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INDO-US WORKSHOP - CUM TRAINING IN

TREE NURSERY TECHNOLOGY AND MANAGEMENT IN AGROFORESTRY

HELD AT :

COLLEGE OF FORESTRY
KERALA AGRICULTURAL UNIVERSITY
VELLANIKKARA, TRISSUR, KERALA, INDIA

MAY 06 - 18, 1991

BY

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MAY 24, 1991

USAID AGRICULTURAL RESEARCH PROJECT

WINROCK INTERNATIONAL
7, POORVI MARG, VASANT VIHAR
NEW DELHI -- 110 057

326-0000-C 5031-00

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Executive Summary

A Tree Nursery Technology and Management Workshop was held at Kerala Agricultural University from May 06 to 18, 1991. Twenty-four participants from 13 states including nine people from Kerala completed the Workshop. In addition, there were about a dozen students who attended part or all of the program. At any given point in time there were about 30 persons in attendance.

The workshop dealt with all aspects of forest and agroforestry nursery production ranging from seed collection up to and including out-planting. About 50 per cent of the time was spent specifically on nursery management.

It was concluded that improvement in regeneration of forests, degraded lands, desertified areas, and agroforestry planting must be approached as an integrated project in which the nursery production is part of a well coordinated chain of events to attain success in the field. It was apparent that both large and small scale nurseries were needed to produce the seedlings required for the ambitious regeneration targets.

We observed a critical lack of communication within the group assembled and must surmise that exchange of knowledge and expertise already present within the Indian system could significantly improve the nursery production system. (see Section 4.2).

We visited a variety of nursery and propagation facilities. The great breadth and depth of information on some species and some nursery operations was apparent. There were, however, many shortcomings and much potential for improvement. (see Section 4.1). The greatest gains may be made by testing nursery technologies for possible adoption in India.

It became apparent that India could profit greatly technologies, expertise and critical thinking available the international scientific community (IUFRO). Such could flow to India should it undertake sponsorship of IUFRO symposium on production and planting of fore agroforestry propagules.

Post-workshop visits to the Central Research Institu Dryland Agriculture (CRIDA), Hyderabad and the Central Soi Water Conservation Research and Training Institute (CSWC Dehra Dun were made by Drs. Emmingham and Rose. At location, research and training were discussed with the Direc and various scientists. In particular, the Ph.D. program study plans of Mr. Mohammad Osmann at CRIDA, Hyderabad, and Rajiv Singh at CSWCRTI, Dehra Dun were received, improved approved. These projects are now cleared to be initiated wi the beginning of the rainy season.

1. Background

1.1 Workshop :

Tree seedlings of many species are needed for many reforestation issues facing India. Seedlings are required for projects dealing with erosion control, desertification, agroforestry, species diversity, tree improvement, and commercial forestry. Of the 170 million hectares in crop land there is an estimated 85 million that are degraded. The forest base is 70 million hectares and that is estimated to decline by 1.5 million hectares of forest per year. Within the forest base it is estimated that 5 million hectares need to be planted each year. Assuming all of these estimates are true there is a demand for 10,000,000,000 seedlings per year if 2000 seedlings are needed on average per hectare! Obviously, this staggering need is not being met.

The size of nurseries in India is generally small, seldom producing more than 150,000 plantable seedlings per year. Most, if not all, of the nurseries utilize large amounts of labour and seed. The demand for seedlings is met using little or no technology. It appears on the surface that production levels are adequate to meet the needs, but this is clearly not the case.

The workshop originated from the idea that many of the nurseries do need to be upgraded with better technology. It was felt that some training and familiarization with technologically based nursery systems could lead to the eventual development of several modern fully equipped research nurseries to serve as pilot nurseries for larger scale operations to be built in the future.

1.2 Pre-Workshop Proforma - Summary

Eighteen of the delegates filled out the pre-workshop proforma. Of those responding half were working at a University and half were in Research Organizations. Two-thirds of the participants were doing primarily research and one-third were primarily teaching. About one-third had Ph.D's mostly from India while the rest had the equivalent of an M.S. About half of the participants specialize in Forestry while the rest were spilt between botany, agronomy and other fields.

Two-thirds of the delegates had had courses in soils, plant physiology and ecology while almost half had a course in agroforestry. Only a few had any training in horticulture. Although few had any background training in nursery management, most participants had considerable experience in raising seedlings of some kind. About one-third had experience with a production nursery.

Information needs listed by participants covered the complete range of topics from seed collection to out-planting. A large number of questions concerned specific phrases of production or problems with a particular species. Many questions concerned bare root vs. contained technology; a few concerned natural regeneration, economics of nursery management, and vegetative propagation. (see Appendix 20-B for Pre-Workshop Proforma).

2. Objectives

Objectives of the Mission :

- The objective of the consultancy was to present a workshop on the nursery technology and management.
- Develop contacts and establish collaborative ties among scientists.
- Develop proposals for development of nursery technology in India.
- Review study plans of Oregon State University Ph.D. candidates - Mr. M. Osmann and Mr. R. Singh.

3. Workshop

3.1 Observations and Specific Recommendations :

A. Teak Nursery at Nilambur, Kerala.

The nursery looked very good, taking into account the limited resources available. The system depends upon large inputs of seed, human labour, and luck. Out of each bed of 7500 seeds planted, 1000 seedlings are picked. Surprisingly, seedling survival after outplanting (we did not see any newly planted plantations to confirm this, however) is 78 per cent after having the lateral roots plucked off. All root systems must be as straight as possible. Insect and root damage at this nursery was severe. Insect damage was heaviest where insects have fallen from teak limbs over hanging the nursery beds. The seedlings that survived the insects, the rats, and moisture limitations looked very good. Clearing a 15 m border around a nursery of tree species susceptible to insects should help to reduce by one the vectors used by the insects to get into the nursery. The rosewood tree in the middle of the nursery was untouched by insects and the seedlings under it looked good.

Unless there is a change in philosophy and allocation of resources toward modernizing nursery production there is very little to recommend. The practice of removing and discarding the fast growing seedlings in a bed so that the rest will not be shaded out is not sound from a genetic selection point of view. Perhaps the genetically superior seedlings are lost in this manner.

B. Challenge

If resources could be made available, many of the currently accepted notions used in growing teak seedlings could be challenged. There seemed to be considerable resistance to changing the following accepted attitudes toward growing teak seedlings :

a) Teak nurseries are moved and rebuilt so as to put them close to the planting sites.

b) Cutting the roots off at lifting is acceptable.

c) Eighty-seven per cent losses are acceptable.

d) Prevailing environmental conditions can be depended upon to produce enough seedlings for planting.

The implementation of a tree improvement program using such a system would be almost impossible. Planting healthy vigorous seedlings of improved genetic quality could help the seedlings out-compete the weeds, and produce straight boled high value timber.

C. Social Nursery

The social nursery concept is just outstanding. Growing bare root stock to give to private individuals for growing in poly bags is good. Purchasing the seedlings back and then giving them away for planting is an excellent idea.

What is tragic is that a nursery with such an important function operates on such thin margins. There is no irrigation, but there is potential for irrigation. There is even the potential to grow the seedlings to plantable specifications without poly bagging.

So long as everyone is happy with this system there probably is not much reason to change it. Like the teak system shown at Nilambur, the nursery uses a lot of labour and no technology whatsoever. As a small operation it seems to work just fine, but will not lend itself to a large scale operation.

The seedlings looked good overall. There was the usual rate of damage. There does not seem to be any figures on losses to rats, insects, weeds, high density, improper handling, etc., prior to sending the seedlings out for poly bagging. The 10-20 per cent loss between growing in poly bags and re-purchase seemed excellent. That is a pretty low cull rate for an operation like this.

Weeding could be improved.

Control of density in the beds would help produce a larger, more uniform seedling.

4. Proposed Actions in Agroforestry Nursery Management and Reforestation

4.1 Forest Nursery and Tree Improvement Needs :

4.1.1 Needs

The following needs were identified :

- Better networking is needed among nursery managers, plant breeders, seed collectors and handlers and the users of seedlings. They should meet once per year for next three years then every other year.

- The whole seedling production system is full of untested practices that need to be improved and verified. Seedling failure in nurseries is unacceptably high (87 per cent in some cases).

- Information is urgently needed on what practices (seed storage, scarification, pot size and shape, lifting, handling and planting techniques) produce the highest possible success rate on the out-planting site.

- An organizational mechanism is needed to get nursery managers together with seedling users to exchange information about seedling production methods. Target seedling parameters should be a focus on an on-going effort to improve reforestation success.

- Seed storage coolers are needed - for many species seed storage times are too short.

- Regional seedling research facilities which can interface with tree improvement programme.

- Encouraging women to study in the U.S.A; ICAR and other organizations in India should be aware that outstanding Indian women applicants would be very welcome in forestry universities in the U.S.A. Current policies encouraging acceptance of well qualified women could work to bring acceptance. Indian women would be easily accepted into the U.S. culture.

- Improved communication skills would aid in exchange of information. We observed many poor communications habits among delegates which block exchange of information. There are ways to improve such communication and they can be learned. Perhaps such methods could be incorporated into future workshops.

4.1.2 Important Findings

An important finding to come out of the Workshop was the total lack of coordination between the on going seed collection, forest nursery operations and tree improvement. Using a high value crop like teak as an example, every year is a lost opportunity if seed from select trees goes unused in the planting program.

The delegates unanimously agreed that no facilities exist to store seed, and next to no information is available on how to process seed for storage longer then a few months. This constitutes a serious "bottle-neck" toward integrating the reforestation program with the

tree improvement program. A great deal could be learned in a short period of time if seed could be stored locally, grown locally, and planted locally. At Weyerhaeuser Co. in the U.S. when field foresters saw what superior seed collection and growing healthy target seedlings did for field success they insisted on a continuation of the link between nurseries and tree improvement.

It takes a well-run nursery to make tree improvement an operational reality. Nurseries should have their own seed processing facilities. In many cases, the seed processing, nursery, and seed orchards are all in the same general area.

There is a need to build centers for genetic improvement, nursery production, target seedling research, and testing of field success for out planting.

As part of our assignment we developed the following set of recommendations for the betterment of tree nursery production in India .

4.1.3 Workshop Improvements

1. A pre-workshop planning meeting should occur the week before the workshop. This would help solidify the program and plan for better coordination during the workshop.

2. Orientation training is needed for U.S.A. resource persons in tropical species and systems.

4.2 Agroforestry Nursery and Reforestation Council :

A small 10-15 member group of knowledgeable nursery management and technology experts may be established to promote and coordinate the future development of nursery management in India. The objectives of such a group would be to :

1. Promote exchange of information and innovation (i.e. hold in-country workshops and create an information sharing network and database);

2. Recommend corrective or developmental actions that need to be taken to achieve the reforestation needs of India.

3. Publish a "Best" Practices Guide to Propagule Production for important Forestry and Agroforestry Plants of India. Fifteen species should be addressed each year until all important species are covered. Each species will have a separate document that can be kept in a 3-ring binder. In this way, individual copies can be distributed, and corrections and revisions can be easily published without having to publish an entire volume.

Nine of the members should have formal training and experience in nursery management/reforestation. One member from each climatic region should be appointed. Service on this council will be carried out with the support of the research agency or university which employs the appointee. Most of the coordination work will be done by telephone or by correspondence. However, the council should formally meet once each year to share information and make preparations for a semi-annual information - sharing

meeting. Money will have to be allocated for coun activities.

4.3 Pilot Nursery Network :

The following is proposed in cooperation USAID/Winrock International :

Develop a small number of pilot nurseries within Ind to accomplish the following objectives :

1. Test Nursery Management Methods and Practices :
(e.g. root wrenching, fertilization, soil fumigation to see which ones work well and promote greater efficiency in nursery operation).

2. Test Nursery Technology :
(e.g. container types root wrenches, irrigation equipment).

3. Coordinate and Disseminate Information on Nursery Methods and Technology :

The intention is to create and operate a few medium sized (100,000 seedlings) nurseries (large by Indian standards) to improve the efficiency of nursery production and the success of outplanted trees. These nurseries would borrow and use techniques found to be successful in other lands or on a smaller scale in India. The intention is for these nurseries to serve as a testing ground for technology and innovation. They would be encouraged to try new and sometimes costly methods and equipment in the hope of finding methods or equipment that could be economically used in existing or new Indian nurseries.

These nurseries should be developed as centers for research with the objective of improving the linkage between all phases of nursery production including :

1. Selection of good genetic material (i.e. seed, cuttings).

2. Collection, handling and storage of seeds or cuttings.

3. Germination methods.

4. Nursery production.

5. Seedling lifting/storage/transportation.

6. Plantation success including vegetation management.

The minimum number of nurseries to be developed would be two. We see the need for three in the following order of priority :

1. <u>CRIDA, Hyderabad</u> :

   - Arid and semi-arid zone species for desertification and

   - Containerized nursery with controlled climatic conditions.

2. <u>CSWCRTI, Dehra Dun</u> :

   - Species needed for reforestation of the Shiwaliks and Himalayan regions
   - Bare root and containerized nurseries

3. Kerala Agricultural University :

- Tropical and sub-tropical timber, fruit and fibre species.

- Bare root and container nurseries.

4.4 IUFRO Meeting on Agroforestry Nursery Management and Reforestation (in India/Tropics, etc.) :

The newly formed Agroforestry Nursery and Reforestation Council (ANRC) will plan and organize a International Union of Forestry Research Organisations (IUFRO) meeting centred around the purpose for the Council. The objective will be to bring together in India invited speakers on subjects of interest, viz., seed collection and storage. The conference would produce a proceedings filled with specific recommendations as well as related facts. One component of the conference would be to define problem areas, state criteria to define the scope and accomplishment of the problems, and prioritize the most important problems, given limited resources.

IUFRO meetings are not that difficult to organize. They do call for much advanced planning to keep the participants focused on the problems at hand and motivated to produce substantive papers that will be useful to all delegates. However, the advanced hard work could prove very rewarding.

The ANRC can aid greatly in setting the tone and focus of the meeting by first deciding on up to 20 topics with proposed titles. The topics should start with a paper on Agroforestry Nurseries and Reforestation. This would lead into a paper on seed collection and storage, etc. In other

words the papers should offer the participants a logical sequence that covers the gamut of agroforestry nurseries and reforestation work. By good strong centralized leadership and by pressing the authors for early submission of the papers for review it would be possible to keep the papers linked with each other.

5. Collaborative Research/Training Project Graduate Studies:

During our stay in India, through the Workshop and in visits to other sources, we were approached repeatedly about collaborative research and study opportunities in the U.S.A. Dr. Emmingham met with forestry students from Kerala Agricultural University to explain the application procedures and idiocyncracies of the U.S. University graduate education systems.

5.1 Winrock/USAID Project :

Of the people involved in the Workshop at Kerala Agricultural University, we were favourably impressed with Mr. J.V. Rao and Mr. Avtar Singh. Both came forward with proposals and took feedback from Drs. Emmingham and Rose. We feel they are worthy candidates for further collaborative work with U.S. scientists.

5.2 Kerala Agricultural University :

The faculty at the College of Forestry, Kerala Agricultural University were very helpful and contributed in a major way to the success of the workshop. We were particularly impressed with the competence of Drs. Mohan Kumar, K. Sudhakara and P.K. Askan. Dr. Emmingham and Dr. Mohan Kumar developed a joint proposal that will be submitted for PL480 funding.

6. Evaluation of Workshop :

From the beginning of the workshop when the pre-workshop proforma was distributed, it was emphasized that an evaluation would be conducted at the end of the workshop. There are three aspects of this evaluation : (1) the proforma, (2) the consensus critique and (3) highlights for improvement.

6.1 Post-workshop Performance - Summary :

A post workshop proforma was distributed on the last day and returned by most (20) of the delegates.

Overall the delegates seemed to have thought well of the experience. The single most negative of the workshop was the food (x = 3.2). No other rating exceeded a 3. It appears that the ants in the housing accommodations were of less concern than the food!

The field trips came in at a moderate rating of around 2.5. The course content lecture ratings ranged between a 1.5 for technology transfer to a 2.45 for irrigation systems. In total, the field trips and course content fell within acceptable limits to the delegates.

The group was well divided on which lectures should be left as is or expanded. No one lecture drew a clear outright majority in either category. Only a total of three votes were cast suggesting the omission of a lecture. A positive is the fact that between 35-50 per cent of the delegates wanted to know more.

The long days took their toll on close to 50 per cent of the delegates. However, the two weeks seemed to have been "about right" for a slight majority.

Course design and delivery seemed to have come off quite well. Individual consultations with instructors scored very well (1.60) as did the course handouts.

The hands down winner of the instructors was Dr. Emmingham, who scored almost all in all categories. He did an outstanding job of getting everyone involved.

Acceptance of this course was quite high with 19 out of 20 delegates willing to recommend the course. (see Appendix 20-C for Post-workshop Proforma).

6.2 Consensus Evaluation of Workshop :

An oral critique of the course in which delegates were asked to work in groups of four to agree on good, bad, and improvements needed for three aspects of the workshop; a) Arrangements, b) Course Content, and c) Other. All items identified by the groups were listed on the blackboard and delegates further prioritized the importance by voting for only three of the seven or eight items needing improvement.

6.2.1. Arrangements

A. Good :

1) Refreshments.
2) Travel facility for field trips and to and from class.
3) Interaction with staff on problems.
4) Class room facility.
5) Services by volunteers who helped with food and arrangements.

B. Bad :

1) Food (quality was poor).
2) Accommodation at the College of Forestry was dirty, ant-infested and poor in general.
3) No recreation (needed facilities for T.V. and Video tapes).
4) No information counter was provided throughout the Workshop.
5) Planning of program changes was irregular and poorly coordinated.

C. Improvement :

1) Adequate lodging room amenities (clean bathroom, mosquito nets, kill ants).
2) Hygiene (toilets should be clean).
3) Needed to have supper/dinner at the campus.
4) Information throughout the course duration should be provided at an information counter.

By far the most serious problem was the poor lodging afforded to the local delegates. Clearly, they did not have a living environment conducive to study and learning.

6.2.2 Course Work - Content :

A. Good :

Class room lectures, field trips, slides were good, guest talks were informative.

B. Bad :

1) Lack of practical exercises.
2) Depth of subject coverage was limited.
3) Examples (were given) of temperate region forests and nurseries.

4) Lack of expertise in tropical forestry.
5) Course duration is too long.
6) Repetition of certain topics.

C. Improvement :

1)* More emphasis on tropical species.
2)* Field trips need to be comprised of more diversified forests and agroforestry systems
3) Need more field trips.
4) Repetition should be avoided.
5)* Need more on vegetative propagation in nurseries.
6) Needed more narrow focus on water stress subject.
7) Needed to use more video tapes.
8) It was suggested that classes be held in morning sessions with field trips and practical exercises to be conducted in the afternoon sessions.

*Of the eight items listed above, items 1,2 and 5 were voted as the most important.

Delegates felt the need to deal with additional tropical species and were less interested in the examples used from the temperate zone. In addition most were interested in knowing more about vegetative propagation. Delegates were interested in seeing even more of the forest and agroforestry systems and the nurseries that serve these functions.

6.2.3 Problems and Improvements

1) Lack of interaction among the delegates. Need small group exercises.

2)* Some delegates had little interest in the subject matter, i.e. there needs to be a better selection of delegates.

3) Participants were put to hardships because of delayed payment of travel allowance and daily allowance.

4) A senior ICAR Representative should be present throughout the workshop. (Supposedly this would motivate participants to learn).

5)* Need training of USA experts in tropical subject.

6)* Delegates and resource persons from FRI (Forest Research Institutes) should be invited.

7) Need more travel funds for long distance field trips. Participants wanted to see the rain shadow zone.

*Of the items 1-7 listed above, it was the consensus of the class that numbers 2,5 and 6 were of greatest importance. Therefore;

1) A better process of selecting delegates is needed (there were no nursery managers present as delegates to the workshop) There should have been nursery managers and senior forest officers involvement.

2) The U.S. resources people need better training in tropical forest systems (there are not many of these in the U.S.A.).

3) Scientists from the Forest Research Institute should have been more involved as both delegates and resource people.

6.3 Highlights for Improvement :

Finally, the U.S. resource people, (Drs. Emmingham and Rose) have highlighted many items that could improve such work shops in the future.

1) No one commented formally about the $100. plus worth of books brought per person, yet all of the extra reading materials disappeared within three days!

2) Delegates may not have done all of the readings partly because their quarters were not conducive to study. They wanted to be away from their quarters in the evening.

3) There are many different inherent in planning a Workshop in an unknown location, by organizers from two different cultures and from several locations. Under the circumstances the Workshop was very successful, inspite of the many rough spots.

4) It would help to have the local and foreign organizers meet the week prior to the Workshop to finalize the agenda and other arrangements.

5) Most of the delegates were agronomists with little tree growing experience. One was in animal nutrition! Future delegates need to be more carefully chosen. Care should be taken to get nursery managers and foresters involved.

6.4 The "No Problem" Problem :

This particular workshop might have been more productive if it were not for the "no problem" problem. Xeroxing was "no problem", but the xerox machine never worked. Getting a pressure bomb to demonstrate plant water potential was "no problem" except that an available one could not be located. These and other "no problems" were a problem.

7. Field Visits

7.1 Visit to Hyderabad :

Drs. Emmingham and Rose visited Hyderabad on May 19-21, 1991. Mr. M. Osmann and Mr. J.V. Rao were active in hosting us for the visit. Mr. Osmann met us at the airport even though we were delayed in arrival. The Central Research Institute for Dryland Agriculture (CRIDA) provided transportation for our entire visit, and this convenience allowed us to accomplish much in a short visit even though we were there on election day.

We visited the CRIDA field location, the CRIDA headquarters and discussed at length the Ph.D. project of Mr. M. Osmann and a proposed study of Mr. J.V. Rao. The CRIDA Demonstration and Research Station is an excellent example of how research studies and demonstration areas can be combined. In particular, the overall layout with research and demonstration plots along both sides of the entry way made for maximum use of the demonstration value.

A thorough review of Mr. M. Osmann's Ph.D. thesis project was conducted by Drs. Emmingham and Rose. Several important changes were incorporated into the objectives and hypothesis tests to be carried out during the study. Also, experimental methods were modified in several cases. Overall, Osmann's study is very well planned, and represents an extremely useful advance in understanding of the structure and function of Agroforestry systems in semi-arid regions. This is an important and ambitious study, and Mr. M. Osmann will require the full support of his organization to successfully complete this study and his Ph.D. at Oregon State University (OSU). ICAR must be alert to the need of sponsoring Mr. Osmann's return to OSU some three years hence to complete his dissertation and defend it. A minimum of three months in residence in U.S.A. will be necessary.

Drs. Emmingham and Rose had separate meetings with Dr. C.K. Ramanathan Chetty, Director and Dr. Shivniwas Sharma, Head of Resources Management Divisions, CRIDA. We discussed the recommendations presented in this regard and confirmed the need for continued collaborations among CRIDA and OSU researchers and teachers. Dr. Chetty expressed interest in hosting an IUFRO meeting at Hyderabad in cooperation with ICRISAT.

Unfortunately, Drs. Emmingham and Rose were unable to visit ICRISAT due to shortness of their stay and the election-day holiday.

7.2 Visit to Dehra Dun :

Drs. Emmingham and Rose, along with Dr. Chinnamani visited Dehra Dun on May 21-23, 1991. Mr. Rajiv Singh acted as our host. We appreciated the company of Dr. Chinnamani on the journey to Dehra Dun, since we were able

to discuss the results of the workshop, and be informed about what we were seeing in the countryside.

On May 22, we visited the Central Soil and Water Conservation Research and Training Institute (CSWCRTI) Selakui field station and looked at the erosion control work; this work is very impressive, especially that with some agroforestry system developed by Dr. Nahrain. It was also a pleasure to see the timber stands of Shorea robusta and the work of Rajiv Singh. We saw and approved the study site (T-12) that Mr. Singh will use for his Ph.D. work.

We discussed the future exchange of scientific staff between OSU and the CSWCRTI. It was suggested that a good opportunity exists to have OSU faculty come to India on sabbatical leave. Such visits could lead to further exchange of Indian scientists to the U.S.A. as joint projects take shape. Clarifying what facilities are available, probable cost of living and collaborative possibilities would facilitate initiation of such exchanges.

Mr. Rajiv Singh's Ph.D. thesis project was reviewed with Dr. Gupta and staff. The project was approved, and will be initiated as soon as possible. Mr. R. Singh will require the full support of his organization to successfully complete his Ph.D. study. A potential problem is the fact that some of the instruments needed to analyze his data are not yet in functional status.

We also visited the CSWCRTI headquarters where we had a short tour of the Soil Laboratory and the museum. We met with the Director, Dr. Raj K. Gupta, and the heads of the Engineering, Soils, Plant Science and Land and Water Divisions. Each division head explained their research program and some of their major findings.

ICAR and CSWCRTI must be alert to the need of sponsoring Mr. Singh's return to Oregon State University in 1994 to complete and defend his dissertation. A minimum of three months will be required for his stay in the U.S.A.

8. Summary and Conclusions

The objective of the consultancy was to present a workshop on tree nursery technology and management. The workshop was successfully carried out with lectures that covered nursery management from seed to field planting of seedlings. Numerous field trips reinforced the lectures and gave focal points for discussions.

Numerous contacts were made with scientists throughout India due to the broad based selection of delegates. Many collaborative proposals were discussed. Everyone was in favour of future interactions.

Proposals were introduced to help spawn nursery technology in India. It was suggested that an Agroforestry Nursery and Reforestation Council (ANRC) be formed. Further, it was proposed that IUFRO meeting be held in India centered around the needs of the ANRC. It was proposed that at least two pilot research nurseries be built in India to research agroforestry nursery related problems.

Both Mr. Osmann and Mr. Singh's, Ph.D. research projects were reviewed. The proposals were approved and are now being implemented. Close contact will be maintained with each Ph.D. candidate over the next three years.

Overall the Workshop was a success, but several suggestions have been offered to make future workshops more useful. The delegates were a fine group of individuals and were enjoyable to work with.

9. Acknowledgements

There are many people to thank. Dr. S. Chinnamani was everything we could have hoped for in an organizer of the Workshop. He was very helpful before, during, and after the Workshop. Dr. Abraham kept the Workshop on a plane for which we are most grateful. We also acknowledge the assistance of the Faculty and Staff at KAU. All of the Winrock personnel were excellent. We are grateful to Colin McClung and P.S. Srinivasan for their great assistance and patience.

We are greatly saddened by the death of Mr. Rajiv Gandhi.

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LIST OF APPENDICES

1.	Program for the Workshop	W.H. Emmingham & R. Rose
2.	Program for the Workshop	Amended by ICAR
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4.	List of Participants	
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6.	General Tree Nurseries in India with special emphasis to Agroforestry	S. Chinnamani
6A.	Water Harvesting in Non-Agricultural Land for Fuel and Fodder System	S. Chinnamani
7.	Seed Technology for Forest Species in India	T.V. Karivaratharaju
8.	Tea Nursery Technology	V.R. Chitarapu
9.	Pest Management in Tree Crop Nurseries	C.C. Abraham
10.	Tree Disease Management in India	R. Jeyarajan
11.	Early History of Teak Planting in Nilambur	Field Trip Notes
12.	Reforestation and Agroforestry in Oregon	W.H. Emmingham
12A.	Using Leaf Area Meter	W.H. Emmingham
12B.	Measurement of Canopy Transmittance to Estimate Leaf Area Index	W.H. Emmingham
12C.	Literature on Portable Area Meter	General Information
13.	Cocoa Propagation Nursery	Field Trip Notes
13A.	Nursery Techniques in Cocoa	Field Trip Notes
14.	Outplanting & Competition	W.H. Emmingham
15.	Vegetation Management	W.H. Emmingham
16.	Statistical Considerations in Tree Nursery Research	B. Mohan Kumar
17.	Collection, Processing, Grading, & Storage of Seeds	K. Sudhakara and K.V. Peter

LIST OF APPENDICES (CONTD ..)

18.	Technology Transfer	W.H. Emmingham
18A.	Organization for Technology Transfer	W.H. Emmingham
18B.	Systems Approaches for Improvement in Agriculture and Resource Management	Copy of Chapter 1 from the Book by Wilson & Morren, Macmillan Co.
19.	Exercise - Using the Pressure Bomb	W.H. Emmingham
19A.	Laboratory Exercise - Plant Water Potential	W.H. Emmingham
19B.	Procedures for Mitotic Index Determination	Lecture Notes
20.	Distribution of Workshop Material	W.H. Emmingham & R. Rose
20A.	Problems & Questions	W.H. Emmingham & R. Rose
20B.	Nursery Management Workshop - Pre-Workshop Proforma	W.H. Emmingham & R. Rose
20C.	Nursery Management Workshop - Post-Workshop Proforma	W.H. Emmingham & R. Rose
21.	Group Photograph	Workshop Participants
22.	Certificate ofCompletion Awarded to Workshop Participants	

Appendix 1

NURSERY MANAGEMENT WORKSHOP
TRICHUR, INDIA

MAY 5-18, 1991

Drs. W.H. Emmingham & R. Rose

Sunday, May 5, 1991

Day prior to start of workshop
Fill out questionnaire to hand in on Monday
Do pre-assigned readings in
- Forest Nursery Manual (FNM)
- A Technical Guide for Forest Nursery Management in the Caribbean and Latin America (TGCLA)

Readings: Pre-workshop
- FNM 2, 7, 8, 9, 10, 16
- TGCLA 3, 4

Monday, May 6, 1991

9:00 A.M.	Inauguration of Meeting
10:00	Tea
10:30	Lecture (RR) - Overview of World Reforestation
11:30	Reforestation and Agroforestry (BE)
12:00 P.M.	Reforestation in India (Harsh)
1:00	LUNCH
2:00	Bareroot Nursery Development (RR)
2:30	
3:00	General Tree Nurseries - (speaker ?)
4:00	Discussion and Problem Solving Format (RR & Harsh)
5:30	END - Turn in all questionnaire materials
7:00	Evening - Start assigned readings

Day 1. Review FNM 2, 6, 7, 8, 9, 10, 16 TGCLA 3, 4

Tuesday, May 7, 1991

9:00 A.M.	Lecture: Container Nursery Development
10:00	Tea
10:30	Lecture - Discussion of Readings (RR)
11:30	Visit nearby container operation _____
12:30 P.M.	
1:00	LUNCH
2:00	Lecture: Containers (Harsh) Advantages and Disadvantages of Different Containers Types/Mixtures for Raising Seedlings
2:30	Discussion (Harsh and RR)
3:00	Teak Nurseries - _____
4:00	Discussion and Problem Solving (Harsh)
5:30	END
7:00	Evening - do assigned readings

Day 2

Wednesday, May 8, 1991

9:00 A.M.	Lecture: Seed/genetic variation/source/seed physiology (RR)
10:00	Tea
10:30	Lecture: Germination and Testing of Seed (Harsh)
11:30	Discussion (Harsh)
12:00 P.M.	Visit seed collection and handling facility _____
12:30	
1:00	LUNCH
2:00	Lecture: Seed Technology in India _____
2:30	
3:00	Lecture: Coconut and Pepper Nurseries _____
3:30	
4:00	Tea
4:30	Discussion and Problem Solving (Harsh) - Seed Technology
5:00	
5:30	END

Day 3, FNM 4, 5, 17, 19, 20 TGCLA 7, 8, 9, 10

Vol. V The Biological Component: Nur Pests and Myco 1, 2

Thursday, May 9, 1991

9:00 A.M.	Lecture: Target Seedlings (RR)
10:00	Tea
10:30	Lecture: Seedling Nutrition (RR)
11:00	Fertilization and Irrigation Discussion of fertilization strategies
12:00 P.M.	Nutrient, Media, and Water - Techniques used in India _____
1:00 P.M.	LUNCH
2:00	Lecture: Vector Diagrams (RR)
2:30	
3:00	Social and Community Forest Nurseries
4:00	Tea
4:30	Disease and Pest Management in India _____
5:30	END

Day 4, FNM 8 SNI 1, 2, Bigg article
SNI = Seedling Nutrition and Irrigation

Friday, May 10, 1991

8:00 A.M.	Field Day at Nursery
9:00	* * * ALL DAY * * *
6:00 P.M.	END OF TRIP

Day 5, Want to cover in the nursery the many subjects already talked about in lecture: seed, seed handling, bareroot vs. container, nurtition, irrigation, problems

Saturday, May 11, 1991

9:00 A.M.	Irrigation system (Harsh, RR, and group)
12:00 P.M.	Discussion of irrigation system
12:30	
1:00	LUNCH
3:00	Catch up on readings/discussion

Day 6,

Sunday, May 12, 1991

8:00 A.M.	Day off
9:00	Rose and Emmingham go sight-seeing

Monday, May 13, 1991

9:00 A.M.	Lecture: Seedling Quality - Target Seedlings (RR)
10:00	Tea
10:30	Lecture: Seedling Morphology (RR)
11:00	Using the Leaf Area Meter (BE)
12:00 P.M.	Discussion of Seedling Morphological Quality in India (Harsh and RR)
12:30	What seedling characteristics work best in India for each species in India?
1:00	LUNCH
2:00	Continued discussion of morphology (Harsh)
2:30	Discussion
3:00	Tea and Coffee Nurseries _____
4:00	Tea
4:30	Discussion and Problem Solving - Root Volume (RR)
5:30	END
7:00	Evening: Catch up on reading

Day 7, FNM 14, 15, 17 ESQ 3, 4, 5, 6*, 8, 9
ESQ = Evaluating Seedling Quality

* Read this chapter thoroughly.

