hec. in extent, the area can be divided Into sections of 5 Ha. each and merit of each section shall then be studied.
- The roguing of phenotyplcally inferior trees should be made as a first step towards the improvement of the stand. Then, the successive thinnings can be made in stages depending on the observation of gradual crown development. Care should be taken not to open up the crown at one stage because they will result in the development of malformed crown and suffer from the risk of wind damage.
- It is recommended that a fully developed SPA of teak should have 100-120 trees for Hec. For the optimum crown development and maximum fruit production.
- Evidence of flowering and seeding in the area proposed for SPA should be known. This Is especially Important in species planted off site and exotics where flowering may fail or seed does not develop. This might be because of the lack of suitable pollinating agents or climatic factors.

SPA must represent the range of planting zones especially where the afforestation area is heterogenous.

Location of SPA should take into account the easy access for seed collection.

- Consideration should be given to reduce pollen contamination from inferior sources and so the clearance of inferior teak trees to a distance of 100 Mts. from the periphery of the SPA should be made.
- When establishing SPA in plantations, the origin of the seed from which the plantation was established should be known wherever possible. In case of dioecious trees (Casuariana) a dominance of female trees should be maintained, but one must take care for sufficient evenly scattered male trees in order to provide pollen.
- In order to keep under-story growth down for collection purpose, the sowing and enrichment of pasture grasses, fodder etc. should be encouraged along with grazing by live stock.

- Application of fertilizers to increase the seed production is considered to be an important step in the management of the SPAs. Nitrozen is believed to promote vegetative growth often at the expense of flowering. So, it is preferred that application of granulated PK with micronutrients may be applied. Timing of fertilization may need to coincide with the time of flower differentiation and therefore species specific. Soil analysis on the nutrients level is useful for the determination of quantity and quality of the fertilizers.

- It is generally recommended to dig up circular trenches of 30 cm. depth and 3 mt. away from the tree and apply the fertilizers in doses so that leaching of fertilizer becomes gradual. Promotion of Insect pollinators at the time of flowering should be explored such as through the introduction of bees. This work is particularly relevant in trying to increase the production of seed orchards.

- Flowering can be improved by application of flower inducing hormone or inducing stress to the plants.

- Record malnenance for seed production area is extremely important. Record must indicate the source, longitude, latitude, altitude, rainfall In the year, soil analysis data, number of seed bearers, rogueing intensity, quality and quantity of fertilizer applied, flowering intensity, fruit setting intensity, quantity of pure and aborted seeds/ fruits formed, harvested quantity etc.

GUIDELINES ON ESTABLISHMENT OF SEED PRODUCTION AREAS (SPA) :

Development of Seed Production Area is an important tree improvement programme, since it often provides the first source of superior planting material. It is not directly linked to the establishment of seed orchards, which are advanced sources of improved planting material. But, It often forms an interim source until progeny tested seeds can be obtained from the seed orchards. .

Seeds produced from a non-progeny tested Seed Production Area will not give the same gain as seed produced from a progeny tested seed orchard. Yet, It is an improvement as compared to seed produced from a non-selected stand. Further, the use of Seed Production Area usually gives better information of the origin of the seeds viz. adaptability, genetic base etc.

The Seed Production Area is a phenotypically superior stand, that has been thinned and treated to cause abundant seed production of better than average seed. It is only a temporary or intermediate source to meet the Immediate demand of better than the routine seed, until the seed orchards come into production.

Seed Production Area is established in natural stands or plantations with a high frequency of phenotypically good Individuals. The stand should be healthy, vigorously growing with trees of good bole formations, well developed crowns and free from diseases. The crop should be middle aged having high reproductive vitality. The crop should be atleast 4.0 Ha. in extent for proper upkeep and maintenance.

The stand is then upgraded by removing all the inferior, suppressed and disease infected trees. The canopy should be manipulated by removing the stems in phased manner so as to give a final population of 100-150 trees per ha. depending on the site quality. Trees thus selected for retention, should be well placed so that they have adequate space for crown development for ultimate production of seeds. The developed crown should be exposed to the sun, as much possible as it plays an important role in flowering and fruiting of trees. Other cultural operations are taken up including removal of miscellaneous growth, giving fertilizers for increasing the production.

FLOW CHART FOR THE ESTABLISHMENT OF SEED PRODUCTION AREA

↓

Delineation

↓

Thinning to remove inferior trees and increase the production

↓

Seed Production Area

↓

Seed Collection for planting programmes

METHODOLOGY :

The Seed Production Areas are established by culling the inferior trees from the best of the available plantations/ Seed Stands. An assessment of available plantations for their growth, form and preponderance of superior trees by sampling and ranking them would help in selecting the best plantation for conversion into Seed Production Area. Further, it is not always the whole stand that is converted into Seed Production Area, but only a part of it, for various reasons. When such plots are selected it is essential to lay sample plots of 0.25ha. with 3 to 5% sampling intensity, for making the comparison. The sample plots help in making comparison not only between the selected plot and the whole seed stand/ plantation, but also between stands.

While converting, the selected seed stand or a plantation into a Seed Production Area, the trees retained for seed production should be the best trees in the population. This can be achieved by ranking of trees for selected traits and culling out the inferior trees. As the number of trees to be scored for various traits in a seed stand are quite high, it is not easy to score for all the traits as is done in the case of plus tree selection. Hence a modified method for comparison of different stands and between selected plots within a stand based on preponderance of superior trees and comparison and ranking of trees based on the growth, form and health within the selected plot, is presented below.

Seed stands are selected by surveying the plantations three times the area required for final conversion into SPA. The seed production area are established in different zones of the state based on the site quality and age of the plantations.

SAMPLE PLOT :

Sample plots are required to be laid out in all plantations. Seed stands which are identified as having potential for conversion into SPAs. Where portion of the plantation is selected sample plot is required to be laid out both within the selected area and outside for comparison.

SIZE AND NUMBER OF SAMPLE PLOTS :

The size of the sample plot is fixed as 0.25 ha. the sample plots have to be laid out in each of the identified stands. The number of sample plots depend on the size of the stand. Generally it should be 3 to 5% of the total area. The sample plots have to be laid out both in the selected plot having potential for conversion into SPA and outside, for the purpose of comparison.

SCORING OF TREES IN THE SAMPLE PLOTS :

The scoring is done for both quantitative and qualitative traits. The traits selected for scoring are:

1. Height (total height)
2. Clear bole Height
3. Diameter at breast height (DBH)
4. Straightness of stem
5. Roundness of stem
6. Crown
7. Health

The first three traits are quantitative measurements with high degree of heritability and higher correlation with volume production, whereas the rest of the traits are subjective assessments. The point grade method is followed for scoring the above traits. The maximum score a tree can have is 100. The traits such as Length, Clear Bole Height and DBH are given maximum net score or 72 as these are the primary economic traits with high heritability.

SCORING FOR HEIGHT/ CLEAR BOLE HEIGHT:

% of Superiority of each tree m the sample plot over average of sample plot	Score
<-20	0
-12to-16	1
-15 to-11	3
-10 to-6	5
-5to-l	7
1-15	9
6-10	11
11-15	13
16-20	15
>20	18

SCORING FOR D.B.H:

% Superiority of each tree in the sample plot over average of sample plot	Score
<-20	0
-12to-16	2
-15 to-11	6
-10 to-6	10
-5to-l	14
1-15	18
6-10	22
11-15	26
16-20	30
>20	36

SCORING FOR STRAIGHTNESS :

Character	Score
Crooked	1
Wavering with 1 or 2 bends	5
Straight	9

SCORING FOR ROUNDNESS :

Character	Score
Heavy fluting	1
Medium fluting	5
Round	9

SCORING FOR HEALTH:

Character	Score
Heavily infested leading to death	0
Moderately infested	2
Healthy	5

SCORING CROWN:

Character	Score
Poor crown	1
Analysis	5

ANALYSIS :

(a) Comparison between stands or between a selected plot and outside within a stand

Within a sample plot all the trees are scored by the above method and the scores are summed up. The sum of all the scores of all sample plots representing a plantation or the selected area is totalled and the average score for the stand Is calculated.

All these stands are ranked in a descending order based on the average score of trees in the sample plots representing them. Then the stands are selected for conversion into SPAs from the top of the list, based on the are required to meet the seed demand.

(b) Comparison of trees within a stand selected for conversion in the SPA identification of trees for culling.

After selecting the stand/ plantation, all the trees in the whole of selected seed stand/ plantation are numbered and each of the tree is cored for the traits as described above. These trees are ranked in a descending order based on the scores obtained. Predetermined number of trees can be selected from the top of this list and the remaining trees can be culled out. The number of trees to be retained per hectare depends on the species, site quality, and the age of the stand. In case the selected trees are closely spaced than required for an SPA, some trees below the cut off point can also be selected, culling an equal number of trees from above the cut off point.

SCORING SHEET FOR EVALUATION OF THE SAMPLE PLOT:

1. Species : ....
2. Aee : ....
3. Natural stand : ....
4. Plantation : ....
5. Seed source : ....
6. Forest type : ....
7. Compt. No ....
8. Range ....
9. Division ....
10. Site Quality ....
11. Total area ....
12. Area selected ....

Tree No.	Total Height (Cm)	Clear bole height	DBH (cm)	Height Score	Clear Bole height	DBH Score	Starighness score	Roundness score	Health score	Crown Score	Total score /tree
Total											
Average											

COMPARATIVE ASSESSMENT OF PLANTATIONS/ SEED STANDS :

Name of the plantation	Sample plot no.	No. of trees in the sample plot	Total score
1.	1. 2. 3.		
Total Average score = Sum of total score/ No. of trees			
2.	1. 2. 3.		
Total Average score			

RANKING OF PLANTATIONS BASED ON AVERAGE SCORE :

Name of the plantation	Average score of trees in the sample plot

RANKING OF TREES FOR RETENTION/ CULLING IN A PLANTATION IDENTIFIED FOR CONVERSION INTO SPA :

Name of the plantation : ....

Year of plantation : ....

Location : ....

Tree No.	Score

ECONOMICS OF SELECTION OF SEED PRODUCTION AREA :

The Increment cost of using high quality planting stock Is relatively Insignificant compared to total plantation establishment costs. Cheap, low quality seedlings are frequently used and result m costly plantation failures.

Efficient seed source selection- produce the largest gain in a tree improvement program, while subsequent stages provide less gains. Seed production areas can generate physical gains ranging from 10-30%. Half-Sib seed source trials indicate that another 13-25% gain can be achieved after selecting superior individuals with in a Seed Production Area. Thus 23-55% gain can be achieved from selecting a Seed Production Area (World Bank Technical Paper No.281, 1996).

Although, the biological effectiveness of selection of Seed Production Area can be Indicated in volume gain, there are other benefits that have been harder to quantify. Those benefits include Improved quality (straightness, roundness and fewer branches .... etc.),

increased resistance to diseases, increased survival, reduced cost of weeding and seed collection. These benefits help reduce processing costs and increased product revenue which ultimately result in higher profitability.

SEED ORCHARDS :

The genetic quality of seeds from the Seed Orchards, whether Clonal Seed Orchard (CSO) or seedling Seed Orchard (SSO), constitute the highest level of improvement in the genetic improvement gradient of the seed source.

- It is worthwhile to plant some annual intercrops of leguminous spp. whose flowering time coincides with teak so that the activity of entomophtilic organisms Is increased in the Clonal Seed Orchards.

ESTALISHMENT AND MANAGEMENT OF SEED ORCHARDS :

Seed orchards are stands planted especially for the production of abundant superior seeds.

A seed orchard consists of trees where the phenotype is usually of minor importance as long as the trees will produce seeds. Only when the seedling seed orchard is combined with a genetic test (cum progeny trial) are the phenotypic characters of the trees important.

There are two main types of seed orchards, named according to the way of establishment.

1 Clonal Seed Orchard: Seed orchard from select clones propagated by grafting. Cutting, air layering or tissue culture.

2 Seedling Seed Orchard: Seed orchard raised from seedlings produced from selected parents through natural or controlled pollination.

Which type of orchards is best in the particular situation is dependent of, e.g. species and the breeding programme. It is subject of current discussion. Some characteristics of the two types are listed below:

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. Necessary when e.g. incompatibility between scion and stock or other constraints make vegetative propagation difficult.	Generally preferred when vegetative propagation is possible and the seed orchard only serve 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

Note :

Under the circumstances where a genetic test/progeny test is converted into a seedling seed orchard, these are the following constraints in terms of locations and management.

1. Genetic tests are carried out In areas similar to the potential planting area of future plantation programmes. This is not necessarily conducive for flower and seed production.

2. Genetic tests are carried out at narrower spacing with strong competiton whereas seed production requires wide spacing.

SIZE AND LONGEVITY OF SEED ORCHARD :

The size of the seed orchard is determined by the seed demand and the expected seed production from the orchard. Both figures are subject to estimates. Planting targets may be altered in the future and the seed production from individual trees are often only subject to qualified guesses. A minimum of atleast 25 clones or families to assure a sufficient genetic base and limit selfing A minimum should be used.

A seed orchard can in theory be operative as long as the trees are physiologically capable and producing seeds. In practice, however, a seed orchard will only be operative until a new improved seed orchard has been established, based on next generation progeny test. Seed Orchards are usually referred by generation, 1st, 2nd, 3rd etc.

LOCATION OF THE SEED ORCHARD :

Since the seed orchard is planted entirely for the production of seeds (with the exception of the combined genetic tests/seed orchards) the conditions should benefit flowering and fruiting. Selection of the appropriate site for the seed orchard will ease the management during and after the establishment.

1. SPECIES SPECIFIC REQUIREMENTS:

Climate: temperature, precipitation, photo-period, wind exposure.
Soil: texture, nutrients, pH, drainage
Topography: flat/hilly/mountainous, exposure.
Altitude: meter above sea level.

Knowledge of the species specific requirement and especially reproductive biology is crucial for .proper matching of species and site, i.e. to be sure that the species will produce fruits at the site in question. The seed orchard should be established in the main portion of the species geographical and ecological range. For exotics, a seed orchard should be established only once the flowering and fruiting having been successfully proven in the area. The site should be selected in order to promote seed production only unless It Is combined with a genetic test. **A site with average fertility is preferred to .an area with high fertility since the latter may promote vegetative growth on the expense of reproduction.** That may be especially important for low demanding species. A poor soil fertility can be manipulated with the application of fertilizer.

A flat or slightly undulating area is generally preferred since such area is generally homogenous in soil structure and fertility.

In a mountainous area, mountains will cast shade according to sun position (season and time of the day), that may have a crucial Influence upon the reproductive biology of the trees. Special threats such as termites should be taken into consideration when selecting the area in areas where, e.g. termites are problems.

2. MANAGEMENT REQUIREMENTS :

Accessibility
Labour availability
Close to administration.
Close to nursery.
Gentle topography.