Thursday, May 16, 1991

8:00 A.M.	Field Trip - Forest Planting
9:00	Stand management, protection, handling, veg man
10:00	* * * ALL DAY * * *
11:00	Coastal Area
12:00 P.M.	Eucalyptus, cashew, coconuts
6:00	END

Day 10 to cover stand development and management, growth and yield, forest protection

Friday, May 17, 1991

9:00 A.M.	Lecture: Technology Transfer (BE)
10:00	Tea
10:30	Lecture: Organizational Models (BE)
11:00	Problem Solving
12:30 P.M.	
1:00	LUNCH
3:00	Discuss Field Trips (BE, RR, & group) - Regional Problems to Solve
4:00	Tea
4:30	Oral Critique of Course
5:30	END

Day 11,

Saturday, May 18, 1991

9:00 A.M.	Discussion and wrap-up

Tuesday, May 14, 1991

9:00 A.M.	Lecture: Seedling Quality - Physiology (RR)
10:00	Tea
10:30	Physiology, continued
11:00	Seedling Physiological Research in India _____
12:00 P.M.	Discuss readings (RR)
12:30	
1:00	LUNCH
2:00	Lecture: Seedling Handling and Planting (Harsh)
2:30	
3:00	Reserve Forest Nursery _____
4:00	Tea
4:30	Exercise: Using the pressure bomb (BE)
5:30	END
7:00	Evening: Catch up on readings

Day 8,

Wednesday, May 15, 1991

9:00 A.M.	Lecture: Outplanting/Competition (BE)
10:00	Tea
10:30	Lecture: Vegetation Management (BE)
12:00 P.M.	Lecture: Statistics and Design of Nursery and Field Trials (RR)
12:30	
1:00	LUNCH
2:00	Statistical Applications to Nurseries in India _____
2:30	
3:00	Temperate Forest Nurseries _____
4:00	Tea
4:30	Exercise: Design Nursery/Field Experiments (RR and speaker?)
5:30	END

Day 9, FNM 28

Appendix 2

INDO-U.S. WORKSHOP-CUM-TRAINING ON AGROFORESTRY IN "TREE NURSERY TECHNOLOGY AND MANAGEMENT"

VENUE : College of Forestry
Kerala Agricultural University
Vellanikkara, Trichur, Kerala

PROGRAM

Pre Workshop Assignment

MAY 5, 1991 - Sunday

Forest Nursery Manual (FNM) - 2, 7, 8, 9, 10, 16

A Technical Guide for Forestry Nursery Management in the Carribbean and Latin America (TGCLA) - 3, 4.

WORKSHOP-CUM-TRAINING AGENDA

MAY 6, 1991 - Monday (Day - 1)

09:00 - 10:00 hrs. - Registration and filling of biographic data.

10:00 - 11:15 hrs. - Inaugural session

Welcome - Dr. C.C. Abraham
Associate Dean & Special Officer
College of Forestry
Kerala Agricultural University
Vellanikkara, Trichur

Inaugural Address - Dr. E.G. Silas
Vice Chancellor
Kerala Agricultural University
Vellanikkara, Trichur

Address - Background of Agroforestry and Tree Nursery Technology in India

Dr. S. Chinnamani
Asst. Director General (Agroforestry)
I.C.A.R., New Delhi

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		Nursery Technology and on the Indo-U.S. course. Dr. W.H. Emmingham Professor & Head Department of Forest Science Oregon State University Corvallis, Oregon, U.S.A.
Vote of Thanks	-	Dr. L.N. Harsh Scientist Central Arid Zone Research Institute Jodhpur (Rajasthan)
11:15 - 11:30 hrs.	-	Tea Break
11:30 - 12:30 hrs.	-	Lecture : An Overview of World Reforestation - Dr. Robin Rose Oregon State University
12:30 - 13:30 hrs.	-	Lecture : Reforestation & Agroforestry in India - Dr. S. Chinnamani Asst. Director General (Agroforestry) I.C.A.R., New Delhi
13:30 - 14:30 hrs.	-	Lunch Break
14:30 - 15:30 hrs.	-	Lecture : Bare Root Nursery Development - Dr. Robin Rose
15:30 - 16:45 hrs.	-	Lecture : General Tree Nurseries for Agroforestry- Dr. S. Chinnamani
16:45 - 17:45 hrs.	-	Discussion and problem solving over framework of reading assignments. Discuss site selection - the good and the not-so-good. Start reading assignments. Day 1 Review FNM 2, 7, 8, 9, 10, 16 TGCLA 2.4

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MAY 7, 1991 - Tuesday (Day - 2)

09:00 - 10:00 hrs.	-	Container Nursery Development - Dr. Robin Rose
10:00 - 11:00 hrs.	-	Discussion on readings
11:00 - 11:15 hrs.	-	Tea Break
11:15 - 13:15 hrs.	-	Visit KAU Main Campus. Nurseries. Cashew Nursery at Madakkathara. Teeos Nursery, Vellanikkara Dr. K. Gopikumar Associate Professor
13:15 - 14:15 hrs.	-	Lunch Break
14:15 - 15:15 hrs.	-	Lecture : Containers - Relative merits and demerits
15:15 - 15:30 hrs.	-	Tea Break
15:30 - 16:30 hrs.	-	Lecture : Teak Nurseries - Mr. K.V. Subramoniam Divisional Forest Officer Nilambur South
16:30 - 17:30 hrs.	-	Discussions and problem solving.

MAY 8, 1991 - Wednesday (Day - 3)

09:00 - 11:15 hrs.	-	Lecture : Seed/Genetic/Variation/Source/Seed Physiology - Dr. Robin Rose
11:15 - 11:30 hrs.	-	Tea Break
11:30 - 12:15 hrs.	-	Lecture (continued) - Dr. Robin Rose
12:15 - 13:15 hrs.	-	Visit - Seed collection and handling facility, College of Horticulture & College of Forestry - Dr. K.V. Peter and Dr. K. Sudhakara, Kerala Agril. Univ.
13:15 - 14:15 hrs.	-	Lunch Break

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14:15 - 15:15 hrs.	-	Tree Seed Technology in India - Dr. T.V. Karivaratharaju, Professor and Head, Department of Seed Technology, TNAU
15:15 - 15:30 hrs.	-	Tea Break
15:30 - 16:30 hrs.	-	Lecture : Tea & Coffee Nurseries - Dr. V.R. Chitarapu, IFS, Managing Director, TANTEA, Coonoor, Nilgiris
16:30 - 17:30 hrs.	-	Discussion and problem solving

Day - 3 Assignments

FMN	-	4, 5, 19, 20
TGCLA	-	7, 8, 9, 10
Vol. V	-	The Biological component Nursery Pests and Mycology 1, 2

MAY 9, 1991 - Thursday (Day - 4)

09:00 - 10:00 hrs.	-	Lecture : Target Seedlings - Dr. Robin Rose
10:00 - 11:00 hrs.	-	Lecture : Pest Management in Tree Crop Nurseries- Dr. C.C. Abraham, Kerala Agricultural University
12:15 - 13:15 hrs.	-	Small Group Exercise
Changed	-	General Discussion - Class & Instructors
13:15 - 14:15 hrs.	-	Lunch Break
14:15 - 14:45 hrs.	-	Delegate Reports on Nursery Management Problems -
14:45 - 15:00 hrs.	-	Tea Break
15:00 - 16:00 hrs.	-	Lecture : Social and community Forest Nurseries - Sri. T.V. Balaraman, Asst. Conservator of Forests, Social Forestry, Thrissur

16:00 - 17:00 hrs. - Lecture :
Disease Management in Nurseries -
Dr. R. Jeyaraj
Professor & Head
Department of Plant Pathology
TNGDNAU, Coimbatore

Day - 4 Assignments

FNM 8 - Seedling Nutrition ; and
SNI 1,2 - Irrigation

MAY 10, 1991 - Firiday (Day - 5)

Field Day- Nurseries

08:00 hrs. - Proceed to Nilambur en-route visit Social Forestry and Foresy Nurseries

11:30 - 13:00 hrs. - Nilambur Field Station, KFRI
Teak Nursery of the Social Forestry wing of Kerala Forest Department

13:00 - 14:00 hrs. - Lunch at Nilambur

14:00 - 18:30 hrs. - Visit to Conolly's Teak Plantation
Chathu Menon's Permanent Preservation plot for super quality Teak

20:30 hrs. - Return.

MAY 11, 1991 - Saturday (Day - 6)

09:00 - 12:00 hrs. - Lecture :
Build Drip Irrigation System -
Dr. K. John Thomas
Professor (Ag. Engg.) Kerala Agril. University

12:00 - 13:00 hrs. - Discussion on Drip irrigation system
Dr. K. John Thomas

13:00 - 14:00 hrs. - Lunch Break

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14:00 - 17:00 hrs. - Catch up on readings and discussion on seed handling

Lecture :
Forestry in Oregon -
Dr. W.H. Emmingham

Bare Roots Vs. Container Nutrition, Irrigation

17:00 - 17:15 hrs. - Tea Break

17:15 - 18:15 hrs. - Discussion -
Problem Solving and Vector Diagram

MAY 12, 1991 - Sunday (Day - 7)

Day Off.

MAY 13, 1991 - Monday (Day - 8)

09:00 - 10:00 hrs. - Lecture :
Seedling quality - Target seedlings -
Dr. Robin Rose

10:00 - 10:30 hrs. - Lecture :
Seedling Morphology -
Dr. Robin Rose

10:30 - 10:45 hrs. - Tea Break

10:45 - 12:00 hrs. - Lecture :
Using Leaf Area Meter - Excerise -
Dr. W.H. Emmingham

12:00 - 13:00 hrs. - Discussion of Seedling Morphological quality in India -

What Seedling characteristics work best in India for various species -
Dr. Robin Rose
Dr. L.N. Harsh

13:00 - 14:00 hrs. - Lunch Break

14:00 - 15:00 hrs. - Discussion -
Reports of Group Exercise (3 Reports) -
Dr. Robin Rose
Dr. W.H. Emmingham
Dr. L.N. Harsh

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15:00 - 15:15 hrs. - Tea Break

15:15 - 16:15 hrs. - Lecture :
Coconut and Pepper Nurseries -
Dr. P. Rathinam
Asst. Director General, I.C.A.R.

16:15 - 17:30 hrs. - Discussions and Problem Solving

Day - 7 Assignments

FNM - 14, 15, 17, ESQ. 3, 4, 5, 6, 8, 9
(ESQ: Evaulating Seedling Quality)

MAY 14, 1991 - Tuesday (Day - 9)

09:00 - 10:00 hrs. - Field Trip to Cocoa Propagation Nursery

10:30 - 10:45 hrs. - Tea Break

10:45 - 11:15 hrs. - Lecture :
Seedling Quality/Physiology
Dr. Robin Rose

11:15 - 13:00 hrs. - Lecture :
Seedling Physiological Research in India through - VCR.
Lecture :
Nurseries in S.E., U.S.A. -
Dr. Sudhakara
Kerala Agricultural University

13:00 - 14:15 hrs. - Lunch Break

14:15 - 15:15 hrs. - Lecture :
Reports - 1, 2, 3
Agroforestry
Teak Plantation

15:15 - 15:30 hrs. - Tea Break

15:30 - 16:30 hrs. - Lecture :
General Forest Nursery -
Dr. N.V. Trivedi Babu, IFS
Silvicultural Research Officer
Forest Hqrs., Thiruvanathapuram

16:30 - 17:30 hrs. - Catchup readings
Coordnators Meeting - Develop
Recommendations Jointly - OSU ; KAU

MAY 15, 1991 - Wednesday (Day - 10)

08:00 - 10:00 hrs.	-	Field Visits
(8:15 - 9:15 hrs.	-	Agril. Research Station, Mannuthy
9:20 - 10:15hrs.	-	Cashew Research Station, Madakkathara)
10:00 - 12:30 hrs.	-	Visit Tree Nursery, KFRI
	-	Visit Laboratories of KFRI, Peechi Lecture on - Stand management in Eucalyptus, Teak etc., by KFRI Scientists at Peechi
13:00 - 14:00 hrs.	-	Lunch at Vellanikkara
14:00 - 18:00 hrs.	-	Proceed to Chowghat and visit costal stands of Casuarina en-route visit Social Forestry Plantings of Eucalyptus, Acacia and Agroforestry systems involving Ailanthus and Horticultural Tree Crops Return to Hqrs. at 18:00 hrs.

MAY 16, 1991 - Thursday (Day - 11)

09:00 - 10:00 hrs.	-	Outplanting/competition Dr. W.H. Emmingham
10:00 - 10:30 hrs.	-	Tea Break
10:30 - 11:00 hrs.	-	Lecture : Vegetation Management - Dr. W.H. Emmingham
11:00 - 12:00 hrs.	-	Radio Tracer Lab
12:00 - 13:00 hrs.	-	Lecture : Statistical Application for Nursery Research in India - Dr. B. Mohankumar College of Forestry Kerala Agril. University
13:00 - 14:00 hrs.	-	Lunch Break
14:00 - 15:00 hrs.	-	Discussions - Statistical Problems in Nursery Research Dr. W.H. Emmingham, OSU Dr. J.V. Rao, CRIDA, Hyderabad. Dr. B. Mohankumar College of Forestry Kerala Agril. University

15:00 - 16:00 hrs.	-	Lecture : Conifer Temperate Forest Nursery - Dr. Sudhakara
16:00 - 16:15 hrs.	-	Tea Break
16:15 - 17:30 hrs.	-	Excerise: Design Nursery/Field Experiments - Dr. W.H. Emmingham (Rao's experiment as example)

MAY 17, 1991 - Friday (Day - 12)

09:00 - 10:00 hrs.	-	Lecture : Technology Transfer - W.H. Emmingham
10:00 - 11:00 hrs.	-	Lecture : Organizational Models - Dr. W.H. Emmingham
11:00 - 11:15 hrs.	-	Tea Break
11:15 - 13:00 hrs.	-	Problem Solving
13:00 - 14:00 hrs.	-	Lunch Break
14:00 - 15:15 hrs.) 15:30 - 16:30 hrs.)	-	Discuss personally designed experiments.
15:15 - 15:30 hrs.	-	Tea Break Finalise Course Recommendations - Dr. W.H. Emmingham ; and Dr. C.E. Abraham
16:30 - 17:30 hrs.	-	Oral critique of the course -

MAY 18, 1991 - Saturday (Day - 13)

10:00 - 12:00 hrs.	-	Plenary Session
Welcome	-	Dr. C.C. Abraham Associate Dean and Special Officer i/c (Local Convenor), KAU, Trichur
Chairman's address	-	Dr. E.G. Silas Vice Chancellor Kerala Agricultural University

Valedictory address- and distribution of certificates	Focal theme : Forest Nurseries Dr. K.J. Joseph Principal Chief Conservator of Forests, Kerala
Coordinators Overview of the Course	Dr. W.H. Emmingham, Professor & Head Department of Forest Sciences Oregon State University, U.S.A.
Address	Dr. Maharaj Singh Winrock International, New Delhi
	Dr. A.G.G. Menon, Director of Extension Kerala Agricultural University
Participants Overview	
Vote of Thanks	Dr. L.N. Harsh, CAZRI (I.C.A.R.)

* * * *

Appendix 3

ITINERARY

Dr. W.H. Emmingham and Dr. Robin Rose

Short-term Consultants : Agroforestry Sub-project

May 1991			
Fri., 03	Arrive New Delhi	2315 hrs.	BA-36
	Stay at : Taj Palace Hotel		
Sat., 04	Free day		
Sun., 05	New Delhi/Cochin	0540/0940	IC-467
	Cochin/Thrissur		By Road
	Stay at : Elite International Hotel, Thrissur		
Mon., 06 to Sat., 18	Nursery Technology Workshop Kerala Agricultural University, Thrissur		
Sat., 18	Thrissur/Cochin		By Road
	Stay at : Malabar Hotel, Cochin		
Sun., 19	Cochin/Bombay	0755/0940	IC-162
	Bombay/Hyderabad	1440/1550	IC-617
	Stay at : Gateway Hotel on Banjara Hills, Hyderabad		
Mon., 20	Visit to CRIDA (Dryland Project, ICAR), Hyderabad		
Tue., 21	Hyderabad/New Delhi	0755/0955	IC-440
to	New Delhi/Dehra Dun	1300/1830	By Road
Thur.,23	**Stay at : Madhuban Hotel, Dehra Dun**		
Thur.,23	Dehra Dun/New Delhi	0700/1300	By Road
Fri., 24	Debriefing Meetings at USAID and ICAR and submission of Report		
	Stay at : Taj Palace Hotel, New Delhi		
Sat., 25	Departure from New Delhi to U.S.A.		

Appendix 4

List of Participants

1) Shri.Avtar Singh,
Asst. Silviculturist,
Dept. of Forestry & N.R.,
Punjab Agricultural University,
Ludhiana - 141004.

2) Dr.Asokan, P.K.,
Associate Professor,
College of Forestry,
Kerala Agricultural University,
Vellanikkara, Trichur 680654,
Kerala.

3) Shri.Dash, B.B.,
Scientist S-1 (Soil Cons.),
Agroforestry,
Orissa University of Agriculture & Technology,
P.O. Box No.10, Sunabeda-2,
Koraput - 763002,
Orissa.

4) Dr.Dastagir, M.G.,
Professor of Forestry,
Forestry Research Station,
Tamil Nadu G.D. Naidu Agrl. University,
Mettuppalayam 641301,
Tamil Nadu.

5) Shri.Desai, A.R.,
Scientist (Hort.),
I.C.A.R. Research Complex for NEH Region,
Shillong - 793103,
Meghalaya.

6) Shri.Devaranavadgi,
Asst. Professor of Forestry,
Agricultural Research Station,
P.B.No.18,
Bijapur 586101,
Karnataka.

7) Shri.Doraisamy,
Associate Professor,
Institute for Animal Nutrition,
Livestock Research Station,
Kattuppakkam,
Chengai-Anna - 603203,
Tamil Nadu.

8) Shri.Gawande, R.W.,
Scientist S-II,
AICRP on Agroforestry,
College of Agriculture,
Nagpur - 440001,
Maharastra.

9) Dr.Gopikumar, K.,
Associate Professor,
College of Forestry,
Kerala Agricultural University,
Vellanikkara - 680654,
Trichur, Kerala.

10) Shri.Induchoodan, N.C.,
Forest Range Officer,
Forest Resource Survey,
Mylippadam, Trichur - 680005,
Kerala.

11) Dr.Kumar Amrendra Singh,
Scientist SG (AF),
ICAR Research Complex,
Sikkim Centre,
Tadong (Gangtok) 737102,
Sikkim.

12) Shri.Kuppuswamy, P.,
Assistant Professor,
Krishi Vigyan Kendra,
Tamil Nadu G.D. Naidu Agricultural University,
Pondicherry - 605013.

13) Dr.Mohan Kumar, B.,
Associate Professor,
College of Forestry,
Kerala Agriculture University,
Vellanikkara, Trichur 680654,
Kerala.

14) Shri.Premkumar, T.,
Junior Assistant Professor,
College of Forestry,
Kerala Agricultural University,
Vellanikkara, Trichur 680654,
Kerala.

15) Shri.Rajeswar Rao, G.
Scientist (Forestry),
National Research Centre for Agroforestry,
Jhansi - 284003,
Uttar Pradesh.

16) Dr.J.V. Rao,
Senior Scientist (Agronomy),
Central Research Institute for Dryland Agriculture,
Santhosh Nagar, Hyderabad - 500659,
Andhra Pradesh.

17) Shri.Samantha, A.K.,
Farm Manager,
Central Agricultural Research Institute,
P. Box 181,
Port Blair - 744101,
Andaman.

18) Shri.Shiek Hyder Hussain, S.,
Research Range Officer,
Kerala Forest Department,
Vellore Colony, Patturaikal,
Trichur 680650,
Kerala.

19) Shri.Shukla, V.K.,
Junior Scientist (Agronomy),
Department of Forestry,
Agroforestry Project,
J.N.K.V.V., Jabalpur - 482004,
Madhya Pradesh.

20) Shri.Sonney George,
Junior Asst. Professor,
College of Forestry,
Kerala Agricultural University,
Vellanikkara, Trichur 680654,
Kerala.

21) Dr.Sudhakara, K.,
Associate Professor,
College of Forestry,
Kerala Agricultural University,
Vellanikkara, Trichur 680 654,
Kerala.

22) Shri.Suresh Babu, K.V.,
Junior Assistant Professor,
AICRP on Agroforestry,
Livestock Research station,
Thiruvazamkunnu, P.O.,
Kerala.

23) Dr.Tewari, J.C.
Scientist (Forestry),
Division of Perranial Cropping Systems,
Central Arid Zone Research Institute,
Jodhpur, Rajasthan.

24) Shri.Thomas Mathew,
Junior Assistant Professor,
AICRP on Agroforestry,
Livestock Research Station,
Thiruvazamkunnu, Palghat Dt.,
Kerala.

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Appendix 5

Afforestation and Refforestation in India

S. CHINNAMANI

Afforestation and reforestation is taken up on a large scale in India. In wasteland alone about 5 million ha/year is the target but about 2 million ha is hardly achieved. In addition about 1 million ha of land in reserved forest and farmers field is also targeted for afforestation and reforestation. The target is never achieved due to various problems. The most important problems is the availability of the planting material, seeds and seedlings at the appropriate time of planting and the correct species. Added to it, the problems of site preparation, soil and water conservation measures in eroded and denuded areas create additional problem. The after care from protection from fire, grazing and following is another problem that has to be reckoned with. The small farmers and large farmers require of seedlings are in hundreds while the wasteland development agencies and State Forest Department require seedlings in millions.

The afforestation and refforestation of farmers field is our main objective out of 140 million ha of farming land about 60 million ha is marginal and under various degrees of erosion. Added to it the climate parameters play an important role, too little rainfall or too much of rainfall, snow etc. Arid, humid, temperature, alpine climate and southern aspect in himalayas play an important and ~~critical~~ crucial roles.

CHOICE OF SPECIES

For any afforestation and refforestation in India choice of species is the most important. These plants should be hardy and should be able to withstand biotic edaphic and climatic stresses. A few important species are given below:

HIMALAYAS

Robinia pseudeacacia, Alnus nepaulensis, Luecaena sp., Pinus sp., Cedrus sp. Cupressus sp. Grewia optiva, Morus alba Celtis australis, Bauhinia sp., salix sp. poplars.

ARID AND SEMIARID TRACT

Prosopis juliflora, P. cineraria, Acacia nilotica, A. tortilis, Neem, Tecomella undulata, Eucalyptus cameldulensis E. teritocornis, Anogeissus species, Leucaena sp.

INDO GANGEIC PLAINS

Acacia nilotica, A.catechu, Dalbergia sissoo, Leucaena Sp. Albizia lebbeck, Poplars, Butea frondosa, Shorea robusta, Eucalyptus tereticornis, Prosopis sp.

HUMID AND SUBHUMID

Shorea robusta, Tectona grandis, Bamboos, Mango, Jamun, Kadamb, Casuarina, Lucaena, Sesbania, Lagerstroemia Terminalia

TROPICAL ZONE

Acacia nilotica, A.planifrons, A. m arnsii, A.leucenloea Hardwickia, binata, Neem, Tamarind, Kanok, Pongamia pinnata, Casuarina equisetifolia, palms, Prosopis, Eucalyptus tereticornis, E.grandis, E.globulus, Tectona grandis, Artocarpus sp, Ficus sp.

SOIL AND WATER CONSERVATION

The run off has to be harvested for the use of moisture conservation. While excess run off should be drained. Run off from hill streams can be diverted to provide irrigation to the afforested area. The important planting techniques used are:

I Pits

a) Simple pits
b) Shellved pits
c) Shallow pits
d) Ring pits
e) Saucer pits
f) Trench pits
g) V pits

2. Trenches, furrous and bunds:

a) Contour furrows
b) Contour bunds
c) Stone bunds
d) Diversion bunds
e) Staggered trenches
f) Continous trenches.

3. Culley control

a) Brush wood checkdam

b) Earthen dam.
c) Stone & RCC check dam
d) Spill way
e) Chuttes
f) Nalabunds
g) Contour wattling.

4. Ferrent control and planting along rivers streams

5. Planting along sea shore against cyclones
6. Planting in saline and alkaline soils

Planting:

It is done with naked or container seedling Direct sowing is done in some places Planting is done in the following times.

Premonsoon- April-May
South East Monsoon -June-Sept
North east monsoon-Oct-Dec
Winter -Dec-Jan
Advance Planting - Feb-March

Fertilizer is added @ 25-50 g/ (N.P.K)/N Ist year
50-75 IInd Year
75-100 IIIrd year
0 4th onward

After care

Casualty replacement is done in Ist and IInd year
Weeding & Soil working is carried out

Ist year	2 to 4
IInd year	1 to 2
III year	0 to 1

Watering is given if essential.
Climber cutting support are given to seedlings.
The plantation and forest is protected till the end of rotation of forest crop of 5 to 50 years.
Natural regeneration is also taken advantage of and natural seedling are protected.
In agroforestry boundary planting, alley cropping mining blocks, road side plantation, silvipasture are encouraged in farmers field and community land. It is profitable and yields are higher compared to forest area.

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Appendix 6

GENERAL TREE NURSERIES IN INDIA WITH SPECIAL EMPHASIS TO AGROFORESTRY

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Agroforestry is the land management system wherein woody perennials are deliberately grown alongwith annual crops and/or livestock on the same land management unit, either sequentially or simultaneously with the intent of increasing overall productivity. Thus, planting trees form an integral component of all agroforestry programmes. The species used for agroforestry planting often include trees yielding one or more of the following products or benefits such as timber, fuel wood, fodder, green manure, fruits, food, soil fertility improvement, checking soil erosion, wind breaks etc. There are a large number of multipurpose trees and shrubs that are capable of meeting these diverse land management objectives. However, often farmers encounter difficulties in obtaining the right type of planting stock, both in terms of species choice, seedling quality and vigor. Moreover, many Agroforestry situations are characterized by harsh environmental factors, such as erratic rain fall, infertile soils, high alkalinity and salinity, water logging, excessive biotic pressure and so on. Under such situations direct seed sowing is likely to be unsuccessful. Thus agroforestry nurseries are going to play a vital role in the afforestation and reforestation programmes in our country.

The National Wasteland Development Board has estimated that the annual requirement of planting stock for India would be of the order of about three billion seedlings for planting the 1.5 million hectares of land. At present a large portion of the huge seedling requirement is met from the 'decentralized nurseries' of the Forest Departments. The Forest Departments usually have both permanent nurseries and temporary or flying nurseries.

Tree nurseries in an important initial step for raising successful tree plantations. Healthy and sturdy plants from very good nurseries are essential for cent percent success in plantations. Tree nurseries is an ancient tradition in India which was prevalent from time immemorial. A good nursery should be located at a suitable site and should be based on soil, water and labour availability including good transport facilities. Improper sites like ill drained soil, saline and alkaline soils, steep slopes should be avoided. Perenial source of irrigation like canal, tube well or open well is essential. Irrigation should be attempted by fine rose cans manually or by sprinklers or drip. Mist chambers are common in modern nurseries.

All India Co-ordinated Research Project on Agroforestry have 31 regular centres. 9 voluntary centres and one National research centre of Agroforestry at Jhansi. Out of this, seven centres are distributed in Himalayan, five centres in Indo-Gangatic plains, four centres in humid and sub-humid tracts, nine centres in arid and semi arid areas and six in the tropical region. In all, there are forty one centres.

These centres have various types of tree species to deal with and a few are as follows.

<u>CONIFERS</u>:- Abies, Picea, Cedrous, Pinos, Pinos, Janiperus, Cupressus, Podoplyllum etc.

<u>Broad leaved</u>

<u>Temperate</u> - Oak, Salix, Acer, <u>Betula utilis</u>, Alnus etc.

<u>Tropical</u>

<u>Evergreen</u> - Dipterocarpus, Hopea, Artocarpos, Bamboos, Ficus etc.

<u>Deciduas</u> - Teak, Sal, Bamboo, Terminalia, Anogeissus, Albizzia, Neem, Adina etc.

<u>Xerophytes</u> - Acacia, Prosopis, Zyziphus, Euphorbia, Agave, Balanitis, Salvadora etc.

Halophytes - Suaeda, Atriplex

Mangroves - Avicennia, Rhizophora

Palms - Coconut, Date, Tad, Caryota, cane.

The selection of nursery depends on the choice of species, climate, soil, physiography aspect and biotic factors. In India, nurseries in the forests are divided into two major division and are called Permanent and temporary nurseries. Permanent nurseries are maintained for more than 5 years while temporary nurseries are maintained for 6 months to 2 years. Of late social aspects have taken predominant role in the formation of nurseries. They are Kisan nurseries maintained by farmers. Women nurseries maintained exclusively by women in rural India and is very popular in Rajasthan and Maharashtra. School children play are important role in school nurseries which are maintained by teachers and students in rural and urban area. For agroforestry these nurseries are important. In addition, backyard home nurseries are maintained by small farmers and landless persons and is a source of additional income to them.

The temporary nurseries are cheaper and are established to supply seedling for the following season. The species selected for the temporary nurseries are simple to raise and should be ready for out-planting in a short period after sowing in beds. Farmers nurseries are prepared and maintained by farmers and their families in their own land. Such nurseries deal with one or two species at the most. The school nurseries have similar targets but they are established on the school premises. The students look after them under the guidance of one or more teachers. In Kerala and some other States the Social Forestry wing of the State Forest Departments have embarked on a programme of establishing Forestry Clubs in the schools and Colleges. The main responsibility of these clubs are to raise nurseries for which the materials such as seeds, poly bags and also the technical knowhow will be supplied by the Department. The Department also provides all materials and the technical knowhow to the farmers for establishing nurseries. In addition, they will 'buy back' planting

stock is [illegible] at a cost of 30 paise per seedling. Various non Governmental organisations like Women's Co-operative and private individuals also establish nurseries in different parts of the country. In Kerala, one can find a very large number of fruit and ornamental plant nurseries falling under the category of private nurseries. A majority of them concentrate on commercial trees should as rubber, coconut, arecanut, fruit trees, tree spices, ornamental plants and the like.

Site selection with proper soil, irrigation availability, labour potential and transport network in essential in addition to protection of tree nurseries by live hedges, barbed wires and trenches. Electric wire fencing were adopted during 1960 in deserts of Rajasthan. Nursery beds have to be well prepared with ploughing by tractor, bullock or manual labour removing roots, rocks etc, giving good tilth to the soil. The normal size of the nursery bed in India is 10 m. long 1 m wide, 0.15 to 0.45 m height or deep. Sunken, raised, level, terrace in hills are few types of beds which are common. Normally in India seeds are collected from selected trees on general stands. Germination percent, seed quality, viability etc. are tested before sowing seed. Pre-treatment is done by cold and hot water, sulphuric acid, burning and cherring rubbing seed coat. Of late seeds are collected from elite trees and plus trees for the improvement of germplasm. Sowing is carried out by various methods. Broadcast, line sowing, hand drills etc. Germination is carried out in germination trap, pots and germination bed. Once the seedling are 1 to 5 cm. in height they are pricked out and transplanted in transplanting bed and sometime in storage beds. For nurseries various type of containers are used.

Old types: - Earthern pots. Bamboo tubes, Bamboo baskets, leave domes, mossed plants, Zinc tin containers and planting brick, earthen balls, etc. These old type of containers are still prevalent in rural India. Some of them have become obsolete but is of historical importance.

New type :- Various types of polythene bags, plastic tubes, tray pots etc. are used. The container sizes have become too small so that more number of plants can be transported.

Eucalyptus, Casuarina and pines are raised in billions in these containers.

Manures and fertilizers are given to the nursery bed and containers along with cattle manure, tank silt etc. Plant protection measures against insects and fungus diseases are common and in particular small seeds.

The types of seedling used varies depending on species. Tall seedling are usually preferred for boundary plantings and road side plantation as well as problem areas. Naked seedlings are also common and are comparatively cheaper which can be used efficiently for various species like Pines, cuprusses, sissoo etc. Stumps root shoot cuttings are common for teak. Age of seedling varies from 2-3 months, 6 months-9 months, 1-2 years, 2-3 years, container plants are very common-3 months old seedlings are preferred for casuarina and 2 years old for Cedrus deodara.

There is a profound variability regarding the size between places and species. Agroforestry nurseries are usually small. Generally speaking size of the nursery is mainly determined by factors such as (i)level of annual plant production (ii)method of raising seedlings - containers occupy more bed space than bare rooted seedlings, but the latter are often worked on crop rotation and fallow areas have to be allowed for; and (iii) nursery life of plants in the tropics, there is a wide variation in the time different species take to reach a suitable size for planting. As a thumb rule, the total area needed for an annual production of one million seedlings, including space for sheds, access tracks, storage areas, etc. is 4.0 ha.where the nursery life of plants is more than one year, 1.5-2.0 ha where it is between four months and a year, and 0.5-1.0 ha where it is less than four months and several crops are grown in one year.

Choice of location is determined by factors of management and silviculture. Careful setting of a nursery is important. Of first importance for management there must be good access to and within a nursery at all times. Secondly a continuous water supply for irrigation is usually essential.

Thirdly, there should be ready access to local labour.

Extremes of climate should be avoided such as frost prone areas in the highlands and, in the lowland tropics, where local topography renders the site excessively hot. Exposed sites known to suffer from hail, persistent or squalls wind, and lightning are all unsuitable.

The soil for nursery beds or filling containers must be readily workable, of good texture, and free draining such as sandy loam. Clayey soils are unsuitable. High natural fertility is not required but acidity should be about 5.5 to 7.0 for broad-leaved species. Nursery sites also should be substantially weed-free. A detailed discussion on site selection for tree nurseries would be given during the discussion session that follows.

There are two different methods of raising tree seedlings: (i) in an open bed from which seedling plants are lifted and planted with roots bare of soil;(ii) in individual containers which are taken to the planting site and the seedlings planted with a ball of soil around the roots. There are many variations in both methods arising from their historical development in the search for simplicity and convenience. Initially tropical practice followed that of temperate countries raising seedlings in open beds and planting then out as bare root stock. Survival was often poor. However, survival improved when seedlings were taken from the nursery beds with soil attached to the roots in containers such as bamboo pots, earthenware pots, baskets,metal tubes veneer sleeves, reinforced paper, styro blocks and the like. The choice of containers depends on cost and convenience. Some times pre-filled containers are used. These are individual units of growing media for each seedling. Peat is usually used, it is highly compressed, dried and has to soaked before seeds are used. The advantage of pre-filled containers is they do not require filling with soil; after soaking they are ready for sowing. However, they are much more expensive. A comparative account of the bare rot and containerized operations are given in Table-1. I will address the container system because it is the most widely used in India, and is likely to remain so for all smaller nurseries.

Polythene bags(polypots) are by and large the most popular containers in use today. It is very cheap and light. Two hundred guage (0.05 mm thick) transparent polythene are becoming increasingly popular. The latter should be used at higher altitudes, where plants have to be kept longer in the nursery and where polythene breaks down faster because there is more ultra-violet light and more frost. Black is better above 1500m, or where the pot has to last longer than about twelve or fifteen months. The dimensions used commonly range from 2 cm to 7.5 cm in diameter and 10 cm. to 20 cm. in length. Necessary holes are to be provided to facilitate drainage of excess water.

However, the impervious containers have two distinct disadvantages. First, time must be taken to remove or slit container at planting, otherwise root growth is distorted which leads to instability of the tree. Secondly, seedlings left too long in impervious containers become 'pot bound'. The roots unable to grow outwards, coil around inside the container, a habit which continues even after planting. Normal lateral root development is hampered and the same instability problem occurs.

One of the most important reasons for the poor quality of the plants produced in many nurseries is the poor quality of the potting mixture. It is necessary to find out what kinds of soil, sand and compost are locally available. The texture of the mixture is most important. It determines whether or not the plants get air, moisture and nutrients in the right amounts. A sandy soil or loamy sand, which contains 40-70 per cent sand is considered ideal. These can be recognized in the field as follows: try to roll a little moist soil between the fingers, to pencil thickness. If it is not possible, there is too much sand. If the roll can be bent in a semi-circle without breaking, there is too much clay. An ideal potting mixture has the following characteristics:

-light weight
-homogenous
-easily available
-fertile and retains nutrients
-a pH between 4.5 and 6.0
-well drained, but retains sufficient moisture
-sufficiently cohesive to maintain the root ball after removal of the container.

In forest nurseries, only the forest top soil is most commonly used. However, it is desirable to make potting mixtures with top soil, sand and compost in proportions of 1:1:1, 1:2:1, 2:2:1, 3:0:1, 3:1:0 etc. subject to the availability of sand and compost and the texture of local soil. In a study on Sweitenia macrophylla conducted at Vellanikkara(Kerala) it was found that 1:1:1 mixture of sand, soil and Farm Yard manure markedly increased the germination and growth of seedlings (Table 2).

Table 2. Emergence (at three weeks after sowing) and mean height of mahogany seedlings (45 days after sowing)

Treatments	Number of seedlings out of 360 seeds	Mean Height(cm)
Soil	105(31)	17.6
Soil + FYM + sand	297(63)	20.3
Soil + Forest soil	142(39)	21.8
CD(0.05)		1.7

Figures in parenthesis indicate percentage values.

RHIZOBIUM AND MICORRHIZA INOCULATION

Many trees will grow properly if their roots are in association with micorrhizal fungi. Many genera of legumes are well known as nitrogen fixing trees. They owe this ability to another kind of symbiotic association, between their roots and the bacteria of the genus Rhizobium. These mutually beneficial association between microbes and plants are called 'Symbiosis'. The presence of the appropriate strains of these microbes must be ensured in the media.

In a containerized operation tree seeds can be either directly sown into the filled containers or seedlings 'pricked out' from a mother bed can be planted into it. Generally bigger seeds, having higher germination potential are used for direct seeding. Shoot and root cuttings bulbils leaves and tissue culture are also used for various species. Bamboos and Eucalyptus can be raised by rhizome cuttings and branch cuttings. Important popular clones like C3, D48, D100, D75, D61, D121, D67 and Euro-American 78/58,Lux 69/55 are raised by cuttings. 61

Eucalyptus is raised by cuttings on large numbers in Mist chamber, central nurseries and glass chambers in several parts of India. Normally 0.2 hectare of a nursery gives 50,000 seedlings. Grafting, budding and layering is also adopted. [illegible] can also be used. Natural seedlings are also pricked out [illegible] grown in nurseries, eg. Silver oak. In agroforestry [illegible] of high quality, fast growing with good fuel, fodder, [illegible] and minor forest produce is in great demand. The demand is always for smaller number. In regular forestry and waste land development several million fair to good quality seedlings are required. The farmers in Agroforestry system want seedlings which are of uniform genetic character like agricultural crops. They are willing to give Rs.2/- to Rs.10/- per seedling. There is a general awakening for tree nurseries and tree planting by the farmers in the cultivated land along boundary as mini blocks, alley cropping, sil/pasture, Agri-silvi-horticulture, Homestead, multistoreys etc. Hence the importance of nursery in India is of general importance and have to be implemented scientifically and efficiently. Good quality seedlings have to be produced at cheaper cost to make tree plantation a success.

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TABLE 1

COMPARISON BETWEEN CONTAINER AND BARE-ROOTED METHODS OF RAISING SEEDLINGS

	Container system	Bare-rooted system
Materials	Need as many containers as seedlings. Supply of good soil for potting mix	Nursery site with easily worked soil suitable for bed cultivation.
Equipment	Container filling device, soil sieving screen, Potting shed	Tractor and several implements for ploughing, renovating, bed formation, seed sowing, undercutting, lifting, etc.
Labour	Labour intensive, not easily mechanized. Much labour needed for container filling, seed sowing, weeding and container removal at planting. Typically 10-20 man per million seedlings produced.	Well suited to mechanisation. Most labour intensive component is lifting and packaging, but even these may become mechanised in the future. At Beerburrum, Queensland, 2-3 men raise 1.4 million seedlings per year.
Transport	Bulky and heavy to transport, costly over long distances	Plants easy to transport over long distances.
Silviculture	Excellent survival at planting. Over grown plants become pot-bound and suffer serious root deformation and later instability	Good survival depends on careful timing of lifting and planting, to coincide with wet weather, and adequate conditioning of plants. Gives poorer results where climate is unreliable.
Supervision	Easier to get satisfactorily, timing of operations not too critical, but may suffer more from casual neglect of watering, shading, etc.	Requires a high degree of supervision to ensure proper timing and regularity of operations.
Protection	Fresh soil in every container reduces chance of build-up of pathogens or soil pests. Diseased seedlings easily isolated and discarded. Weed control tedious.	Re-use of same soil may lead to build-up of pathogens or soil pests. Pest and diseases more likely to affect all seedlings in a bed.

	Container system	Bare-rooted system
Cost	High labour intensivity tends to produce more costly seedlings. Cost per seedling including overheads are: A. cunninghamii in Queensland, using metal tubes US $ 70 per 1000 (1978) Pinus caribaea in Fiji (small tubes) US $ 30 per 1000 (1978) E. camaldulensis in Niger US $ 140 per 1000 (Delwaulle 1977 b) Albizzia falcataria in the Philippines (short nursery life) US $ 10 per 1000 (1978)	Capital intensive but at high levels of output unit costs are low. Costs per seedling including overheads are: P. caribaea in Queensland US $ 20 per 1000 (1978) E. camaldulensis in Niger US $ 60 per 1000 (Delwaulle 1977 b)
Suitability	All smaller nurseries and especially: (i) for goods survival in arid conditions; (ii) when many different species are raised (iii) where plants are distributed to the public and post-planting care is likely to be poor, e.g. extension nurseries..	(i) Large production nurseries raising only a few species for planting and where climate is dependable; (ii) Raising 'stump' plants and as a cheap method for hardy species.

Appendix 6-A

WATER HARVESTING IN NON-AGRICULTURAL LAND FOR FUEL AND FODDER SYSTEM

S. CHINNAMANI**

Abstract

Water harvesting in non-agricultural lands is essential for the establishment and growth of manmade, social and agro-forestry system. These help in providing the much needed fuel, fodder needs of the local people in rural and urban areas. In addition, water harvesting in natural grassland, and natural forest, increases the yield of fuel and fodder by two folds. The paper describes various methodologies that can be adopted and species that respond to these techniques.

INTRODUCTION

Water harvesting in non-agricultural lands is tricky and is subjected to various climatic, edaphic and topographical consideration of the land. These lands are highly eroded, with various degrees of sheet, rill, gully and ravine erosion. In several places the sub-soil is exposed, the soil is skeletel and gravelly and devoid of fertility. To produce fuel and fodder from these lands is extremely difficult but is possible, if the water harvesting methods are followed with right type of species. In addition rigid protection from grazing and illicit felling is essential. Litter removal and removal of undergrowth should be discouraged.

NON-AGRICULTURAL LANDS

Non-agricultural lands can be broadly divided into:

a) LAND ON HILLS - These occur on hills with varied slope of 10% and above.
b) LANDS ON PLAINS - These occur in plains whose slope is mostly below 10%.

Once again the above land fall under

i) Arid to Semi arid areas with precipitation of 200 to 1000 mm.
ii) Humid and Perhumid areas with a precipitation above 1300 mm.

On hills water harvesting becomes essential because of the slope, gravelly and exposed sub soil, the rainwater is drained of quickly and poor soil condition makes the moisture retension practically impossible. In arid to semi-arid are the rainy days are 5 to 65 in a year while in humid to per-humid areas there are 150 to 200 days. Thus we have 160 to 360 non rainy days in arid and semi-arid areas. Hence the water harvesting methods are equally important to both the regions due to moisture deficit occuring at different periods.

WATER HARVESTING TECHNIQUES

Some of the important water harvesting methodologies are as follows:

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a) Water spreaders - Divert the first order channels, small hill streams, by providing an artificial obstruction and directing the water over a long shallow channel of 100 to 300 m on both the side of the first order hill stream (Fig. 1). By this [illegible] water in these stream gets diverted spread on both sides to a total width of 200 to 600 metre.

This helps:

a) Natural grasses of the hills which are mainly three types

1) Ischaeda - Arundinella types of lower hills
2) Deyuxia - Deschampsia grass-lands of high temperate areas of Himalayas
3) Chrysopogon subtype grassland of high hills of Western Ghats, Nilgiris 1500 m and above respond well, they provide 100 to 150% increase in yield of fodder and resist frost to a good extent.

In plains dig continuous shallow trench V shaped 15 cm wide 15 cm deep 2 to 4 m apart this harvests rain water and increases grass yield in Dichanthium, Schima, Cerchrus by 20 to 50% (Fig. 2). As regards the natural forest these water spread helps the natural shrubs, trees to grow fast and provide much needed fuel and fodder. Along these channel. subabul, Black locus, Acacia melanoxylon, Sesbania species, Glyr cidia sepium and other fodder species can be planted to get additional and quick return. They will also provide much needed fuel. The pure fuel species that can be planted are Eucalyptus. Subabul, Babul and others.

CHECK DAMS: Various types of check dams can be constructed in gullied areas in small, medium, deep and very deep gullies and ravines. These check dams harvest the water and due to siltation the gullies beds become fertile, water gets impounded in tropics in plains these beds can be planted with plants, whose water requirement are higher. Hence Bamboos, Eucalyptus, Subabul fruit trees can be grown successfully. These lands which were once useless, by water harvesting techniques give a return of Rs.6000 to 23000/ha/year.

C) TERRACES: In hills with steep slope terraces of 0.5 m to 1 m wide level and inward slope can be constructed at 2 to 10 m horizontal interval (Fig. 3). The water harvested from the upper catchment gets collected and helps the tree to establish and grow. Dig pits of 0.3 x 0.3 x 0.3 at 1 to 2 m apart and plant species suitable to the locality. They are also called peradonces.

D) TRENCHES: Water harvesting can also be done by continuous contour trenching staggered trenches at an horizontal interval of 10 to 50 m (Fig. 4). Inter trenched area should have pits (with water harvested by shallow trenches or bunds). Plant sows species in trenches, this technology is very useful and timetested. Sow and plant species suitable to the locality.

E) PITS: Various types of pits have been employed for water harvesting in non-agricultural lands. Here I will like to tell only a few which are very important and useful,

1) Simple-pits (Fig.5(a) Dig simple pits of 0.3 x 0.3 x 0.3
   a) Arid and semi-arid Fill 3/4 leave 5 to 6 cm for water to store.

Fig.1 : Water spreader

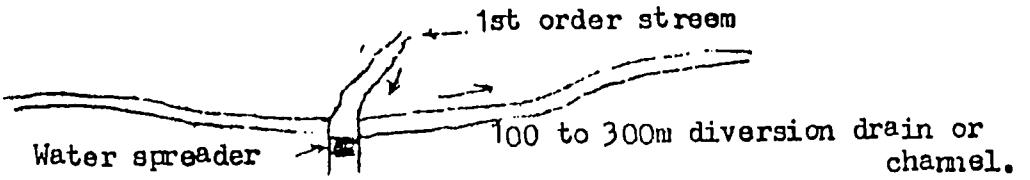
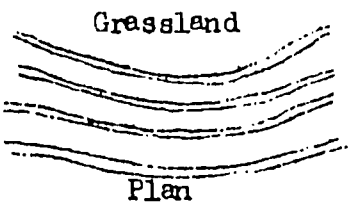


Fig.2: Contour shallow trench



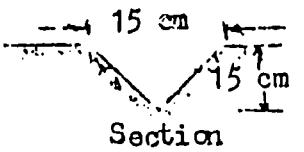
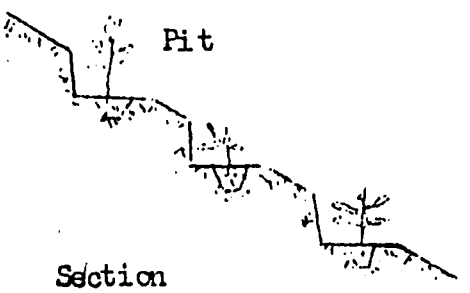
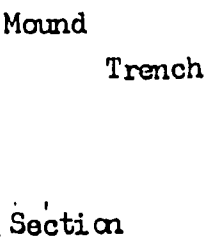


Fig.4: Trenches

Fig.3: Terraces / GRADONIES





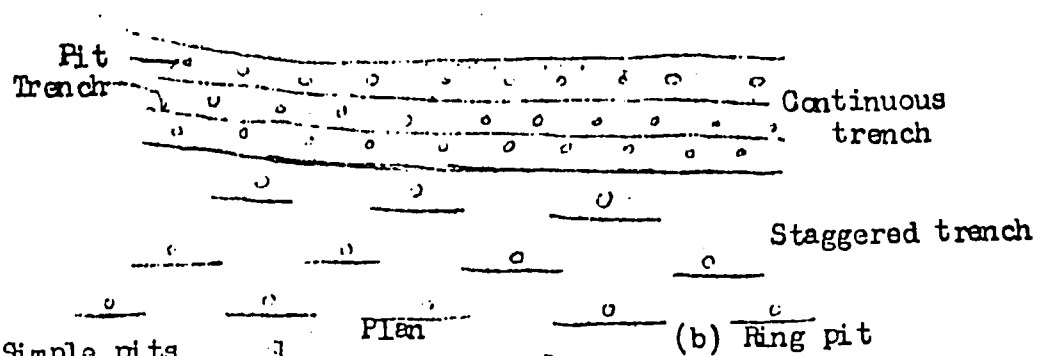
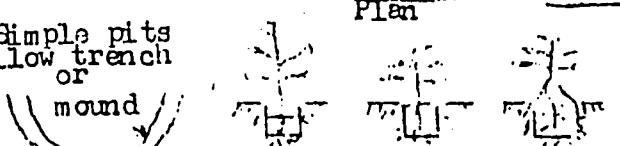
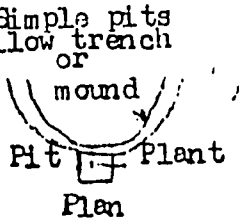


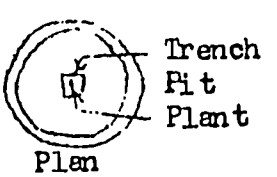
Fig.5 Pit a) Simple pits



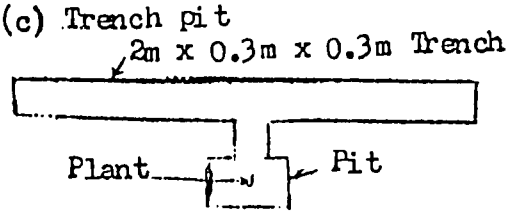
(b) Ring pit



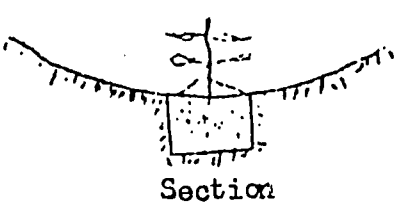
(c) Trench pit

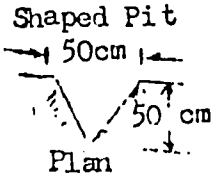


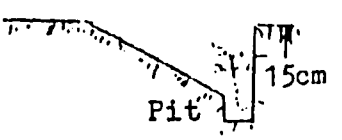
(d) Saucer pit



(e) V Shaped Pit







---ultural lands for fuel and fodder

b) In humid and subhumid area Fill in level or provide. Central mound not to stagnate water in the pit.

In both make semicircular bund or shallow trench so that water is harvested and comes to the pit and benefits to the plants or seedling.

ii) Ring pit: Dig a simple pit of 0.3 x 0.3 x 0.3 and all around dig circular trench 1 m radius with a cross section of 0.3 x 0.3 x 0.3 (Fig. 5(b) plant seedling this gets water from the trench.

iii) Trench pit: Dig a trench of 2.0 x 0.3 x 0.3 m connect with a pit of 0.3 x 0.3 x 0.3 m and plant tree in pit (Fig.5(c). Trench harvests water and provides to the seedling.

iv) Saucer pit: Dig 1 m dia saucer sloping in the centre, 15 cm deep and dig a pit of 0.3 x 0.3 x 0.3 in the centre and plant (Fig.5(d).

v) V shaped pit: Dig a V shaped pit 50 cm vide at top sloping down to 1 cm, sides of V 50 cm and 15 cm deep. The water collects at bottom, plant in pit or by crowbar (Fig.5(e). It is the latest and most efficient. This water harvesting techniques is used in the world.

All the pits should be provided with mulch of stone, straw, brushwood, polythene, grass etc. this helps to retain the harvested water and reduces evaporation.

CHOICE OF SPECIES: The important species which respond well or water harvesting are,

Tropics: Arid and semi-arid, Acacia nilotica, A. planifrons, A. tortilis, A. catechu, Albizzia sp., Prosopis juliflora, P. cineraria, Subabul, Ailanthus excelsa, Bombax caeba, Bamboo, Casuarina equisetifolia, Feronia eliphantum, Neem, Eucalyptus terticornis, E. camaldulensis, Tamarind, Siris.

Humid and perhumid: Ailanthus malbarica, Albizzia falcataria, Artocarpus integrofolia, Eucalyptus grandis, Subabul, Teak, Sal, Aini, Cashew, Lagestroemia species, Terminalia species, Bamboos.

Temperate, Semi arid and Humid: Pinus roxburghii, P.excelsa, P. patula, Cupressus torulosa, C. macrocara, Black locust, Acacia mearnsaii, A. melanoxylon, Cryptomeria japonica, Eucalyptus globulus, Grewia obtiva, Quercus species.

ESTABLISHMENT AND AFTERCARE

Plant and sow the seeds, plant polithene bags seedlings. Plant during rains. Tall seedlings should be used. Apply farm yard manure or sheep and goat manure a handful per pit. Apply fertilizer 25 to 50 gms DAP or NPK mixture per plant. Weed 3 times in Ist year, 2 times in 2nd year replace casualties. Protect the plant from biotic factors. The plants get ready for harvest in 5 to 30 years.

RETURN

The water harvesting technique provides 82 to 90% establishment and good and fast growth. This increases the yield and return. The yield of fuel in 200 to 500 m^3/ha/

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per rotation. The return range from Rs.20,000 to 100,000/ha/ per rotation depending on species. Water harvesting increases the yield and return by 20 to 50%.

CONCLUSION

Water harvesting in non-agricultural lands can be done with success for the excellant establishment of fuel and fodder species. This also enhances the yield by 20 to 50%. Various methods to be adopted for establishing fodder fuel plantation is furnished, Babul, Neem, tamarind, Eucalyptus, Sisoo, Siris, Subabul, Black locust, Semal, Bamboo respond well to water harvesting techniques.

ACKNOWLEDGEMENT

The author is thankful to Dr.V.V.Dhruva Narayana, Director, Central Soil & Water Conservation Research and Training Institute, Dehradun for the encouragement and help.

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Appendix 7

SEED TECHNOLOGY FOR FOREST TREE SPECIES IN INDIA

Scarification - Experiment

Dr. T.V. KARIVARATHARAJU,

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India.

No requirements for seed quality

Dr & Post Doctoral Program

No seed zones -

With the increasing demand for reforestation and afforestation seed is becoming a valuable commodity and its collection, identification, processing, testing and storage require prudent planning together with technical skill and capacity. The seed trade in sylvicultural crops is a minor activity when compared with that in agricultural seeds, but its importance is steadily increasing. The current trend will be to take up more intensive forestry with 'genetically' improved stock which will increase the demand for seeds to achieve economic gains. It is now very well understood that genetic gain will force us to intensify efforts to improve methods for seed collecting, cleaning, storing and testing. Isolation distances inclusive of physiological isolation may have to be utilized for achieving these gains. Only when these phases of operation are closely controlled, can a continuous production of planting stock and supply of seeds for direct seedling requirement be guaranteed.

Season of flowering &

Forests are also closely concerned with animal production as many forest trees provide leaf, flower and pod palatable to the animal besides the grasses and small legumes growing underneath the trees. Forests constitute 22.7% of the total area in the country and 15.6% in Tamil Nadu. The Committee on Fodder and Grasses of the

Seed zones -- Storage conditions for hand crated seeds.

National Waste lands Development Board has estimated that between 1951-52 and 1975-76 while 25 lakh hectares of fresh area was diverted for agricultural purposes, about 4.8 lakh hectares was lost to river valley projects and 57000 hectares to the construction of roads. This sort of encroachment and decrease in the forest area can be on the increase day-by-day.

Seed zones become uniform ecological units in natural forests delineated for the control of transfer of seed and planting stock. The zones established thus on the basis of climatic and physiographic characters can be used as guides for collection.

FORESTRY PRODUCTION SYSTEM:

Seeding forage trees, pasture and leguminous species in forest areas can be done to rejuvenate these areas for which aerial seeding methods to afforest largest areas in the shortest possible period can be thought of. Sites that are inaccessible, steep, remote and of rugged terrain can be covered with acrual seeding and in the upon canopy direct seeding can be done during the monsoon rainy period. This area can be made more productive by progressively replacing the non-fodder trees with fodder trees suitable for cattle, sheep and goat. Experiments done in Agro-Forestry by Environment and Policy Institute, East-west Centre, Hawaii, USA, indicates that a number of nitrogen fixing trees can be made use of for this purpose (Vergara, 1982) Cassia siamea, Acacia auriculiformis, A.mangium, Pithocollobium dulce, Mimosa scarbrella, Prosopis alba, Leucaena

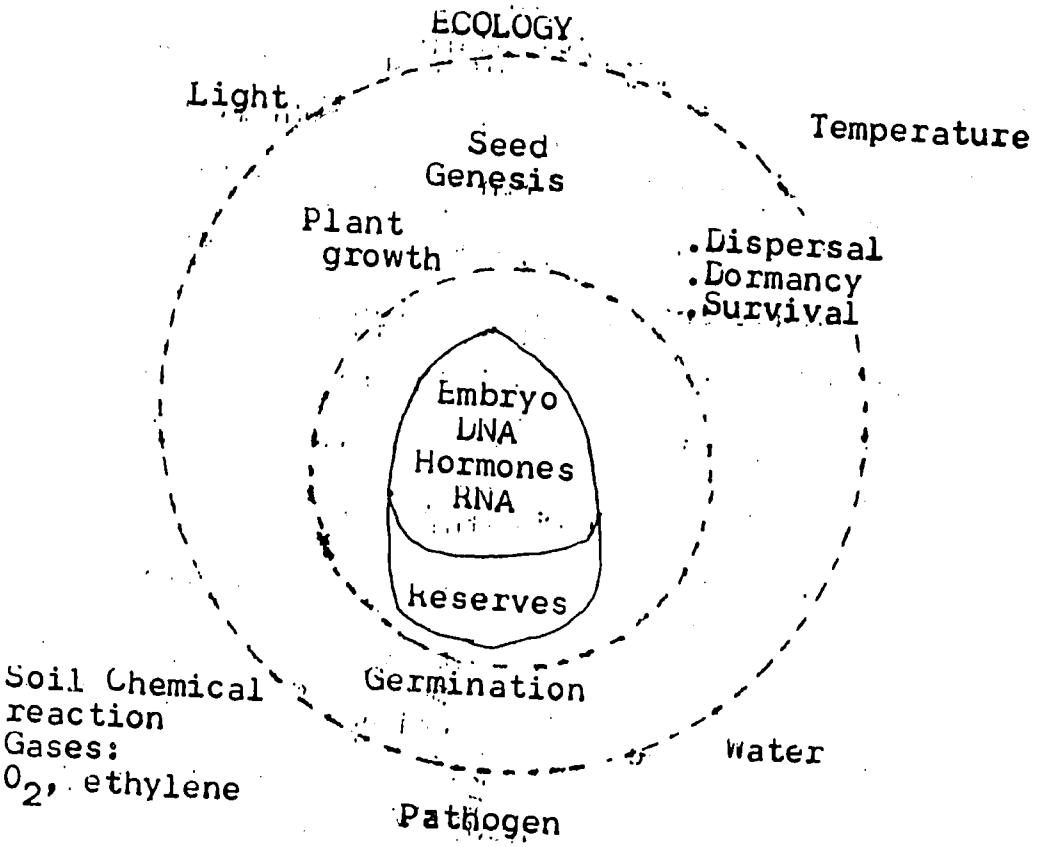
leucocephala, L. diversifolia, Prosopis chilensis, Sesbania bispinosa, S.grandiflora, Albizzia lebbek, A.falcataria, Glyricidia sepium, Calliandra calothyrsus, Acacia mearansis, A.senegal, A.seyal, Dalbergia sisoo, Samania saman. Some of these are used as fuel wood, pulp wood and forages and according to the need and utility, different tree species can be grown at different agroclimatic zones. Of those trees Leucaena spp. has a good potential for high green fodder production. Inter-specific hybridisation of Leucaena diversifolia with L.leucocephala has resulted in some plants with lower mimosine content in the leaves and high diameter at breast height indicative of high biomass. By conventional method of breeding, evolving high yield strain with low mimosine content will take many years in this perennial tree crop. Hence the best high yielding inter specific hybrid can be further multiplied by tissue cultures and allied methods.

Genetic improvement programme through maintenance of seed orchards will have a big impact on the tree seed business. In forest trees, development of strains is a slower process than in agricultural species.

Research results already show potential gains in volume production alone of 10 to 20% major gains in disease resistance and wood qualities. When compared to attempts taken on doubling of seed yield in corn, just a 10% gain for wood does not seem to sound well. To furnish the seeds, foresters have to establish seed production areas and seed orchards. Seed production areas should be in natural

stands of good phenotypes that bear good seed crop; the stands are carefully tended to stimulate seed production. Seed orchards should be established with clones selected for production of improved seeds.

Provenance in relation to seed quality of selected species.



Seed Production in Agro-ecological situation

* Season
* Manuring
* Spacing
* Supplemental foliar application

Tree growth and performance (age etc.)

Seed Production

* Pre-harvest sanitation.
* Harvest, physiological maturity
* Processing
* Storage
* Mid storage correction
* Pre sowing treatment

Orchards (Seedling, clonal) should be located where topography and site quality favour easy maintenance, care,

collection and high seed production. Seed orchard managemen procedures are aimed at reducing potential, seed loss.

Sowing quality of seeds should have the following components:

1. Genetic purity.
2. Freedom from other crop and weed seeds, inert matter, pests and diseases, field and mechanical damage as well as drying injury
3. High germinability and
4. High vigour.

The programme for seed production in tree crops should include the following components.

<u>Quality seed production and distribution (Suggested)</u>

* Seed production (Research)
* Multiplication
* Storage (includes) mid storage correction)
* Marketing
* Seed certification
* Seed Act and Rules
* Seed analysis
* Seed Testing & Field Testing
* Seed control
* Inspection and Seed Law enforcement.

Voluntary certification programmes have to be included for the supply of forest tree reproductive material. The work on Neem (*A. indica*), Casuarina (Casuarina Sp) and Ailanthus (*A.excelsa*) need to be strengthened.

HARVESTING TREE SEEDS:

Seed collection is a problem mainly in respect to size of seed b aring trees than with other crops. Large, single seeded fruits, can be collected from the ground only after they fall from the trees. This procedure requires more labour and hence it is expensive.

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Species like conifers etc. have small seeds and they pose problem because the seeds are disseminated when they fall on the ground. Hand picking from the standing trees of these species is difficult and it should be collected by means of elevated platforms etc. Tree shakers may solve harvesting problems for many species in areas where trees can not be cut down, as in seed orchards and seed production areas.

Most seeds are still collected by hand from trees and this method is cheap where labour force is available in plenty.

A major problem in collection is how to know when seeds are mature. The standard method for pine is based on specific gravity of the cone. If the cone floats in SAE-20 motor oil, then specific gravity is below 0.89 and collection should be made immediately: on the other hand if it is 0.70, cones start opening. In general, the maturity is judged based on these change of fruit/seed colour and it will be essential to find out a fool proof improved technique besides the time, method and period of collection.

i) HARVEST BASED ON TIME:

a) Studies carried out in the Department of Seed Technology, Tamil Nadu Agricultural University, Coimbatore revealed that in Kapok (Ceiba pentandra G.) seeds collected from (i) trees that are 15-20 years old (ii) well matured fruits measuring in length from 26 to 29 cm and in breadth from 4.6 to 4.9 cm and (iii) fruits that have turned to straw colour at harvest (84 days after anthesis), split open at the pedicil end and containing dark brown hard coated seeds with 8 per cent moisture content, were good for seed

quality characters.

b) In Leucaena leucocephala (Hawaiian giant type) the seed quality characters were found to be influenced by age of the trees. Seeds/pods collected from 48 month old trees exhibited maximum seed quality characters than with younger trees. Selection procedure such as this will have great influence in obtaining quality level.

ii) HARVEST BASED ON COLOUR:

Experiment conducted under sylvipasture conditions, germination in Desmanthus sp. declined to the extent of nearly 10 per cent due to use of off-coloured seeds. To ensure maximum germination, seed gradation on the basis of seed colour and use of normal coloured seed is recommended.