The seed orchard should be established as strategic for rational management as possible. Since the seed orchard is labour intensive both in terms of operation (establishment, maintenance, seed collection, etc.,) and administration (record management, organisation of labour, etc) a central place, e.g. near to a local forest administration office and nursery is preferable. Such areas may also be easier to protect. A flat or slightly hilly area Is preferred because it permits mechanical operation by tractors and other machines.

3. PROTECTION:

Strong winds, cyclone, etc.
Fire
Illegal logging/ fuelwood collection
Destroying animals

A seed orchard site should be established far from places where natural disasters are frequent. In areas where strong winds and cyclones occur, It should be placed as little exposed as possible, i.e., sheltered by hills or mountains. Fire is mainly caused by man and it is advisable that the orchard site be placed where e.g. grass fires are rare. In areas with severe wood shortage and consequent cutting and fuelwood collection, the orchards may be in danger unless the area has been negotiated with local communities. Both wild and domestic animals can be destructive to seed orchards. Location close to national parks/ game reserves or close to villages where for example, goats and cattle graze freely may be destructive. In general remote places should be avoided since they may be difficult to approach.

4. SPECIFIC ORCHARD REQUIREMENTS :

Isolation from pollen contamination (distance and time).

The seed orchard should be placed as far as possible to stands of the same species or species with which they can hybridize. If the species has a different phenology, crossing will be separated In time. Establishment of pollen dilution zones and, especially for wind pollinated species, a design with long axis of the orchard with the direction of the prevailing wind decreases the risk of pollen contamination. The seed orchard should provide optimal conditions for the pollination agent. In case of exotics with very specific pollination (e.g. birds or bats) pollination may be restricted due to lack or proper pollination agent.

5. OTHER SIDE REQUIREMENTS :

Land tenure. Possible future land requirement.

Establishment of a seed orchard on community land may give problems with local community interest since it may interfere with possible traditional or alternative land use. Knowledge of possible plans for future alternative land use, e.g. roads, buildings, inclusion into urban zones, etc., is important for the longevity of the seed orchard.

SPACING OF THE TREES IN THE SEED ORCHARD :

The trees in the seed orchard have a much wider spacing than those in normal plantations. For most species a final spacing, i.e., after rouging, of = 10 meter is preferred. That corresponds to 100 trees per hectare. The initial spacing should be designed with the expected thinning in mind. If the trees are initially planted in 4 trees plots, with expected 3 of them plus may be 50% of the families to be culled, then a planting stock of 800 trees per hectare should be used, I.e., a spacing of 2.5 x 5 meter.

SITE PREPARATION AND ESTABLISHMENT OF ORCHARDS :

The plants (either vegetative propagated or seedlings) are vulnerable to competition from weeds, to fire, diseases, browsing, termites, etc, during the first year of establishment. The better the site is prepared before planting, the easier the future management.

CLEARING: Left woody material may attract pests, diseases, Increase the risk of fire and impede mechanical management. The ideal one is a completely cleared area, free from trees, shrubs, stumps and big stones. That will ease the access to the area and mechanical operation. If the seed orchard is established on forest land, all trees and shrubs should be cut and removed or burned on the site.

SOIL PREPARATION : Proper soil preparation improves the growth of the tree plants and promotes their competition with other plants. The site should be completely weeded before planting, e.g. by ploughing and harrowing. Mechanical cultivation improves soil structure, and consequently water holding capacity and draining. A hardpan impedes draining. It can be caused by tractors or If the soil has podzol profile. Hardpan is broken by deep ploughing or sub soiling.

The soil should have the optimal acidity and nutrient level for the tree species to be planted. Soil tests are carried out prior to planting possible time and fertilizer is applied before planting.

Weed control can be facilitated by proper soil preparation. Several mechanical cultivations promote weed seed germination. Germinated seedlings are then destroyed by mechanical cultivation or by leaf herbicides. Soil herbicides can be used for difficult weeds.

NOTE: Some soil herbicides have a long term effect. Care should be taken that the type will not affect the tree plants. In case of e.g. termite problems, specific insecticides may be applied.

NOTE: insecticides may be harmful to other soil organisms. Precautions should be taken in terms of time and doses.

ESTABLISHMENT OF POLLEN DILUTION ZONES (PDZ) : Cleared areas are established between the seed stand and possible contaminating sources. The PDZ is a zone where trees of the same species and species that can hybridize with the species are removed. The wideness depends on the species and pollination pattern. The zones also serve as fire-breaks. For wind pollinated species a short vegetation of the PDZ is desired, usually 200-400 m, depending on species and wind exposure. If there is a prevailing wind during the pollination period, the width of the PDZ may be diminished from the other sides. For insect pollinated species the width and the vegetation of the PDZ depends on the behaviour of the pollinator. Information should be sought on individual species.

PROMOTION OF POLLINATION : Promotion of the pollination is easiest for wind-pollinated species. Spacing is a method of improving the condition for wind pollination.

The effect on insect pollinated species is probably different from species to species according to pollinator, but details are poorly known. Promoting pollination by insects by putting up beehives is widely used in fruit orchards and agriculture and is applicable to seed orchard.

DEMARCATION OF PLOTS AND ROWS : The orchard design is clearly demarcated. Replications, blocks and plots should be distinctly demarcated. The corners should be marked with conspicuous persistent poles/signs indicating necessary details. The material and way of putting up should be so that it will be difficult to be removed or stolen.

DEMARCATION OF PITS AND PITTING : Follow the normal silvicultural practices.

A final spacing in seed orchards of 10 meters is reasonable for most species in order to allow free crown development. Depending on the expected thinning the initial spacing may be 2-6 meters.

PLANTING : Normal silvicultural practices. Extra care should be taken with grafted and budded material since the grafting or budding site may still be vulnerable. Sometimes the root stock is planted in the field before grafting and consequently carried out in the field.

The planting usually involves several clones or families, and it is important that the planting is done according to a prescribed (orchard design) so that the identity of the individual tree is clear/Following measures should be taken in order to avoid confusion/ mixing up of the plants.

1. A plan of the orchard design should be brought to the field and used when planting spots are demarcated distinctly on the plan with the identity of the plant to be planted on the spot (clone/family- letter/number).
2. The plants (or scions in field grafting) should be distinctly marked and kept separately.
3. The plants are marked with a tag when planted. The tag carries a number/symbol of the plant similar to that of the map.

REPLACEMENT OF CASUALTIES : Correct replacement of dead seedlings is crucial. If wilted, seedlings or grafted plants are replaced, and care should be taken that the replacement will not disturb the orchard design, i.e, plants should be replaced with the same clone/family.

COVER CROPS : A temporary legume cover crop may be planted between the tree plants. The cover crop is beneficial to the soil and may facilitate weed control and diminish erosion.

NOTE: The cover crop should be controlled so that it will not climb or in other ways compete with the trees.

ORCHARD DESIGN :

The general requirement in the orchard design is;

1. Minimize selfing.
2. Maximize out-crossing and mating of all genotypes.
3. Simple and easy establishment and management.
4. Allowing any number of clones or families to fit Into the design.

The two most frequently used designs are complete randomized design and randomozied complete block design:

COMPLETE RANDOMIZED DESIGN: All available ramets of all clones or all families are distributed randomly all over the site.

RANDOMIZED COMPLETE BLOCKS: The area is divided into equally sized blocks which include one ramet of each clone or one member of each family. The ramtes or families are located randomized within each block.

NOTE: Randomization in either of the two models may be modified in order to avoid accidentally planting of two ramets of the same clone or two members of the same family next to each other, e.g., m adjacent blocks. Various computer models exist that can make a design to fit any number of clones or families and maximize the distance between ramets or members of the same family.

Randomized complete block design Is the most frequently used if the design initially serves as a progeny test.

CONTROLLED POLLINATION IN SEED ORCHARDS :

Controlled pollination can be conducted in which case pollen is collected from the desired male parent(s) and is applied to the flowers of the female parent(s). Controlled pollination may involve emasculation and isolation of the flowers of the female parents.

If the orchard Is designed entirely for hybridization, planting of each clone in rows in preferred.

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.

1. **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 may be cut or completely removed. If chemical weeding is applied, care should be taken in terms of time, weather condition, and doses of application.

NOTE : Small plants are generally more vulnerable to herbicides than bigger plants.

2. **ROUGEING :** Once the result of the progeny test is available, the undesired families or ramets are cut and removed.
3. **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.
4. **FERTILISATION 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.
5. **FLOWER INDUCTION :** If flowering fails or is unsatisfactory, it may be induced or promoted by (1) imposing stress or (2) applying flower inducing hormones during flower differentiation.

IMPOSING STRESS : Various methods of stress-imposing promote flowering.

Water stress can be Imposed if water availability can be manipulated by artificial watering or irrigation. A brief drought during floral differentiation will usually induce flowering. The watering should be re-continued after flowering.

NOTES:

1. The time of imposing the stress factor is crucial for the effect. In some species flower differentiation occurs long time before the flower buds are visible.
2. Some of the stress factors may seriously damage the tree that may affect the fruit development and seed maturing. Secondarily, it may affect the amount of future crops.

HORMONE APPLICATION : The active hormone in flower differentiation Is gibberellin. Artificially manufactured versions of the hormone are sold under various trade names. Hormones can be applied by spraying flowering branchlets with the remedy or by applying to the cambium.

SEED COLLECTION

There are various methods available for collection of forest tree seed. In each case the choice of methods depends on many factors e.g.. Fruit, Tree, Stand and site characters, quantity to be collected, available equipments etc. Generally, the seed unit should receive the indent of requirement of seeds of various species, from the different Forest Divisions and accordingly the seed unit should calculate the total quantity of seed of different species to be collected during a particular year. It is emphasised that the seed users in the forestry sector should order the seed well in advance rather than at the time of sowing.

The purpose for which the seed is required and the quantity of the seed required must be identified. The strategy of seed collection for research purpose should be different than the bulk seed collection for planting from identified and improved stand.

Once the seed unit knows as to which species and provenance is to be collected, it is essential to plan an efficient and practical collection strategy. Adequate funds must be made available and sufficient well trained staff should be made use for the activities. The seed unit should give all the information on the species and provenance of the seed to be collected including the data of the reproductive phenology and detailed maps of occurrence and the location of the seed production areas of the concerned species. Generally, it is found that the species of different agro-climatic zones exhibit periodicity in flowering and fruiting and so it is highly desirable on the part of research staff to visit the stands to be sampled well in advance of the fruiting in order to assess the timing and suitability of the crop. It is important that the clear guidelines have to be drawn up for the selection of seed trees. The selection criteria will vary considerably according to whether the collections are for large scale reforestation projects or small scale nursery plantings for research purpose. Often it is necessary to compromise between obtaining sufficient seed to meet the user requirement and superior phenotypic selection for greatest genetic quality. It is essential to avoid collecting seed from below average phenotypes. For collection in natural stands, it is important to collect from a minimum of 10 trees from across the range of provenance area and m excess of 25 trees where the seed is to be used in the establishment of genetically improved seed stand. Trees should as far as possible be unrelated. To achieve this, seed trees wherever possible be minimum to 2 trees heights apart and in case of tall forest trees minimum of 100 mt., apart.

For the details of flowering and fruiting period, the time of collection and the method of collection of different species etc., "A.P.SEED MANUAL" published by A.P.FOREST DEDPARTMENT should be referred.

Depending on the species, the seeds can be collected from the ground or from the standing trees by lopping the branches. In the collection of seed in SPA, the floor of the forest is cleaned by undertaking a coppice cutting of under-shrubs. In case of bamboos, the cloth pieces are joined together and kept underneath the bamboo clump so that when the panicles are beaten up by a stick the caryopses fall on the cloth which can be cleaned up subsequently and transported.

The documentation and labelling of the seeds at the time of collection are very important from several points of view:

(a) a record of what, where and how the seed collection was made.

(b) It enables collection teams to return to a good seed collection area next year

(c) It provides phonological information about of flowering and seeding time.

(d) It allows specific seed source to be provided where required

(e) The minimum information which should be recorded whenever any collection Is made or stand from which collected (natural seed stand, SPA,CSO), location (general description with latitude longitude and altitude), no. of trees from which seed collected, date of collection and name of the officer in-charge.

(f) In order to ensure identity of collection in the field and as a permanent record, each collection team leader should have their own sequential field numbers prefixed by their initials and record in a Field Register Book in duplicate. The original goes with the seed while the copy remains in the book and kept by the collection team leader responsible for seed collection. For bulk collection from a particular SPA one number can be given for each SPA and for Individual tree collections one number per each tree is given. This number is distinct from the registered seed lot number which is issued in the seed godown. The field number Is recorded on the labels or written on the container. The field number is also recorded on the collection data sheet.

(g) When the seed comes to the godown, the seeds can be stored in appropriate containers. The source wise species can be given different lot numbers, in the godown.

SEED PROCESSING :

Seed coming from the field Is rarely suitable for immediate storage. Dyring, extraction from the fruit and further cleaning are commonly required. It is important to ensure that these operations do not harm the seed. It is equally important that the identity of each seed lot is maintained. Processing methods and equipment vary according to species, the amount of seed being handled and the cost benefit comparison between labour Intensive methods Vs sophisticated machinery.

Fruits arriving at the centre should be unloaded immediately, inspected, pre-cleaned and placed in temporary storage awaiting extraction. Free cleaning Involves the removal of twigs, bark, foliage or in the case of teak, removal of exocarp to facilitate dry and further cleaning. Temporary storage should be provided to protect from rain and allow continuous free air circulation around the fruit. Fruit may be loosely stored in open bags or spread out on tarpauline sheets in the open to dry.

Depulping of fleshy fruits like Gmelina aroborea, Azadirachta indica, Syzygium cumini, Giwtia rottleri formis could be done soon after collection to avoid fermentation and heating. A method in common practice is to soak the fruits till they become soft. The pulp is then mashed carefully when crushing the fruit. When adequate water is added, the pulp will float while the fruit or seed sinks to the bottom. Once cleaned, the fruit should be allowed to slowly air dry with frequent turning so that the moisture content is reduced to an expected level of 6 to 10%.

It Is often required to dry the fruit before the seeds can be extracted. In case of Acacias, Alhizzias, Casuarinmas, Eucalyptis, Emblica fficinalis for example the parts or fruits are dried sufficiently/ for the easy extraction of the seeds.

After drying, the seed must be removed from the fruit without affecting the seed viability. The extraction depends on the species characteristics and maturity. The most widely used extraction methods are thrashers for hard woods. However, depending on the species the extraction procedures varies.

Generally it is believed that in case of teak, the bigger size of the fruits germinate more efficiently compared to the smaller size of the fruits. Therefore, it is essential that the teak fruits should be graded according to the size and very small fruits after the graduation should be discarded. For other species, winnowing is widely used for cleaning the seed. Manual winnowing is most effective. With the aid of an air current, light fractions (waste) is separated from heavy fractions mainly seed. For more controlled air flow conditions in the laboratory, aspirators, Dakota blower, fans etc., are used.

When a large seed lot is to be stored in several containers, it is desirable that seed homogeneity between containers be maintained as far as possible so that each container is equally representative of the seed lot as a whole.