In Acacia decurrens, seeds collected from brown colour pod registered higher seed quality than those from greenish brown pod.

The size of seed bearing trees presents collection problems not normally faced with other crops. Some single and multi seeded fruits can be gathered from the ground after they fall from the trees. This procedure requires manual labour and is therefore expensive. Many valuable species have small seeds, some in multi seeded fruits and collection after dispersal is difficult. Determining physiological maturity is very important.

Devices such as tree shakers, climbing nets, ladders and baloons will have increased use in near future for maintaining quantity and quality of seeds.

DRYING, EXTRACTING AND PROCESSING:

Tree seeds collected can be handled the same way as crop seeds. They must be dried, extracted if they are in multi seeded fruits, cleaned and then processed. Seeds are usually spread in shallow layers on sheets shelves, or racks for initial drying. A common method is to spread the fruits on screens through which the seeds can pass. The fruits are turned occasionally and seeds are caught as they fall through the screen.

Various types of equipments are available for extracting and cleaning small lots of tree seeds. Berry-like fruits, such as mulberry, can be thoroughly macerated in kitchen blenders and the pulp removed by floatation in water. The same procedure can be applied on a large scale in wild plums and black cherry with motor-driven macerators.

Winged seeds like pines etc. are dewinged after extraction to facilitate sowing. The usual dewinger is similar to a dehardening machine, but the inside arms are more flexible and the action is softer. Improper dewinging can badly damage tree seeds.

In <u>Emblica officinalis</u> intact fruits were kept in an incubator at 40°C temperature for 2 hr and then the fleshy parts removed. The capsules were then placed inside the brown paper cover and dried under sun. The capsules dehisce and scatter the seeds, which may be used.

The ratio of empty to full seeds is very high in some species. Without a procedure to separate full from empty seeds, the nursery man has to sow what he gets; this practice usually results in very poor control over seedling density

in the nursery bed. For small lots cleaning and separating by hand is still the best method for seed extraction. Anatomical and physiological potential through X-ray analysis will come in a big way to identify quality seeds.

In Kapok for raising nursery moderately heavy seeds that are graded by specific gravity separator were found to be the best.

In bamboo (Dendrocalamus strictus L.) seeds retained on 8/64" round perforated sieve after degluming showed maximum recovery and better seed quality character like germination, vigour and second internodal length.

In Eucalyptus hybrid, grading seeds of variety "Mysore gum" to secure very high germination and seedling vigour in a processing sequence of an air-sereen cleaner, gravity separator and an electronic colour sorter to the near elimination of the chaff on colour criterion is suggested for commercial processing.

STORAGE:

Irregularity of tree seed crops has led foresters to depend on seed storage probably more than farmers do. Seed yield of most species is of small quantity, sometimes seed crop failure also occur. Further more, collection when the crop is small, is very expensive. Seedling production for large-scale regeneration efforts, such as those with pines, frequently must depend on stored lots to produce the seedlings.

Good seed storage is essential to successful seed marketing. Proper storage preserves seed viability from harvest to sale and protects the producer's investment, profit

and reputation. Seed may be produced under a rigorous system of insepection, harvested properly, and processed to the highest purity, but the investment on time, effort and money may be lost if the seeds are stored under poor conditions or packaged at too high a moisture content.

Good storage can be achieved only by maintaining favourable environmental conditions and seed moisture during storage. In a climate favourable for seed storage, the only need is to dry seed to a safe moisture content, package and protect the seed from moisture, rodents and insects. Howeve the favourableness of a climate for seed storage is relative and depends on the period of time the seeds must be stored.

The aim of forester is to store tree seeds longer than farmers do for crop seeds. As a result, the storage environment for tree seeds is more exacting. The standard stores conditions recommended for pine seeds are 0°F with seed moisture content of no more than 10 per cent. Under these conditions, there should be no significant loss in viability for atleast 10 years.

Seeds of most tree species can be dried to low moisture contents and stored at about 32°F for several years without significant loss in viability. Certain seeds, can not be readily dried to low moisture contents without killing them.

Seeds storage studies conducted in this department revealed that Kapok seeds with initial seed moisture content of 6 per cent can be stored for a long time in cloth bag without reduction in seed quality. Techniques to eliminate the dead seeds is also needed. Fruit characteristics and extent of hard seededness also decide the storage potential

and mid storage correction for improving the shelf life of seeds also decide the quality, sowing quality.

Seeds that are mature exhibit a delayed germination or dormancy, and some treatment is necessary to enhance germination percentage. Dormancy is of three types is external dormancy (Exogenous) or internal dormancy (Endogenous) or both. Example for external dormancy is presence of inhibitor in the seed coat or hard seed coat and internal dormancy relates to immaturity of embryo and other parts. The external dormancy can be broken by a process known as scarification; and stratification relates to internal dormancy. To overcome the third category, both treatments are followed.

The presence of inhibitor on the seed coat can be removed by washing the seed in water. The presence of hard seed coat will be overcome by acid searification or thermal or mechanical scarficiation. The internal dormancy can be removed by cold or warm stratifications; here the seeds are stored over winter in layers with alternating layers of moisture-holding materials, such as peat or sand, in large pits in the ground. As refrigerators become available, cheese cloth bags can be substituted in place of cans or drums in cold storage for out door pits. Fully imbibed seeds in polyethylene bags not over 4 mils thick (400 gauge) omit the moisture-holding medium, and hence a small amount of water may be added a naked stratification.

The common stratification temperature range is 33° to 40°F. The length of treatment may vary due to species and agroclimatic zones. In general, seeds that mature in the spring show no dormancy. If the type of dormancy is

known it is easy to control by chemical regulators.

Experiments carried out in Seed Technology Department of Tamil Nadu Agricultural University showed that in Kapok, the seed pre-conditioned for 30 minutes in Conc. sulphuric acid was better in germination.

Treatment with 3 ml of acid for 30 minutes is advocated for Acacia nilotica for obtaining maximum germination and in A. planifrons a concentration of 4 ml for a duration of 25 minutes is recommended.

By thermal scarification in Adenanthera pavonina a progressive increase in germination was evident with increase in duration up to 25 minutes. Further increase in duration only depressed the germination. A duration of 25 minutes is therefore considered optimal for maximising germination.

In Punnai (Calophyllum inophyllum L.) removal of hard outershell significantly reduced the germination period and increased the germination and vigour potentials during initial stage of growth and development.

Bamboo seeds of different sizes were graded and subjected to germination studies with and without intact glumes. The seeds after removal of glumes exhibited clear cut differences among seed sizes, germination, vigour and internodal length. The lesser germination in intact seeds may be due to the presence of a possible water soluble germination inhibitors in the glumes. As it inhibits the internodal elongation, the mechanism of action may be interaction between inhibitor, possibly abscisic acid and gibberellin like substances.

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RAPID ANI TESTS:

Testing of germinability in most of the tree seed takes a long period than crop seeds. To resolve this problem, various rapid test methods have been developed and tested and prescribed as alternative test methods for many dormant tree seed species. These include an excised embryo test, biochemical staining test, X-ray contact and contrast methods and chemical tests.

Conflicting results with respect to the accuracy and efficiency of these rapid test method, have been published and continued comparative studies of these methods and their applicability to certain tree seeds are therefore felt necessary.

NURSERY MANAGEMENT:

Nursery management is important in order to get good seedling for establishing elite seedling orchards. This is only an improved agronomic practice for tree seedlings.

Studies to determine the optimal nursery seed rate for Casuarina equisetifolia indicated that seedling attributes in terms of shoot extension, root length and collar diameter did not vary due to seed rate. Number of germinated seedlings per unit area declined beyond 10 g/m^2 after registering a progressive increase. A seed rate of 10 g/m^2 is therefore, recommended for raising nursery of the species.

In Bambusa bambos (Hollow bamboo) with increase in seed rate, there was concomitant increase in number of germinated seedlings without detriment to seedling quality as assessed by shoot extension, root length and collar diameter. The prevailing recommended seed rate is 15 g/m^2.

Study on container size on seedling vigour in Acacia revealed the superiority of the polypot size of 25 x 13 cm for shoot extension, length and breadth of phyllode and number of phyllodes per plant recorded a linear increase, with increase in size of the container.

In Kapok, inclusion of soil management with enriched compost has improved the vigour of the seedlings.

There are rapid advances in techniques for handling forest tree seeds. The problems are also common with that of agricultural seed workers. Hence, strengthening of tree seed research activity is becoming an important one.

Rapid advances in techniques for handling forest tree seeds are required. The workers in tree seeds face many problems in common with agricultural seed workers and have many problems that are unique to forest tree seeds. Awareness on the following lines requires to be created:

1. Seed zones of uniform ecological units in natural forests delineated for the control of transfer of seed and planting stock must be established on the basis of climatic and physiographic characters for use as guides in seed collection.

2. Survey, collection, classification and documentation of seed zones.

3. Environment protection as reflected in seed polymerphism in some of the sylvicultural species of economic importance.

4. Flowering, seed set and seed quality in forest plantation as influenced by agro-techniques affecting the ecological balance.

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5. Elite seed production of economically useful plant species.

6. Pollutants affecting the ecological balance, flowering seed set and seed quality in forest plant.

7. Elite seedling production and their distribution in respect of economically useful plant species in eco-preservation and development.

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Appendix 8

cost per plant 0.80 1.05 Rs

TEA NURSERY TECHNOLOGY

Dr V. R. Chitarapu,

The TANTEA (The Tamil Nadu Tea Plantation Corporation Limited, engaged in raising of new tea plantations over extensive areas in the state of Tamil Nadu since 1969 for its own use as well as for supply to private farmers (mainly during the period 1975 to 1977), the Corporation has been raising very large scale tea nurseries. Thus this lecture notes is more in the nature of an abstract based on the field experience than a truly scientific or a research paper. At the conclusion of the lecture, a few slides of tea nursery would be shown followed by question and answer session.

Though tea nurseries do not truly qualify as tree nurseries, raising of tea is likely to play a very significant part in the future of agro-forestry schemes mainly in areas where tea could be grown. With the prevailing trends of prices and consumption patterns, it is likely that tea growing would be a very attractive proposition for farmers in the foreseeable future.

The Genus Gamellia has about 45 species of evergreen shrubs and trees distributed in the tropical and sub-tropical parts of Asia. The most important among them is C. sinensis (L) O. Kuntze cultivated for its leaves, from which the tea of cammerce is made.

Habit:

18" Tall Top.

Under natural conditions it is a tree, growing to a height of 15m, but under cultivation it is usually pruned down to 0.5 to 1.5 m and trained as a low spreading bush.

Varieties:

Numerous varieties and races of plants, variously classified by different authors are known. The following 3 main types originating from Assam, China and Indo-China

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Lecture notes by the Managing Director, Tamil Nadu Tea Plantation Corporation Ltd., Coonoor 643 101.

(Cambodia) are important.

(1) Assam : C. sinensis var. assamica
(2) China : C. sinesis var. sinesis
(3) Indo-China : C. sinesis var. cambodiensis

For practical purposes, the cultivated farms may be considered under 3 main groups namely (a) China Tea (b) Assam Tea and (c) Hybrid Tea - which is a cross between China and Assam tea. All clonal production

(a) China Tea:

The China tea comprises the slow growing, multistemmed, dwarf plants with small, erect, carinate (keel like), dark green, leathery leaves. They are more resistant to adverse climatic conditions, possess better cup quality than Assam type, but the yield is less.

(b) Assam Tea:

This comprises of the tall, quick growing types with large, drooping, deflexed leaves, well adapted to tropical conditions and are high jats.

The tea plant is highly cross pollinated and it gives rise to a very heterogenous seed crop, as in the commercial crop which is raised from seeds, there will be a wide variation among the individual bushes in the field. Commercial pure line varieties scarcely exist.

Early history of Indian Tea:

In our country the small leaved, dwarf, China tea plant was introduced from China in the year 1700. In the year 1826 a broad leaved, indigenous plant was discovered from Assam which is commonly known as Assam tea. The large scale tea cultivation in N.E. India was started in the year 1887. The tea plant was introduced in the Nilgiris District of South India in the year 1863.

Sustainability ex - 100 - 150 years

300 - 750 man days/Ha/year
year round
1 worker/acre/all year

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Grevillea robusta (Silver oak) 250 TPA as shelter

V.P. TEA NURSERY

also ~~Tea~~ Pepper & cardimum Cinnamon

(i) Location:

A site with a proper drainage should be selected. The nursery should be situated near a parennial water source and should preferably be naturally protected from wind.

(ii) Preparation of soil:

The rooting medium should be of a sandy loam texture with pH ranging from 4.5 to 4.8, though a pH up to 5.5 is not entirely harmful. But, the soil pH beyond 5 tends to promote excessive callusing at the expense of rooting. At higher levels of pH, the roots of young nursery plants die back, resulting in what is known as 'bitten off' disease. River sand, free of calcium carbonate, should be used in the rooting medium: too fine a sand may be avoided. Both soil and sand should be sieved separately through a 8-10 mesh.

Clay (forest soil) : sand = 3:1 (comprises the bottom 9" of the sleeves).

Red soil : sand = 1:1 (comprises the top 3" of the sleeve).

Soil and sand should be mixed in appropriate proportions to arrive at the desired texture.

The following simple test could be applied to assess the texture. The soil sand mixture on moistening sufficiently and pressing in the hand should roll into a ball, which, when dropped on the ground from waist height should crumble.

(iii) Pre-treatment of rooting medium:

(a) Amendment of pH: Soil pH can be reduced by treating with Aluminium Sulphate or Ferrous Sulphate.

...4...

For pH range between 5.1 - 5.5 treat with 1% Alumnm. Sulphate
for pH range between 5.6 - 6.8 treat with 2% Alumnm. Sulphate

If the pH is more than 6, the soil should not be used for nursery purpose.

For a bed of 1 m width, 8 cm height and convenient length, drench 2.5 sq.m. with 10 litres of the solution. Over this, another layer of soil about 8 cm height may be spread and again drenched with the solution of Aluminium Sulphate as above.

This may be repeated up to a convenient height. The soil should be mixed thoroughly and drenched with an equal quantity of water, twice before use. Soil should be allowed to dry, checked for pH and then used in the nursery.

Aluminium Sulphate can also be applied after filling the sleeves with soil. Depending upon the initial pH, 50 or 100 ml of 2% solution of Aluminium Sulphate should be applied per sleeve. This should be followed by two waterings, each time an equal quantity of water should be applied per sleeve, as that excess Aluminium Sulphate is reached down and uniform pH and EC levels are obtained.

2% solution of Aluminium Sulphate should be prepared by dissolving 2 kg of the chemical in 10 litres of water by boiling and making up the solution to 100 litres. The solution should be prepared in clay or plastic containers.

$$Al(SO_4)_3 + 6H_2O - 2\ Al(OH)_3 + 3H_2SO_4$$

(ii) <u>Treatment against root-knot eelworm:</u>

One of the following methods should be adopted as a routine practice to eradicate the eelworm population from the soil to be used in the nursery.

— a nematode
Stunting of roots
— young plants 5...

(a) Heat treatment: - pretreated to pesticides

Soil ready for use in the nursery, should be heated on a metal sheet. Soil should be spread uniformly, not exceeding 8.0 cm in thickness. Water should be sprinkled occasionally and the soil should be stirred constantly. The steam by heating moist soil, kills the eelworm population. The soil should be heated between 60°c. Below 60°c. eelworm will not be killed and above 80°c the solubility of manganese increases and high amounts of mangenese will be released into available form, leading to mangenese toxicity. A simple but effective test, to see whether the desirable temperature is obtained, is to hold the soil in the hand, the soil should be just not enough and cannot be held in the hand for long.

(C) Preparation of sleeves:

Polythene sleeves of 150 gauge or 200 gauge may be used in the nursery. It is desirable to use a 10 cm lay-flat polythene tube of 30-45 cm length. The lower three-fourths of the sleeves may be filled with jungle top soil mixed with appropriate proportions of sand to make it a sandy loam. The top one-fourth portion of the sleeve should be filled with the rooting medium. Too much campaction of soil in the sleeves should be avoided.

Sleeves filled with soil may be staked in rows in a bed. In a square metre there will be approximately 225 filled polythene sleeves. They could be held together by supports of bamboo.

An arched frame of about 75 cm height should be made over the bed. Such a frame can be made with bamboo reeds or thin iron rods.

(D) Shade:

When the cuttings are raised under a polythene sleeve

be raised on which a coir mat with 6 mm mesh may be spread. During drought periods another layer of coir mat may be a spread over the first mat or some plant material may be spread uniformly. The idea is to allow about 33% sunlight at midday into the nursery, which is about ideal.

(E) Mother bush and its treatment: - up to 30 or 40 years old.

The mother bush should be treated in the following way:

(i) 3-4 months prior to taking the cuttings prune the bush at 18-24" height.
(ii) 2-3 weeks prior to taking the cuttings pinch off the terminal buds. This initiates the axillary buds to sprout.
(iii) 3 weeks prior to taking the cuttings spray the plant with 1% $ZnSO_4$ (50-100 ml/bush).
(iv) Spray 1% urea 14 and 7 days prior to taking the cuttings.
(v) While taking cuttings, each time apply 30-60 gm of 60:90 NK mixture/plant.

(F) Preparation of cuttings: 13,500 plants / ha
10% mortality not good.

Harvested shoots should be transported from the field to the nursery, with the bottom cut ends dipped in a bucket of water and covered above with some fresh green plant material.

Apical tender portion and the bottom brown wood portion of the shoot may be discarded. Green, semi-hard wood, with one leaf cuttings consisting of one full leaf and an internede should be taken with a sharp knife without injuring the bark or causing jagged cuts. The cut should be planted away from and as close as possible to the axillary bud. After each cut, the cut end of the shoot should be dipped in water. The separated cuttings should be immersed in a bucket of water.

Have nursery close to the planting site - i.e. < 10 km

...7...

(G) Planting of cuttings:

The polythene sleeves ready to receive the cuttings should be watered thoroughly in the evening prior to putting out cuttings. Planting of cuttings should start as soon as possible after the cuttings have been taken. Planting is an important operation and should be done carefully without damaging the barkd and the cut end. Holes may be punched in the soil with a small stick of approximate thickness of the cutting and then the cuttings may be inserted. The node and the potiole should not be buried or touch the soil. The soil around each cutting should then be firmly pressed to avoid air pockets. A light watering should be given immediately after planting. Soon after watering the polythene cleche should be placed over the frame work and the ends sealed without any leak on all the sides.

Cuttings may take 4-5 weeks for callusing and 10-12 weeks for rooting during favourable seasons and longer during other periods. After about 50 days (when all the cuttings have rooted) the cloche is gradually removed.

(H) Manuring:

After the tent is removed, the cuttings may be sorted and restaked and the application of soluble nursery fertilizer mixture may be commenced.

Composition of Soluble Nursery Fertilizer Mixture:

ammonium sulphate
No urea

Ammonium Sulphate	:	8 parts by weight (20.6% N)
Ammonium Phosphate	:	35 parts by weight (16% N + 20% P2O5)
Potassium Sulphate	:	15 parts by weight (40% K2O)
Magnesium Sulphate	:	15 parts by weight (24% MgO)
Zinc Sulphate	:	3 parts by weight

30 gm of the above mixture may be dissolved in 10 litres of water and then spray the litres over 4 sq.m. of the bed once in two weeks.

maintain pH = 4-5 in plantation

(I) Hardening the cuttings:

The young plants of 4-6 months could be hardened by removing the shade gradually in stages over a period of 4-6 weeks, removing the shade for a few hours every day and extending the time of exposure gradually.

NURSERY MALADIES

(a) Zinc deficiency:

Yellowing, resette appearance and sickle shaped leaves are the general symptoms of zinc deficiency. For this spray Zinc Sulphate 100 gm, MnZO4 16 gm and Boric acid 6 gm in 10 litres of water. Spray 2 or 3 times at fortnightly intervals. Spraying may be done with a knapsack sprayer or bakpak sprayer, covering 2000-2500 plants with about 4.5 litres of spray fluid.

(b) Pests and diseases:

Usually pests and diseases are not a problem in the V.P. nursery. However, a close watch may be kept for pests like rats, aphis, caterpillers, white grubs, root mealy bugs, thrips, mits, etc.

For aphids and thrips spray with Thiodon or Zolone @ 20 ml in 10 litres of water.

Mites can be controlled with Kelthane or Zolone @ 20 ml in 10 litres of water.

The spraying against pests should be carried out in the evenings and the polythene cleche should be left open overnight on either sides. If this is not done, the fume emitted by the insecticides/fungicides will scorch the leaves.

Zinc –

Boron – [illegible]

Magnesium deficiency / – [illegible] – in sand.

...9...

(c) Falling off of mother leaves:

In a nursery, if all the mother leaves have fallen off, the reasons attributed to this are namely--

(i) Deep planting
(ii) Improper compaction of soil around the cuttings
(iii) Over watering, especially in clayey soils
(iv) Too much of shade during the monsoon
(v) Improper application of pesticides/fungicides.

(d) Presence of shoot growth but no root growth:

If only shoot growth and no root growth is noticed in a nursery, it is due to the fact that the shade provided is inadequate.

80% success

It is likely to take about 18 months to raise tea plants by this technique, suitable for planting out in the field. The period of 16 months is the outer limit and plants about 45 cm tall with the root growth of 30 cm may become available in small proportions as early as 6 months in a specially conducive combination of factors.

Zinc added

3-1 kg/ha/yr — noticed

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VRC/sr/-4.5.91.

Appendix. 9

PEST MANAGEMENT IN TREE CROP NURSERIES*

Dr.C.C. ABRAHAM**

Protection of tree crop nurseries against pests is an important aspect of agroforestry management. In India climatic conditions range from typical temperate in Northern Himalayas to tropical humid warm in the Southern peninsula and naturally the pest problems in tree nurseries show considerable variations in time and space. Detailed studies on the pests of seedlings raised in the forest/agroforestry nurseries have not been carried out in the country and only very little information is available on the phenology and control of the major pests.

Defoliators

Among the defoliator pests occurring in the teak nurseries, the teak defoliator, Hyblaea purea (Lepidoptera : Hyblaeidae) and the Teak skeletoniser Eutectona macheralis (Lepidoptera : Pyraustidae) are relatively more important. Larvae of the former feed on the entire leaves leaving only the major veins, while, those of the latter feed only on the green matter leaving all the veins intact. Younger leaves are more preferred by the defoliator, while, the skeletoniser feeds mostly on older leaves. Heavy defoliations begin sporadically during the pre-monsoon season and then spread rapidly.

*Notes on the lecture given on 9-5-91 in the Indo-US Workshop cum Training on Tree Nursery Technology and Management held in the College of Forestry, 6-18 May, 1991.

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Looking into phenomena

Recommendations for managing teak defoliators have emphasised the retention of natural forests between plantations and encouraging selected understorey vegetation within the plantations to serve as refuge for parasitoids. Biological control by the utilisation of pathogenic bacteria and the nuclear polyhedrosis virus will be the most ideal method to reduce the population loads of the defoliator pest in teak trees below the economic threshold levels.

For the protection of teak nurseries, it is necessary to ensure reduction in the local population loads to the maximum extent. Thorough application of quinalphos 0.05% or endosulfan at 0.05% during May to the nursery plants will provide good protection against the defoliator larvae for 2-3 weeks. For the protection of the nurseries, application of Neem Kernel Suspension at 0.3% to 0.5% is likely to be very promising to confer feeding deterrency against the larvae. The triterpenoids occurring in the Kernels of the Indian neem tree Azadirachta indica and the China berry Melia azedarch possess excellent feeding deterrency against several lepidopterous larvae.

In Paraserianthus (Albizzia) falcatoria nurseries, open feeders such as larvae of the pierid moth, Eurema blanda silhetana as well as the tortricid, Archips micaceanus and Adoxophyes moderatana have been found to be the important pests. The larvae of these pests also occur on freshly planted

saplings of Paraserianthus. In Kerala, larvae of Lymantria ampla (Lymantridae) and Archips micaceanus (Totricidae) have been recorded to feed on the foliage of Eucalyptus seedlings in the nurseries. The latter is also recorded on Acasia nilotica, Albizzia procera, Cassia fistula and Tectona grandis.

Root and collar feeding insects

White grubs, termites and cutworms cause very serious damage to tree crop nurseries in India. Holotrichia consanguinea and H. longipennis occur widely as sub terranean pests of tropical tree species. Hilyotrogus holosericea and Melolontha furcicauda are associated with coniferous trees mostly pines in temperate zones at higher elevations ranging from 1500-3000 m. The grubs feed on the roots of seedlings causing them to wither and dry up. White grubs have a prolonged life-cycle extending from one to two years. Peak populations of the grubs occur in April-May, particularly, after the receipt of the first pre-monsoon rains. Soil application of phorate 10% granules at 2.0 kg ai/ha in the nursery beds and raking them into soil by gentle forking once in April-May after the rains and again after the cessation of the monsoon will control the white grubs infesting the nursery.

Subterranean Termites (Odontotermes spp.) are the most serious pests of nurseries of many trees including Eucalyptus sp. On Eucalyptus spp. termite attack is usually concentrated on

the tap root just below the collar region and the damage causes seedling mortality. Infestation is severe in the nurseries and also in freshly planted saplings.

Against termites prophylactic measures should receive greater emphasis than curative methods. Drenching the container soil with suspensions of aldrin/chlordane/heptachlor soon after the seedlings establishment is the most economic and effective method of ensuring protection against the termites. For prophylactic treatment, a dosage rate of 0.12 g ai per container is required. One litre of aldrin 30 EC or 1.50 litres of heptachlor 20 EC per lot of 2,500 container seedlings (required for 1 ha) will give a terminal dose of 0.12 g ai/ container. For drenching one container, about 50 ml water will be needed. Drenching is to be carried out with a rose can, applying the liquid in 2-3 consecutive instalments to cover the entire lot of container seedlings.

Sap feeders

Psyllids have been recorded in *Pterocarpus marsupium* nurseries during the month of June-July. These can be controlled by application of endosulfan at 0.05%. On *Lagestromia microcampa* nurseries, infestation by mites have been found to be moderately severe during the summer months. For controlling mites, Dicofol (Kelthane) and sulphur preparations such as Sulfex are very effective.

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Appendix 10

Tree disease management in India

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Forest trees are affected by several diseases caused by plant pathogens like fungi, bacteria, viruses and mycoplasma like organisms both in nursery as well as in plantations. The methods of management adopted in agricultural crops cannot be applied ~~on soil~~ as such for forest diseases for obvious reasons. However nursery disease management consists of many integrated methods similar to agricultural crops. In forest trees, introduction of new pathogens either from other states or other countries should be carefully avoided by adopting domestic and foreign plant quarantine. Diseases like sandal spike seriously threaten the tree and so far no economic method of management is available.

I. Nursery diseases :

1. Damping off : It is the most serious of all nursery diseases of forest tree seedlings. It reduces the number of seedlings and consequently upsets the planting programme.

Symptoms : In pre-emergence damping off the seed and seedlings die prior to the emergence. Post-emergence damping off refers to infection on the lower part of the stem, on the roots or on both, in the first few weeks after the plants emerge from the soil. The stem loses its ~~farmers~~ firmness and cannot support the seedlings above it, and the seedling falls over on the soil. Late damping off occurs if infection of new succulent portions of roots occurs after lignification of stems and roots is initiated. Usually this type of infection is not fatal.

Causal agents : This disease is caused by a number of fungi, like *Pythium*, *Phytophthora*, *Fusarium* and *Rhizoctonia* in different forest tree seedlings (Table 1).

Management : Heavy soils should be avoided or a sand and organic matter should be mixed in such soils. Nursery should be located in well drained site without overhead shade. Watering

should be done to the minimum extent necessary while germination is taking place and in the early stage of seedlings growth.

Adopt shallow sowing to a depth of about 0.7 cm.

Avoid dense sowing and high seedling population per unit area.

The nursery plots may be covered with polyethylene sheets for 55 days (soil solarization).

Trichoderma harziamum spores impregnated clay granules were effective as a biocontrol agent for Phytophthora Cinnamomi causing damping off in pine seedlings. The seeds can be pelleted with 50 ml spore suspension of Trichoderma (10^6/ml) + 8 ml rice gruel for one kg of seeds, shade dried before sowing. This affords two-pronged protection against seed borne - pathogens and prevent infection by soil-borne pathogens because the biocontrol fungus grows in the foot surface and provides a shield along the root surface. In addition to disease control Trichoderma also has a growth promoting effect. It has been estimated that 20% of the production potential of plants are wasted to neutralise unfavourable soil micro-organisms and their toxins. When Trichoderma takes up this job, the entire energy of the plant is utilised for its own growth.

In pine, Rhizoctoria solani can be managed by applying spores of Streptomyces hygroscopicus var. incances and Bacillus subtilis, T. viride and saw dust 20 days before sowing. The nursery soil can be sterilised by applying 250 ml formalin diluted to 4 l/sq.m. 2 weeks before sowing.

Captan, Thiram or Cuman (25 g/sq.m.) may be broadcast and raked into the top 15 cm of soil one day before sowing. This is effective for conifers with epigeal germination. For other seeds with hypogeal germination seeds may be treated with captan or thiram at 2g/kg one day before sowing. Spruce seedlings may be drenched with 0.2% Blitox. C. equisetifolia may be drenched with 0.05% vitavax or 0.1%emisan in nurseries.

2. Web blight : Rhizoctonia solani

Hosts : Melia azedirach, Azadirachta indica, Cassia nodosa, Ceiba pentandra, Albizia falcataria and Eucalyptus

Symptoms : Web of mycelium entangles a group of seedlings. Infected leaves are held together by the fungus hyphae presenting a cob-web appearance.

Management : Avoid dense sowing of seed. Remove infected seedlings as soon as the disease appears in the bed. Raise seedlings in polypots instead of beds. Drench soil with 0.1% Bavistin a week before sowing and at weekly interval.

3. Bacterial wilt : Pseudomonas solanacearum

Host : Casuarina equisetolia

Sudden wilt and shrivelling of leaves. Root tissue of wilted plants show brown discoloration.

Chir pine (Pinur roxburghii)

Fusarium sp.

Needles in the growing shoots become flaccid, droop down and finally dry up. The drying they advances.

II Foliar diseases

1. Powdery mildew

Teak : Phyllactinia guttata, Uncinula tectonae

Eucalyputs : Oidium eucalypti

Hawthorn : Podosphaera oxycanthae

Hazel : Phyllactinia corylea

Lilac : Oidium spp.

Maple : Uncinula aceris

Oak : Microsphaera alphitoides

Willow; Uncinula salicis

Symptoms : White, powdery coating appears on the lower surface of leaves. Defoliation is common at later stage.

2. Rusts : Rusts attack nurseries and plantation and cause leaf pustules, stem gall and canker.

Delbergia sissoo

i. Uredo sissoo - Minute, scattered uredosori appear during October - April on the upper

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surface of leaflets. Severely rusted leaflets turn yellow and drop prematurely.

2. Maravalia achora : Leaves and juvenile twigs are attacked and killed resulting in dieback and subsequent death of seedlings. Uredosori are formed on the lower surface of leaves.

Teak : Olivea tectonae : It occurs during October - February. Uredia and telia are orange yellow and occur on the lower surface of leaf, and almost plaster the same. The upper surface of leaf exhibit paling.

Albizzia lebbeck : Ravenelia japonica
It occurs during June to October.
Seedlings are deformed, crumpled and die subsequently.

Eucalyptus : Puccinia psidii : It attacks foliage and young twigs of 3-12 months old seedlings resulting in defoliation and death.

Bamboo (Dendrocalamus strictus) : Dasturella divina
It affects seedlings in nursery ~~the seedlings.~~

Management : Spray 0.1% Bavistin or 0.5% wettable sulphur at 20 days interval in nursery. Provide adequate sunlight and aeration. Fallen leaves should be collected and burnt. Infected plant parts should be pruned and destroyed.

III. Leaf blights and spots

1. Needle blight of Chir pine : Cercoseptoria pini densiflorae
It occurs in Orissa, Bengal, Andhrapradesh and Bihar. First manifests on lower needles and slowly spreads upwards during monsoon season. Pale green lesions first appear which turn yellow brown at later stage. Diseased needles dry and curl around the stem.

Management : Spray 0.2% Dithane M-45 or 0.1% Calixin at 20 days intervals from the onset of mansoon.

2. Leaf spot of poplar : Cladosporidum humile
It causes premature defoliation.

Management : Spray 0.2% Dithane M-45.

3. Seedling blight and stem canker of Casuarina equisetifolia : Rhizoctonia solani

Symptom : It affects 2-3 month old seedlings. Small necrotic lesions measuring 2-5 mm are produced in stem. Later the infected areas develop into sunken canker. Under high humid condition, disease spreads to foliage causing blight. The pathogen also causes root rot. Leaves turn yellow. The roots decay leading to death of seedlings.

Management : Apply vitavax 0.05% in nurseries

~~Leaf spot of Ceibu pentandra : Corynespora cassicola Dithane M-45 effective.~~

4. Leaf blight and die back of Eucalyptus : Macrophomina phaseolina

Symptoms : The tender leaves become black, necrotic and curly.

Management : Drench with 0.1% carbendazim, thiabendazole or Topsin both as protective and eradicant.

5. Seedling wilt of Albizia falcataria : Fusarium solani

Symptoms : It occurs in March - April. Lower leaves turn brown and are shed. Seedlings are stunted in growth with only 1-2 leaves remaining at the apex. Root show prominent discoloration. Seedlings die within one month.

Management : Drench with 0.1% Bavistin.

6. Leaf spot of Dalbergia latifolia : Physalospora dalbergiae

Symptoms : Leaves of all ages are susceptible. It occurs during September, October as conspicuous amphigenous necrotic spots. Later black, shiny dot like ascomata develop in groups on the upper surface of the leaf.

Management : Spray 0.2% Dithane M-45, or Capton or Fytolan.

7. Colletotrichum leaf spot of Dalbergia latifolia : C. gloeosporioides

Symptoms : It occurs during July-September. Circular brown spots appear, coalesce forming large irregular reddish brown patches, mostly along the margin and tip of the leaf. Necrotic tissue sheds leaving shot-holes in the lamina.

Management : Spray 0.2% Fytolan or Dithane M-45

8. Collar rot of Bombax ceiba : Rhizoctonia solani

Symptoms : Small water soaked lesions appear on the hypocotyl. They turn brown and later gets decayed. Seedlings collapse from the decayed portion and dies.

Management : Drench the soil with 0.1% Emisan at an interval of 10 days.

9. Leaf blight of Bombax ceiba : Corticium rolfsii

Symptom : Small brownish yellow spots appear in cancentric rings on the leaflets. They coalesce covering the entire leaf and even the petioles. Because of rotting of petioles, such leaves bend downwards and dry. The disease spreads through contact with diseased leaves.

Management : Two foliar sprays of 0.1% Emisan at weekly interval.

Stem Diseases :

Stem wilt of Casuarina equisetifolia : Trichosporium vesiculosum

Symptoms : Bark of affected stem peels away from wood. A thick black coating of powdery spore mass occur on the stem surface. The branches wilt. Young trees 1-3 years old are severely affected. It spreads through root contact as well as pruning and topping injuries.

Management : Isolate infected plants by a trench. While lopping branches, give a clean cut. Remove infected plants.

Root disease

Root rot of Agave sisalana - Rhizosphaera olivaceonigra

Symptoms : Leaves turn yellow and dry. Roots decay. Plants die in patches. This was observed in Anamalais of Tamil Nadu in 1986.

Management : Spot drenching with 0.1% Emison.

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Table 1.

Tree Species	Causal Organism
Abies pindrow	*Pythium* spp., *Fusarium avenaceum*
Acacia catechu	*Ganoderma lucidens*
A. koa	*F. oxysporum* f. sp. *koae*
A. nilotica	*Macrophomina phaseolina*
Albizia falcataria	*F. solani*
Anacardium occidentale	*Cylindrocladium camelliae*, *Gibberella baccata*, *Phytophthora palmivora*, *Pythium spinosum*
Araucaria augstifolia	*C. clavatum*
Azadirachta indica	*F. solani*
Bombax ceiba	*Rhizoctonia solani*
Casuarina equisetifolia	*M. phaseolina*, *Pseudomonas solanacearum*, *R. solani*
Eucalyptus spp.	*Cylindrocladium* spp., *F. oxysporum*, *Pythium* spp. *R. solani*, *Sclerotium rolfsii*
Gmelaina arborea	*S. rolfsii*
Picea smithiana	*Pythium* spp., *Rhizoctonia* spp.
Pinus caribbae	*M. phaseolina*
P. roxburghii	*Fusarium* spp.
Santalum album	*Pythium* spp.
Sweitenia	*Macrophylla Cylindrocladium* spp. *S. rolfsii*
Tectona grandis	*S. rolfsii*
Dalbergia [illegible]	[illegible]

Sandal Spike - Mycoplasma like organism (MLO)

Symptoms :

The new leaves and shoots of a spiked tree become stiff and erect like bristles. The internode becomes shorter, leaves become smaller narrower and more pointed and give an appearance of spikes. Spiked branches do not produce flower or fruits. Disease may appear in the beginning in one or two branches and later spread to other branches, finally tree dies in one or two years. The colour of spiked leaves become pala bluish green which changes to reddish brown. Roots show decay.

Vector - *Redarator bimaculatus*

Management :

1. Remove and destory the spiked sandal trees.
2. Selection of host plants like casuarina, Eucalyptus, *Cassia siamea*, *Azadirachta indica*.

Teak

Disease	Causal organism	Symptoms	Control
1. Wilt	Pseudomonas solanacearum	In the leaf, small brown coloured patches appear between the veins, sometimes spreading to give it a scorched appearance, followed by wilting of leaves and the plant. Discolouration of vascular tissues occurs in the roots.	1. Suitable site should be selected for nurseries with good drainage. 2. Nursery beds should be treated with formalin, about 2 weeks prior to planting.
2. Root rot	Helicobasidium compactum	Decline of the foliage, production of sprouts followed by death of the plant	1. Suitable site should be selected for nurseries with good drainag 2. The spread of the disease may be arrested by making trenches to isolate diseased patches.
3. Root rot	Peniophora rhizomorpho-sulphurea	The fungus attacks only the spawood in which it causes yellow fibrous rot. Yellow mycelial mat of the fungus develops in the decayed wood. Affected trees become wind-blown due to decayed roots losing foothold in the soil.	--
4. Root rot	Polyporus zonalis	It causes root and bult rot. Decay of roots and butt results in wind throw of trees.	1. Healthy stumps should be selected for planting. 2. Freedom from injury to trees is essential.
5. Pink disease	Corticium salmonicolor	Infected young branches may be killed outright, while infection in older branches results in the formation of cankers and longitudinal bark-cracking.	--

Disease	Causal organism	Symptoms	Control
6. Stem canker	Nectria haematococca	Cankers appear as slightly sunken bark fissures upto 40cm long, mostly located at or near the ground level, accompanied by a slight flow of reddish sap. Removal of bark exhibits pink stain in the underlying wood. Trees die from top downwards, leaves, turn yellow and are shed off prematurely.	--
7. Leaf spot	Cercospora tectonae	Dull-brown to grayish-brown or white angular spots appear on teak leaves. Spots coalesce into large blotches	--
8. Powdery mildew	Uncinula tectonae	The infected leaves are coated with a dull white mycelium lotted with black fruiting bodies, presenting a bluish-gray mealy appearance. Heavily infected leaves are shed	--
9. Leaf rust	Olivea tectonae	Orange-yellow coloured pustules occur on the lower surface of the leaf. The corresponding upper surface of the leaves may present a gray appearance due to the formation of flecks. It causes premature defoliation.	Nursery - application of sulphur-based fungicidal spray Plantation - opening the canopy

2. Casuarina

Disease	Causal organism	Symptoms	Control
1. Stem wilt	Trichosporium vesiculosum	In the infected trees, the needles become pale and dry up. Blisters develop on the bark which eventually rupture in the form of flakes and the black powdery mass of spores, appearing like charcoal dust, becomes exposed.	1. The spread of the disease can be checked by trenching diseased trees. 2. Illicit lopping and pruning of branches should be stopped.

3. Sal (Shorea robusta)

Disease	Causal organism	Symptoms	Control
1. Root rot	Polyporus shoreae	The affected trees show symptoms of top-drying. Such trees become wind-blown because they loose foothold in soil due to decay of roots. In some cases, the trees may put forth epicormic branches. Small, light yellow mycelial felts of the fungus develop on bark of roots.	1. The dead trees and also trees in advanced stages of the disease should be removed.
2. Leaf spot	Cercospora sp.	Gray-coloured necrotic spots appear on leaves. The necrotic regions fall off after the rains producing a shot hole symptom.	
3. Heart rot	Fomes caryophylli	In incipient stage of decay, the wood is stained dark brown. In advanced stage, white rot is produced and wood becomes spongy. Yellow mycelial mat may develop in decayed wood. Decay may also occur as circular rings associated with punk knots which arise at different depths of the wood and open up in the bark as 'eyes' or pox-marks.	

4. Khair (*Acacia catechu*)

Disease	Causal organism	Symptoms	Control
1. Root rot	*Ganoderma lucidum*	The pathogen attacks and kills the bark and causes spongy rot in the sap wood. Affected plants exhibit pale foliage which eventually dries up. Young plants are killed soon after infection and mature trees are killed when most of the roots become affected.	The lateral spread of the disease can be chcked by digging isolation trenche
2. Heart rot	*Fomes badius*	The fungus causes decay in the heart wood only. The colour of the heartwood changes to a deeper shade. In advanced decay, heart wood becomes yellow, spongy and light and presents a mottled appearance due to formation of long, black, indistinct streaks and zone lines. Sporophores develop at different heights on the tree.	1. Freedom from injuries to trees due to animal is essential. 2. The sporophores should be removed and destroyed systematically.
3. Powdery leaf spot	*Microstroma acaciae*	The pathogen produces showy-white tufts on lower surface of leaves	--

5. *Albizia*

1. Pit canker	*Fusarium solani* f. *albizziae*	It causes grayish black cankers on 15-20 year old trees. The canker may extended 2-4m on the stem. In severe infections, the canker may almost girdle the stem resulting in drying up of the crown. The trees may snap at the region of the canker.	--

Disease	Causal organism	Symptoms	Control
2. Leaf spot	*Cercospora albiziae*	Spots occur on both sides of leaves. Spots are brownish to whitish gray in the centre surrounded by narrow, brown to blackish ring. Later, the centre of the spots gives a deep grayish powdery appearance.	--
3. Leaf rust	*Ravenelia japonica*	It produces dark brown rust pustules occurring solitary or in groups on both surfaces of leaflets and pods. Seedlings when heavily attacked are deformed, crumpled and may die subsequently.	--

Appendix · 11

KERALA AGRICULTURAL UNIVERSITY
COLLEGE OF FORESTRY

EARLY HISTORY OF TEAK PLANTING IN NILAMBOOR

In 1750 England faced a shortage of timber supplies especially for ship building for military and navigational purposes, due to the depletion of its oak forests. To ensure uninterrupted timber availability, the East India Company and the Government of British India initiated a number of steps.

1. A timber syndicate was formed in Malabar with Mr. Maconochil as its head.

2. In 1805, the Court of Directors of the East India Company enquired to the Government of Bombay to report as to what extent the Royal Navy might depend on a permanent supply of teak in Malabar. This enquiry resulted in the constitution of a Forest Committee charged with a comprehensive programme of enquiry both into the capacity of forests and into the proprietary rights in them.

3. On 10th November, 1806, Cap. Watson was appointed as the first Conservator of India to ensure sustained supply of teak and other timber suitable for ship building.

4. On April 25, 1807, a general proclamation was issued declaring royalty rights in teak.

5. The Conservator, who was in charge of Malabar and Travancore, soon established a Timber Monopoly and supplied the Government with a plentiful supply of cheap timber. However, the Conservatorship was abolished in 1823, probably due to the hurt feelings of the proprietors and contractors on account of the harsh methods adopted by him.

6. In 1842, the Court of Directors suggested improvements of forests by the formation of teak plantations. This work was initiated by the then Collector of Malabar, Mr. H.V. Conolly. However, before this, in 1840, the Govt. acquired on lease from Thrikkaliyoor Devaswam an area of about 20 sq. miles of forest.

In the initial stages the technique of establishing teak plantations were not known. To get the teak seeds germinated itself was very difficult. The work of sowing and transplanting was started during monsoon period of 1842. However, the first attempt was a total failure. As a result,

Mr. Smith, who was in charge of the programme was fired from the job by Conolly. Sergeant Graham who succeeded Mr. Smith resigned in disgust. The whole responsibility now fell on Shri. Chathu Menon, sub-conservator at that time. He with the help of Mr. Bates, the Head Accountant of the Collector's office managed to get a number of teak seedlings raised in 1844. The planting was carried out with better success at Nilamboor. The great success of teak plantations in India must be attributed to the hard work and dedication of M/s. Conolly and Chathu Menon. By 1876, 1255 ha of teak plantations came into being in Nilamboor.

The idea of planting teak in old Travancore was originated by Diwan Raja Sir T. Madhava Rao. Accordingly teak was first planted at Vemburam in Malayattoor on 13th of May, 1865.

Planting of teak in Ariencavu was started in 1888-90. The system of planting 4 month old seedlings from nurseries raised in dry season was given up and one year old seedlings were outplanted in the following year. This continued until 1891, when Bourdillon found that the seedlings were too big and so he stumped them and planted at a distance of 1.5x1.5 m in Ariencavu. This plot is maintained even now as a Permanent Preservation Plot.

PROGRAMME FOR NILAMBOOR VISIT ON 10.5.1991

07.30	- -	Departure Vellanikkara
08.30	- 09.00	Visit Social Forestry Nursery at Viyyoor
11.00	-	Arrival at Nilamboor (en route visit local nurseries)
11.00	- 13.00	Visit Nedumkayam Teak Nursery, Elephant Camp etc.
13.00	- 13.30	LUNCH
13.30	- 14.00	Discussion with Nilamboor South DFO regarding forestry operations in his Division
14.00	- 14.40	Visit Conolly's plot
14.40	- 18.00	Visit KFRI Field Station, Teak planting at Valluvassery, Chathu Menon's permanent preservation plot etc.
18.00	-	return to Vellanikkara.

Appendix 12

NURSERY MANAGEMENT WORKSHOP

MAY 6, 1991 -- 11:30 - 12:00

REFORESTATION AND AGROFORESTRY: IN OREGON a discussion

INTRODUCTION/ BACKGROUND: R. Rose - Overview of World Reforestation.

REGENERATION IN AGROFORESTRY

What are the characteristics of Agroforestry - and seedlings needed for agroforestry? Why should agroforestry seedlings be different and what are the similarities to plantation forestry?

1. OUTPLANTING CONDITIONS

small scale
non-plantation spacing
competitive environment
potential for more tending/ irrigation, weeding
potential for induced competition from planted crop

2. TREE SPECIES: diverse species -
multipurpose species
Many introduced species - exotics - So, relativly little maybe known about their behavior in a new locale.

3. FARMERS: farmers are experienced with crops, perhaps not with trees.

4. OTHER:

What implications does the above cited information have for growing seedlings that can be successful outplanted?

5. SEEDLING CHARACTERISTICS:

size - appropriate for outplanting conditions-
tall - to escape browsing.

vigorous - to get a good start

dormant - to avoid stresses in handling.

other -

6. CONCLUSIONS:

Appendix 12-A

Dr W.H. Emmingham

MAY 13, 1991 - 11:00 - 12:00 USING THE LEAF AREA METER

I. INTRODUCTION / BACKGROUND

Importance of leaves: small but critical component of plants.

plant structure - function -

plant leaf dynamics - sun leaves - vs shade leaves

Leaf area and leaf shape - cross sectional areas

specific leaf weight - weight/ unit area

II. MEASURES OF LEAF AREA:

PROJECTED (ONE SIDE) LEAF AREA

TOTAL LEAF AREA - the whole surface

LEAF AREA INDEX - canopy

SAPWOOD - LEAF AREA RELATIONSHIPS

PERCENT COVER -

III. What are these measures good for:

general relationship - more leaves are better

sun-shade leaf interactions

IV. LEAF AREA METERS: and how they work

expected accuracy - projected leaf area

V. Demonstration-

VI. Interpreting the Results:

VII. Summary

Appendix 12-B

MEASUREMENT OF CANOPY TRANSMITTANCE TO ESTIMATE LEAF AREA INDEX

Objective: To estimate leaf area index of a plant canopy using light measurements.

I. Background

Plants absorb light for photosynthesis in the visible wavelengths (400-700 nm) of the light spectrum. Photosynthetically active radiation (PAR) can be measured with light sensors which are sensitive to these wavelengths. PAR intercepted by the canopy can be used in models to estimate leaf area index.

Light is either absorbed, transmitted, or reflected. Reflectance from forest canopies is typically 5 - 12 % of incident radiation, most of which is in the infrared portion of the spectrum. Plants absorb strongly in the blue and red portions of the visible wavelengths, and reflect and transmit in the green portion of the visible, thus appearing to have "green" leaves.

II. Measurements

A. Canopy transmittance (the amount of light transmitted through the canopy) is sampled with single or multiple light sensors on an array (e.g. Decagon Devices, Inc. Ceptometer, which has 80 photon sensors on a 1 meter rod). Measurements are taken:

1) above the canopy (in the case of low vegetation) or in a near-by opening, such as a large clearcut to estimate incident radiation, and

2) below the canopy, over the sample plot. A grid pattern of sampling, or transects across the forest is recommended. A large number of samples are necessary for stands of larger trees, and open stands, to reduce sampling variability due to canopy gaps.

The incident PAR measurements would be ideally taken simultaneously with the below canopy readings. If this isn't possible, measure incident PAR immediately before and after each transect or plot.

Measurements are taken as close to solar noon as possible (1000 to 1400 h), in order to ratio the above and below canopy measurements with a minimum of side lighting.

The best weather conditions are a high, light overcast. Sampling should not be conducted during cloudy weather.

III. Estimation of LAI from PAR intercepted by the canopy

Canopy transmittance (Q_i/Q_o) for each transect or plot is calculated by dividing the average below-canopy PAR (Q_i) by average total incident PAR (Q_o). Leaf area index (LAI) can be approximated by the Beer-Lambert Law:

$$LAI = -\ln(Q_i/Q_o)/k$$

LAI = projected LAI
k = light extinction coefficient

The extinction coefficient (attenuation of light with distance from the top of the canopy) is difficult to calculate independent of LAI, because it is a function of canopy structure, and sun angle (Pierce and Running 1988). The range of extinction coefficients is 0.40-0.65 for conifers, and 0.29-0.57 for broad-leaved trees (Jarvis and Leverenz 1983). The Beer-Lambert Law assumptions are that leaf inclination angles are spherical (like a faceted "disco" ceiling ball), and randomly distributed.

More complex models are available for estimation of LAI from light measurements, for different leaf angle distributions, discontinuous canopies, and use in agricultural crops (Campbell 1986, Lang and Xiang 1986).

References

Campbell, G.S. 1986. Extinction coefficients for radiation in plant canopies calculated using an ellipsoidal inclination angle distribution. Agric. For. Meteorol. 36:317-321.

Jarvis, P.G., and J.W. Leverenz. 1983. Productivity of temperate, deciduous and evergreen forests. Ch. 8. in Physiological Plant Ecology, IV. O.L. Lange, P.S. Nobel, C.B. Osmond, and H. Ziegler, eds. Encyclopeadia of Plant Physiology, Vol. 12D. Springer, Berlin.

Lang, A.R.G., and Y. Xiang. 1986. Estimation of leaf area index from transmission of direct sunlight in discontinuous canopies. Agric. For. Meteorol. 37:229-243.

Marshall, J.D., and R.H. Waring. 1986. Comparison of methods of estimating leaf area index in old-growth Douglas-fir. Ecology 67(4):975-979.

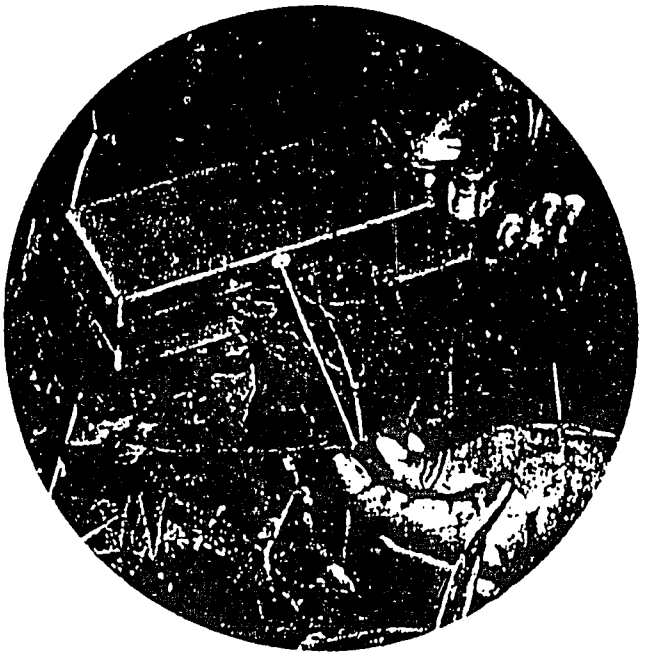
Pierce, L.L., and S.W. Running. 1988. Rapid estimation of coniferous forest leaf area index using a portable integrating radiometer. Ecology 69(6):1762-1767.

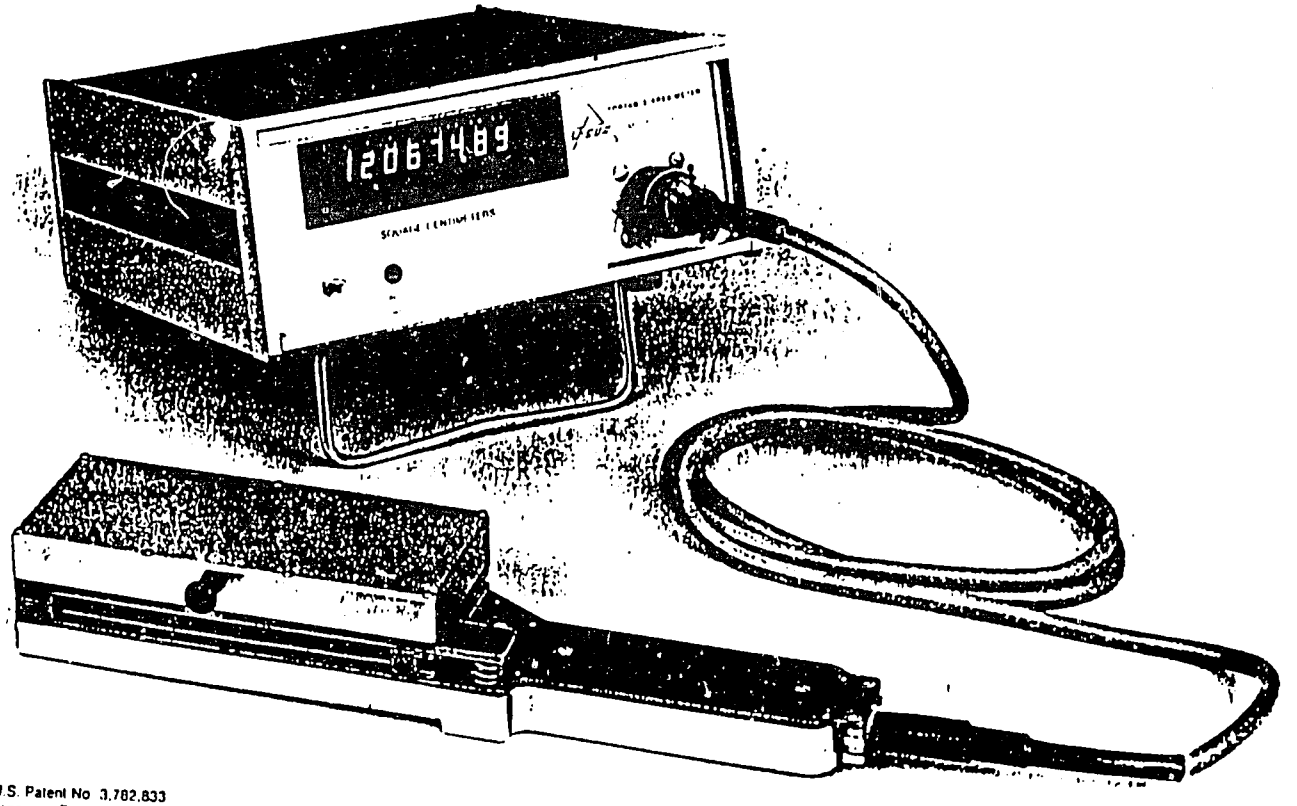
Appendix 12-C

LI-3000

Portable Area Meter

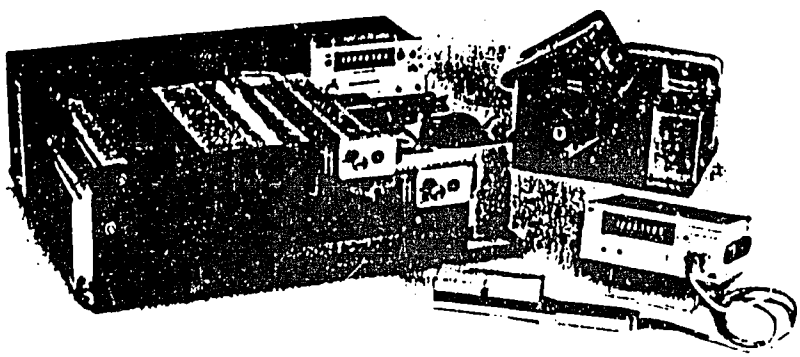
*Leaf Area of **Living** Plants or Detached Leaves in the Field or Laboratory*





U.S. Patent No 3,782,833
Japanese Patent No 960,011
Australian Patent No 54,433

AREA METERS



Precise Automatic Area Measurement

LI-COR Area Meters are specially designed to meet your requirements for precise and automatic area measurements. As a result, they have become standard equipment to many phases of plant and biological research. Time and guesswork using area approximation techniques is completely eliminated. This means work that used to take hours, now takes only minutes — with precision results.

Area Measurement Applications

PLANT SCIENCE

- Correlations between plant growth and environmental conditions
- Leaf area index (LAI) studies
- Reduction in leaf area due to insects, drought, disease or air pollution
- Leaf area as it relates to crop yields
- Biomass studies

ELECTRONICS INDUSTRY

- Determination of precious metal requirements for printed circuit boards
- Substrate area of wafers

MEDICAL FIELD

- Area determination of portions of X-ray negatives
- Bacteria colony areas

GEOGRAPHY & HYDROLOGY

- Land and water area using aerial and contour maps

Automatic area measurement in the field was an impossibility until the advent of the LI-3000 Portable Area Meter. State-of-the-art electronic and optical design has been the foundation of the LI-3000's proven performance under demanding research requirements.

The LI-3100 Area Meter gives you the flexibility and accuracy you need for precise measurements of very small and large objects. Resolution of 0.1 mm^2 is provided for small samples, or widths up to 25 cm are measured with 1 mm^2 resolution.

LI-3000
Portable Area Meter

LI-3100
Area Meter

- Nondestructive leaf area measurement in the field
- 1 mm^2 resolution
- Accuracy within ±2%
- Measures over 500 living leaves per hour
- Accumulates 1 mm^2 to 999,999.99 cm^2
- Easy-to-read 8-digit display
- Lightweight for portability
- Internal rechargeable battery
- Precise measurement of perforated and irregular margin leaves
- Easily interchanged to a belt conveyor system for lab use (using LI-3050A)

The LI-3000 Portable Area Meter provides a non-destructive, precise method for monitoring crop canopy development or individual plant growth in the field and growth chamber. Leaf area reduction and recovery associated with conditions relating to insect infestation, drought, disease or air pollution can be evaluated by measuring the same plants throughout the season.

Leaf area development can be measured without damaging the plants. This allows precise plant growth evaluation throughout a growing season. Effects of diminishing the stand density that occur with sacrificial data collection techniques are eliminated.

Remaining area of insect-damaged leaves can be measured. Data can be collected from the same individual plants throughout a life cycle. In some cases a transparent sheath can be placed over severely damaged leaves to support the remaining tissue.

Measurements which involve large numbers of small harvested leaves can often be performed in the field by placing the leaves in a transparent sheath. This technique allows area data collection in the field before the detached leaves appreciably shrink or curl. For many experiments, the need to transport samples away from the plot site is eliminated.

Forest stand or urban foliage development can be recorded for purposes such as evaluating air pollution effects or pest damage. Nondestructive leaf area measurement facilitates many phases of orchard physiology research. The LI-3000's lightweight construction and long-life rechargeable battery (8 to 10 hours) provide extensive field use versatility.

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Open the scanning head and place it over the leaf. The length encoding knob is held stationary against some stable object, usually the stem at the base of the leaf.

Close the scanning head at the base of the leaf and reset the display using the reset button.

Draw the closed scanning head over the leaf, allowing the leaf apex to pass through completely. *Drawing speed need not be constant.*

THEORY OF OPERATION

The LI-3000 Portable Area Meter utilizes a state-of-the-art electronic method of rectangular approximation providing 1 mm² resolution. The major components are the *scanning head* and the *readout-control unit*. Area data is accumulated on the display of the readout-control unit as the scanning head is passed over a leaf.

Width Scanning

Object width is scanned by means of a flying spot which appears on a row of 128 narrow-band red light emitting diodes (LED's) located on 1 mm centers in the upper section of the scanning head. This electronic flying spot light source is located along a line 6.4 mm from the edge of the upper section, permitting measurement close to the base of the leaf.

The lower section of the scanning head contains a lens-photodiode system which responds to the LED light. When one or more LED's are masked by some object which passes through the scanning head, the width is measured (i.e. 3 LED's masked are sensed as 3 mm width). The LED's and associated digital circuitry provide measurements which are unaffected by leaf transmission properties or ambient light.

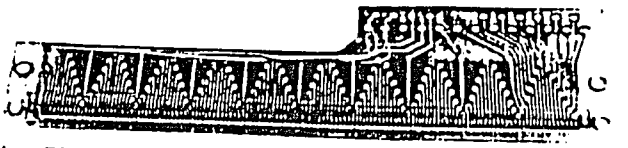
Scanning Cycles

As the scanning head is drawn away from the length encoding knob, the LED's are pulsed one at a time to produce the flying spot scan. A single scanning cycle consists of 128 individual 3.5 microsecond LED flashes progressing sequentially across the assembly. This scan occurs once for each millimeter travel of the length encoding cord.

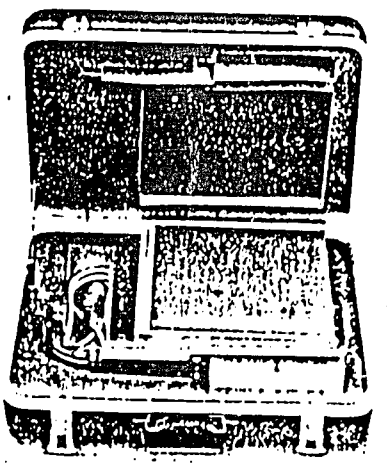
For example, if a 20 mm width x 100 mm length object is measured, 20 LED's will be masked for 100 scanning cycles resulting in a display of 20.00 cm². *Accuracy is unaffected by the scanning speed* (1 meter s⁻¹ maximum rate). An error light is displayed if the scanning head is drawn away from the length encoding knob in excess of 1 meter s⁻¹.

Area

The area is integrated and displayed as the scanning head is drawn over the leaf. Leaves with irregular margins or with holes, as in cases of insect damage, are correctly measured by the LI-3000. As the portion of leaf with the hole passes through the scanning head, the lens-photodiode system senses the LED light. That particular LED location does not contribute to the accumulating area until it is once again masked by a portion of leaf without a hole. The area data is presented on the display.



Light Emitting Diode Scanner (128 illuminated LED's in the foreground). This hybrid microcircuitry was developed by LI-COR as the scanning light source for the LI-3000 scanning head. Scanning head accuracy and durability is greatly enhanced by using this sophisticated solid-state light source circuitry. The LED's are mounted by LI-COR using high technology microelectronic die and wire-bonding techniques to insure high reliability and durability.



2003-3000 Carrying Case

This foam-lined case provides an excellent transport and storage means for the LI-3000 and is recommended as an accessory. Size: 33.0 W x 45.7 L x 17.8 cm D (13" x 18" x 7"). Weight: 2.5 kg (5.5 lbs)

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SECTION I
GENERAL INFORMATION

1.1. INSTRUMENT FUNCTION

1-1a. The LI-3100 Area Meter is designed for biological or industrial applications requiring rapid, precise projected area measurements. Samples are placed between the guides on the lower transparent belt and allowed to pass through the instrument. As items travel under the 15 watt fluorescent light source, the image is reflected by a system of three mirrors to a solid state scanning camera within the rear housing. The mirrors are mounted on the instrument base plate. Two are visible under the transparent belts. The third is within the rear housing.

1-1b. Object width is sensed by the scanning camera. Length information is provided by the current frequency as related to belt velocity.

1-1c. Area integration is accomplished by components of the main printed circuit board mounted within the rear housing on the instrument rear plate (figure 1).

1-1d. Data is presented on the light emitting diode (LED) display. Decimal location on the display is changed to suit the 1.0 or 0.1 mm^2 resolution requirement (Section IV).

1-2. INITIAL OPERATION PREPARATION

Prior to initial operating, all steps in Section II must be performed.