Before storage, seed or fruit should be fumigated or dusted with Insecticide powder to kill insect pests. Carbon disulphide is frequently used as a fumigant and is likely to be the most practical method of fumigating large quantity of seeds (20 Kgs.). The method suffers from the concern of operator safety unless careful precautions are taken. The method of carbon disulphide fumigation Is to place 3-5 Ml. of fluid on a wad of cotton wool. The cotton wool in operation is placed on a petri dish on top of the seed. The seed and cotton wool should be closed in an air tight container and left for 7 days. Operator should avoid inhaling the fumes at all times or having any contact with the skin.

For small lot upto 20 kgs., it is recommended that carbondioxide be used. Seed is stored in carbondioxide contained in sealed laminated plastic bags or air tight containers. Following storage for 14 days, the seeds can bed removed and placed in storage containers.

For large bulk lots as in the case of teak the fruit can be dusted with insecticide powder based on malathion, pyrethrums, and benzene hexachloride.

SEED STORAGE :

Setting up a proper seed storage system particularly for low viable seeds is extremely and important part of seed unit. The seeds will be stored under controlled relative humidity and temperature conditions atleast for 1 or 2 years so that the initial germination capacity of the forest seeds will be maintained.

The most important factor in seed storage Is moisture content. If orthodox seeds are dried to 8% to 10% moisture **and maintained at that level**, then temperature is not an important factor. To accomplish this, seed moisture contents must be known when the seeds go into storage, and storage must be in moisture-proof containers. There are no good techniques for storing recalcitrant seeds, such as Neem and Syzygium, for more than a few weeks or months, so the main emphasis should be on orthodox seeds. There is much current reesearch on the storage of recalcitrant seeds, and new techniques may emerge at any time. Orthodox seeds should be stored in moisture-proof containers, such as large plastic drums, or in polybags with a wall thickness of at least 0.10 mm, and seed moisture should be measured before storage to insure a proper beginning moisture level. The type of container is not so important, but is must be moisture-proof. When there is doubt, a polyliner (0.10 mm thickness) can be placed inside and sealed at the top when the seeds are placed in it. Even the burlap bags can be sued if polyliners are inserted, but punctures are likely to happen, so this is a last resort. The metal cans will do fine with polyliners. Moisture levels of small seeds can be checked to within + 1.0% with battery-operated seed moisture meters, but ovens or infra-red driers will be needed to determine moisture contents of seeds, such as Teak, Teminalia, or Petrocaprus. The electric meters will require some tests to calibrate the readings, but this is simple to do. The target seed moisture for storage of all orthodox seeds is 10% (dry weight basis). In the hottest times of the year, some temperature effect may be evident even with the dried orthodox seeds, so steps should be taken to prevent extreme heat in the godowns.

The seed godowns need exhaust fans to circulate air and lower extreme temperatures during the hottest times of the year. There should be at least 4 louvers along each side of the godowns, with the exhaust fan at the end of the building, preferably at the top of the gable.

To maintain good air flow, the louvers must remain open, except during rains, and the fans should run about 5 minutes every hour. The best way to do this is to wire them into a time clock that will automatically turn them on and off. These steps are particularly important on weekends and holidays while no work is going on at the godown. Seed containers should be stacked vertically with air spaces surrounding each stack. A rough rule-of-thumb for storage is that 1 cubic meter of space should hold 140 kg of seeds. For teak and other large seeds, a smaller figure of 100 kg per cubic meter can be used.

To assist the genetics program, cold-storage units should be installed for long-term seed storage for germplasm conservation purposes. There should be one small unit for sub-freezing storage of orthodox samples and one small unit that can be set as low as 5° C in which experimental storage of recalcitrant seeds can be tested.

In many aras the best trees are often felled illegally and this material is then available only through vegetative propagation. Even then, material in clone banks may not be completely safe from theft. Long-term seed storage can be an Inexpensive back-up system to preserve valuable germplasm. Most orthodox seeds can be stored for many years at sub-freezing temperatures.

SEED TESTING :

Seed Testing has primary purpose of providing factual information on the purity and germinative capacity of a seed lot. The information Is essential to both the supplier and user m terms of determining the physiological quality of the seed, optimum treatment and amount of seed required in order to meet planting requirement. It is therefore mandatory that the Seed Umt has seed testing facilities.

Many types of tests can be made on seed and each has its special purpose. The most common test is done with an objective to determine the capacity of seed to germinate and grow Into normal seedlings. Other tests are purity, vigour, moisture content, seed weight, authenticity and seed health.

SAMPLING METHODS:

The most critical step in evaluating a seed lot is the drawing of a representative sample. Different samples are prepared before it comes for testing.

Primary sample :	a small portion taken from one point in the lot.
Omposite sample :	Is formed by combining and mixing all the primary samples taken from the lot

Submitted sample : ample submitted to the testing station. It may comprise either the whole, or a sub sample of the composite sample.

Working sample : le obtained at the testing station by reducing the submitted sample

A modified sampling intensity and size is given based on International Seed Testing Agency (ISTA) (2 samples per container).

Upto 5 containers	-	sample each container
6-10 containers	-	sample 5 containers or 1 in 5
31-400 containers	-	sample 10 containers or 1 in every 10
401 or more	-	one in every 20 containers

As rule of thumb, the working sample should consist at least 1000 seeds, which will be used first for a purity test. Then for a 1000 seed weight determination, 400 of the working-sample seeds are used for germination test. Finally the remaining seeds can be used for a moisture test.

A sample is obtained from the seed lot by taking small portions at random from different positions in the lot and combining them. From this sample, smaller samplers are obtained by one or more stages. At each stage, thorough mixing is followed either by progressive sub-dividing or by abstraction and combination of small portions at random.

Two methods are followed :

a) Small sub-samples are taken at random and joined together to form a sample. This would be common practice for large seed lots and combined with second method.

b) Progressive sub-dividing or successive halving, where the seed lot is divided into two equal portions in a seed divider. One portion is taken and halved again. This halving procedure is repeated until a sample of approximately the quantity required is obtained.

There are several methods available for manually or mechanically mixing a seed lot and/ or taking a sample

a) Seed Triers

b) Seed divider

i) Soil divider

ii) Boerner divider

PURITY ANALYSIS :

The object of purity analysis is to determine the percentage composition by weight of the sample being tested and by inference the composition of the seed lot, and to identify the individual species of seed and inert particles of which the sample Is composed. The working sample is separated into three components: Pure seeds, seeds of other spp., and inert matter. When purity analysis is done, it is the first test to be carried out because subsequent tests are made only on the pure seed component. Magnifiers, hand lenses and binocular microscopes are very useful in accurately identifying seeds and in separating small seed units from inert matter.

The percentage of pure seed is calculated as follows:

$$\text{urity \%} = \frac{\text{Weight of pure seed fraction}}{\text{Total weight ot working sample}} \times 100$$

When a laboratory tests a large number of samples for purity, the purity analyst edamines and separates seed samples on a "Work board" placed on a top of a desk or table fitted with a magnifying glass and a lamp. To separate the sample, a scapula or flat wooden knife Is used. The work board can be adjusted to a desired height, usually, 7-15 C.M. above the table height. It has a smooth, completely flat surface.

SEED WEIGHT :

Seed weight is determined on the pure seed component separated by the purity test. Weight is normally expressed as the weight of 1000 pure seeds. The 1000 seed weight is determined on an analytical balance with an accuracy of 1 milligram.

TESTING MOISTURE CONTENT :

The viability period of seed is mainly determined by the moisture content and storage temperature of the seeds. In order to control the operations of drying of seeds in preparation for storage, and to check the stability of moisture content during storage, it Is essential to have reliable methods of measuring the amount of moisture in a given sample.

There are number of methods for determining seed moisture content.

a) Oven method: The principle of this method is the elimination of water from the seed by head under precisely controlled conditions. The moisture analysis is carried out on two independent samples which are weighed to an accuracy of 1 mg. The weight of the sample varies according to the size of the seed. For fine seed (Eucalyptus), the weight should be about 4-5 gms. While for teak fruit it would be better to select a set number of fruits (30). Two oven methods are normally followed:

i) Low constant temperature oven method where the seed is dried in the oven for 17 hours at 103° C. At the end of the prescribed period the container is cooled in a dessicator for 30-40 minutes. This method is recommended where there is any uncertainity over which method to use including a wide range of forest species and those which are fleshy or oily.

ii) High constant temperature oven method where the seed is dried in an oven for 1 hour at 130° C. This method is used for most non-agricultural seeds and for Eucalyptus.

The calculation of moisture content should be made on a wet or fresh weight basis.

$$\text{Moisture content \% (Wet weight basis)} = \frac{\text{Original weight - Oven dry weight}}{\text{Original weight}} \times 100$$

The difference in moisture content between two samples should not exceed 0.4% for orthodox seed at normal moisture contents.

QUICK METHODS FOR MOISTURE DETERMINATION :

A variety of brands and types of rapid moisture meters are available. The quick test methods should be calibrated or checked against the standard oven method, and in general less accurate than the oven method. Two methods can be mentioned.

i) Infra-red lamp method.

ii) Electric moisture meters.

GERMINATION TESTING :

The main aim of laboratory germination test is to estimate the maximum number of seeds which can germinate in optimum conditions and the use of standardised ideal conditions ensures uniform and reproducible results. Results obtained under ideal controlled conditions in the laboratory are not directly applicable in the field nursery, where only limited control over environmental conditions are possible. Each nursery man should apply his own correction factor, derived from experience over the years, to convert the germination potential of a seed lot, as determined from laboratory tests, to the actual field germination he can except under his local conditions.

All germination tests should be made with pure seed or fruit where it is impractical to extract seed. The pure seed must be well mixed and counted into random replicates. The seeds should then be spaced uniformly on the test substrate. Normally a test consists of 400 seeds In 4 replicates of 100 seeds each, but if 100 seeds over-crowd the test substrate, the replications may be broken down into a large number of small replicates of 50 to 25 seeds each. A general recommendation is to leave 1.5 to 5 times the normal seed width or diameter between seeds in order to discourage the spread of fungal moulds.

GERMINATION CONDITIONS:

a) **SUBSTRATE:** The choice of media on which the seed is placed for germination depends on equipment, the species, the working conditions and experience of the operator.

Most laboratory tests on small seeded species are made on paper including germination blotters, paper towelling and laboratory filter paper. Sterile sand is widely used for large seed and is preferred for spp., that have a longer germinative period. Other materials used include granulated peat moss and expanded mica.

b) **CONTAINERS:** There are many types of germination containers available including petri dishes (90mm.diameter) and plastic boxes (150 x 200 or 200 x 300 x 60 mm,)

c) **TEMPERATURE :** Temperature Is one of the critical factors in the laboratory germination of seeds and must be regularly checked. When alternating temperatures are required, the test is usually held at the low temperature for 16 hours and at the high temperature for 8 hours each day. Optimum germination temperature for wide range of seeds is between 25° - 30° C.

d) **LIGHT :** Light is required for germination in many tree seeds. In laboratory tests, cool white fluorescent light is recommended for 8-12 hours.

GERMINATION EQUIPMENT:

Two types of germinators are suitable for seed unit, i.e., room germination and germination cabinet.

The room germinators should have the capacity to operate in the range of temperature between 20°-35° C with cool white flourescent lighting set for 8-12 hours per day above the germination trays.

Germination cabinets should have controlled temp. ranging 15° - 40° C. Stainless steel interior will help in ensuring good hygiene and prevent rusting.

VIABILITY TEST :

The object of viability tests are:

- To make a quick estimate of the viability of seed samples in general and those showing dormancy in particular.
- In the case of particular samples which at the end of a germination test reveal a high percentage of dormant seed: to determine the viability of individual dormant seeds or the viability of a working sample.

a) TETRAZOLIUM TEST :

The tetrazolium test technique defines living and dead areas of the embryo and endosperm by differential, topographic staining. When seeds are Incubated for 4-16 hours in tetrazolium chloride solution, dehydrogenase enzymes m actively respiring areas of the embryo and endosperm produce hydrogenious which react with the colourless tetrazolium to form the red-coloured formazan. By evaluating the location and intensity of the formazan stains, one can differentiate between healthy and damaged part of the seed.

b) HYDROGEN PEROXIDE METHOD:

300 seeds from the sample are withdrawn at random and soaked overnight in 1% H_2O_2. After carefully cutting the radicle end of the seed, pour 150 ml. Of H2O2 into each of the 4 beakers and add 50 seeds to each beaker. After having counted the seeds with evident radicles, the remaining seeds are incubated for 4 extra days. Radicles are then counted.

c) CUTTING TEST :

The simplest viability test is direct eye inspection of seeds which have been cut open with a knife or scalpel. If the endosperm is of normal colour and texture with a well developed embryo, the seed is expected to have a good chance of germinating. This test is not reliable for small seeded hardwoods.

A complete list of Seed Testing Equipment required for seed testing lab :

1. Seed processing

- Seed Extractor (Rotatory Drum)
- Gravity separator
- Seed Grader
- Seed Aspirator
- Sieves (Assorted)

2. Sampling Mixing and dividing

- ❒ Seed sampling triers-sleeve type triers, Nobbe triers and double tube type of various sizes
- ❒ Seed divider (soil type)
- ❒ Garnet divider
- ❒ Sample pans (assorted size)
- ❒ Pan type Weighing balance (capacity one Kg.)

3. Purity Analysis

- ❒ General seed blowers model ER type with kit and transformers
- ❒ Seed blower (Dakota type)
- ❒ Sieves of different sizes
- ❒ Diaphanoscope (Purity workboard)
- ❒ Binocular Magnifier
- ❒ Microscope
- ❒ Spatula (metallic)
- ❒ Forceps
- ❒ Brush
- ❒ Purity dishes (Assorted)
- ❒ Single pan, electric weighing readability 0.001 g balance (capacity 100 g)

4. Moisture Estimation

- ❒ Electrically heated oven with thermostatic control
- ❒ Grinding mill (of ISTA specification)
- ❒ Desiccators (with suitable desiccants)
- ❒ Balance with readability upto three decimal places
- ❒ Tongs
- ❒ Samples weighing bottles
- ❒ Aluminum boxes

5. Germination, Viability, Vigour test

- ❒ Seed Germination Chamber (a room of about 4M X 4M dimension fitted with split type 2 ton room air conditioner to maintain temperatures around 25 to 30 °C).
- ❒ Seed Germination cabinets (3 Nos)
- ❒ Seed Scarifier

- Refrigerator (165 ltr.)
- Hot Air Oven (Sand sterilizer)
- Conductivity meter
- Waste trolley (movable type)
- Moveable open trolley
- Sensitive and accurate thermometer
- Sensitive and accurate hygrometer
- Distillation unit/ De-ionized water plant
- Metallic tray (40cm X 50 cm)
- Maximum-minimum thermometer
- Analysis chairs (Revolving type with height adjustment)
- Counting board (Assorted)
- Germination paper
- Wax paper (50.5 cm X 36.5 cm)
- Scalpel and blades
- Scissors (12 or 30 cms)
- Foreceps (15 cms or 6 in) pointed
- Wash bottle (plastic)
- Plastic bucket (large)
- Rubber band
- Petri-dishes (classic: 15 c da)
- Class-funnel (15 cm dia)
- Measuring cylinder (lt.)
- Pipette (Graduated: assorted)
- Volumetric flask (250 ml)
- Measuring cylinder (2 ltr.)
- Glass marking pencils
- Potassium Nitrate
- Thio-Urea
- Gibberellic acid
- Triphenyl Tetrazolium Chloride/ Bromide

6. **Seed Storage**

- Seed Drying Unit
- Deep Freezer (-18° C)
- Low Temperature Cabinets (2 Nos. for storage)
- Desiccators
- Desiccant
- Seed Storage Bins (Assorted sizes)
- Tin Foil Pouches

Laminated bags/ polythene bags

SEED COLLECTION DATA

IDP-PTI No. ______ Seed Collector's No. ______

Provenance : ______

L State ______ Forest Division ______

0 Range ______ Block ______

C Compt. ______ Coupe ______

A Details of locations: NATURAL/ PLANTED ______

L ______

I ______

T ______

Y Latitude: ______ Longitude ______ Altitude ______

S Slope : ______ Aspect ______

I Drainage: ______ Annual Rainfall : ______

T Monthwise Rainfall and Temperature

J	F	M	A	M	J	J	A	S	O	N	D	Total	AV.