1-3. OPERATIONAL FEATURES

1-3a. An instrument with interchangeable 1.0 mm^2 and 0.1 mm^2 resolution capability is furnished with a 35 mm and 105 mm lens. A 25 cm wide sample guide is provided for the 1.0 mm^2 resolution configuration. The 7.5 cm wide sample guide is associated with the 0.1 mm^2 resolution capability.

1-3b. The upper belt assembly can be removed for operations hindered by the upper belt. Sample thickness can be increased then to 2.5 cm (Section VIII).

Ongoing Experiments in the Tissue Culture lab, College of Horticulture.

Cocoa

1. Improvement of cocoa through *in vitro* techniques.

Objectives: - To standardize the technique of *in vitro* multiplication of elite plants through axillary bud culture, to produce haploids through anther and flat bean culture and to produce somatic embryoids.

Result

The techniques of shoot proliferation and rooting were standardized for both explants from *in vitro* raised plants and mature plants from field. Multiplication of shoots is yet to be obtained. Cultured anthers produced callus and a few embryoids were produced. Somatic embryoids could be induced from immature cotyledons a few of which germinated into feeble plantlets. A few suspected haploids were recovered through *in vitro* culture of flat beans.

Pepper

2. Improvement of black pepper through *in vitro* techniques.

Objectives: To standardize the most suitable culture medium and explant for differentiation of callus as well as for multiple shoot production and embryogenesis in black pepper.

Result

Multiple shoots were obtained from nodal explants, which were successfully rooted and planted out. Callus mediated organogenesis was also successful in pepper.

Ginger

3. Tissue culture and somaclonal variation in ginger

Objectives: To standardise a commercially feasible method for tissue culture of ginger and to exploit the somaclonal variation in cultured tissues and plants to develop disease-resistant high yielding superior quality genotypes.

Results

Plantlets have been developed *in vitro* and their somaclonal variation is being studied.

..... 2

4. *In vitro* mutagenesis in ginger

Objectives

To fix the effective irradiation dose in ginger and to induce variability under *in vitro* conditions.

Result

Different doses of γ rays have been tried for irradiating the rhizome pieces and their response is under observation.

5. *In vitro* production of hybrids in ginger.

Objectives:

Exploitation of *in vitro* methods to obtain hybrids in ginger.

Result

In vitro pollination has been done and ovary development is being observed.

6. Standardisation of *in vitro* techniques for rapid multiplication of difficult-to-root and endangered species of medicinal plants.

Objectives:

To standardise *in vitro* techniques for multiplication of various medicinal plants like Kaempferia, Gymnema etc.

Result

In vitro plantlet regeneration has been standardised in Kaempferia and the plantlets have been successfully planted out.

7. Standardisation of *in vitro* techniques for rapid multiplication of cinnamon.

Objectives:

To standardise *in vitro* techniques for multiplication of cinnamon.

Results

Indication of multiple shoot production has been noticed from nodal explants in cinnamon.

8. Clonal multiplication in rose wood through bud culture.

Objectives: To standardise the technique of *in vitro* clonal multiplication in rose wood.

Result: Successful multiple shoot production has been obtained, which were rooted and subsequently planted out successfully.

Nursery techniques in cocoa

Nursery techniques in cocoa consist of raising seedlings from seeds, producing budded plants and rooting of cuttings.

1. Raising cocoa seedlings: This consists of extracting seeds from cocoa pods within seven days of harvest, sowing inpotting mixture contained in polythene bags and growing them for four to six months before planting. The seeds are to be sown either flat or with helium end down and the depth of sowing should be just only enough to cover the seeds. Seedlings of four to six months growth are used for planting.

2. Budding: Budding is usually done using seedlings that are six to nine months old by which time the stem should have reached pencil thickness. Buds are collected from the desired plant and the bud wood should be of the same thickness and physiological age. For root stock of six to nine months, this will be the browning stage. The common methods of budding used for cocoa are patch, T,inverted T, Forkert and Modified Forkert methods. There is found to be little difference between these methods in success rate. After three weeks, the budding tape is to be removed, the stock stem to be cut half way through about 2cm above the bud union and the stem snapped back. It is to be left as such till bud grows and differentiates and at least two leaves harden. After about six months of budding, these can be field-planted. Peculiar early growth of budded plants and necessity of periodical removal of stock shoots upto about a year after planting are some of the problems. With experienced budders, success percentage of budding will be over 90.

3. Rooting of cuttings: This consists of collection of a shoot at the greening stage, preparing cuttings of two to three nodes and planting them after a hormonal dip of the cut end. The leaf laminae are cut back

.....2

to stumps of about 5 cm before setting. The hormonal treatment that is found to be the best in IAA at 6000 ppm for five seconds. The treated cuttings are planted in potting mixture contained in polythene bags and a batch of bags are covered with a polythene sheet to maintain high humidity. The cuttings strike roots in about a month and the plants will be ready for field planting in about six months. The final success rate of this method will be about 23 to 30 per cent only.

Dr W.H Emmingham

Appendix 14

MAY 15, 1991 9:00 - 10:00 OUTPLANTING AND COMPETITION

I. Introduction - This is one of the main problems in reforestation and agroforestry: Unless seedlings survive the initial outplanting, nursery efforts are futile. It pays to understand what happens to seedlings after they leave the nursery. You look bad if your seedlings don't survive. Who's to blame for dead seedlings? Teamwork and cooperation is the answer.

II. SITE RESOURCES AND COMMUNITY DYNAMICS i.e. development

Plants and Environment: How plants sense their environment.

FACTORS: light, water, temperature, nutrients, physical.

Planting into occupied sites

Role of disturbance - fire, clearing, site preparation.

Competition interactions

III. COMPETITION STUDIES:

Basic Competition Studies - Examples

Local Experience - Examples

IV. SUMMARY & CONCLUSIONS

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Appendix 15

Dr W.H. Emmingham

MAY 15, 1991 10:30 - 11:30 VEGETATION MANAGEMENT - 1 HOUR

I. INTRODUCTION: Unless there is active / effective vegetation management, seedlings have little chance for success.

The Thresholds of Competition Diagram:

Survival -

Growth -

There is an enormous difference between simple survival and the growth potential of the typical planted tree!!!

II. VEGETATION MANAGEMENT METHODS

Mechanical Weeding - Tried and true, but labor intensive

Herbicides - O.K. for single crop - eg trees,

Hard to use on multiple crop systems, new herbicides -

Types of herbicides:

Grazing - Can reduce moisture demand - expand growing season

Requires management of hungry animals -

Works only with well fed animals??

Introduced Competitors - Grass forage seeding-

Spot Treatment of weeds

Fire - Its' natural and historic role.

Use in todays agroforestry systems

Local Experience with Vegetation Management:

SUMMARY AND CONCLUSIONS

Appendix 16

STATISTICAL CONSIDERATIONS IN TREE NURSERY RESEARCH

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Nursery managers are often experimentalists themselves. It may be required for them to conduct experiments for finding out solutions to many problems encountered by them or to establish cause-effect relationships by observing how certain response variables (e.g. height, diameter) are influenced by specified levels of one or more factors (e.g. fertilizers). Tree nursery research, however, is not different from other contemporary biological investigations in that all of them require a basic appreciation and knowledge of statistical techniques. Many of the biological investigations especially those in Agriculture and Forestry have become quantitative and the observations consist of numerical facts called data. As treatment differences are measured or counted, it becomes imperative that some objective methods should be available to the investigator in presenting and analyzing numerical research data.

The aim here is to review some of the common experimental designs available for conducting research in Tree seed and Nursery management and also to provide some insights into the analysis of experimental data from a nursery man's perspective.

HYPOTHESIS TESTING

The scientific method allows researchers to quantify the uncertainty with which they accept or reject hypotheses formulated before an experiment. A statistical hypothesis is testable by experimentation in the sense that experimental results will either tend to support or refute it. However, because it can never be totally proven or disproven, researchers calculate the level of confidence on the decision to accept or reject.

Statistical hypothesis are usually formulated as null hypotheses - that is the effects under investigation are assumed to have no effect on the response variable. Examples are (i) all fertilizer regimes yield the same number of plantable seedlings (ii) bed density has no effect on collar girth. A researcher then carry out the experiment and calculates the probability of observed differences between two treatment means occurring by chance. If there are only a small chance (say 5%) of obtaining the observed differences if the null hypothesis is true, the researcher concludes that treatments differ - and rejects the null hypothesis

Statistical theory informs us that if the null hypothesis is true, then the groups MS, as well as the error MS, will be an estimate of the total variance, common to all 't' populations.

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But if the t population means are not equal, then the groups MS will be greater than the error MS. Therefore, the test for the equality of means is a one-sided variance-ratio test:

F = groups MS/error MS

with the groups DF being associated with the numerator of the ratio and the error DF associated with the denominator. Thus the critical value for this test is $F_{(t-1),(n-k)}$. If the calculated F is at least as large as the critical value, then we reject HØ. But remember that all we conclude in such a case is that all the t population means are not equal.

MULTI-SAMPLE HYPOTHESIS

Biologists often collect measurements of a variable from three or four samples. In such a situation, testing all possible pairs of samples by applying two-sample tests (e.g. t test, Mann-Whitney test etc.) is clearly invalid. The situation calls for multi-sample tests like Analysis of Variance. Here one might proceed to test the null hypothesis $H_Ø : \mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k$ rather than by testing all the following null hypotheses: $HØ : \mu_1 = \mu_2$, $HØ : \mu_1 = \mu_2$, $HØ : \mu_2 = \mu_3$. In the latter case, the calculated test statistic, t, and the critical values in the t table, are designed to test whether the two sample statistic X1 and X2, are likely to have come from the same population (or from two populations with identical means).

PITFALLS

TYPE 1 ERROR

In employing this test, it is possible that we randomly draw two sample means from the same population and wrongly conclude that they are estimates of different population means ie. the true null hypothesis will be rejected. This is called [illegible] error in statistical parlance. Also called [illegible] and has a probability of alpha (significance level; usually 5% or less). That is if H_0 is in fact a true statement about a statistical population, it will be concluded (erroneously) to be false 5% of the time. However, consider that the random samples were taken from a single population, as previously stated three possible t tests can be performed, and the probability of wrongly concluding that two of the means estimate different parameters is considerably greater than alpha. In fact, if alpha is set at 5% (critical values of t test, alpha = 5%) and three means are tested, two at a time, by the two sample test, there is a 13% chance of committing a Type I error. As the number of means increase, the probability of committing a type I error also increases and it approaches certainty with a very large number of means.

TYPE 2 ERROR

There can be situations where in the null hypothesis is accepted when it is really false. That is statistically

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significant differences are not declared even though they actually exist.

ANALYSIS OF VARIANCE

Therefore to test the null hypothesis HØ : $\mu_1 = \mu_2 = \mu_3 = \mu_k$ of k samples, we need to test their means simultaneously. R.A.FISHER (1890-1962), the British Statistician, has developed a large area of Statistical Methods called Analysis of Variance to facilitate the simultaneous testing of a large number of sample means.

Let us assume that we wish to test whether four different seed pre-treatments result in different field emergence in *Dalbergia latifolia*. Since we are to test for the effect of only one factor (viz. seed treatment) on the variable in question (viz. field emergence), the appropriate analysis is termed "single factor" (or "single criterion" or "single classification" or "one way") Analysis of Variance. Furthermore, each seed pre-treatment is said to be a level of the factor. The design of this experiment should have seed samples (in trays, poly bags etc.) being assigned at random to receive one of the four pre-treatments. Although equal sample sizes are not required for the single factor Analysis of Variance, such a situation is statistically desirable.

Completely Randomized Design:

The single factor Analysis of Variance is said to represent a completely randomized experimental design. Completely Randomized experimental design (CRD) forms an appropriate design, if we can control the experimental error (plot to plot uncontrolled variation due to extraneous factors) and is suitable for conducting laboratory experiments, green house studies etc. E.g. if you want to compare 'n' number of seed pre-treatments (to break seed dormancy), the seed pre-treatments can be evaluated with the help of a laboratory experiment in CRD. This design is not useful for conducting field trials as it would be difficult to control the experimental error.

Sources of variation:

ANOVA MODEL: $y_{ij} = \mu + a_i + e_{ij}$

where y_{ij} = jth response to ith treatment
$\mu + a_i$ = deterministic effects, can be explained as the treatment effects
e_{ij} = error term or variation unexplained by treatment.

The amount of variability among the k groups can be partitioned into within group and among group variations. The former is referred to as error variance. In summary each deviation of an observed datum from the grand mean of all data is due to a deviation of that datum from its group mean plus the deviations of that group mean from the grand mean.

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Summary of calculations for a single factor ANOVA

Sources of variation	Sum of squares (SS)	Degrees of freedom (DF)	Mean Square (MS)
Total	Σy^2-CF	N-1	
Among groups	Σt^2-CF	t-1	Group SS/t-1
Error	total ss-group ss	remainder	error SS/error DF

note: CF = (Grand total)^2/n, where N is the number of observations, and t = number of treatments

TWO TYPES OF ANOVA

In the example below the experimenter designing the trial was interested in whether all the four TGRs have the same effect on seedling biomass. That is, these four treatments were not randomly selected but were specifically chosen. When the levels of a factor are specifically chosen, one is said to have designed a fixed effects model or Model I ANOVA. In such a case, the null hypothesis : HØ : $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k$, is appropriate.

However, there are some instances when the levels of a factor are indeed chosen at random. For instance, we might be interested in the effect of geographic origin of teak seeds (provenances). It is possible that our concern might be with certain specific locations (e.g. Nilamboor, Konni etc.) in which case we would be employing a fixed effects model ANOVA. But we might, instead, be interested in testing the statement that in general there is a difference in growth rates of teak from different locations. That is instead of being concerned with only the particular locations used in the study, the intent might be to generalize, considering the locations in our study to be random sample from all possible locations. In this random effects model, or Model II anova, all calculations are identical to those of the fixed effects model, but the null hypothesis is better stated as $H_Ø$: there is no difference in the growth rates of teak among geographic locations.

Example 1 A single factor analysis of variance (Model I) In a nursery trial on tree growth regulators (TGRs), four TGRs (Cytokinin - 200 ppm; GA_3 - 200 ppm; IAA - 200 ppm; BA - 200 ppm) were applied to one-month old teak seedlings. The data on total root and shoot biomass (mg plant^{-1} after six months are furnished below. We would like to know whether the biomass are the same for all TGRs.

HØ : $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k$, H_A: The mean biomass after TGR application are not equal

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TGR I	TGR II	TGR III	TGR IV
60.8	68.7	102.6	87.9
57.0	67.7	102.1	84.2
65.0	74.0	100.2	83.1
58.6	66.3	96.5	85.7
61.7	69.8	-	90.3

n_i	5	5	4	5	N=19
Y_{ij}	303.1	346.5	401.4	431.2	
$\bar{Y}$	60.62	69.30	100.35	86.24	

$CF = (303.1+346.5+401.4+431.2)^2/N = 21969116.84/19 = 115627.2$

Total SS $= E(Y_{ij})^2 - CF = (60.8^2 + \ldots\ldots + 90.3^2) - C = 119981.90 - 115627.2 = 4354.7$

Groups SS $= (303.1^2/5+346.5^2/5+401.4^2/4+431.2^2/5) - CF = 119853.55 - 115627.20 = 4226.35$

Error SS = total SS - groups SS = 4354.7-4226.35 = 128.35

Summary of the Analysis of Variance

Source	SS	DF	MS
Total	4354.70	18	
Groups	4226.35	3	1408.78
Error	128.35	15	8.57

F = Groups MS/Error MS = 1408.78/8.57= 165

$F_{(0.05)3,15} = 3.29$

Reject H0

MEAN SEPARATION

The objective of our analysis is often not to test the overall difference but to see which treatments differ. Analysis of variance forms only the first step in this direction. If the null hypothesis is rejected in an analysis one of the following types of 'follow-up' analysis needs to be performed. That is, a significant F value immediately raises the question : which of the mean values are significantly different? Two widely used methods for mean separation are briefly described below:

i) Least Significant Difference

This test should be used unless the F test is significant. Strictly speaking, LSD should be used only to compare adjacent means in an array (means arranged in an order of magnitude). When it is used indiscriminately, to test all possible differences among several means, certain differences will be significant but not at the level of significance chosen. Instead of making comparisons at 5% level, comparisons between means further apart than two in an array will be made at lower levels of significance. LSD can be used to make meaningful comparisons that are planned before the data are examined, it should not lead to many errors. The great advantage of LSD is that it is easy to calculate and provides a single figure for making comparisons.

LSD is a form of t test as its formula is derived from the formula for the t test to test the statistical significance of the difference between two means. LSD is a fixed range test, since it provides one range for testing all differences.

LSD = $t_{(.05)} * \sqrt{2*\text{error mean square}*(1/r_i+1/r_j)}$ where r_i and r_j are the number of replications of the ith and jth treatments and LSD(0.05) = $t_{(.05)} * \sqrt{2*\text{error mean square}/r}$, in the case of equal replications.

MULTIPLE RANGE TESTS

These tests are so named because they provide multiple ranges to make pair-wise comparisons among several means. With means arrayed from the lowest to the highest, a multiple range test gives significant ranges that become larger as the means to be compared are farther apart in the array. A conservative multiple range test that is considered to keep all the mean separations at the level of significance is the Student-Newman-Kuels (SNK) procedure. Here I will discuss only Duncan's Multiple Range Test since it and/or the intelligent use of LSD following a significant F for treatments are adequate procedures for making logical pair-wise comparisons.

Duncan's Multiple Range Test

This test is the most widely used of several multiple range tests available. It provides protection against making mistakes inherent in the indiscriminate use of the LSD test. The test is identical for LSD for adjacent means as they are more widely separated in the array. This test is used most appropriately when several unrelated treatments are included in an experiment; for example, for making all possible comparisons among the yielding abilities of several varieties.

The test involves the calculation of shortest significant differences (D) for all possible relative positions between the treatment means when they are arrayed in order of magnitude. The 'D's are then used in an orderly procedure to determine statistical differences among the means. The formula for D is D = QS$\bar{Y}$ where Q is a tabularised value depending up on the chosen level of significance, the degrees of freedom for error, and the relative separation of means in the array and S$\bar{Y}$ is the standard error of mean $\sqrt{MSE/r}$

Start by comparing the largest mean with the smallest, using the D for their position relative to each other in the array. If the difference between these means equal or is larger than the D, the means are significantly different. Next compare the largest mean with the next smallest. Then the largest with the next smallest. When a non significant difference is found, a line can be drawn connecting these means. Then repeat the process; start by comparing the second largest with the smallest, and so forth.

There is an exception rule used in DMRT. It states that a

difference between two means can not be declared significant if the two means concerned are contained in a subset of means with a non-significant range. Thus, if there are five means, ABCDE, in an array, A has been found not significantly different from D, that is ABCD E and B is significantly different from E, it is not necessary to test B against D and C as they are in a subset with a non-significant range. The next step would be to test C against E, if this difference is not significant, C and E are connected ABCD E, AND further testing is unnecessary. this procedure avoids making test between means that are already connected by a line. Often letters are used to show significant differences even if the means are not arrayed.

RANDOMIZED BLOCK EXPERIMENTAL DESIGN

Consider an experimenter wants to test the influence of certain root treatments such as wrenching, under cutting etc. on the root regeneration potential, which incidentally is positively related to seedling establishment in the field. Then he might want to test them in a field experiment. The experimental field, however, is by no means uniform. therefore, we divide the the area into homogenous plots and the treatments are applied at random to the plots within a block. Such an experimental design is called Randomized block design (RBD). Here by grouping the plots into blocks we achieve precision by reducing the error variance.

The analysis of the RBD is performed as a mixed model two-way analysis of variance. In the present case, root treatment is the fixed factor, and block is always a random factor. The null hypothesis of equal root biomass is readily tested.
Example 2. A Randomized block analysis of variance (Model II- two factor ANOVA). HØ = The mean fine root biomass is the same in all treatments ($\mu 1 = \mu 2 = \mu 3 = \mu 4$)

HA = The mean fine root biomass is not the same in all treatments
Four experimental treatments such as wrenching, under cutting, exogenous application of cytokinin-1ØØ ppm, Soil application of nitrogen @1ØØ kg/ha, were applied randomly to four blocks of nursery beds having 1ØØ seedlings each. The seedlings within a block receiving different treatments (25 per treatment) were separated in space. The table below gives the biomass in g of the fine root biomass of the seedlings one year after outplanting (nine seedlings per treatment).

Block 1	Treatment 3 (2.1)	Treatment 4 (1.3)	Treatment 1 (1.5),	Treatment 2 (2.7)
Block 2	Treatment 1 (1.4)	Treatment 3 (2.2)	Treatment 2 (2.9)	Treatment 4 (1.Ø)
Block 3	Treatment 3 (2.4)	Treatment 2 (2.1)	Treatment 4 (1.1)	Treatment 1 (1.4)
Block 4	Treatment 4 (1.3)	Treatment 2 (3.Ø)	Treatment 1 (1.2)	Treatment 3 (2.Ø)
Block 5	Treatment 1 (1.4)	Treatment 4 (1.5)	Treatment 3 (2.5)	Treatment 2 (3.3)

The preceding data (biomass in g) is summarized in the following table.

Blocks	Treatments 1	2	3	4	Total (B)
1	1.5	2.7	2.1	1.3	7.6
2.	1.4	2.9	2.2	1.Ø	7.5
3.	1.4	2.1	2.4	1.1	7.Ø a=4
4.	1.2	3.Ø	2.Ø	1.3	7.5 b=5
5.	1.4	3.3	2.5	1.5	8.7 N=2Ø
Total(T)	6.9	14.Ø	11.2	6.2	Grand total: 38.3

$CF = GT^2/N = 73.3445$

total SS = $y_{ij}^2 - CF = 82.67 - 73.3445 = 9.3255$

Treatment SS = $T^2/b - CF = (6.9)^2 + (14.Ø)^2 + (11.2)^2 + (6.2)^2/5 - 73.3445$
=8.1535

blocks SS= $B^2/a - CF = (7.6)^2 + (7.5)^2 + (7.Ø)^2 + (7.5)^2 + 8.7)^2/4 - 73.3445$
=Ø.393Ø

Analysis of variance summary table

Source of variation	SS	DF	MS
Total	9.3255	19	
Treatments	8.1535	3	2.7178
Blocks	Ø.393Ø	4	Ø.Ø982
Remainder	Ø.779Ø	12	Ø.Ø649

To test HØ F= Treatment MS/remainder MS = 2.7178/Ø.Ø649=41.9

$F_{Ø.Ø5,\ 3,\ 12} = 3.49$

Therefore reject HØ

TWO FACTOR ANALYSIS OF VARIANCE

A simultaneous analysis of the effect of more than one factor on population means is termed *a factorial analysis of variance*. There are important advantages to such an experimental design. Among them is the simple fact that one experiment can suffice for the analysis, and it is not necessary to perform a one-way ANOVA for each factor. thus we may economize with respect to time, effort and often money. Also factorial analysis of variance procedures can test for interaction among factors.

MULTIWAY FACTORIAL ANALYSIS OF VARIANCE

In a two-way analysis of variance one can determine whether either of the factors has a significant effect on the magnitude of the variable and also whether the interaction of the two factors significantly affect the variable. By expanding the considerations of the two-way analysis of variance, we can assess

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the effects on a variable of the simultaneous application of three or more factors; this being done by what we may refer as a multiway analysis of variance.

Three-factor analysis of variance

For a particular variable, we may wish to assess the effects of three factors: let us refer to them as factors A,B and C. For example, we might desire to determine what effect the following three factors have on seedling growth rate: Species, Available nutrient concentrations in the medium and TGRs.

Example 5: A three-factor analysis of variance (Model I), where the variable is seedling height (m)

1. HØ: Mean seedling growth rate is the same for all three species ($\mu 1=\mu 2=\mu 3$) HA: Mean seedling growth rate is not the same for all three species

2. HØ: Mean seedling growth rate is the same for all three nutrient levels ($\mu_{low}=\mu_{med}=\mu_{high}$) HA: Mean seedling growth rate is not the same for all three nutrient levels

3. HØ: Mean seedling growth rate is the same for both TGRs ($\mu 1=\mu 2$). HA: Mean seedling growth rate is not the same for the TGRs

4. HØ: Differences in mean growth rate among the three species are independent of the the three nutrient levels; or, differences in mean growth rate among the three nutrient levels are independent of the species (TESTING FOR A X B INTERACTION). HA: Differences in mean growth rate among the three species are not independent of the the three nutrient levels;

5. HØ: Differences in mean growth rate among the three species are independent of the TGRs; or, differences in mean growth rate between the two TGRs are independent of the species (TESTING FOR A X C INTERACTION). HA: Differences in mean growth rate among the three species are not independent of the TGRs; 6. HØ: Differences in mean growth rate among the three nutrient levels are independent of the TGRs; or, differences in mean growth rate between the two TGRs are independent of the nutrient levels (TESTING FOR B X C INTERACTION). HA: Differences in mean growth rate among the three nutrient levels are not independent of the TGRs;

7. HØ: Differences in mean growth rate among the three species are independent of the other two factors (TESTING FOR A X B X C INTERACTION). HA: Differences in mean growth rate among the three species (or nutrient levels or TGRs) are not independent of the other tow factors.

Species 1

Low nut. level		Med nut. level		High nut. level	
WR1	WR1	WR1	WR1	WR1	WR1
1.9	1.8	2.3	2.4	2.9	3.0
1.8	1.7	2.1	2.7	2.8	3.1
1.6	1.4	2.0	2.4	3.4	3.0
1.4	1.5	2.6	2.6	3.2	2.7

Species 2

Low nut. level		Med nut. level		High nut. level	
WR1	WR1	WR1	WR1	WR1	WR1
2.1	2.3	2.4	2.0	3.6	3.1
2.0	2.0	2.6	2.3	3.1	3.0
1.8	1.9	2.7	2.1	3.4	2.8
2.2	1.7	2.3	2.4	3.2	3.2

Species 3

Low nut. level		Med nut. level		High nut. level	
WR1	WR1	WR1	WR1	WR1	WR1
1.1	1.4	2.0	2.4	2.9	3.2
1.2	1.0	2.1	2.6	2.8	2.9
1.0	1.3	1.9	2.3	3.0	2.8
1.4	1.2	2.2	2.2	3.1	2.9

Summary of analysis of variance table

Source of variation	SS	DF	MS
Factor A	1.81750	2	0.90875
Factor B	24.65583	2	12.32791
Factor C	0.00889	1	0.00889
A x B	1.10167	4	0.27542
A x C	0.37028	2	0.18514
B x C	0.17528	2	0.08764
A x B x C	0.22056	4	0.05514
Error	2.00500	54	0.03713

From the ANOVA table we can prepare the following summary:

Effects in hypothesis	Calculated F	Critical F	Conclusion
1. Species	24.475	$F_{.05,\ 2,54}$ =3.18	Reject H0
2. Nutrients	332.024	do	do
3. TGRs 0.239		$F_{0.05,1,54}$= 4.03	Accept H0
4. AxB	7.418	$F_{.05,4,54}$ = 2.56	Reject H0
5. AxC	4.986	$F_{0.05,2,54}$= 3.18	do
6. BxC	2.360	do	Accept H0
7. AxBxC	1.485	$F_{0.05,4,54}$ =2.56	do

SPLIT PLOT EXPERIMENTS

In field experiments, wherein one factor requires large areas or plot sizes and other factors could be accommodated in smaller areas and that they also exhibit wide variability between them and also that one factor needs to be tested with greater precision. Then a split plot design is preferred.

Model ANOVA

Source of variation	SS	DF	MS
Total			
Replication		r-1	
Main plot analysis			
A		a-1	
Error (a)		(r-1)(a-1)	
Sub-plot analysis			
B		b-1	
AxB		(a-1)(b-1)	
Error (b)		a(b-1)(r-1)	

Comparisons of treatment means

LSD for any two A marginal means = $t_{E(a)} * \sqrt{2Ea/rb}$

LSD for any two B marginal means = $t_{E(b)} * \sqrt{2Eb/ra}$

Interactions: B means at the same level of A = $t_{E(a)} * \sqrt{2Eb/r}$

A means at the same level of B = $t_{b(b-1)} * Eb + taEa/(b-1)Eb + Ea * \sqrt{2(b-1)Eb.Ea/rb}$

Example 4. Analysis of variance for split plot experiment (model i). A field experiment was conducted to test the growth response in respect of three factors, water regimes (I1 and I2), need control treatments (W1, W2 and W3) both requiring relatively large plot sizes for the convenient application of the treatments and nitrogen levels (n1,n2,n3 and n4). Sapling biomass from three replications are given below (g/plant)

N	I1W1	I1W2	Rep 1 I1W3	I2W1	I2W2	I2W3
n1	23.11	29.79	28.83	27.25	11.95	22.97
n2	40.12	33.47	40.08	44.56	25.78	27.99
n3	82.64	35.06	56.72	68.42	50.11	31.50
n4	118.67	40.79	36.81	65.31	30.94	37.25
Total	264.54	139.11	162.44	205.54	118.78	119.71

N	I1W1	I1W2	Rep 2 I1W3	I2W1	I2W2	I2W3
n1	20.04	19.31	22.50	16.90	9.41	16.41
n2	51.80	23.18	26.79	56.11	16.85	7.73
n3	63.42	21.87	25.50	45.97	42.11	22.14
n4	67.03	16.29	22.46	65.82	30.64	15.18
Total	202.29	80.65	97.25	184.80	99.01	61.46

N	I1W1	I1W2	Rep 3 I1W3	I2W1	I2W2	I2W3
n1	21.53	13.68	6.47	30.68	14.54	12.38
n2	45.02	18.74	22.50	38.10	14.08	19.92
n3	66.00	38.26	7.25	63.38	25.10	22.18
n4	88.60	27.34	29.32	96.70	30.24	19.26
Total	221.15	98.02	65.54	228.86	83.96	73.74

Grand total = 2506.85, N = 72
CF= GT^2/N = 87281.902
Total SS = y^2-CF = 35005.833

Main plot factor X replication two-way table

replications	Main plot treatments						
	I1W1	I1W2	I1W3	I2W1	I2W2	I2W3	Total
1	264.54	139.11	162.44	205.54	118.78	119.71	1010.12
2.	202.29	80.65	97.25	184.80	99.01	61.46	725.46
3.	221.15	98.02	65.54	228.86	83.96	73.74	771.27
Total	687.98	317.78	325.23	619.20	301.75	254.91	2506.85

Total SS for the two-way table = $264.54^2+139.11^2+\ldots\ldots+73.74^2/4-$
CF = 17391.774
SS for replications: $1010.12^2+725.46^2+771.27^2/24$-CF = 1946.9329
SS for Main plot treatments= $687.98^2+317.78^2+\ldots+254.91^2/12-$
CF=14344.429
Error (a) SS = Table SS-Rss-Mpss = 1100.412
IxW two way table

	W1	W2	W3	TOTAL
I1	687.98	317.78	325.23	1330.99
I2	619.20	301.75	254.91	1175.86
TOTAL	1307.18	619.53	580.14	2506.85

Total SS for the IW table = $687.98^2+\ldots+254.91^2/12$-CF =
14344.429
ISS = $1330.99^2+1175.86^2/36$-CF = 334.24019
WSS = $1307.18^2+619.53^2+580.14^2/14$-CF = 13930.573
SS for IxW interaction = Iw table ss-Iss-Wss = 79.6158
IxN Two-way table

	I1	I2	Total
n1	185.26	162.49	347.75
n2	301.70	251.12	552.82
n3	396.72	370.91	767.63
n4	447.31	391.34	838.85

IxN table SS = 8607.2791
In interaction SS = 44.738

WxN two-way table

	W1	W2	W3	Total
n1	139.51	98.68	109.56	347.75
n2	275.71	132.10	145.01	552.82
n3	389.83	212.51	165.29	767.63
n4	502.13	176.24	160.28	838.85

NxW Table SS = 27556.757
NxW interaction SS = NW Table SS-Nss-Wss = 5400.8833

Three-way table

	I1			I2		
	W1	W2	W3	W1	W2	W3
n1	64.68	62.78	57.80	74.83	35.90	51.76
n2	136.94	75.39	89.37	138.77	56.71	55.64
n3	212.06	95.19	89.47	177.77	117.32	75.82
n4	274.30	84.42	88.59	227.83	91.82	71.69

IxWxN Table SS = $64.68^2+\ldots\ldots+71.69^2/3$=CF= 28674.047
IxWxN interaction SS = 28674.047- IWSS-INSS-WNSS = 109.7826
SUMMARY OF ANOVA TABLE

Source	SS	DF	MS	F(cal)	F (table) 0.05	0.01
Total	35005.833	71				
Repln	1946.9329	2	973.466	8.846**	4.10	7.56
I	334.2402	1	334.2402	3.037	4.96	10.04
W	13930.573	2	6965.2865	63.297**	4.10	7.56
IxW	79.6158	2	39.813	<1	4.10	7.56
Error(a)	1100.4121	10	110.041			
N	8225.3010	3	2741.767	30.05**	2.87	4.39
IxN	44.7380	3	14.9126	<1	2.87	4.39
WxN	5400.8833	6	900.1472	9.866**	2.37	3.36
IxWxN	658.6956	6	109.7826	1.203	2.37	3.36
Error (b)	3284.4411	36	91.2345			

CD for main effects
W marginal means = $t_{e.05}*\sqrt{2*E(a)/r*i*n}$
= $2.228*\sqrt{2*110.041/24}$ = 6.7469
N marginal means = $t_{e.05}*\sqrt{2*E(b)/r*i*w}$
= $2.03*\sqrt{2*91.2345/18}$ = 6.4633
CD for interaction
N means at the same level of W = $t_{e.05}*\sqrt{2*E(b)/r*i}$
= $2.03*\sqrt{2*91.2345/6}$ = 11.1948
W means at the same level of N =
$\sqrt{2[(3)*91.245+110.041/24]*(3*91.2345*2.03+110.041*2.228)/3*91.2345+110.0}$
=5.6550*2.08677 = 11.8007
Marginal means for I
I1 = 36.9719; I2 = 32.6628

Marginal means for W
W1 = 54.4658; W2 = 25.8138; W3 = 24.1725

Marginal means for N
n1 = 19.3194; n2 = 30.7122; n3 = 42.6461; n4 = 46.5917

Note: An experiment where all possible combinations of levels of the factors exist as in the previous examples is often described as a *crossed* experimental design in Statistical parlance. the cells of the data are formed by each level of one factor being the combination with each level of every other factor. In some experimental designs, however, we have different levels of one factor occurring in combination with the levels of one or more factors, and other distinctly different levels occurring in combination with others. This situation is commonly encountered in animal experiments e.g. Two drug types and two drug sources. Each drug is obtained from two different sources, but the two sources are not the same for all the drugs. Thus the experimental design is not crossed, rather it is called nested or hierarchical. here one factor viz. drug source, being nested within another, drug type.