E Nearest Weather Station (Name): ______

S Density : ______ Age ______ Heieht ______ Diameter ______

T Stem form : ______ State of stand : ______

A Associated species : ______

N ______

______

D Miscellaneous remarks : ______

S Date of Collection : ______

E Method of collection : ______

E Number of Trees : From which seed has been collected : ______

______

D Yield per tree (Average) : ______

(continued)

C Description of Seed bearers (Selection criteria) : ______________________

O ______________________

L ______________________

L ______________________

E Quantity of seeds/fruit : ______________________

C ______________________

T ______________________

I Condition of seeds : ______________________

O Seed yield per unit/ volume of fruits : ______________________

N ______________________

Remarks (Miscellaneous relevant information if any):

____

____

____

Name of Seed Collector : ______________________

Designation and address of seed collector: ______________________

____

____

N.B:- Please fill in as much information as possible, but do not detain this form on account of lack of some information.

SEED COLLECTION DATA SHEET

Species ______________________, Seed Lot No. ______________________

Collection locality ______________________ Date of collection ______________

Latitude ________ 'N Longitude ________ 0 ________ 'E, Altitude ________ (m)

Aspect ____________ Slope ____________ Rainfall ______________ (mm)

Rainfall time ______________ Agro-climate zone ______________

Associated species ____

Geology & Soil ______________________ pH ______________

Tree No.	Tree Parameters			Fruit Wt.(g)	Seed Wt.(g)
	Height (m)	d b h (cm)	Description*		

Work Supervised by : ______________________ Date : ____________

(Tree description Form - straight, bent, twisted, fluted, buttressed, clean holed, forked; Health-diseased, damaged, good seed bearer etc.)

GERMINATION TEST FORM

Test ______________________ Species ______________ Storage ______________

Official Identity No. ______________ Origin ______________ Date of receipt of sample ______________

Sample No. __________ Representing ____________ Kg. Can. No. ________ Date of receipt ________

																										Mouldy Removed	Insect Damage	Empty	Fresh	Total No. of seeds
Date																														
Days																														
REPLICATES	A																													
	B																													
	C																													
	D																													
	E																													
Total																														
Av.																														
" "																														

Seed Treatment	Germination test	
Method : Time : Temp "C :	Method : Temp "C : Time : No. of seeds :	Germination : Variation : Tolerance : Germn. capacity :

Supervised by : ______________________________ Date : ______________

SEED MOISTURE CONTENT TEST FORM

(Fresh weight basis)

Date	Replicate		
Wt. Container + fresh seed	A	B	C
Wt. Container + dried seed			
Wt. Container			
Fresh wt. of seed			
Dried wt. of seed			
Wt. of moisture removed			
% moisutre content			
Average % m.e.			

Drying ^0C : ____________________

Hours in drying oven ____________________

Seed crushed / unchrushed ____________________

Supervised By : ____________________ Date : ____________________

PURITY TEST FORM

Date	Replicate				
Composition	A		B		
Sample	Weight (g)	%	Weight (g)	%	Pure seed (%)
Pure seed					
Other crop seed					
Inert matter					
Total weight of seed					Total
Original weight of sample					Av.

SUMMARY

Pure seed % : ________ 1000 pure wt. (Av.of 8 replications of 100 sseds) ____________ g

Other crop seed % : ____ Weight of unsorted sample containning 1000 pure seeds ______ g

Inert matter % : _______ No. of pure seeds per kg. ____________________________

Moisture content % _____ No. of pure seeds per Kg. _______________ unsorted sample

1000-pure seed weight ____ g No. of germinable seeds per kg. ________ unsorted sample

Supervised By : ______________________ Date : _______________

Andhra Pradesh Forest Department
State Siviculturist / Forest Geneticist

C) Seed Production Area Record Form

Species :	D) **LOCATION MAP**
Forest Type :	
Generation : virgin / nat. Regeneration / Planted	
Stand Description and Selection Criteria	

Division	Range	Block & Compartment	Estd. Age	Area (Ha.)	No. of Trees	Total Seed Collected

SOIL

TOPOGRAPHY

DATE OF SELECTION

SELECTED BY

APPROVED BY

DATE OF APPROVAL

E) STAND PHOTOGRAPH

III. OPERATIONS CARRIED OUT

VEGETATIVE PROPAGATION

OBJECTIVES :

1. Production of true to type and uniform population of identified individuals.
2. Transmission of important phenotypic traits of parent to its offspring.
3. Deviation of a genetically uniform assemblage of individuals from single plant.
4. Large scale propagation of elite clones from specific parent lines.
5. Production of disease free propagules.

METHODS OF VEGETATIVE PROPAGATION :

A. **Propagation by cuttings :**

- Stem cuttings
- Leaf cuttings
- Leaf bud cuttings
- Root cuttings

B. **Propagation by grafting :**

- Approach grafting
- Veneer grafting
- Root grafting
- Cleft grafting
- Crown grafting
- Top grafting

C. **Propagation by budding:**

D. **Propagation by layering :**

E. **Propagation by suckers, bulbs, corms, Rhizomes, Tubers etc. :**

6. **PROPAGATION BY STEM CUTTINGS**

Production of physiologically identical individuals from the vegetative stem portion of identified trees.

Concerns :

- Clonal scion material
- Propagation structure
- Equipment and material
- Chemicals and Hormones

1. Clonal Scion Material:

To make available required cutting material for Vegetative Propagation.

- Selecting the plus trees - Required character oriented
- Shoot production - Age, Size, Environment, Height, Spacing, Timing
- Cutting preparation - Harvest technique, Removal of twigs, Retention of green material, wounding

2. Propagation structures:

Manage Light, temperature, water and gases.

- Mist House
- Green House
- Lath Houses

3. Equipment and materials :

- Pruning shears
- Sharp blades
- Potting media
- Containers

4. Chemicals and Hormones :

- Fungicide
- Insecticide
- Growth Hormone

PROCEDURE :

- COLLECTION OF SHOOTS
- PREPARATION OF SHOOT CUTTINGS
- TREATMENT WITH FUNGICIDE
- TREATMENT WITH GROWTH REGULATORS
- TRANSFER TO MIST SYSTEM
- HARDENING OFF
- TRANSFER TO FIELD

1. Collection of shoot material:

- Select disease free, moderate vigorous with foliage.
- Segment of shoots should contain lateral or terminal buds.
- Should not be from extremely rank growth with abnormal long internodes.
- Shoot should have ample stored foods to nourish the developing roots and shoots.
- Tender shoots and Tips are to be discarded.
- Care should be taken on seasonality to avoid dormancy.
- Collect in early hours of day.
- Not to expose cuttings to wind, direct sunlight.
- Maintain moisture to be fresh of cuttings (for the cuttings to be fresh).

2. Preparation of Cuttings :

- Cuttings vary in length from 10 to 30 Cms.
- Atleast 2 nodes are included in a cutting.
- Basal cut has to be just below a node.
- Top cut 1-2.5 cms. above node.
- Make sure of uniform length of cuttings.
- One or two pairs of leaves.
- Remove any twig on cutting.

- Use sharp cutter to avoid damage.
- Wound before soaking in a fungicide and rooting hormone.

3. **Hormone - Fungicide treatment:**

- Keep ready the growth hormone media - powdered hormone or liquid hormone in required concentration (IAA or IBA or NAA)
- Keep fungicide solution ready. (Capstan, Benlate or Thiram)
- Tie 50 - 100 cuttings together into bundle.
- Dip into hormone 0.5 - 1.0 Cms. deep.
- Dip in fungicide of required dilution.

4. **Sticking the cuttings in rooted medium :**

- Select the light weight, porous, low cost rooting medium.
- Should be free from weed seeds and nematodes.
- Soil well aerated, sandy loam Is preferable.
- Select right container and stands to place.
- Careful to stick in right direction at the centre of container.
- Label with details.
- Work all above under shade.

5. **Transfer of treated cuttings to mist chamber :**

- Transfer the cuttings in to mist chamber at an earliest possible time.
- See that chamber is clean, sterile and properly working.
- Maintain regular misting to manage humidity.
- Control the temperature with overhead shade.
- Take every precaution to guard against accidental failure of mist application.
- Fix up time clock for regulating misting.
- Make sure of quality of water used.
- Visit and observe carefully.

6. **Hardening - Off :**

- Grow to the required maturity, move the cuttings as soon as they are rooted to drier environment.
- Move them to under shade area with relative desired humidity.
- The high temperature causes damage, hence not to expose to direct sunlight.
- Apply nutrient solutions / minerals.
- Slowly,shift them to direct sunlight.

Advantages :

- New trees can be raised at anytime irrespective of seed problem.
- Can speed up domestication to allow urgently needed tree planting with a mixture of superior selection.

Disadvantages :

- Genetic homogeneity enhances and vulnerable to pest attack.
- On long process true type and uniformity is lost and become poorer than seedling.
- Inebility to manipulate to genetical and physiological ageing.

CONDUCTING ROOTING EXPERIMENTS FOR FOREST TREE SPECIES

ROOTING OF LEAFY CUTTINGS :

In tropical countries, one of the most difficult problems in propagation of forest species is seed supply. Forest trees do not bear fruits regularly when subjected to certain conditions. When they do fruit they produce low quality seeds because of frequent insect and fungal attacks. It Is, therefore, very difficult to predict the yield and quality of seeds for an afforestation program. Vegetative propagation of tropical species by cuttings Is an important alternative for production of high quality and uniform planting stock for a large scale afforestation.

A cutting is a part of a plant that will produce roots when put In soil media and eventually produce a new plant, quite true to the parent plant. A cutting may be a piece of stem, a leaf or part of a leaf, a piece of root or rootstock, or even a scale of a bulb. The part of the plant from which cuttings are made depends upon the growing habit of the plant. But whatever portion of a plant is used m making cuttings, it must have the ability to produce its missing parts.

Stem cuttings offer several advantages over seeds. They save time and labour in seed collection and storage and produce uniform planting material reflecting the genetic purity of

superior parent stock. Stem cutting is also inexpensive and easier to practice than other vegetative propagation methods.

Finally, it can produce a continuous supply of planting stock throughout the year for afforestation activities. Also as the plant develops and grows on its own root system, the complex stock-scion relationship that exists m a graft can be avoided. However, the greatest disadvantage of this method is that some plants do not readily form roots on cuttings and the benefits derived from using some desirable rootstock cannot be exploited.

IMPORTANT FACTORS AFFECTING ROOTING OF CUTTINGS:

The success of rooting mainly depends on the species. Sometime cutting materials taken from different individuals within a species also vary in their rooting capacity. There are several physiological and environmental factors which influence rooting.

PHYSIOLOGICAL FACTORS:

1. Juvenility and age of stock plants,
2. Nutrition and carbohydrate reserves,
3. Presence of buds and leaves and
4. Size of cuttings and node position

ENVIRONMENTAL FACTORS:

1. Water relations
2. Light and
3. Temperature

OTHER FACTORS:

1. Rooting medium and
2. Plant growth substances

JUVENILITY AND AGE OF STOCK PLANTS:

This is of major significance in relation to vegetative propagation of trees by conventional or in-vitro methods. The stage of growth of the seedling following germination is described as the juvenile phase. This is a phase of very active growth when the tree does not initiate flowers and vegetative propagation is usually achieved readily. This phase continues for a number of years that varies according to species, but eventually the tree attains the capacity to produce flowers, fruits and seeds. The tree now enters the adult phase, which is characterized by a decreased capacity for vegetative propagation.

However, the transition from the juvenile phase appears to be reversible to some extent and some tissues of the adult trees have some physiological characteristics of seedlings such as high growth rates and high capacity for adventitious shoot production. Such tissues, described as "rejuvenated" may occur naturally like shoots (suckers) arising directly from the roots of adult trees, or may be induced by various treatments such as pruning, vegetative propagation, grafting onto seedlings or spraying with growth regulators.

In general, cuttings taken from young seedlings root more easily than those of older plants. Apart from rooting percentages, the speed of rooting, root length, number of roots, survival and growth of rooted cuttings also decrease with increasing age of the parent material. The difficulty in rooting of cuttings from mature trees may possibly be related to

1) Increasing production of rooting inhibitors as plants grow older,

2) Decreasing phenolic levels which act as an auxin cofactor or synerglst in root initiation of stem cuttings,

3) Lignification of the stem and

4) Anatomical barriers such as a schlerenchymatous sheath

MAINTENANCE OF JUVENILITY IN STOCK PLANTS:

1. By regular pruning or hedging treatments,
2. Serial propagation or rooted cuttings,
3. A high Carbohydrate: Nitrogen (C : N) ratio is generally favourable for rooting cuttings. This is usually found near the basal region of the stump. To maintain this ratio, do not apply heavy N^2 fertilizers to stock plants. If higher doses of N2 are applied, the plants put forth more vegetative growth. Thereby the reserve carbohydrates are used up, resulting in decrease in C : N ratio.
4. Do not irrigate the stock plants upto one-week after coppicing. The stock plants are subjected to stress during which the carbohydrates are accumulated, increasing C :
N ratio.

5. NUTRITION AND CARBOHYDRATE RESERVES:

Nutrition Is also considered as an important factor in the rooting process of cuttings. During the time of root formation, the supply of carbohydrate reserves and nutrients in the cuttings must be adequate to satisfy metabolic requirements.