COMPACT FAMILY BLOCK DESIGN

Provenance tests in which multiple families from the same provenance are kept separately identified have been established in forest genetics with the objectives (1) to identify patterns and amount of genetic variation in natural forest populations and (2). to provide estimates of breeding values for selection within the tests. These tests are called 'Provenance/progeny tests' to distinguish them from 'provenance tests' where reproductive material is bulked as a provenance lot rather than kept separately by family. The compact family block design is a split plot arrangement of families in a randomized block design, with provenance as whole plots and families as the sub-plots. Assume that there are 'a' provenances of 'i' families each, and each family is represented by one randomized sub-plot of 'n' trees for each of 'q' replicates.

The linear model will be :

$$Y_{ijkl} = \mu + o_i + f_{j:i} + d_k + (od)_{ik} + (fd)_{kj:i} + e_{l:kj:i} \quad \ldots(1)$$

where:

Y_{ijkl} = Phenotype of the lth individual of the jth family from the ith provenance in the kth replication

μ = the population mean

o_i = effect of the ith provenance (assumed random)

$f_{j:i}$ = effect of the jth family from the ith provenance (assumed random)

d_k = effect of the kth replication (assumed random)

$(od)_{ik}$ = (formally) the effect of the interaction between the ith provenance and the kth replication, but is actually assumed to be the random common environmental effect for trees grown in the same ikth provenance plot

$(fd)_{kj:i}$ = (formally) the effect of the interaction between the kth replicate and the jth family of the ith provenance, but is

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actually assumed to be the random common environmental effect for the trees grown in the same jth family plot within the ikth provenance plot and

$e_{l:kj:i}$ = the effect of the lth tree within the jth family plot of the ikth provenance plot.

DATA TRANSFORMATION

For valid application of Analysis of variance and the related procedures, certain basic assumptions must be met such as:

(i) the data for each group were obtained randomly from a normal population

(ii) the sampled population must all have equal variances. Such a situations referred to as *homoscedastic*, the opposite situation being *heteroscedastic* (iii) the effects of the factor levels must be additive. ie. the assumption $\sigma_1^2=\sigma_2^2=\sigma_3^2=\sigma_4^2$ should be true in order to apply the ANOVA to HØ $=\mu_1 = \mu_2 = \mu_3 = \mu_4$ and each of the k samples should have come from a normal population. In factorial ANOVA, the underlying assumptions are that the data in each cell come from a normal population and that all of these populations have the same variance. Bartlett's test for homogeneity might be used to determine whether the assumption of equal variance is met.

If we have three or more samples, and we compute a variance for each ($\sigma^2 = \Sigma(x_i-\mu)^2/N$ or $s^2 = \Sigma(x_i-\bar{x})^2$ where σ^2 = population variance and s^2 = sample variance), then we can test the hypothesis that all the samples came from populations with identical variances.

Fortunately, the ANOVA is robust, operating well even with considerable heterogeneity of variances, as long as all sample sizes n_i are equal or nearly equal. If the n_i are quite different, then the probability of a Type I error will depart markedly from a, to a degree dependent on the heterogeneity; if larger variances are associated with the larger samples, the probability of a Type I error will be <a, and if they are associated with the smaller samples this probability will be >a.

Regarding additivity (sometimes referred to as linearity), consider the following examples. In example 4, the effect of A is said to be additive, for each datum in level 2 differs from the corresponding datum in level 1 by the addition of the same amount (1Ø g). Similarly, each datum in level 3 differs from it corresponding level 2 datum by a constant value (5 g). Examining the effect of the two levels of factor B, we also observe additivity (by a constant value of 1Ø g). What we are assuming is that the population, on an average, the effects of the factor levels are additive. Occasionally, however, the effect of a factor may not be additive; multiplicative effects are such an instance. in example 4b, we can see that factor a has an effect such that each datum in level 3 differs from its corresponding

member in level 2 by a multiplication factor of 2, and each member of level 2 differs from that in level 1 by a factor of 3. Examining the two levels of factor B, we can see that the data are affected by a multiplication factor of 2.

Example 5 Additive and multiplicative effects

A. A hypothetical two-way analysis of variance design, where the effects of the factors are additive (Data in g)

Factor B	Factor A: Level 1	Level 2	Level 3
Level 1	10	20	25
Level 2	20	30	35

B. A hypothetical two-way analysis of variance design, where the effects of the factors are multiplicative (Data in g)

Factor B	Factor A: Level 1	Level 2	Level 3
Level 1	10	30	60
Level 2	20	60	120

C. The two-way analysis of variance design of example 4B, showing the logarithms of the data

Factor B	Factor A: Level 1	Level 2	Level 3
Level 1	1.00	1.48	1.78
Level 2	1.30	1.78	2.08

Although analysis of variance and t tests are usually robust enough to perform well even if the data deviate from the requirements of normality, homoscedasticity and additivity. But severe deviations can lead to spurious conclusions.

Corrections for heteroscedasticity, nonnormality and nonadditivity are possible by means of changing or transforming the data from their original form (X values) to a different form (let us call X' values). The most commonly employed transformations are described in the following sections.

A. THE LOGARITHMIC TRANSFORMATION

If the factor effects of an analysis of variance are, in fact, multiplicative rather than additive, then the logarithm of the data will exhibit additivity (see example 4C). Instead of the transformation, $X' = \log X$, however, $X' = \log (X+1)$ is preferred on theoretical grounds and is especially preferable when some of the observed values are small numbers (particularly zero)

A second instance when the logarithmic transformation is

applicable is when there is heteroscedasticity and the standard deviations are proportional to the means (ie. there is a constant coefficient of variation). This transformation may also convert a positively skewed distribution into a symmetrical one (lognormal). using the transformed data, we can now proceed with parametric testing.

B. THE ARCSINE TRANSFORMATION

Statistical theory says that percentages or proportions form a binomial rather than a normal distribution, the deviation from normality being great for small or large percentages (0 to 30% and 70 to 100%). If the square root of each proportion, p, in a binomial distribution is transformed to its arcsine (ie. angle whose sine is $\sqrt{p}$), then the resultant data will have an underlying distribution that is nearly normal. This transformation $p' = \arcsin\sqrt{p}$ is performed with the aid of tabularised arcsin transformation tables. The arcsin transformation is frequently referred to as the "angular transformation" and "inverse sine" or "$\sin^{-1}$" transformation.

C. THE SQUARE ROOT TRANSFORMATION

The square rot transformation is applicable when the group variances are proportional to the mean. This most often occurs in biological data when samples are taken from a Poisson distribution (i.e.), when the data consist of counts of randomly occurring objects or events). Transforming such data by utilizing their square roots results in a sample whose underlying distribution is normal. However, $X' = \sqrt{X+0.5}$ is preferable to $X' = \sqrt{X}$, especially when there are very small data and/or when some of the observations are zero.

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— KISS Principle → Separate experiments
— Control - how one - what is it?
— Accept the results - 17 [illegible]
— Range of treatments - Never enough
— ANOVA vs Regression
— [illegible] - complex - studies
— Biological significance vs statistical significance

Appendix 17

COLLECTION, PROCESSING, GRADING AND STORAGE OF SEEDS

Dr. K. Sudhakara[1] and Dr. K. V. Peter[1]
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Seeds are miniature living plants. It is the most vital component in the continuity of plant's life. It carries the full genetic potential and embodies the whole physico-chemical and morphological entity. Being the beginning and the end of the plant life, collection of seed, its processing, grading and storage assume importance. Seeds are collected *in situ*, through correspondence and through exchange. *In situ* collection involves actual field visits to centers of divergence/origin of a crop. Collection through correspondence within a country does not demands much formality except for a few crops where regional quarantine regulations are in existence. International exchange demands import permits, phytosanitary certificates and port of entry certification. Harrington's thumb rule states that good seed storage is achieved when the relative humidity in the storage environment and the storage temperature in ^{o}F add up to 100. Medium and long term storage demands cold storage facilites. At $-25^{o}C$ seeds are stored for longer periods.

The International Bureau of Plant Genetic Resources, Rome is vested with the mandate for surevey, collection, evaluation, cataloguing and maintenance of crop germplasm, as per a U.N. Mandate. In India IBPGR, New Delhi performs the above function.

A good quality seed contributes to 30 per cent of the crop productivity. Hybrid seeds contribute still higher due to heterosis. There are specifications for seed production in categories of seeds like foundation seed, registered seed, and certified seed. Breeder seed, though having no specification, the breeder is vested with responsibliites for its purity.

The Seed Act and later its regulations specify field standards, crop standards and seed standards for a successful seed production programme. Seed production of forest crops is gaining economic importance recently in India. Except for few, most of the forest tree species are progated by seeds. However, so much study remains to be done in the case of tropical forest species. Scientific information about the floral and seed biology, maturity indices, appropriate storage method, different types of seed dormancy and best germination treatments have to be obtained in the case of many tropical forest tree species.

Practical notes circulated among the participants of the Indo-US Workshop cum Training on Agroforestry in the area of Tree Nursery Technology & Management (May 6 - 18, 1991).

1. Associate Professor, College of Forestry. 2. Professor and Head, Dept. of Vegetable Crops, College of Horticulture.

Appendix 18

MAY 17, 1991 TECHNOLOGY TRANSFER - 1 HOUR

I. INTRODUCTION: This is the way to gain success in your nursery program. Teach others how to grow trees!

II. BASIC CONCEPTS OF TECHNOLOGY TRANSFER:

1. BARIORS TO SUCCESS:

2. DEFINING EXTENSION POLICY OBJECTIVES

3. CHOOSING EXTENSION STRATEGY.

A. who does it?

b. It depends on? the problem, farmer, mission.

4. EXTENSION RESEARCH LINKS:

5. CONCEPTS FOR EXTENSION MODELS:

Diffusion - Problem Solving - Social Interaction

6. INFLUENCING HUMAN BEHAVIOR:

A range of options from coercion to social change:

7. INFLUENCING HUMAN PERCEPTION:

8. COMMUNICATIONS -

A. Exchanging coins or ideas.

B. Communications Models:

C. Communications Techniques:

9. INNOVATION ADOPTION:

A. Stages of adoption:

B. Characteristics of Innovations:

10. GROUP EXTENSION METHODS

III. LOCAL EXPERIENCE:

Discusion: The Soft Systems Approach

IV. SUMMARY AND CONCLUSIONS

Appendix 18

by [illegible]

I. ORGANIZATION FOR TECHNOLOGY TRANSFER: MODELS

The OREGON STATE UNIVERSITY - USA - EXTENSION MODEL

Extension of Research Based Information
Specialist - Agent - Client Model
Slide Presentation

II. KINDS OF FORESTRY EXTENSION ORGANIZATION:

1. SPECIALIST NETWORK: Similar to the USA model.

   (Build from the bottom up)

2. ADOPT YOUR LOCAL FORESTRY ORGANIZATION

   (Train foresters to do extension)

3. ADOPT THE LOCAL EXTENSION ORGANIZATION IN FORESTRY

   (train other extensionists about forestry)

4. ADOPT THE LOCAL AGRICULTURE EXTENSION ORGANIZATION

   (train agriculturists about forestry)

5. DEVELOP SPECIAL PROJECT EXPERTISE

   (Train anyone to do a special narrow job)

III. PLANNING FOR TECHNOLOGY TRANSFER:

1. Identify users
2. Identify needed / desired results - Goals & Objectives
3. Identify and select the best extension approaches
4. Define responsibilities:

   tasks - what has to be done

   people - who will do it

   when will it get done

   (This looks simple, but it is critical)

5. Logistics - Costs - organization - political support

IV. LOCAL EXPERIENCE

V. SUMMARY AND CONCLUSIONS:

Contributors

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National Agricultural and Natural Resources Curriculum Project Richard H. Merritt, *Rutgers University*, Director

Appendix 18-B

Systems Approaches for Improvement in Agriculture and Resource Management

Kathleen Wilson *University of Hawaii*

George E. B. Morren, Jr. *Rutgers University*

Macmillan Publishing Company
NEW YORK

Collier Macmillan Publishers
LONDON

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CHAPTER 1

Managing Complexity and Change in Food, Agriculture, and Natural Resources

Making decisions about managing enterprises in changing environments or developing and using new technologies is a difficult task. In addition, the general public, private organizations, and government agencies are no longer willing to view food, agricultural, and natural resources enterprises as strictly private affairs. Realistically, they are seen as multifaceted—producers of essential commodities and services, users of common resources, and subject to social values and ethical standards such as those associated with safety and quality of life . . . as well as profit-making organizations.

Newly minted degree holders in food, agriculture, and natural resources increasingly find that their new jobs place them in messy and dynamic situations. "Messy" means that the parties involved in a situation do not agree on either the definition of problems or on what technological and management improvements should be developed, or both. Thus, the introduction of a technological package or the reallocation of resources to correct or improve a situation is not straightforward. "People factors" loom large. Similarly, "dynamic" means, quite simply, that things keep changing; that yesterday's problem definitions or solutions involve factors that have now changed or no longer exist. Accordingly, in order to deal with these kinds of situations, professionals entering the field need new competencies and inquiry methodologies.

These competencies and methodologies go beyond the problem-solving approaches and limits to inquiry that are traditionally taught in most of our schools and colleges. Nor are they usually provided in undergraduate general education core requirements. Graduates need an array or "tool bag" of inquiry approaches to help them understand and act on the interactions, impacts, and complexity of situations in ways that are conceptually valid and practically effective.

The Four Approaches to Inquiry

This book provides an overview of four approaches to inquiry that are currently used by managers of food, agricultural, and natural resources enterprises: basic science, applied science, hard systems, and soft systems. The soft systems approach to inquiry receives particular emphasis. The objective is to enhance the reader's ability to create and apply knowledge in real-world settings. The main

thesis of the book is that food, agricultural, and natural resource professionals face many challenges and opportunities. Responding to them requires new competencies and a broad array of inquiry methodologies and knowledge. This book aims to help students — professionals-in-training — to develop such knowledge and competencies.

The Soft Systems Approach

Each of the four approaches to inquiry deserves its own text to adequately cover the detail needed to understand and practice it. There are four reasons for this book's emphasis on the soft systems approach.

First, the other three approaches are well represented by textbooks, particularly in fields and disciplines that predominately use one or two of them. Basic science inquiry is represented in chemistry and biology texts, for example. Applied science is exemplified by textbooks in the animal and agricultural sciences, medicine, and engineering. There are also numerous texts in economics, systems engineering, and management that present hard systems modeling approaches. This book is the first to bring the soft systems approach to undergraduate students in the food, agricultural, and natural resources sciences.

Second, quite a few of the complex situations that many graduates will be called upon to handle require the knowledge, sensitivities, skills, and specific inquiry techniques that are part of the soft systems approach. This is particularly relevant to such food, agricultural, and natural resources job categories as management, service, field and sales representation, merchandising, technician, information, education, communications, and agricultural production. According to the U.S. Department of Agriculture, approximately 70 percent of projected jobs in the industry will be found in these categories (Coulter, Staaton, and Goecker, 1986).

Third, it is a central thesis of this book that, in tackling a typical situation, the soft systems approach should be used first before proceeding to use one or more of the others. This is because the approach helps to develop agreement on such key issues as the nature of the problems, what will constitute an improvement, and the kinds of technologies and other techniques appropriate to achieving specific goals. Such agreement cannot be achieved without significant involvement and input from all the parties involved in a situation. The soft systems approach provides the procedures and tools to help reach such agreements. This contrasts with the other three approaches, which tend to assume that the objective of inquiry (the improved state being sought) is not in question. This statement is not intended as a criticism of the other approaches, but rather describes a major difference in the assumed starting point of inquiry. Soft systems analysis is carried out in order to reach a point where parties agree on the improved state of affairs they will seek and on the means that are appropriate to achieve it.

Fourth, the management of the biological and physical world for economic purposes, as well as to sustain or improve the quality of people's lives, requires effective and efficient organizational systems. Without such systems, people do not

stay in business or are subject to constant and costly pushes and pulls from external forces beyond their control. The soft systems approach provides procedures and techniques for the development, assessment, and revision of the organizational systems of a given food, agricultural, or natural resource management situation. All graduates should gain employment that involves the operations of one or more organizations. Familiarity with the procedures of soft systems analysis will help graduates to contribute competently to the ongoing effectiveness, efficiency, responsiveness, and strategic planning of the food, agricultural, or natural resources enterprises employing them.

Systems Thinking: A Holistic Approach

The book provides an expanded perspective that may strike production-oriented readers as too public or outsider oriented. This is unavoidable if the objective is to develop the idea that *we live in a complex world that people in groups and organizations of various kinds view very differently*. This is part of the challenge faced by professionals. So the issue is not ignoring a production orientation but strengthening that perspective by understanding the others and, more importantly, *learning how to gain an understanding* of other perspectives. The next section of this chapter discusses a series of food, agricultural, resource, and management concerns that is currently the subject of debate and divergent opinion. Its presentation is intended to be illustrative and provocative rather than exhaustive and final. Those readers who are tackling the book as part of a course may wish to spend time, even a formal session, debating and further widening the perspectives offered on particular issues presented here. The strategy of such debates is to be comprehensive and accommodative rather than narrow and exclusionary. The purpose is to practice approaching questions openly and to develop ways of better accounting for differing perspectives.

Another reason for introducing the book with a discussion of challenges and opportunities is to help students who have little or no work experience in food, agriculture, and natural resources to begin with a broader, more holistic view of the field and the activities associated with it. The following sections are presented in a way that suggests interactions among organizations of people and biological and physical properties. A holistic view implies paying attention to such interactions, to the controls that are present, to communications between parts, to properties that emerge as a result of real or projected interactions, to the kinds of operations that are present or absent, and to the impacts of interactions between the parts on the environment. Thus, a key first step toward systems thinking and practice is to develop one's ability to explore experience holistically. Systemic thinking is essential to your future ability to develop improvements or solutions to the complex problems faced by most agricultural and natural-resource enterprises.

This chapter offers illustrations of such interactions. Subsequent chapters will present techniques for developing abilities to see and record them. This chapter

concludes with a summary of the key points found in the rest of the text, chapter by chapter. In addition, each chapter begins and ends with summaries of key points. Reading a summary first may help some readers to clarify the more detailed substance of a chapter. Others who find the summaries repetitive are free to read ahead.

Management and Systems Thinking

Managing enterprises in a changing natural and socioeconomic environment is far from simple. Management requires that professionals make wise decisions about things they can manage and accommodate and respond to the natural and socioeconomic forces in the environment that they cannot control. As challenges and opportunities are discussed subsequently, note the kinds of forces at work. The next section begins with an overview of the nature of food, agricultural, and natural resources industries and their connections to and impacts on the rest of society. Following this, selected challenges and opportunities are presented to give readers a sense of the importance and value of careers in the field. The examples presented illustrate some of the complexity and messiness of managing enterprises in the field and, hopefully, also highlight the need for training that will assist readers to tackle such situations effectively in the future.

The Primary Industries

Agriculture

The food, agricultural, and natural resources industries are often referred to collectively as *primary* industries because they provide the energy and raw materials upon which the rest of a modern industrial economy depends. Here the concern is with how modern societies are powered and provisioned with energy, food, fiber, timber, minerals, water—the most basic inputs that modern consumers and citizens tend to take for granted. Without these essential inputs, or even if one or two of them are only marginally interrupted, our life-style pauses until supplies are restored or other kinds of adjustments are laboriously pieced together; jobs, travel, necessities, as well as comforts, all hang in the balance. Accordingly, the enterprises involved in this vast provisioning system are not going to go away easily.

These industries contribute vitally to the U.S. economy and people's sense of well-being. In fact, American agriculture alone is the world's largest commercial industry, with assets exceeding $1 trillion. The industry employs approximately 20 percent of America's labor force—more than 20 million people. The agricultural industry includes the producing, as well as the transporting, processing, manufacturing, retailing, and research and development of food and fiber. It accounts for 20 percent of the nation's gross national product ($610 billion in 1985).

These formidable figures show that agriculture's contribution to the total economy depends on a tremendously complex and interdependent system of producers, suppliers, transporters, distributors, researchers, and information disseminators. And their employees, in turn, directly depend on the food and fiber system for a living.

Agriculture and Codependent Industries

The people of this vast network engaged in food and agricultural activities are also consumers. Their purchases for their agricultural enterprises benefit local businesses—stores, banks, repair services, fuel distributors, and so on. They are also private consumers looking out for home and family. A recent "NBC Reports" television program estimated that for every five farms that go out of business, one supporting service enterprise, such as a bank, clothing store, food store, or drug store goes out of business. Agriculture creates jobs, not only in local communities, but across the nation. These purchases are in addition to the basic $140 billion that farmers and agribusiness firms spend annually for the goods and services used to produce our nation's food and fiber products.

These purchases affect the viability and sustainability of many other industries. For example, purchases by the agricultural and food industries generate 37 percent of the jobs in the glass and glass products industry, 69 percent of metal container industry employment, and 26 percent of the jobs in the paper products industry. The agricultural and food industry consumes 45 percent of the output of the paperboard container and box industry, 26 percent of the chemical and chemical products industry, and 25 percent of the crude petroleum and natural gas industry. In addition, the petroleum and related industries, the rubber and plastics industries, the iron and steel manufacturers, coal mining, transportation, and warehousing businesses (rail, truck, barge), printing and publishing businesses, plastics and synthetic materials industries, machine shop products industry, and motor vehicle and equipment manufacturers are all strategically tied to the agricultural sector's use of their products (Phillips, 1985).

Thus, every region of the U.S. has some portion of its employment base linked to agriculture. No matter where a person lives in the United States, about 20 percent or more of employment is so dependent. On a national basis, that is one job in five.

Opportunities in Agriculture and Natural Resources

The security, sustainability, and viability of the United States economy and the well-being of its people rely on the continued stewardship and development of scientific and professional expertise in the food, agricultural, and natural resource sciences. A recent study conducted by the U.S. Department of Agriculture, however, reported that there will be a shortfall of graduates trained in these fields during the next decade in relation to job openings. Through 1990, scientists, engineers, managers, sales representatives, and marketing specialists will account for three-fourths of the total annual U.S. employment openings for new college graduates with expertise in agriculture, natural resources, and veterinary

medicine (Coulter, Stanton, and Goecker, 1986). These figures are good news for readers who are contemplating careers in food, agriculture, or natural resource management. They are less than good news for those concerned about the future of these sectors of our economy.

America's food, agricultural, and natural resource system is one of its greatest success stories. In the past, national leaders have recognized that agriculture is the foundation on which overall development of the nation must rest. Investment by both the public and private sectors in the United States guaranteed the development of a scientific base and research and extension capability. Returns on the dollars thus allocated to agricultural development have been very high (Ruttan, 1982). Great strides in technology development have been made. Tremendous breakthroughs in the understanding and alteration of biological, chemical, and physical properties of water, plants, soils, and animals have led to many new agricultural, natural, and synthetic resource technologies and applications. Indeed, for the reader who is contemplating a career in one or another of the food, agricultural, or natural resource sciences, there are many opportunities and challenges. These fields of applied science have had an important, productive past and look to a promising future.

Current and Future Challenges

The future of these industries, however, presents many challenges. These challenges are complex and demand new competencies of those who choose a career in a related field. As noted previously, the food, agricultural, and natural resource sectors are connected in very complex ways with other major industries in the U.S. What happens in one industry affects what happens in another. Agricultural and natural resource production can no longer be thought of as isolated areas of endeavor. Food, agricultural, and natural resources enterprises constitute an interconnected complex of human activities involving transactions between people and their environments in the broadest sense. Bad or insular decisions and choices have effects far beyond the bounds of a single firm, organization, or agency.

Throughout this text, improvements in agricultural and natural resource management are conceptualized as *human activity systems*, with the people involved—the farmers, growers, ranchers, public employees, food process technicians, agribusiness men and women, employees of natural resource industries, researchers, or families—as the subjects of our concern. There is an important role for professionals to help clients such as these learn to manage change more effectively so that their life-styles and businesses are more sustainable no matter what happens to the environments in which they operate. Sustainability results from the quality of interaction among the family; the business enterprise; and the physical, biological, and socioeconomic environments. Effectiveness in dealing with change is a function of the learning of family members and employers and employees involved in the management of those environments. Peter Checkland, who developed the concept of the human activity system, notes that natural and

designed physical and biological systems are "inevitably linked closely to the human activity" associated with these systems (Checkland, 1971).

The growing recognition of the complexity of the management of agricultural and natural resource enterprises locally, statewide, nationally, and internationally has led some to postulate that the role, value, and responsibilities of professionals within the agricultural and natural resource sectors have changed significantly. No longer do many see the role, value, and responsibilities as only producing as much food, fiber, and natural resource products as possible or economically viable. Rather, many see the greater challenge to be learning how to manage food, agriculture, and natural resources in a responsible and sustainable manner, so that the impacts on people, families, nations, and environments are as positive as possible. This is no small challenge!

The Boom–Bust Cycle: Policy and Politics

Farm Management

The management challenge is one that we have not yet dealt with very well. The television stories and newspaper headlines of the past decade all too often remind us that our attempts to improve or support agriculture in the U.S. and around the world have had less than desirable effects. The *Time* magazine cover for February 18, 1985, captures the beginning of a bitter debate over the government's role and ability to facilitate a sustainable and viable agricultural base. The cover headline, "Going Broke—Tangled Policies—Failing Farms," well summarized the situation.

The 1970s were a decade of high prosperity in the croplands. Worldwide demand for U.S. grain and fiber boomed. The government encouraged farmers to plant as much as they could. The farmers complied, were able to sell at well above the federal support levels, and borrowed a lot of money to buy more land to plant more crops and buy more machinery. The more people bought, the more the land prices rose. Then the world recession of 1981 struck. Worldwide demand for crops declined abruptly. Crop prices and land values tumbled. Deflation hit, yet growers were managing their businesses based on an inflation mentality (which is to maintain an asset–equity ratio in the 30–70 percent range). Farmers, largely those who grew between $40,000 and $500,000 worth of food or fiber a year, began losing a lot of money. A crisis of mounting debts, foreclosures, and a fast-changing debate and projection about the sustainability and viability of agriculture in the U.S. rages on even as we write in 1989.

Medium-sized farm enterprises got caught in the middle of changing policies and their own inability to sort out competing views of where the world was heading. The cautions of Schumacher's (1973) popular book *Small Is Beautiful* seemed not to reach the agribusiness manager during this time, as so many real estate, financial, and government advice-givers were pushing a "big and more is better" philosophy. So by 1986, farmers in America owed more money than the nations of Mexico and Brazil combined. Perhaps the impacts of government

policies on the farmer are best summed up by the remarks of Don Paarlberg, former chief economist of the U.S. Department of Agriculture under presidents Nixon and Ford, "We were speeding at 80 miles an hour, then, instead of slowing down as prudent drivers should, the government slammed on the brakes. It plastered farmers against the windshield" (Robbins, 1985). While policy decisions were based on current and anticipated conditions, many people have questioned not only the approach selected but the level of debate that led up to it.

Growth Pressures

The 1970s also saw "boom and bust" in other primary industries, such as energy and minerals. Space does not permit even a cursory overview, but the general pattern resembles and is probably linked to the agricultural crisis discussed earlier. The important point to note is that national and regional economies, as well as communities and individual enterprises, that are dependent on such commodities as petroleum, coal, copper, and the like are highly vulnerable to swings of world markets. Boom times, when world market conditions are favorable, subject such communities to extraordinary growth pressures. These pressures result from (1) the rapid influx of migrants, including people from other countries, who are also new residents, neighbors, consumers, and employees; (2) the pressure to rapidly expand governmental services and infrastructure in order to help new businesses become established and to accommodate more residents; (3) the emergence of new environmental problems; and (4) the need to meet the concerns and complaints of existing residents, who may see themselves as not benefiting from growth.

All bubbles ultimately burst, and the effects on dependent nations, communities, firms, and individuals of price declines for their marketable commodities are devastating; impacts cited in the literature include unemployment, emigration, bankruptcy, individual stress, governmental insolvency, and the irreversible and uncompensatable environmental and cultural impacts associated with the past development-boom phase.

Risks

Financial Risks. The North American Arctic, embracing both Alaska and northern Canada, has been caught up in a boom–bust cycle for more than a century. The area has had anything but a stable economy (Dixon, 1978). The first boom, in the mid-nineteenth century, was the fur trade. The second was the gold rush, beginning in 1897 in the Canadian Klondike (London, 1900) and in 1903 in Alaska. Another major boom involved military construction, starting in the 1940s and extending into the 1950s, with the construction of air-defense facilities, including the DEW Line of radar stations along the Arctic Circle. The most recent boom has been associated with the development of north-slope (Alaska) and Beaufort Sea (Canada) oil and pipeline construction. Construction of the trans-Alaska pipeline officially commenced in 1974, in turn setting off another cycle. Each of these periods of frantic growth, even including the latest one, has been followed by hard times. In other words, this pattern of development seems not to foster sustainable development, but rather the reverse.

One can only begin to imagine what it is like to manage an enterprise and attempt to adjust to the ever-changing circumstances that have characterized the North American Arctic region. The consequences of the oil boom in Alaska have been documented as they have occurred (and continue to occur). One of the problems with periods of rapid economic growth is that they are difficult to anticipate and prepare for, especially in small-sized communities and family businesses. According to Dixon (1978), what happened in Fairbanks, Alaska, was that although everyone knew that oil development was going to happen *sometime*, state and local government and most of the business community either lacked capital or was reluctant to invest it and other resources to prepare for the boom. Yet, when pipeline construction seemed imminent in 1970, some forward-thinking business people did invest heavily in facilities and inventory. When the pipeline was delayed by lawsuits, the forward-looking businesses were burned. According to the mayor of Fairbanks, "Because of lack of commitment by the oil industry, it was difficult for people here to justify spending money, either their own or the public's, on preparation for the boom that might never come" (cited in Dixon, 1978:135).

This conservative, wait-and-see attitude adopted by many people in this example may be attributed to the long history of boom–bust cycles in the area and a wise strategy at the time. Such insights are important, since the various inquiry approaches described in this book are intended to help people plan the changes they want and need. However, real life does not always proceed in the ways we anticipate or for which we plan.

Social Risks. One possible confounding factor in this and many other situations is that some of the key parties in a situation may choose to act in ways that influence the success of the other parties' actions. For example, the specific source of delay in construction of the pipeline was the conflicting views of oil companies, environmentalists, Native Americans, state officials, and other development interests regarding specific impacts, ownership of needed basic resources, and the distribution of potential costs and benefits. Matters were tied up in the courts for several years and ultimately were resolved only through a seemingly incongruous alliance of oil companies and Alaskan natives to drive a unique legislative package through the Congress in Washington.