The cuttings should have an ample supply of stored carbohydrates to nourish the development of new roots and shoots until the new plant becomes self-sustaining. Generally, when leafy cuttings are grown in light, they root well because they contain more carbohydrates. Cuttings collected from stock plants, which contain higher carbohydrates and lower nitrogen levels normally, root more easily than poorly nourished trees. A higher rooting percentage can be was obtained when cuttings are taken from the basal part when compared to those taken from the terminal part, as the basal part of the stem had higher carbohydrate to nitrogen ratio than the terminal parts.

BUDS AND LEAVES:

There is a positive relationship between the formation of adventitious roots and the presence of buds and leaves. Normally the presence of buds and leaves Increases root-formation.

If the buds and leaves are removed, it can delay root formation or cause a total failure in rooting.

A specific root- forming substance is manufactured in the leaves, which moves downward to the base of the stem, where It promotes root formation.

A budless cutting would not form roots even when trees are subjected with an auxin rich preparation. This indicates that a factor other than auxin, presumably is produced by the bud, was needed for root formation. If cuttings are taken in mid winter when the buds are in the rest period, they have no stimulating effect on rooting, but if the cuttings are made in early fall or in the spring, when the buds are active and not in the rest influence, they show a strong root-promoting effect.

There is considerable supporting experimental evidence that the presence of leaves on cuttings excerts a strong stimulating influence on root initiation. Thus carbohydrates translocated from the leaves undoubtedly contribute to root formation.

The co-factors are naturally occurring substances that act synergistically with auxins in promoting rooting. The easily rooted forms of plants have a large content of such co-factors. One of the rooting co-factors is abscisic acid, which promotes root initiation by antagonizing the root inhibiting effect of gibberelic acid. Cuttings of certain difficult-to-root plants may fail to root because of naturally occurring Inhibitors. Inhibitors formed in the roots move upwards, accumulating in the shoots, subsequently interfering with root formation. In cultivars whose cuttings rooted easily, inhibitor levels were low. It can be finally concluded that the rooting of cuttings mainly depends on the endogenous balance of carbohydrates, auxins and rooting co-factors. The rooting co-factors interact with auxins to trigger process leading to the regeneration of roots.

SIZE OF CUTTINGS AND NODE POSITION:

For stem cuttings, the suggested length of the cutting depends on the length of internodes. If the intemode is long, the cutting can be one node and If they are short, each cutting may contain two or more internodes.

The rooting ability of stem cuttings decline sequentially with distance from the apex. Reasons for differences in rooting between node positions could be:-

1. **THE LENGTH OF INTERNODES:** The upper node cuttings have longer internodes compared to the basal nodes. Longer cuttings root better due to the influence of greater carbohydrate reserves and the presence of other essential substances for root formation.

2. **THE DEGREE OF LIGNIFICATION :** The more lignifxed and woody cuttings of the lower nodes are unsuitable for rooting.

3. **THE AGE OF LEAVES :** Old leaves of cuttings from the basal nodes readily drop while on the rooting beds before rooting could take place. These cuttings will eventually die when their carbohydrate reserves become depleted.

WATER RELATIONS :

Although the presence of leaves and buds on cuttings are important to stimulate root formation, the loss of water from the leaves due to transpiration can result in death before root

formation can take place. Therefote intermittent mist spray systems are used to maintain high air humidity in rooting chambers to avoid water stress in the cuttings.

LIGHT :

Rooting process depends on the quality, intensity and photo period (day length). Rooting percentage was greatly reduced at low light intensity. The intensity of light needed by cuttings

will depend on the species, their degree of lignification, their carbohydrate reserves and the age of stock plants. A greater light intensity is required for lignified and semi-lighimfied cuttings of mature trees compared to little lignified cuttings with less carbohydrate reerves. Very high light intensity is detrimental to newly planted cutting. In general, most tropical species require about 50% direct sunlight to produce an optimum rooting percentage. The length of photoperiod is also important for root formation. For cuttings of tropical specdies, a 12 hour length day is normally sufficient. The photoperiod under which the stock plants are grown has an Impact on the subsequent rooting performance of cuttings. Light quality may influence the growth, photosynthetic capacity and development of the plants as well as the subsequent rooting of cuttings taken from them.

TEMPERATURE:

Air temperature is an important factor influencing root formation of stem cuttings. The optimum temperature for root formation differs between species. Usually cuttings of tropical and sub tropical species require a higher temperature for rooting than those from temperate and cold countries.

The air temperature surrounding cuttings should be about 5 degree centigrade lower than the temperature of the medium in order to get a good rooting percentage.

ROOTING MEDIUM :

Rooting medium is the substrate into which the cutting materials are inserted. The rooting medium has three main functions.

1. to hold the cuttings upright during the rooting period,
2. to provide moisture for the cuttings and
3. to maintain aerobic conditins at the base of the cuttings.

Appropriate physical and chemical properties of a good rooting medium are:

1. A high water holding capacity,
2. Good drainage,
3. Sufficient porosity to allow good aeration,
4. Freedom from harmful pathogens and
5. A suitable pH level.

The most commonly used rooting media are soil, sand and vermiculite.

PLANT GROWTH SUBSTANCES:

The purpose of treating cuttings with synthetic growth substances is :

1. to increase rooting percentage,
2. to hasten root initiation,
3. to Increase the number and quality of roots produced per cutting and
4. to increase uniformity of root size.

Of the many synthetic substances which act as growth regulators, only a few effectively stiumlate adventitious root formation. They are Beta- Indole Acetic Acid)IAA), Indole 3 Buteric Acid (IBA) and Alpha-Napthalene Acetic Add (NAA). The effectiveness of these substances largely depends on the concentration, the species, the age of stock plants and the type of cuttings.

CLONAL MULTIPLICATION AREA:

Clonal Multiplication ARea is a collection of selected clones from which vegetative propagation material like cuttings are harvested. In CMA ramets of outstanding clones are planted, managed intensively. The ramets of eucalyptus can be planted at 1m x 1m spacement and in case of NTFP species (Tamarind, Usiri, Vciaga and Neredu etc.,) the ramets can be planted at 4m x 4m or 5m x 5m spacement. Generally the size of the CMA could be in the ratio of 1:100 ie., to take up 100 Ha. plantation 1 Ha. CMA Is required.

From the NTFP species grafting material (scion) can be collected from 9 months to 1 year old CMA. In case of teak the bud material can be collected right from the 2 years old CMA. But m case of eucalyptus first coppicing should be done 18 months after planting and afterwards for every 12 months.

Once the eucalyptus CMA is established the following operations should be followed in the production of clonal planting stock through rooting of cuttings.

COPPICING OF SELECTED TREES:

The selected group of trees are coppiced with a slant cut about 15 - 20cm. above ground level. The cut end should be given antifungal treatment (1 gr. Redleae + 1 gr. Copper carbonate in 1000ml. linseed oil or blue copper). Withhold water upto one week after coppicing. Later irrigate frequently based on the requirement. After 30-45 days coppice shoots are ready for

harvest. Each tree could yield 30 nodal cuttings. The shoots should be green, semihard and fleshy. Type of cuttings selected contributes a great deal to percent success of rooting. After every coppice one leader shoot will be allowed to grow which will be coppiced for the next scheduled harvest.

HARVESTING AND PREPARATION OF JUVENILE CUTTINGS :

The juvenile shoots are harvested early in the morning by cutting the shoots close to the stump. These are kept in water with the cut ends immersed in water and kept in shade. Cuttings

of 15 cm. length with atleast one or two lateral buds and two leaves are prepared. The leaves are pruned to half to minimise transpiration. The top portion with apical bud isreJected. This operation is to be done in shade early in the morning. The base of the prepared cuttings are treated with fungicide (0.1% or 1 gr per litre of Emissan or 0.05% or 0.5 gr per litre of Bavistin) for 10 minutes to prevent fungal infection of the cut end. The cuttings must be prepared, treated and transport to the mist chamber within 4 hours after harvest.

PREPARING THE ROOTING CONTAINERS :

The rooting containers will be prepared one day in advance to the harvest of cuttings. The containers are to washed in water containing 3 gr of Dithane M-45 per litre of water. Presoaked vermiculite is used as rooting medium.

TREATING THE CUTTINGS WITH HORMONE :

The cut ends of the cuttings will be dipped into the talc base powder containing. IBA by Dipsmears method to a length of one inch. Excess auxin powder sticking to the cut end should

be tapped off. The cutting should be inserted in the vermiculate medium to one thirds its length and gently firmed. Vermiculate should never be compressed. While the cuttings are Inserted in
the vermiculate, it is to be ensure that auxin powder applied is not split. In order to keep the cuttings turgid water spray should be repeatedly given to the cuttings while perparing and processing them.

PREPARATION OF ROOTING HORMONE :

To prepare powdered hormone (4000 ppm IBA) for 5000 cuttings 1 gr of IBA should be mixed throughly with 250 gr of talc base.

For 5000 cuttings

IBA required	Talc base	Concentration
0.250 gr	250 gr	1000 ppm
0.500 gr	250 gr	2000 ppm
0.750 gr	250 gr	3000 ppm
1.000 gr	250 gr	4000 ppm
1.250 gr	250 gr	5000 ppm
1.500 gr	250 gr	6000 ppm

The auxin prepared Is always kept in a cool and dark place. Only the required quantity is taken out in small container for use. The left out auxin if any in the small container should be disposed off and not added to the stock.

ROOTING:

The cuttings are transferred to mist chamber within 4 hours after harvesting. Humidity should be more than 80% and temperature around 35 to 37 degree centigrade. During first 10
days followed by reduction of humidity. Under these conditions the cuttings roots in 30 to 45 days.

MAINTENANCE DURING LOADING OF THE MIST CHAMBER :

1. If the temperature goes down too much either in the morning or in the evening or at any time, below the required level coolers and fans should not be operated,
2. Misting should be operated from 7000 am to 6.00pm.

3. All decaying and fallen leaves should be promptly removed daily,
4. If one or few cuttings show fungal remove and destroy them by burning. Do not allow them to dry as they will sporulate,
5. Normally the cuttings that root show active bud growth the auxiliary bud shows pink or reddish brown colour before the growth begins,
6. When large number of cuttings show hanging roots more air circulation is essential. So reduce the humidity to 70%

MAINTENANCE OF CUTTINGS DURING HARDENING IN SHADE HOUSE :

During the initial 5-6 days, spray should be given 4-5 times daily. Thereafter in the subsequent week spraying can be reduced to 2-3 times a day. Thereafter, the frequency can be limited to a single spray only. If the humidity is high the spray schedule may be further reduced.

On the first day of 5th week fertilizer treatment in the following composition can be applied per 5000 plants.

Water	-	30 lts
Murate of potash	-	50 gr
Super phosphate	-	200 gr
Micronutrients	-	4 mg

During fifth week all plants should be transfer to open area and irrigated as required.

DIAGNOSTIC APPROACH TO SHOWING CUTTING DEATH :

Cuttings fail to root and die for a variety of reasons. The following list describes the common problems experienced with vegetative propagation of stem cuttings, possible solutions are suggested.

1. ROOTING AT THE BASE OF THE CUTTING:

If the base of the cutting starts to look grey or black and the tissue becomes infected with fungus and bacteria it is possible that the base of the cutting is too wet. There will not be enough oxygen surrounding the cutting base for the process of respiration and the cutting will die.

There are two possible solutions:

(a) lower the water table such that the medium surrounding the cutting base is less wet,

(b) use a less dense medium for eg.,if the propagation medium is sand Includes some large particle sizes.

2. BASE OF THE CUTTING DIES BUT THERE IS LITTLE ROOTING:

If the cutting fails to root and the stem slowly become grey starting from the bottom: It is possible that the media is too dry. The base of the cutting will look and feel dry.

There are three possible solutions:

i) raise the water table such that the media surrounding the cutting base is slightly more wet,

Ii) incorporate a water retaining component into the media like peat, coconut husk etc.,

iii) use a denser medium for eg., if the propagation medium is sand or gravel mixture include less gravel.

3. LEAF ROOTING :

If the leaf roots before the base of the cutting, it is probable that the air in the propagator is too hot. If the temperature goes higher than 40 degree centigrade It will kill the cells m the leaf. There are two ways to cool the air Inside a propagator.

a) reduce the amount of light entering the propagator by shading but some light must be allowed in because the cutting needs to make sugar by the process of photosynthesis. Inefficient light in the propagator will cause the leaf to be low its carbon dioxide compensation point ie., it cannot make enough sugar to survive. This will cause the cutting to shed its leaves. It will go yellow and fall off.

b) Build a water jacket around the outside of a propagator.

4. LEAF YELLOWING AND FALLING OFF:

If the leaf becomes yellow and drops off with a fully developed abscission layer it is a sign that the cutting has rejected the leaf because it was below its carbon dioxide compensation point Ie., it cannot make enough sugar to survive.

The two main causes for this are:

a) Insufficient light reaching the leaf so that it cannot make enough sugar.

The cutting is suffering from water stress which has resulted in the cutting closing its stomatal pores thereby reducing photosynthesis. If this is the cause the cuttings visibly show wilting the there is no condensation on the walls inside the propagator.

The solutions are:

1) Reduce the degree of shading but be careful that the light is not increased to much,

so as to cause the cutting to suffer from water stress,

2) Reduce water stress by increasing the shade.

5. LEAF FALLS OFF WHILE STILL QUTTE GREEN:

If the leaf forms a fully developed abscission layer and drops off very soon aftger being placed in the propagator it is probable that cutting suffered water stress while being taken the stock plant and prepared as a cutting. When plants suffer severe sudden water stress they sometimes respond by producing a plant growth regulator called "etherel" which results in leaf shed. There is little which can be done to save the cuttings although spraying with water may help.

ESTABLISHMENT AND MAINTENANCE OF PROPAGATION UNITS

LATH HOUSE :

Lath house or Shade House of suitably large size Is an important constituent of the Vegetative Propagation Complex.

1. Functionally, lath houses are essential for hardening rooted plants, rooting cuttings using Non-Mist polypropagators and Open Mist Systems.
2. Lath houses are also essential for hardening Tissue Culture raised plants and for maintaining large number of nursery seedlings / clones.
3. The function of the Lath house is to reduce the light by 50% to 80% that prevents the shock of plantlets removed from mist chamber and protects foliage from scorching.
4. The Lath house reduces transpiration loss of moisture from the plantlets / plants by cutting down the light intensity and protects saplings from strong winds.
5. The U.V.Stabilized Agro-Shade net used for Lath house will filter U.V.Rays and protects the plants from damage and also gives long life to the net (Dr. K.Gurumurthy and C.K.Jayachandran, IFGTB, Coimbatore andM/s Plantsland suppliers, Hyderabad).
6. The Lath house is also required to protect the freshly grafted Teak Clones as the Clonal multiplication of Teak by patch budding is an important constituent of Vegetative Propagation work.
7. The Approach Grafting and Veneer Grafting of species like Tamarind and Amia clones, which is done at nursery level requires to be done under shade for better success.
8. Lath house is also required to maintain stock plants (Standard) of clonal material under shade which is essential for better response of rooting the cuttings of the same in Mist Chamber.

MIST HOUSE :

In the propagation of plants by leafy cuttings one of the chief problems is to maintain the cuttings without wilting until the roots are produced. The wilting could be overcome by spraying water mist on the cuttings by hand. It is a cumbersome procedure. It will not avoid heat generation in the surrounding environment.

An intermittent mist water spray over the cuttings is very effective in rooting leafy cuttings. This system Is widely used by propagators throughout the world. Such sprays provide a film of water over the leaves and cuttings; this film lowers the temperature and increases the humidity around the leaves thus reducing transpiration and respiration.

This mist technique makes possible the rooting of the cuttings of plants previously considered very difficult or impossible to root. Intermittent mist keeps slow rooting cuttings alive for a long period of time, giving them a change to root before they die from desiccation. By the use of mist propagation techniques in the mist house large number of cuttings can be rooted.

Mist beds can be set up in a mist house for a use in summer and winter or out-of-doors in a lath house or in open sun for use during warmer months of the year. Over these beds, or placed nozzles that produce a fine fog-like mist, spaced so as to give complete coverage of the bed.

MIST NOZZLES :

To basic types of spray nozzles are available with several modifications of each:

(a). Whirling action type

(b). Deflection type

The whirling action type or the oil-burner type nozzles produces an evenly distributed fine spray and uses a relatively small amount of water. This nozzle generally emite a flat, 160 degrees angle pattern mist to give a wide coverage.

The Deflection type nozzle develops a mist by a fine stream of water striking a flat surface. The large aperture used in this type reduces clogging but uses more water.

CONTROLS :

Intermittent mist supplies water at intervals to keep a film of water on the leaves. Since it would be impractical to turn the mist on and off by hand at short intervals throughout the day, automatic control devices are necessary.

(a) SOLENOID VALVE :

The control system includes the use of a "Normally open" solenoid valve (magnetic valve). The valve gets closed if the electronic circuit is made and prevents misting. If the circuit is broken the valve gets open and allows misting.

(b) ELECTRONIC LEAF:

The electronic leaf is a small device of plasting containing two terminals which placed under the mist along with the cuttings In the mist house. The alternate wetting and drying of the terminals makes and breaks the electric circuit which in turn controls the solenoid valve. The electronic leaf would theritically maintain a film of water on the leaves of the cuttings at all times, automatically compensating for changes In the evaporating power of the air. The principal deflecting electronic leaf Is the gradual build-up of a mineral deposit between the terminals, which will conduct electricity. The leaf therefore must be cleaned periodically.

ROOTING MEDIUM :

(a) VERMICULITE :

Vermiculite is micaceous mineral, that expands markedly when heated. When expanded vcrmiculite is very light in weight, 90 to 150 Kgs per Cmt. Neutral in reaction with good buffering properties and insoluble in water, it is able to absorb large quantities of water. Vermiculite has a relatively high caution exchange capacity of thus can be hold nutrients in reserve
and later release them. It contains enough Magnesium and Potassium to supply to the plants.

(b) PERLITE:

It is a gray white silicaceous material, is of volcanic origin mind from lava flows. The crude ore is crushed and screened, then heated in furnaces to high temperature. Perlite holds 3 to 4 times its weight of water. It is essentially natural with pH of 6 to 8 but no buffering capacity like vermiculite and no caution exchange capacity. It is most useful in increasing aeration in a mixture.

(c) SOIL MIXTURE:

Two parts of coarse sand with 1 part of red soil, which drains off excess water quickly is used as media for rooting of cuttings. Soil mixture, if heated, is generally free from many of the pathogens and insects.

POLY PROPAGATORS :

1. What is a polypropagator ?

- It is a simple wooden frame covered completely with clear polythene sheet and contain water below a moist rooting medium.

2. What is the size of the polypropagator ?

- A convenient size is about 1 M wide, 2 M - 4 M long. The height should be between 0.5 M and 1 M, with a sloping cover.

3. What are the requirements to build a polypropagator ?

- WOOD :

0.06x0.06x1.00 M 5Nos.
0.06x0.06x0.75 M 2 Nos.
0.06x0.06x0.50 M 5Nos.
0.025x0.25x2.0 M 2 Nos.
0.025x0.25x1.0 M 2 Nos.
0.025x0.25x2.0,M 6 Nos.
0.025x0.25x1.0 M 10 Nos.

- Polythene sheet: 2 M wide, 10 M long.
- Stones or broken cement blocks
- Gravel
- Coarse sand

4. How to set up a Polypropagator ?

- Align the long axis east-west.
- Level out the ground and spread sand to protect the polythene sheet.
- Put a small piece of bamboo or plastic tube vertically in a corner to check the correct level of water easily.

5. What are the drainage materials and rooting medium required ?

- A thin layer of sand.
- A thick layer of stones.
- A thick layer of gravel.
- A thin layer of sand.
- Adding upto 15 - 20 Cms. Then add water until the drainage layer is fully saturated by checking through the bamboo / plastic tube.
- Now add 10 Cms. depth rooting medium on top. It should be moist but not water logged.

6. **What about the cover ?**

- It should be set at fairly steep angle to run off the condensed water droplets instead of forming large drips.
- To make it easier to work on the lowside of the polypropagator.

7. **Is misting needed ?**

- This is non-mist system - no need for misting.
- A clean hand sprayer giving a fine spray of water is required whenever cuttings are being set/polypropagator opened/rooting medium needs to be moistened.

8. **How to maintain it ?**

- Clean the outside and inside of polypropagator sheet each week with water.
- Check water level each week.
- Patch any holes in the polythene sheet.

9. **How to set the leafy cuttings ?**

- Make a hole with a small stick, put in the cuttings and make the medium firm around it.
- Use a fine spray of water.
- Close the lid of the polypropagator immediately the setting is finished.
- Label should contain clone number, date of setting and the number of cuttings set. It should also indicate treatment given and other variables such as origin, type of cuttings etc. for research purpose.

RESEARCH ON PROPAGATION AND CULTIVATION OF MEDICINAL PLANTS

In India, the use of different parts of several medicinal plants to cure specific ailments has been in vogue from ancient times. The indigenous system of medicine namely Ayurvedic, Siddha and Unani have been in existence for several centuries. This system of medicine cater to the needs of nearly seventy percent of our population residing in the villages. Apart from India, these systems of medicines are prevalent in Korea, China, Singapore, West Asia and other countries. Besides the demands made by these systems as their raw material, the demand for medicinal plants made by the modem pharmaceutical industries has also increased manifold. Thus, medicinal plants constitute a group of industrially important crops which bring appreciable Income to the country by way of export.

Many of the crude drugs which are sources of medicinal preparations still come from the state of their wild growth. The natural resources how-so-ever large are bound to diminish. Time has, therefore, come to bring these plants under plough to meet the rising demand of the resultant product. These plants as a group have a large potential for primary introduction of new commercial crops. There is an increasing demand for plant based drugs, and pharmaceuticals in the world market. India is among the traditional producers and exporters of several medicinal plants. Lack of basic information on different parameters of crop productivity is a limiting factor in this group of plants. There is, therefore, need for Intensive agricultural studies leading to genetic improvement and cultivation methods for expansion of area under medicinal and aromatic plants.

Commercial cultivation of plants useful for modem medicine :

More than 100 medicinal plants are used in modern medicine. Plants used in traditional system of medicine are of over 500 different types. Most of the raw material for traditional medicine of pharmaceutical houses is collected from wild sources. Many of the medicinal plants are cultivated commercially now-a-days for extraction of some Important active constituents for use in modem medicine.

1. For steroidal hormones which are sythesized from diosgenin, hecogenin or solasodine, different species of Dioscores, Solanum and Agave are cultivated.
2. Costus spedciosus is a source of diosgenin.
3. Papaver somniferum is a source of different types of alkaloids, out of which morphine, codeine, papaverine and nascopine are used In medicine.

4. Various species of Cinchona also contain large number of alkaloids in the bark, and most important are quinine and quinidine.
5. Different species of Datura, Hyoscyanws, Atropa, Duboisia, Scopolia and Physochlaina contain tropane alkaloids which include hyoscyamine, hyoscine, atropine and are commonly used in modern medicine.
6. Digitalis lanata is an important plant which contain digoxin and lanatocide-C glycocides.
7. Rauwolfia serpentma, R. canescens and R. vomitora contain reserpine, resinamine and deserpidine, and the species R. vomitoria also contain ajmaline.
8. Catharanthus roseus contains more than 100 alkaloids of which Ajmalicine (ranbasine) is of considerable importance.
9. Cornelia sinensis is a caffeine yielding plant
10. Erythroxylum coca yields cocaine.
11. Cephaelis ipecacuanha and C. acuminata yield number of alkaloids of which emetine and psychotrine are most important.
12. Claviceps purpurea (fungus) grown on rye contains more than two dozen alkaloids of which ergofamine, ergometrine and ergotoxine group of alkloids which are used in medicine.
13. Plantago ovata seed is mostly used in medicine because of its mucilage, which is colloidal in nature and serves as a safe bulk-laxative.
14. Glycyrrhiza glabra contains saponin-like glycosides of which glycyrrhizin in most important.
15. From Cassia anguştifolia and C acutifolia the crude drug senna Is obtained.
16. Various species of Berberis and Mahonia yield berberine.
17. Carica papaya yield peptolytic enzyme.
18. Ammi majus seeds contain furanocoumarin, called xanthotoxine.
19. Strynus-nux-vomica seeds contain strychnine alkalods.

EXPORT OF MEDICINAL PLANTS AND PHYTOCHEMICALS :

India is a leading exporter of the medicinal plants in the world trade. The major export of medicinal plant parts or whole plant from India are poppy husk and seeds, opium crude, psyllium (Plantago ovata) husk and seeds, senna (Cassia angustifoliaa) leaves and pods, chirayata (Swertia angustifolia), galanthus (Alpinia sp.) rhizomes, Tukmaria and Zedoary (Curcuma zedoaria) roots, periwinkle (Catharanthus roseus) roots and leaves, Glycerhiza glabra dried rhizomes, Ipecae dried rhizomes and roots, Kuth roots, nux-vomica dried ripe seeds, sarasparilla, serpentina roots and some ayurvedic herbs.

A part from the medicinal plant parts, India also exports large quantity of phyto-chemicals like beta-lonone, papain, solanesol, quinine sulphate, atropine sulphata, quinine hydrochloride, salts and derivatives of quinine, quinine alkaloides, berberine hydrochloride, emetine alkaloids, strychmine alkaloids and salts, salts and other derivatives of nux vomica, alkaloids and brucine, vegetable alkaloids, salt and other derivatives of ergot, opium alkaloids, ephedrine hydrochloride, ergot alkaloids, hormones, neosoralen, macsoralen and trimetoxy soralen. But India's share of phytochemical exports compared to the overall world trade is very meagre.

Major importer of medicinal plants from India are U.S.A., Japan, Germany, France and Switzerland. Countries like South Korea and China are also important exporters of these plants. South Korea Is the major exporter of Ginseng (Panax sp.) in the world market.

Problems in use and cultivation of medicinal plants :

1. Lack of basic Information on different parameters of crop productivity.

4. Utilization of locally available plants as far as possible by the practitioners of various Indian systems in different parts of India.

5. Information on the use of medicinal plants is scattered and most of it is found in books and periodicals, many of which are out of print and are not available In large libraries.

6. Very little work of scientific value was done till the large part of this century and earlier publications on the subject not Infrequently contain confused data derived from old literature copied without critical appraisal.

7. Paucity of authentic information on the identity, habitat, conditions of collection and use of medicinal plants.

8. Medicinal properties, some genuine, some otherwise, have been attributed to a large variety of plants, more than 1500 in number, in different parts of the Country.

9. Many vegetable drugs are used in preparations prescribed by practitioners of indigenous medicine in different regions others are used as household remedies by the common people.

10. Often results have been published as pertaining a plant, while the plant actually investigated was entirely different from the one for which the results are reported.

11. Herbal vendors are unwilling to share the knowledge of several medicinal plants and their curative properties (professional secrets) to the people.

Following reasons may be attributed for the downfall of traditional herblists:

1. With the coming of the fast acting modem synthetic medicine, more people prefer it because of quicker action.

2. Many of the medicinal herbs have disappeared from the natural habitats due to their over utilization and exploitation.

3. They remain ignorant about the several new human diseases and their etiology.

4. Lack of formal training on human health and hygiene is perhaps the greatest single factor for their downfall.

5. Apathy of the Government and the health authorities who do not give them any recognition to practice their brand of herbal medicine freely with honour and dignity.

6. Under the impact of modernization and economic compulsions they are forgetting their ancestral tradition and knowledge.

7. The nomadic life style is posing another serious handicap in the modern times.

Suggestions for improvement in usage of Medicinal plants :

1. Identification of the products which are in good demand in the markets.

2. Conservation of existing germplasm.

3. Selection of plants which are highly effective or with more and rare active ingredients are to be made.

4. Identification of plant species and authentication of plant material.

5. Collection of germplasm from different parts of the country and their maintenance and assessment.

6. Gene bank of medicinal plants for characterisation of genotype pharmacognostically and pharmacologically.

Detailed studies are needed on the following issues:

i) Floral biology of seed propagated plants.

ii) Commercial cultivation of suitable species and types.

iii) Package of practices and economics for cultivation of various medicinal plants.

iv) Use of tissue culture for large scale multiplication of plants.

v) Standardization of optimum conditions required for germination of seed.

vi) Morphological variation and ecological adaptation of plants from seedling to harvest stage in order to find out the stage when the active principle content is maximum.

vii) Ecological factors influencing growth and active principles content of plants under different altitudes and climates.

viii) Effect of trace elements, plant protection chemicals, organic and inorganic manure on the variation of active principle content of plants.

ix) Pathological investigations for controlling diseases of plants.

x) Collection, curing, drying and storage of plant parts so as to find out the optimum conditions under which the highest active principles may be obtained.

xi) Improvement of plants by sexual method of hybridization or by mutation through chemical and physical mutagens.

xii) Genetic manipulation and biotechnology.

xiii) Chemical studies of plant parts, isolation of active ingredients.

xiv) Pharmacological studies, blo-activity, toxicology and teratology.

xv) Drug information, their clinical evaluation, new dose forms, quality control, standardization and stabilisation.

xvi) Market research and feasibility studies.

ESTABLISHMENT OF ARBORETUM AND MAINTAINING VARIOUS FOREST SPECIES AND IDENTIFICATION OF THEIR PERFORMANCE IN VARIOUS FIELD CONDITIONS

RATIONALE:

Extinction has been the destiny of a great number of plant species including several unique and irreplaceable varieties. Some of these have disappeared from the earth in nature's own process of evolutionary change, but for many others extinction has been caused by man because of his inadvertence as well as ignorance about their economic potential and ecological functions. Realising the ecological importance and utility of plant resources, there Is growing concern throughout the world about the need for conservation and to desist from eroding the richness of gene-pool. While evaluating the need for conservation of plant resources it is imperative that several habitats important for their biological composition, genetic diversity, economic potentiality or significant for other reasons, are necessary for preservation. In addition, a number of individual species even though occurring in biologically less Interesting habitats, are unique in themselves for variety of reasons. Some of them grow in very small populations or numbers, others are unique from biological or evolutionary stand point; still others are under threat of extinction due to habitat destruction or over-exploitation. Thus, it is essential to preserve and if possible, multiply their numbers in man-made habitats like botanic gardens, conservatories, orchidaria or other collection of living plants. Such concern for conservation of plant (tree) resources has found expression in the establishment of an Arboretum.

METHOD :

1. Survey forest areas with assistance of Research Assistants and an expert in Taxonomy for identification of plants.
2. Collection of seed or saplings from natural forests and planting In the places designated
3. Limited entry is allowed into the Arboretum by students, academicians and other
4. distinguished persons till Arboretum is fully established and there after Arboretum will be opened for all others.

5. Recording of growth data for certain species that are introduced.

6. Publication of guide book to the Arboretum with illustrations.

I. COLLECTION AND ESTABLISHMENT OF BAMBOO GENE BANK AND MULTIPLICATION THROUGH VEGETATIVE PROPAGATION

Cultivation of bamboo is very Important as the farmers are showing keen interest to grow bamboo the cultivation of which is economically highly viable. Based on this, there is necessity to carry out several experiments dealing with propagation and rooting techniques.

7 BAMBOO FOREST IMPROVEMENT :

- Efficient system for production of Bamboo planting stock.

OBJECT :

- To evolve efficient Vegetative Propagation method.
- To get good planting stock through genetic improvement.

RATIONALE :

Large scale production of bamboo seedlings to raise bamboo plantations is hampered by long vegetative cycle and death of flowered clumps coupled with short viability of seed. Though planting stock can be produced by vegetative propagation system the synchronous flowering of the vegetatively propagated clumps and parent clumps leads to the death of the entire plantation.

STRATEGY :

i) Survey and exploration of various bamboo bearing areas and study their diversity on phenotic characters and selection of superior phenotypes (Clones).

ii) Establishing gene banks using clones of Dendrocalamus strictus, Bambusa bambos and Dendrocalamus hamiltonii.

iii) Study the performance of various clones and evaluation of clones for traits for various end uses.

iv) Study the vegetative propagation of Dendrocalamus strictus (macropropagation) through cutting of offsets, stem cuttings (culm segments) rhizome cuttings and planting layers.

METHOD :

i) Catchment areas of River Godavari in West Godavari, East Godavari, Visakhapatnam, Khammam districts and River Krishna in Nallamalai forests in Kurnool, Mahaboobnagar districts in Andhra Pradesh are good bamboo bearing areas.

Clump area, number of culms in each clump, new recruits in a year, length of culm, no. of nodes and length of inter nodes, hollowness or solidness of culm, diameter of culm and health are the characters to assess in selection of clones in each area.

Selection of 15 clumps of Dendrocalamus strictus from each district to make 100 clones and cloning them in Regional Forest Research Centres.

ii) Establishing Genebanks for Dendrocalanus strictus, Bamboosa bambos and Dendrocalanus hamiltomii with clones as a clonal archive.

The performance of various clones in different areas for different purposes (end uses) are to be studied.

The end uses are :

- For timber production (mechanical strength, durability)
- For paper making (morphological characters for fibre length and fibre tissue formation.

iii) Schematic representation for high yielding bamboos

Base Population

↓

Selection of Superior clumps

↓

Propagation of selected clumps
under field conditions

↓

+ -- +

↓ ↓

Culm cuttinss Rhizome cuttings

iv) Mass propagation of superior clumps :

Selection of 5 superior clumps for each of its two end uses from each site (Experimental plots)

Establishment of multiplication garden for large scale vegetative propagation.

v) Standardization of efficient macro-propagation system among the following types of vegetative propagation methods based on percentage of success in nursery and plantation level in two different conditions of one at naturally bamboo grown areas and other m farm land areas.

a. **Offset planting :** Offset consisting of 1 - 2 year old culm, cut at about 30 -60 cm height Is excavated along with a portion of rhizome with root system. These offsets are taken and planted during the season of rest, so that during the season of growth, may find them well in position and takes root easily. The rhizome size should be 5 times larger than the basal girth of the culm.

b. **Culm cuttings planting :** Stem cuttings or culm segments without rhizomes but with buds attached with groups of nodes at the base are completely burried leaving only their upper surface is exposed. About 1 meter long culm cuttings of 1 - 2 years old planted horizontally Is one of the methods to be tried.

c. **Rhizome cuttings :** Fresh living rhizomes of the proceeding year about 15 to 30 c.m. long with at least one bud are planted. (Offset planting is different from rhizome cutting as former planting include portions of living rhizomes).

d. **Layering :** One year old culm is pruned without injury to dormant buds. The culm is partly cut near the base, bent and pegged down below the ground which would eventually result in development of roots at the nodes.The internodes are then cut through and the resulting plants are separated and planted.

Plan for macro proliferation

STAGE -1 **AUGUST**

Raising of seedlings by seed Sowing or prick out from forest floor in Polybags (1000)

↓

Multiplication 3 to 6 From each seedling vegetatively

↓

STAGE **APRIL**

Multiplication 3 to 6 From each seedling vegetatively

↓

Separation of propagules by cutting rhizomes and planting in polybags (1000 x 4 = 4000)

↓

STAGE - 3 **JULY**

Saplings for field planting 3000

1000 saplings for further Multiplication

↓

Multiplication

↓

STAGE - 4

Separation of propagules by cutting rhizomes and transplanting in poly tubes 1000 + 3000

↓

STAGE - 5

Multiplication

In the first year field plantable saplings in massive numbers may be available through stage 1,2, and 3. From second year onwards the same number of field plantable saplings may be available from stages 3,4 and 5,2 and so on.

TIMING :

i. Selection of superior phenotypes and bringing material to Research Centre.

ii. Collection of seed/seedlings from forest floor for macroproliferation.

iii. Raising of field plots and Clonal Archive

iv. Assessment for traits in experimental plots.

v. Multiplication garden for mass propagation.

CERTIFICATION OF FOREST REPRODUCTIVE MATERIAL :

The object is to encourage the production and use of seeds, parts of plants and plants that have been collected, transported, processed, raised and distributed in a manner that ensues their trueness to name and quality.

Four broad categories of forest reproductive material are recognised. They are:

a) Source identified reproductive material which represents a minimum standard

b) Selected reproductive material

c) Reproductive material from untested seed orchards which give promise of seed of improved quality

d) Tested reproductive material which is genetically improved/ superior.

The forms SC-1, SC-2, SC-3 and SC-4 are used for certificate of provenance for source identified reproductive material, selected reproductive material, material from untested orchards and tested reproductive material respectively. They are as follows :

CERTIFICATE OF PROVENANCE : Form SC-1

(Category : Source Indentified Reproductive Material)

1. State : ______________ 2. Certificate No. __________ Date ______

3. Botanical name of produce : ______________________________

4. Common name or trade name : ______________________________

5. Nature of Produce (Indicate with •)

   a. Seeds ☐ b. Parts of plants ☐ c. Plants ☐

6. Details of source : ______________________________

   a. Division : ______________________________

   b. Range : ______________ Block / Compt. ______________

   c. Type of Soil : ______________________________

7. Seed Zone (Indicate by code number as shown in Seed Zone maps) :

   ____

   ____

8. Origin (indicate with •)

   a. Indigenous ☐ b. Non-indigenous ☐

   c. Unknown ☐ d. Introduced from ☐

   ____

   ____

9. Month and year of seed collection :

   ____

10. Length of time in nursery as seedlings or transplants :

   ____

11. Package

Quantiy	
Number	
Nature	

12. Remarks

____

____

It is certified that forest reproductive material described above has been produced in accordance with the Scheme for Certification of Forest Reproductive Material in India.

CERTIFYING AUTHORITY ;

Name : ______________________ Signature :

Address : ______________________ Date :

____

____

____

N.B. :- Certificate must contain all the information outlined above but the exact arrangement of
the text is at the discretion of the Designated Authority.

CERTIFICATE OF CLONAL IDENTITY (*)
CERTIFICATE OF PROVENANCE (*)

Form SC-2

(Category : Selected Reproductive Material)

1. State : ______________________ 2. Certificate No. ____________ Date ________

3. Botanical name of produce : ______________________________________

4. Common name or trade name : ______________________________________

5. Nature of Produce (Indicate with •)

   a. Seeds ☐ b. Parts of plants ☐ c. Plants ☐

6. (*) National / State Number of Tested Seed Production Area :

   ____

   ____

7. Clone No. : ______________________________________

8. Details of source : ______________________________________

   a. Division : ______________________________________

   b. Range : ______________________ Block / Compt. ____________

   c. Type of Soil : ______________________________________

9. Seed Zone (Indicate by code number as shown in Seed Zone maps) :

   ____

   ____

10. Origin (indicate with •)

   a. Indigenous ☐ b. Non-indigenous ☐

   c. Unknown ☐ d. Introduced from

   ____

   ____

11. Month and year of seed collection :

12. Length of time in nursery as seedlings or transplanation :

13. Package

Quantity	
Number	
Nature	

(*) Delete what is not applicable

14. Remarks :

It is certified that forest reproductive material described above has been produced in accordance with the Scheme for Certification of Forest Reproductive Material in India.

CERTIFYING AUTHORITY ;

Name : ________________ Signature :

Address : ________________ Date :

N.B. :- Certificate must contain all the information outlined above but the exact arrangement of
the text is at the discretion of the Designated Authority.

Form SC-3

CERTIFICATE OF CLONAL IDENTITY AND CERTIFICATE OF PROVENANCE :

(Category : Seed Orchard Material)

1. State : ______________ 2. Certificate No. ______________ Date ________

3. Botanical name of produce : ______________

4. Common name or trade name : ______________

5. Nature of Produce (Indicate with •)

   a. Seeds ☐ b. Parts of plants ☐ c. Plants ☐

6. National / State Number of seed orchard

   ____

   ____

7. Clone Number (s) : ______________

8. Details of source : ______________

   a. Division : ______________

   b. Range : ______________ Block / Compt. ______________

   c. Type of Soil : ______________

9. Seed Zone (Indicate by code number as shown in Seed Zone maps) :

   ____

   ____

10. Month and year of seed collection : ______________

11. Length of time in nursery as seedlings or transplants :

   ____

12. Package :

Quantiy	
Number	
Nature	

13. Remarks : ______

______

It is certified that forest reproductive material described above has been produced in accordance with the Scheme for Certification of Forest Reproductive Material in India.

CERTIFYING AUTHORITY ;

Name : ______ Signature :

Address : ______ Date :

______

______

______

N.B. :- Certificate must contain all the information outlined above but the exact arrangement of
the text is at the discretion of the Designated Authority.

Form SC-4

CERTIFICATE OF CLONAL IDENTITY AND CERTIFICATE OF PROVENANCE :

(Category : Tested Reproductive Material)

1. State : ______________________ 2. Certificate No. ______________ Date __________

3. Botanical name of produce : ______________________

4. Common name or trade name : ______________________

5. Nature of Produce (Indicate with •)

   a. Seeds ☐ b. Parts of plants ☐ c. Plants ☐

6. National / State Number of Tested Seed Production Area / Seed Orchards :

   ____

   ____

7. Clone Number (s) : ______________________

8. Details of source : ______________________

   a. Division : ______________________

   b. Range : ______________________ Block / Compt. ______________

   c. Type of Soil : ______________________

9. Seed Zone (Indicate by code number as shown in Seed Zone maps) :

   ____

   ____

10. Origin (indicate with •)

    a. Indigenous ☐ b. Non-indigenous ☐

    c. Unknown ☐ d. Introduced from

    ____

    ____

11. Month and year of seed collection :

____

____

12. Length of time in nursery as seedlings or transplanation :

____

____

13. Package

Quantiy	
Number	
Nature	

14. Remarks :

____

____

It is certified that forest reproductive material described above has been produced in accordance with the Scheme for Certification of Forest Reproductive Material in India.

CERTIFYING AUTHORITY ;

Name : ____________________ Signature :

Address : ____________________ Date :

____

____

____

N.B. :- Certificate must contain all the information outlined above but the exact arrangement of

the text is at the discretion of the Designated Authority.

Form SC-5

SPECIMEN CERTIFICATE OF LABORATORY TESTS

(Certificate shall contain all the information outlined below, but the exact arrangement of the test is at the discretion of authorities of Seed 'Testing Laboroatry. Form will bear number SC-5).

Name / Address of Seed Testing Laboratory : ______________________

____

____

Species : ______________________ Provenance : ______________________

Lot No. ______________________ Sample No. : ______________________

Lab. Test No. ______________________

A. PURITY :

FRACTION	Replicate (gm)				
	A	B	C	D	Mean%
eed					
matter					

B. GERMINATION :

Date of putting : ______________________

Temperature (°C) ______________________ Substrate ______________ Treatment ______________

No. of Seeds ______________________.

Category	Date		I	I		Total	ean %
al seedlings	First count						
	Final count						
rmal seedlings	Total						
	First count						
	Final count						
Seeds	Total						
ungerminated seeds							
seeds							

Remarks : Mechanical damage
Insect damage
Diseased
Rain infested
Sample too small for test
Probably heated during storage.

Recommendations : The Seed must be cleaned
Drying necessary.
Chemical treatment
recommended

C. MOISUTRE :

(Hot air oven / moisture meter / Mineral oil distillation)

A	B	Mean

D. SEED WEIGHT :

Replicate	Weight in gm	No.
A		
B		
C		
D		

No. per Kg.

E. OTHER DETERMINATIORS :

i Address of Designated Authority :

Source of Identified

ii Category

iii Species :

iv Sub-Species Variety, Cultivar Name :

v Seed Zone :

vi Reference Number of the Certificate and Date :

vii Quantity: ______________ Kgs.

Scheme For Certification of Forest Reproductive Material In India

eme For Certification of Forest Reproductive Material In India

To,

____

____

____

____

Form SC-6(b)

i	Address of Designated Authority :	
		Selected
ii	Category	
iii	Species :	
iv	Sub-Species Variety, Cultivar Name :	
v	Stand number :	
vi	Reference Number of the Certificate and Date :	
vii	Quantity:	________ Kgs.

Scheme For Certification of Forest Reproductive Material In India

eme For Certification of Forest Reproductive Material In India

To,

____

____

____

____

Form SC-6(c)

i Address of Designated Authority :

Seed Orchard

Scheme For Certification of Forest Reproductive Material In India

ii Category

iii Species :

iv Sub-Species Variety, Cultivar Name :

v Orchad number :

vi Reference Number of the Certificate and Date :

vii Quantity: ____________ Kgs.

eme For Certification of Forest Reproductive Material In India

To,

Form SC-6(d)

i Address of Designated Authority :

Tested

ii Category

iii Species :

iv Sub-Species Variety, Cultivar Name :

v Tested Stand or Orchard :

vi Reference Number of the Certificate and Date :

vii Quantity: __________ Kgs.

Scheme For Certification of Forest Reproductive Material In India

eme For Certification of Forest Reproductive Material In India

To,

SPECIFICATIONS FOR LABELS

in Size ngular 12cm X 7 cm with square corners

r r of label shall be as follows

- Source Identified Reproductive Material - Yellow
- Selected Orchard Material - Green
- Seed Orchard Material - Pink
- Tested Reproductive Material - Blue

e of the Scheme e printed with lack background vertically within 2 cm of one end on both sides. Eyelet for binding thread will be within 2 cm of other end at its mid point.

Name shall be *e for Certification of Forest Reproductive Material in India"*

ribed information verse side.

ddress of Designated Authority:
(to be printed)

ategory: (to be printed)
urce Identified / Selected/ Seed Orchard/ Tested
for yellow Green Pink Blue label

ecies (to be filled in):
b-species variety, cultivar name

Seed Zone
Yellow label)

Stand number
(for green label)

Orchard number
(for pink label)

Tested stand or orchard
(for blue label)

eference number of the certificate and date :

uantity ____________________ Kg.

se side will have space for Consignee's address.

N.B. 1. Label will bear from No.SC-6 (a) to (d)
2. Specimen labels are appended

Form SC-9, Form SC-10, Form SC-9, Form SC-10, Form SC-11, Form Sc-12 and Form SC-13 pertain to compilation and circulation of information on approved basic material. They are as follows.

Form No.SC-7

SEED ZONE-WISE DISTRIBUTION OF SPECIES

State:

one No.	*Division*	*Types (Division Wise)*	dinal Limits*	*Species Availability +*						
				Botanical name of species						
1	2	3	4	i)	ii)	ii)	v)	v)	i)	ii)

REFERENCES:

* Altitude Limits : Please give here minimum and maximum altitude of the forest areas in the division concerned to help in subdividing seed zones into sub-zones on the basis of altitude.

It is hoped that sub-division of the seed zone into sub-zones on the basis of altitude will render each sub-zone into more homogeneous ecological unit.

Sub-zones based on 600m, interval i.e., altitude between 0-600 m, 601-1200 m, 1201-1800 m, etc. will each form separate sub-zone for purposes of seed certification.

\+ Species availability : Indicate the availability of species division wise with following symbols.

P = Predominant; R = Rare; F = Frequent; A = Absent,
0 = Occasional: PL = Planted.

Form SC-8

FORMAT FOR SEED PRODUCTION AREA REGISTER

Species : State

Sl.No.	Seed Zone	Division	Range	Block & Compt.	Year of selection/ formation	Estimated age at time of formation	Site	Area in hec.	Average or range of annual seed/fruit cone prod (kg.)	No.of seed bearers	Treated/ un treated	Stand Regn. No.

Form SC-9

SEED PRODUCTION AREA RECORD FORM

Sheet No. 1

STATE : SPECIES	Location Map
YRS OF EXPLOTATION AS PER W.P.	
FOREST TYPE :	
ORIGIN : INDIGENOUS* / INTRODUCED	
GENERATION : VIRGIN*/NAT REGENERATION*/PLANTED* DELETE WHAT IS NOT APPLICABLE	
STAND DESCRIPTION & SELECTION CRITERIA	
ISOLATION :	

Seed Zone	Division& Range	Block and Compt.	Year of Selection/ Formation	Est.Age at Time of Formation	Stie Qty.	Area in Hec.	Av. or Range of Annual Seed/ Fruit Cone Prod (Kg)	No. of Seed Bearers	Treated Untreated	Stand Regn. No.

SEED PRODUCTION AREAS RECORD FORM

Soil :

Topography :

	JAN.	FEB.	MAR.	APR.	MAY.	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Monthly Rainfall in MM :												
Maximum Temperatre in ºC												
Minimum Temperatre in ºC												
Maximum Humidity in %												
Minimum Humidity in %												
Date of Selection												
Selected by												
Approved by												
Date of Approval												
Operation carried out at first formation												

Form SC-9

SEED PRODUCTION AREA RECORD FORM

Sheet No. 2

STAND REGISTERATION NO.

STAND TREATMENT RECORD	19	19	19	19	19	19	19	19	19	19	19 .....
OPERATION DATE											
NO. OF TREES RETAINED											
CROP HEIGHT IN METERS											
FERTILIZER APPLICATION											
KG./TREE											
KG./TREE											
KG./TREE											
KG./TREE											
FLOWER RATING											
CROP RATING (SEED ETC.)											

OTHER OPERATIONS

SEED PRODUCTION AREA RECORD FORM

SEED COLLECTION

Area of Collection	No. of Mother Trees	Month/ Year	Qty. in Kg.	Seed Lot No.	Qty./ Hec	Viability	Germination	Delivered To	Remarks

Ref. TO TESTS EXISTS

Form SC-10

IV. FORMAT FOR PLUS TREES REGISTER

Species :

State :

Sl.No.	Seed Zone	Division	Range	Block & Compt.	Date of final selection	Height in Mts.	Girth at b. h.	Clear bole ht.	Crown dia	Purpose of selection	Regn. No.	Progeny test done/ not done.

Form Sc-11

PLUS TREE RECORD FORM

		SCORING CHARACTERS								
SPECIES	PHOTOGRAPH REF. No.			Plus Tree	Check Trees					
					1	2	3	4	5	6
PLANTATION	NATURALLY GROWN	VIGOUR	TOTAL HEIGHT							
AGE	APPROX FLOWERING TYME		BOLE HEIGHT							
FOREST TYPE			BOLE DIAM							
SITE QUALITY										
AV. ANNUAL RAINFALL IN MM		FORM	BOLE STRAIGHTNESS							
			TAPER							
ANY OTHER INFORMATION			SHAPE							
			GRAIN							
			FLUTING							
		CROWN	EPICORMIC BRANCHES							
			NATURAL PRUNING							
			BRANCH ANGELE							
			PESTS & DISEASES							
			FRUTTING							
			RESIGN : GUM YIELD							
DESIGNATION	DESIGNATION		**TOTAL GUM YIELD**							

Seed Zone	Division	Range	Block& Compartment	Date of Final Selection	HT. IN MTS.	Girth at B H	Clear Bole HT	Crown Dia	Purpose of Selection	Regn. No.	Progeny Test Done / Not Done

LOCATION MAP

BUD WOOD COLLECTION

MONTH & YEAR	QUANTITY	DELIVERED TO

SEED COLLECTION FOR HALF FROGENCY TRAILS

MONTH & YEAR	QUANTITY	DELIVERED TO :

REF TO TESTS / EXPTS.

Form SC-12

V. FORMAT FOR SEED ORCHARD REGISTER

Species : State :

Sl.No.	Seed Zone	Division	Range	Block & Compt.	Year of Planting	Area planted in hect.	Spacing in mtrs.	No. of remetes	No. of clones	Seed orchared Regn. No.	Remarks

Sheet No.1

Form SC-13

CLONAL / *SEEDLING SEED ORCHARD RECORD FORM (*Delete Whatever is not Applicable)

STATE		SPECIES :		
LONGITUDE :	LATITUDE	ALTITUDE	SLO	ASPECT
SOIL DESCRIPTION :				
PREVIOUS VEGETATION :				
PLANTING STOCK :				
SEATING & REBUDDING :				
CLONES USED :				

SEED ZONE	DIVISION	RANGE	BLOCK & COMPT.	YEAR OF PLANNING	AREA PLANTED IN HETC.	SPACING II No. of MRTS LAMETES	No. OF CLONES	SEED ORCHARD REGN No.	REMARKS

CLONAL SEEDLING SEED ORCHARD RECORD FORM (*DELETE WHATEVER IS NOT APPLICABLE)												
IRRIGATION FACILITIES :												
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
MONTHLY RAINFALL (MM)												
AV. MONTHLY MAX. TEMP INC :												
AV. MONTHLY MIN. TEMP INC :												
OBSERVATION												
MONTH & YEAR	AV. HEIGHT			AV. DIAMETER (CM) SPACING IN CM				REMARDS ABOUT FLOWERING FRUTTING DISEASES, SPECIAL ETC.				

Sheet No. 2

Form SC - 13

CLONAL SEEDLING SEED ORCHARD RECORD FORM (*DELETE WHATEVER IS NOT APPLICABLE)

SEED COLLECTION :			SEED ORCHARD REGN. NO.		
MONTH & YEAR	QUANTITY IN KG.	SEED WT.	GERMINATION %	No. SEEDLING CLONES	DELIVERED TO
TREATMENT		19		19	19 | 19 | 19 | 19

CLONAL / SEEDLING SEED ORCHARD RECORD FROM (*DELETE WHATEVER IS NOT APPLICABLE)

REFERENCE TO TESTS / EXPTS	DESIGN & LAYOUT

Sheet No.1

Form SC-13

CLONAL / SEEDLING SEED ORCHARD RECORD FORM (*Delete Whatever is not Applicable)

STATE		SPECIES :		
LONGITUDE :	LATITUDE	ALTITUDE	SLO	ASPECT
SOIL DESCRIPTION :				
PREVIOUS VEGETATION :				
PLANTING STOCK :				
SEATING & REBUDDING :				
CLONES USED :				

SEED ZONE	DIVISION	RANGE	BLOCK & COMPT.	YEAR OF PLANNING	AREA PLANTED IN HETC.	SPACING II No. of MRTS LAMETES	No. OF CLONES	SEED ORCHARD REGN No.	REMARKS

CLONAL SEEDLING SEED ORCHARD RECORD FORM (*DELETE WHATEVER IS NOT APPLICABLE)

IRRIGATION FACILITES :

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MONTHLY RAINFALL (MM)												
AV. MONTHLY MAX. TEMP IN ºC :												
AV. MONTHLY MIN. TEMP IN ºC :												

OBSERVATION

MONTH & YEAR	AV. HEIGHT	AV. DIAMETER (CM) SPACING IN CM	REMARDS ABOUT FLOWERING FRUTTING DISEASES, SPECIAL ETC.

Sheet No. 2

Form SC - 13

CLONAL / SEEDLING ORCHARD RECORD FORM (*DELETE WHATEVER NOT APPLICABLE)

SEED COLLECTION :

SEED ORCHARD REGN. NO.

MONTH & YEAR	QUANTITY IN KG.	SEED WT.	GERMINATION %	No.OF SEEDLING CLONES	DELIVERED TO
TREATMENT		19		19	19 19 19 19

CLONAL / SEEDLING SEED ORCHARD RECORD FROM (*DELETE WHATEVER IS NOT APPLICABLE)

REFERENCE TO TESTS / EXPTS	DESIGN & LAYOUT

SEED COLLECTION REGISTER

Date of Receipt	Locality	Period of collection	Seed collected by	Quantity		Seed lot No.	Date of issue	To whom issued with Rc No.	Quantity		In person (or) by TPT. Agency	Balance	Remarks
				No. of bags	No. of Kgs.				No. of bags	No. of Kgs.			
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.

REGISTER OF BUILDINGS

Sl.No.	Particulars of property	Year of construction	Original cost of the building	Record value			Funds from which	
				Cost of site	Subsequent additions or reducting	Progressive total	Constructed or purchased	Maintained
1.	2.	3.	4.	5.	6.	7.	8.	9.

CONTD.

Object of construction			Assessed standard rent		Nature of building			No. of stories	Superficial plinth area including Verandas	Cubical contents	Remarks
Original	How used from	Time to time	Model FR 45 A	Model FR 45 B	Walls	Floor	Roof				
10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.

REGISTER OF PLANTATIONS

Sl.No.	Name of Research division	Name of the research range	Name of territorial		Name of RF/RL	Name of experimental plot	Area in Ha.	Species	Locility	Year of planting	Espacement
			Division	Range							
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.

CONTD.

Stock percent	Maximum Ht. (M)	Average Ht. (M)	Average girth (cm)	Standing Volume per Ha./date	Expenditure				Total upto date exp. (Rs.)	Remarks
					1st Year	2nd Year	3rd Year	4th Year		
13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.

REGISTER OF PLANTATION

Sl.No.	Name of Research Range	Name of the Research center	Name of the experi-mental plot	Year of estab-lishment	Species	Espace-ment (in Mt.)	Statisti-cal design	No. of families/ clones	No. of replications	Subplot size	Total no. of plants	Dimension of the plot
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.

CONTD.

Area of the plot	Details of the preplanting operation	Manuring fertilizer applied if yes the tye and quantity	Irrigation provided, if yes til what time	Assessment Date *					Expenditure year wise					Remarks
				1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th	
14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.

* The data sheet of assessment must be attached as an annexure.

CANDIDATE PLUS TREES PROFORMA

ANDHRA PRADESH FOREST DEPARTMENT
REPORT ON CANDIDATE PLUS TREES

PAGE :

DATE :

CIRCLE CODE : YEARLY :

NAME OF THE CIRCLE Spl. CODE : TO

Regn. No.	Seed Zone	RF/Compt./ year of planantion / location	Date of final selection species Name	Hieght in Mt. Girth at b.h.	Clear bole Height crown dia. features qualifying	Numbers of clones obtained current year / previous year	Progeny test (Y/N) Deregistered (Y/N) Remarks	Provenance test (Y/N) and location test/ results (Pass/ failed)
1.	2.	3.	4.	5.	6.	7.	8.	9.

CANDIDATE PLUS TREE REGISTER

Name of the Spp.	Location						Regd. No.	Seed zone	Natural forest/ planation	Date of selection	Dimensions			
	Division	Range	RF	Beat	Comptt.	Land mark for location					Total height.	Clean bole ht. in Mt.	GBH. in cm.	Crown dia.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.

CONTD.

Wood property		Latitude	Longitude	Altitude	Type of soil	Annual rainfall	Temp. range	Whether clones collected	Wheather seeds collected for progeny	If so, location of progeny/ clonal trial and date of establishmen	Remarks
Specific gravity (density)	Fiber length										
16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.

STORES REGISTER PROFORMA

Sl.No.	From whom received	Description of article	Nos.	Rate	Per.	Amount Rs.	Vr. No. and Date and month	Used in (or) controlled or under control of)	Nos. used	Balance	Designation and signature of used by / controlled under
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.

MONTHLY RETURN ON PRODUCTION AND SUPPLY OF HIGH YIELDING CLONAL PLANTS

Sl.No.	Species	Clone No.	0.8 of seedlings /grats available	No. of seedlings/ grafts added during the month	No. of seedlings/ grafts distributed during the month	Total distributed grafts/ seedlings	CF R&D Rc. No., Date in which orders were issued for distribution	Closing Balance	Remarks
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

यदैव विद्यया करोति श्रध्दयोपनिषदा
तदैव वीर्यवत्तरं भवति

Duty performed
with Knowledge, Faith and Devotion,
becomes really effective

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No. 25, Jubilee Hills, Hyderabad-500 033. Phone : 3548487, 3543727 Fax : (040)3548887