Other events occurred that might have been handled better if certain governmental and business organizations had implemented appropriate planning procedures and thought more holistically about the emerging situation. Three months after construction of the pipeline was begun, Fairbanks ran out of telephone numbers! And it would take two years to obtain the equipment required to meet existing, to say nothing of projected, demand. The next crisis was in housing, followed by electrical supply, schools, transportation, water supply, and sewage treatment. Crime, ranging from labor racketeering to murder to drug and alcohol abuse to prostitution, escalated. Finally, outside speculators, with better access

to capital, were able to build housing and start businesses when the locals could not. This too generated much bitterness at the time.

Other Themes of Concern

The headlines and social critiques of agricultural and natural resource activity of the past decades also reveal major themes of concern and issues that confront current and future professionals in these fields. Each of these themes raises countless questions about how best to manage food, agricultural, and natural-resource enterprises. They cover the broad issues of the effects of agricultural management practices on the biological, physical, social, economic, and cultural environment. They also cover themes of concern regarding how these factors and environments affect food, agricultural, and natural resource activities.

Perhaps the most prominent themes of concern deal with the massive surpluses of some agricultural commodities, the continued increase in costs of production relative to food prices, and the environmental and health impacts of agricultural chemicals. Other major themes of concern deal with the consequences of current soil management practices on public health, water quality, and water availability and the long-term sustainability of the physical environment.

Sustainability

Practices that cause soil erosion or fertility loss through biological, physical, and chemical stresses cannot be sustained indefinitely into the future. The persistence of chemical biocides in the same soils and the salinization of the water that runs through it are further threats to its integrity. In 1972, the Rural Development Act was established in response to these concerns and in order to establish guidelines for development and conservation of rural land and water resources and to prevent and abate agriculturally related pollution in rural areas. Yet, in 1989, as reported in the news media, in the records of regulatory agencies and courts, and in legislative hearings, abuses persist.

Land Use. Major choices confront us. Much of the potential cropland is now used for grazing or is in forest. Conversion of range or forest to cropland would increase our nation's capability to grow crops, but this would reduce our potential to increase forage or timber production. It would also decrease wildlife habitats. Moreover, the conversion of relatively dry rangelands to crop agriculture increases a region's vulnerability to drought and soil erosion, as occurred in the dust-bowl years of the 1930s. Because of the rapid rise in foreign demand for agricultural commodities and farmers' growing dependence on the international market in order to remain economically viable, the choice about how to manage land resources is far from simple. Indeed, in some regions of the country, the choice is between devoting land to cropland or to housing, water conservation, waste disposal, industrial and commercial facilities, and the infrastructure to support them.

Water. Effective use of water has been at the center of crises and controversies in various regions of the United States throughout the 1970s and 1980s and exemplifies another kind of complexity faced by agricultural and natural resource managers. These situations have involved four kinds of changes: (1) drought, (2) overutilization, (3) declining water quality, and (4) proposals and programs to develop or reallocate water resources. More often than not, a given local or regional situation involved a combination of these. For example, drought has two meanings: (1) a prolonged period of lower-than-normal rainfall and (2) insufficient water to support normal human uses and activities. Thus, if a rainfall deficit occurs in a region that is experiencing population and economic growth, the water-supply system will be very quickly stressed. Moreover, alternative sources may be unusable due to pollution, and authorities will need to make political decisions regarding allocation priorities. Access, protection, conservation, and utilization of water are concerns that many agricultural and natural resource enterprises must tackle immediately.

Agriculture is now the nation's largest consumer of water. More than 250 billion gallons a day are withdrawn from surface waters (U.S. Department of Agriculture, 1982). Total groundwater withdrawals exceed 80 billion gallons a day, including 21 billion gallons that are not replaced through natural recharge. Four times more water is used for producing food and fiber than for all other purposes combined. Irrigation water is a major concern. Irrigated crops, grown on only about 12 percent of the nation's croplands, account for about 25 percent of the total value of crop production in the U.S. How and for what purposes agricultural and natural resource managers use water are now everybody's concern. As discussed earlier, urban, residential, and industrial users compete with farmers and natural resource enterprises for water in many parts of the country.

Inadequate and mismanaged water-supply systems are leading to degraded water quality, wasted water and energy, reduced instream flows, and increased production costs for farmers and other industries. Return flows to streams from irrigated fields are important to downstream water users. Even in average years, stream flows in the Colorado, Rio Grande, and Great Basin regions are inadequate to meet offstream uses and instream needs for aquatic life.

Soils. Soils, another natural resource, are also under pressure. Soil erosion remains a threat to the sustainability and productivity of 13 percent of all croplands in the United States. Annual soil loss and the average annual rate of sheet and rill erosion on cropland in the corn belt are double that in any other region. The average rate of erosion on cropland in Hawaii and the Caribbean area is triple that of any other region, but the average rate also exceeds five tons per acre in the Appalachians, the corn belt, the Mississippi Delta region, and the South-

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east. Holding erosion at a level of under four or five tons of topsoil per acre annually on croplands, pasturelands, and forest lands so that sustained use of the soil is possible is a major national goal (U.S. Department of Agriculture, 1982; Brown, 1984).

Flood. A significant portion of the nation's agricultural and natural resource base rests on flood-prone lands. More than 29 percent of the forest lands, 28 percent of the rangelands, 20 percent of the croplands, and 11 percent of our pasturelands are flood-prone. New efforts are needed to protect these lands from flood damage.

Pollution. Agricultural activity may be the most widespread source of nonpoint source pollution in the nation. Bacteria, nutrients, dissolved solids (e.g., salinity); suspended solids (sediment); and toxic materials are the most common and most serious nonpoint source pollutants in the U.S. This type of pollution comes mainly from runoff or irrigation return flow. Water runoff often increases levels of bacteria, sediment, nutrients, and pesticides in surface and subsurface water supplies that serve homes and industry. Irrigation return flow generally increases the level of dissolved solids, nutrients, and pesticides in streams and rivers. Large-scale animal operations have impacts on water quality similar to the impacts of untreated human sewage. Consequently, more drinking-water sources have become polluted; coastal waters are degraded; and aquatic, marine, and water-dependent wildlife is less abundant in many areas. This issue has taken on international dimensions in the case of treaty-protected migratory waterfowl such as ducks and geese.

Wetland Loss. Because of the pressures to increase agricultural production, thousands of acres of wetlands annually have been drained. Wetlands provide a habitat for a variety of wildlife. They also serve as sediment and nutrient traps for the stream flows into and through them and thus enhance downstream water quality. It is becoming clear that one person's, or family's, or agribusiness's use of an area can have far-reaching effects on the land, water, and human resources in that area. No longer are people willing to see agricultural and natural resource enterprises strictly as private affairs. Hence, as noted earlier, in addition to being viewed as profit-making organizations, enterprises of various kinds are also seen as producers of essential goods and services, as users of common resources, and as subject to the social values and ethical standards associated with quality of life.

The Costs of Technology

Technological developments that have contributed to sustained increases in production per acre are also linked to increased costs. Major production costs for farmers are interest on debt, machinery, fuel, fertilizer, pesticides, and labor. While in the past most inputs needed to manage and operate a farm came from the farm family's human and natural resources, now most are purchased from outside their system. The cost of inputs such as fuel and energy, chemicals, and fertilizer have increased tremendously during the 1970 to 1989 period. In the same period, demand for and costs of farm machinery have also increased. As a result, farmers are at risk of receiving less for their products than their cost to produce them, as well as of being economically devastated by growing loan interest payments and tax increases.

The agribusiness manufacturers and supply firms, who have also been hard hit by the weak farm economy, stand ready to sell inputs to growers and producers. While such inputs sometimes increase efficiency, many managers have difficulty deciding whom to listen to and how to sort out the consequences. Those who earlier adopted a profit-expansion strategy seemingly were later the hardest hit. And for a while, the government continued to encourage the profit-expansion, consumption-oriented approach to agricultural development beyond the point where it no longer made sense to many observers. Indeed, there are many forces at work that make it difficult to decide how to manage agricultural and natural resource enterprises.

Chemical Impacts. Another concern is modern agriculture's reliance on nonrenewable resources that have the potential for destroying natural processes of decomposition and nutrient cycling. For example, use of synthetic biocides that unintentionally kill useful soil organisms has disrupted heterotrophic food chains needed to break down organic materials. It has also resulted in new strains of pests and pathogens resistant to established methods of control. The destruction of natural processes has also created interdependencies among nations, since the novel strains of pests and pathogens often require new inputs that must be imported.

Ethics. The contamination of dairy cattle feed, which resulted in the tainting of several states' milk supplies, is a costly reminder that we all depend on people in the food and feed industries not only to provide quality services and products, but also to act ethically and wisely. They must think not only of their own business profits, but of their moral and social responsibility. The different ways in which officials of the various states' departments of agriculture and health dealt with the knowledge of contamination are revealing and alarming. Some public managers do not appear to serve the public, but rather the industries involved. In the long run (and in some cases the short run too) such malfeasance may lower the quality of life in a state, region, or nation. Ultimately, the industry that officials were trying to protect may also be affected negatively. Once public trust is violated, it is hard to restore. When public officials fail in their duties, their right to manage is often removed or counterbalanced by the monitoring activities of other groups. For good or bad, increasing regulation does reduce management's control over the operation of its private enterprise and increases the complexity of its task.

Irradiation. Technological advances that seem promising to some people are sources of fear and concern to others. Irradiation of fruit and vegetables is a case in point. New irradiation procedures and technologies hold great promise for ridding produce of pests prior to packaging and shipping and for prolonging shelf life. They not only kill insects but also delay ripening and kill microorganisms. Many growers would prefer irradiation over the established double-dip or vapor heat method because, among other reasons, it would mean less time spent on harvesting.

Yet, irradiation technologies have many critics. The source of radioactivity used in the irradiator is Cobalt 60 or Cesium 137. Cesium 137 is a byproduct of plutonium production for bombs and other weapons systems. It can be obtained very inexpensively from the federal government, yet it is one of the deadliest of the high-level nuclear wastes. Some people are annoyed that the government would charge states and other potential users for waste products of which they cannot safely dispose. A "not in my backyard" (or NIMBY) attitude has developed, even among people who aren't opposed to irradiation technology on other grounds. Technical, governmental, and community groups are concerned about the possibility of leakage if a steel tank, in which the radioactive elements are submerged in water and stored, were to crack during an earthquake. There is concern about possible human error during transport or at the plant and the health effects of low-level radiation emissions. There are also concerns about the competence of plant managers and employees to oversee the use of this technology safely. All of the irradiation plants in one northeastern state were closed and their management prosecuted because radioactive materials were improperly handled and, in one instance, allowed to escape into the environment, and company records were falsified. The legislature of that state passed a law banning food irradiation, but the governor vetoed it. There are many viewpoints.

Fertilizers. Another example of technological development that has presented new dilemmas is the introduction of artificial fertilizer to agriculture. There were phenomenal per-acre increases in crop production after artificial fertilizers were introduced. While welcomed as a breakthrough, fertilizers significantly contributed to the accumulation of large surpluses of many commodities, which led to the need for more and bigger storage facilities, followed by a federal excess-disposal program. Surpluses contributed to the decline in prices of the commodities involved. Then legislative action, such as the Agricultural Acts of 1970–1973 and 1977, the Payment-in-Kind (PIK) program of 1983, and the set-aside program of 1987, was seen as necessary to deal with that problem.

Federal Policies

When excess disposal and acreage allotment programs were introduced in the U.S., world agricultural trade and market prices were affected. Accordingly, the active price support programs aimed at cushioning producers against shocks from market fluctuations ultimately did not have the effect designers intended. These supports are complex mixtures of government loans and cash payments to farmers who sometimes have to restrict planting to qualify for them. The supports keep U.S. prices of many major food commodities well above those prevailing in the rest of the world. They guarantee the farmer a minimum price per bushel, with the government making up the difference between that floor (or minimum price) and the price in the marketplace. However, some observers believe that the effect worldwide was to encourage farmers in Canada, Brazil, Argentina, the European Community, and elsewhere to expand production because they knew they could undersell the U.S. grower. The federal price-support program kept U.S. markets from cutting commodity and food prices to regain lost overseas sales. Why cut prices when they can get a higher price from their own government? As a result, export sales of U.S. food products have dramatically decreased. They went from $7 billion in 1970 to a peak of $43.8 billion in 1981, then fell more than 20 percent in the next two years, and then only slightly increased in 1985 to $36.5 billion (Church, 1985). Only in the past few years have policies been altered to encourage export sales.

Current agricultural policy challenges farmers to manage their enterprises in ways that will avoid entrapment in the cost/price squeeze that leads inevitably to surplus production. The latter effect occurs when farmers strive to maintain their incomes by increasing productivity and sometimes expanding production.

Trends in Consumption

As if the national policy and world market situations were not complex enough, the farmer is also beset by the fickleness of fashion and value shifts and their impacts on market prices for a range of food, fiber, and textile products. Eating patterns change. Concern about health can bring marked changes in the diet of consumers, which in turn aggregates into important shifts in demand for certain agricultural products. This at least partly underlies the drift of consumers toward chicken and away from beef and other red meats. Increasing concern about the environment by urban-based advocacy groups can lead to intersectoral pressure to change growers' agricultural practices. These range from worries about widespread pollution to the animal welfare debate.

The decline of rural communities and their agrarian values is a concern to many people. The decline is due, at least in part, to the emigration of members of farm families impoverished by their disadvantageous terms of trade. While arguments are raised about the need to preserve farmland, inevitable conflicts arise over pressures to use land in alternative ways.

Natural Forces

Not only do the actions of other nations and the efforts of agribusiness affect the well-being of Americans in communities depending on agriculture and natural resources, but nature also takes its toll. Thus, managers also must respond to natural changes. In 1985–1986, for example, there were major droughts in the Southeast and the Southwest. In June 1985, even as the sun belt dried up, heavy rainfall and floods washed away at least 80 million tons of Iowa's rich topsoil,

probably the worst rate of water erosion in the state's history. Hailstorms destroy $700 million of crops each year. A massive grasshopper infestation hit the western states in 1985. What is the proper role of government in protecting agriculture against losses due to natural disasters? The Federal Crop Insurance Corporation and the Federal Disaster Assistance Administration offer some protection through the natural disasters payments program. But some business and government leaders do not believe that government should bail out producers.

Global Interdependence and Agriculture

Over the past decade, the complexity of the management problems of U.S. farmers has intensified due to changes in world trade. Many traditional food-importing countries are now self-sufficient in production, and some are producing sufficient surpluses to be net exporters of food, fiber, and other agricultural products. Sometimes this has been accomplished by substituting the production of food crops for inedible cash crops, although more commonly it results from the transfer of new crops and technologies, such as those of the "green revolution." Thus, new interactions and interdependencies have emerged, which U.S. managers must take into account as they plan improvements.

Farmers in China are producing record harvests of wheat, coarse grains, rice, oil seeds, and cotton. In Britain, new winter barley varieties have added a million tons a year to cereal production. Saudi Arabia is literally turning its desert green, using its immense supply of "waste" fossil fuels. In 1985, it set a world record by generating a wheat surplus. Potential new uses for agricultural products are being discovered almost daily. What were once weeds are now processed into sophisticated pharmaceuticals; waste products are now animal feed. Because farmers can produce in surplus, people have been freed from the quest for food.

What is a blessing is also a problem. Globally and nationally, we cannot agree on what to do about surplus production. Secretary of Agriculture Block said in a 1986 speech that if a farmer in North Dakota sneezes, a farmer in India catches a cold! Perhaps the correct simile now is if a farmer in India sneezes, a farmer in North Dakota catches a cold! The growers of the world are more interdependent, and we have less control of our food supply than in the past.

A Diversity of Perspectives on U.S. Agriculture

Because agricultural and natural resources enterprises in the United States face many challenges and dilemmas, several analyses have been made that focus on the nature of these industries and propose appropriate responses. Authorities swing between two extreme and seemingly conflicting views: that agricultural and natural resources systems have chronic, built-in overcapacities or that they are perennially subject to scarcity due to underproduction. *The Roots of the Farm Problem* (Heady, 1965) and *The Overproduction Trap in U.S. Agriculture* (Johnson and Quance, 1972) are two key works that present convincing evidence in support of the chronic overproduction thesis. *Seeds of Change* (Brown, 1970) and *By Bread Alone* (Brown and Eckholm, 1974) support the underproduction stance.

Another perspective that has influenced governmental and industrial action is *An Inquiry into the Human Prospect* (Heilbroner, 1972). It is concerned that people's supposed inability to control rapid population growth will lead to catastrophic famine and disease in the developing world and unrestricted industrial growth and environmental collapse in the developed world.

The widely disseminated, discussed, and interpreted Club of Rome Report, also known as the Limits to Growth report (Forrester, 1971; Kahn, 1976; Meadows et al., 1972), does not paint as gloomy a picture. For example, it is projected that the challenge of the population explosion can be met by technological advances sufficient to feed twice the current world population by the year 2000.

In *The Human Interest*, Lester Brown (1974) advocates regulating population growth and conserving limited resources and food supplies. He purposely avoids the alternative of increasing conventional food production because of potential environmental impacts.

Still other works, such as several studies commissioned by the U.S. Department of Agriculture (National Academy of Sciences, 1974, 1975) propose a world of rigorous supply–demand management in which humanity can and must control itself and its environment, a world in which both technologies and human values change. According to this view, a balanced future is sought in which both quantity and quality of human existence are valued. Rather than rejecting the machine, having blind faith in science, or giving up in despair, they project a vision of a future in which science and people get on with the job of rational analysis and positive action.

New Professional Competencies and Approaches

These U.S. Department of Agriculture/National Academy of Sciences reports imply that we already have the competencies and tools necessary for the required inquiry and action. Yet people do not make decisions and behave entirely rationally or objectively. These reports paint a picture of people that is not borne out in research or everyday observation.

This book has adopted a different view of what is needed. According to this view, which is shared by others in the agricultural higher education community, there is a pressing need for professionals who can deal more effectively with complex, messy, value-laden situations of the sort that face producers, distributors, processors, and consumers of agricultural and natural resources products. Practitioners and professionals in the fields of food, agriculture, and natural resources need to use both systematic and systemic thought and approaches to inquiry. They need to be able to think rationally and intuitively themselves as well as to be able to deal with thinking that appears to be irrational or different from their own ways of viewing a situation. The point is that people bring di-

verse world views and experiences to any problematic situation, and therefore one person's rationality may be viewed by another as ignorance or worse. In fact, the various approaches to the situation are merely different rationalities, which need to be dealt with and accommodated in order to find satisfactory improvements.

Finally, there is a pressing need for food, agricultural, and natural resources professionals who can help the people they serve acquire a stronger orientation toward the future. This means that they must develop the ability to focus inquiry, not on changes that might be needed, but on defining the future *state* toward which specific changes are to be directed. "Don't put the car in gear until you know precisely where you want to go!" This involves learning how to examine an organization's or enterprise's mission and develop strategic plans that relate to particular concerns, opportunities, or challenges.

All natural resource, food, and agricultural organizations and enterprises need the capacity—essentially the personnel with the necessary competencies—to engage in meaningful, ongoing mission evaluation, priority setting, and strategic planning if they are to sustain and enhance their operations in constantly changing economic, social, biological, and physical environments. In introducing the soft systems approach, the objective of this book is to present an inquiry process that readers can use to fully explore their current problematic situations, to develop detailed pictures of improved ways of addressing them, and to produce the concrete strategic plans necessary to achieve the features of that improved state of affairs.

As the introduction to this chapter noted, these days, decisions concerning what technologies to develop and use and concerning how to manage enterprises in changing environments are far from simple. Predicting the impacts of a biological or physical management practice is equally difficult. Graduates in the food, agricultural, and natural resource fields are becoming increasingly involved in situations that are messy and difficult to define. People factors loom large. New competencies and involvements are needed to deal with these situations. These involvements transcend and call into question the adequacy of traditional problem-solving methodologies that are taught in our colleges. Graduates need an array of approaches to inquiry that will help them comprehend and take action on the interactions, impacts, and complexities of situations in ways that are conceptually valid and practically effective.

The Role of Professionals

The traditional role of professionals as interventionists is also changing. Until now, those heading for careers in food, agriculture, and natural resources have been trained to view themselves as intervening in the biological and physical systems of the world. Yet what about the agricultural and natural resource enterprises that respond to, develop, alter, and manage biological, physical, and human systems? Professionals, managers, and other practitioners need to broaden the range of factors to which they pay attention. In addition, in the past, a professional's stance on intervention has been that of expert or advice-giver, while

a more appropriate role may well be that of facilitator of people's own inquiry into their concerns, opportunities, and challenges.

Professionals must also learn to assimilate varying viewpoints and to structure debate in ways that will lead to improvements in a melange of complex and dynamic factors in problematic situations. To do this, new professional competencies are required. It is not simply a matter of taking account of different attitudes because underlying the varied perspectives that are offered for the future development of agriculture and natural resources are profoundly different ways of viewing the same world and of tackling its problems.

Use of Technical Terms

Peter Checkland (1981:11) makes a useful distinction between jargon and technical terms. He says that "It is very noticeable that the word 'jargon' is hurled as a missile at any attempt to use technical terms in discussing human activity or social systems." The renowned sociologist C. Wright Mills (1959) has defined jargon as "a seemingly arbitrary and certainly endless elaboration of distinctions which neither enlarge our understanding nor make our experience more sensible." Following Mills' critique, Checkland argues for the need to use precisely defined terms so that the reader knows exactly what is being discussed. As much as possible, the number of technical terms used in this text will be limited. When a term is used, it will have a body of conceptual or applied research literature that justifies it. The underlying theories, concepts, and empirical findings will be discussed when the term is introduced. A glossary is also provided in the back of this book. Because the presentation of arguments in this book depends on an understanding of technical terms, it is suggested that you pause to commit each term to understanding as it is introduced and take care to check whenever you encounter a term or word that you don't understand. You will also find that a good collegiate dictionary is a useful tool.

The Aims of This Book

The challenge of writing this text is to provide sufficient guidance for you to understand and use the methodologies and techniques it introduces, while not conveying the message that "this is the only way to do it." In Chapters 4 to 8, however, the book details the whats, whys, and hows of soft systems inquiry. This is because it is a relatively new approach, and its applications to food, agricultural, and natural resources issues warrant particular attention. The hope is to communicate with sufficient detail and clarity to give you a base from which to begin your own *experience*. Experience is emphasized because this approach is meant to be used and to be learned by using it. If the authors were with you in person, they would facilitate your discovery of some things on your own before talking about them. Authors of a book are, however, limited by the written

word. So, while the text may appear to assume a fairly direct and prescriptive style, the intention is to communicate approaches to inquiry so that you can begin your own practice. If you are learning the concepts and process introduced in this text with an instructor, you may actually learn through experience (simulated or real) and use the text as a summary of what was said and what you did in order to improve perception, thinking, and action.

Outline of the Book's Main Points

The discussion developed in Chapters 1 to 8 is summarized here:

Chapter 1

1. Chapter 1 illustrates the dynamism and complexity of the world in which we live and, in particular, of the situations in which we must perform as professionals in the food, agricultural, and natural resource sciences. The interdependence of enterprises, governmental bodies, other institutions such as science, and whole nations is by itself a source of difficulty.

2. Today's and tomorrow's food, agricultural, and natural resource professionals face new challenges and opportunities. New kinds of competencies and a broad range of inquiry methodologies and knowledge are needed in order to respond to these challenges. This book is devoted to helping graduates develop such knowledge and competencies.

3. The ability to focus, not on specific technical changes, but on a vision of an improved future state is particularly emphasized.

Chapter 2

1. Learning is the process by which experience is transformed into knowledge and knowledge is transformed into action. It is a dynamic process of adaptation and action in which we repeatedly interact with our social, biological, and physical environment. It follows that learning to tackle real-world problems is a key to being effective in our professional careers as well as in our daily lives.

2. Learning involves four major dimensions, describing types of activities: (1) *prehension*—how we explore experience and find information to determine the meaning of a given situation; (2) *transformation*—how we take action once we think we have understood a situation; (3) *methodology*—how much of the complexity in a given situation we choose to handle; and (4) *insight*—how rational or intuitive we are in deciding what the facts and meanings are and what courses of action should be taken.

3. Individuals develop and use markedly different styles of learning and problem solving in relation to the opportunities and challenges they face in food, agricultural, and natural resource situations. Our learning style is measured by how we deal with experience in relation to the two primary dimensions of inquiry: prehension, involving the concrete experience ↔ abstract conceptualization axis and transformation, involving the reflective observation ↔ active experimentation axis.

4. When these axes are combined, four styles of learning are described: (1) diverging, (2) assimilating, (3) converging, and (4) accommodating. Each style represents a person's particular orientation toward finding out about and taking action in a given situation.

5. Not only do people have their own styles of learning, they also have unique ways of looking at the world. While these techniques are based partly on a person's preferred learning style, many other factors contribute to a person's world view. These factors include values, beliefs, morals, tastes, cultural tradition, past experience, language, attitudes, and personalities. A person's world view will markedly influence the types of observation that person makes, the kind of information he or she collects, the meaning that person attributes to experience, and the lines of action he or she selects. Thus the way people create knowledge, and the substance of that knowledge, are determined by their particular learning styles *and* world views.

6. A model of the learning cycle is applied to review methodologies used in pursuing inquiry into food, agricultural, and natural resource problems, basic and applied science methodologies are presented in Chapter 2, and hard and soft systems inquiry are reviewed in Chapter 3.

7. The distinction is drawn and discussed between *methodology*, the abstract logic justifying our inquiry process, and *technique*, the actual procedures employed to gather data and analyze them.

8. All the competencies associated with the four styles of learning are needed to carry out any given methodology or process of inquiry. While some parts of a given approach will be easier to handle because they seem to come naturally, others will require competencies found in styles of learning different from one's own. These inquiry competencies can be learned.

9. Professionals in the food, agricultural, and natural resource sciences will use at least four different kinds of inquiry methodologies in order to tackle the range of problematic situations typically encountered. Each methodology is better at addressing some types of questions than others and has its own distinct tasks, guided by a philosophical foundation.

Chapter 3

1. This chapter reviews key premises of systems thinking, including the principles of holism, transformation, control, communication, hierarchy, and emergent properties.

2. The stages and uses of hard and soft systems inquiry are discussed and compared.

3. The learning-cycle model and the various inquiry methodologies are now combined and conceptualized as a spiral of inquiry. A key professional competency is the ability to select methodologies appropriate to the questions people

are asking in a particular situation and to decide how definable that situation is. In the abstract, none of the four inquiry methodologies is superior. Rather, the well-rounded professional needs to be competent in the use of a range of methodologies in order to tackle the variety of themes of concern that will be present in most food, agricultural, and natural resource situations.

4. This chapter also introduces the basics of modeling in systems inquiry, including techniques useful in both hard and soft systems approaches.

5. The chapter concludes with an overview of the soft systems approach and compares it to the procedures of hard systems inquiry.

Chapter 4

1. This chapter presents stages 1 and 2 of the soft systems approach in detail.

2. Divergent learning-style competencies are employed in order to enter into situations and to understand them fully and without bias. Assimilative learning-style competencies are employed to synthesize and analyze the information collected.

3. The inquiry process starts by looking at problematic situations rather than at a specific problem. A situation is comprised of people as individuals and in groups, a historical context that bears on the present, key human activities, themes of concern, unease and opportunity, decision-making structures, environmental factors, relational climates, senses of improvement and impact, and differences among viewpoints.

4. A key task is collecting and synthesizing certain kinds of oral and written information. What information to collect and how to collect it are discussed. A beginning set of techniques that facilitates the collection, synthesis, and analysis of information and that is congruent with the philosophy of the work of stages 1 and 2 is suggested, and practice exercises are provided.

5. Striving to view a situation from many angles and from the perspective of the people involved leads to insights that can be used to develop ideas of meaningful change. This process is the first step in trying to develop world views that incorporate and transcend those of individuals and groups; thus, the process provides a basis for collaboration and cooperation.

6. The task of describing and analyzing the situation is carried out by the people involved. Inquiry thus becomes a mutual learning process in which useful knowledge is generated by all. People's capacity to analyze and design improvements is increased by the mutual learning relationship, contrasting with the traditional expert–client relationship in which ownership of the inquiry process remains with the expert.

7. Several techniques are presented for analyzing themes of concern and opportunity in a situation (mind mapping) and for synthesizing information regarding the nature of the groups, human activities, and relational climates present (cartooning). The end product is a situation summary, a record of the conclusions of stage 2, which will be useful throughout the remainder of the inquiry process.

Chapter 5

1. This chapter is about stages 3 and 4 of the soft systems approach.

2. Often people who are interested in change fail to develop an understanding of potential future improved conditions. This chapter discusses how, using systems concepts, future conditions and states can be conceptualized as human activity systems.

3. When members of a group begin to think systemically, they envision an improved situation as if its elements were functioning entities. Using rules and properties defined in formal systems literature, they then conceptualize these entities as constituting an integrated, functioning whole.

4. Assimilative and convergent learning competencies are used to carry out the inquiry tasks associated with stages 3 and 4. Assimilative abilities are used to form ideas about the kinds of transformations that may occur in the future in order to improve problematic features of the present situation. Convergent abilities are used to develop some of these transformations into human activity system models.

5. Participants design potential human activity systems that have specified inputs, transformations, subsystems, outputs, boundaries, measures of performance, actors, owners, environmental constraints, beneficiaries, and victims, as well as a world view that makes all of these features meaningful.

6. These human activity systems are developed as models. Modeling is the mental process we use to build a manageable replica of something. In the case of a human activity system model, the designers essentially are attempting to answer such questions as "What primary human activities will be occurring in an improved state?" "By and for whom?" "With what resources and anticipated outcomes?"

7. In addition to the mandatory human activity systems model of an improved state of affairs, other kinds of modeling may be done in order to communicate complex interrelationships, to determine how present features might behave if changed in certain ways, or to evaluate alternative strategies of change.

Chapter 6

1. This chapter presents stage 5 of the soft systems approach, which is concerned with the need to pause after completing one or more models to compare them with reality, as represented by the situation summary produced in stage 2.

2. Competencies associated with the convergent learning style are called for here. The ability to choose from among alternative solutions is particularly emphasized.

3. Accordingly, there is a strong temptation to slip back into the expert and technology development roles. This can be avoided if the mutual learning approach is maintained in discussions between the people involved in the situation and the professional facilitator.

4. Four specific techniques for comparing a human activity system model with a picture of reality are outlined: general discussion, question generation,

overlay, and historical reconstruction. The choice of which technique to use depends on the nature of the situation.

5. The overall objective of stage 5 is to verify the viability of the models before they are used to generate specific proposals for change and detailed implementation plans.

Chapter 7

1. This chapter presents stage 6 of the soft systems approach.

2. The central task is for the people involved in the situation to debate the desirability and the feasibility of the specific changes generated by the models of an improved future state. The two basic questions are "Is this what we want [it] to be?" and "Can we really do this?"

3. A debate is a discussion or examination of several sides of a question and an opportunity to consider positive and negative aspects of the changes being proposed.

4. Models of future human activity are seen as desirable when participants judge them to agree with their own world views.

5. Models of future human activity are feasible when participants agree that they can be carried out (1) with available or accessible resources, staff, technology, and individual and organizational capabilities and (2) without incurring unacceptable group and environmental risks and costs.

6. The debate phase has much in common with the comparison phase, and they are often done together. While the comparison phase emphasizes convergent learning, the debate stage favors accommodative competencies. The result of stage 6 is a set of concrete changes to be implemented.

7. Because the contexts in which professionals may operate vary so widely, this chapter also provides a detailed discussion of the arenas in which the debate phase, as well as other soft systems inquiry activities, might be carried out: small face-to-face communities, business firms, multiparty disputes, the courts, bureaucracies, and government. Debate techniques that seem appropriate to particular kinds of situations and contexts are also suggested.

Chapter 8

1. This chapter is about stage 7, formally the last phase of the soft systems approach.

2. The competencies associated with the accommodative learning style are particularly emphasized here, since this is the action phase of the approach.

3. The central tasks of this stage involve developing an implementation plan and then moving to implement specific changes.

4. Alternative scenarios, in which the soft systems approach may also be used to monitor or evaluate initiatives that are already underway, are also discussed.

Appendix

1. The book also includes case materials on three situations. While two of them have been fictionalized, all are based on actual cases.

2. These materials are used in discussions throughout the book, but none of them are brought to a hard and definite conclusion. This holds open the possibility that you, the active learner, can use them to work through specific questions or aspects of the approach.

Glossary

1. A glossary of technical terms introduced in the text, with selected cross-references, is provided.

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CHAPTER 2

The Learning Dimensions of Professional Inquiry

Chapter 2 develops much of the theoretical framework for the remainder of this book and is built on the following point: Professionals spend most of their careers solving problems and improving situations. Problem solving is essentially a learning process. Research has shown that while every person's way of learning is unique to some degree, there are nevertheless patterns that provide bases for models describing how people carry out the learning process.

While it may appear novel to begin a text intended for the food, agricultural, and natural resources fields with concepts of learning, the subject is central to the task professionals face of improving typical situations. One must engage in a learning process in order to improve a situation. Learning can be equated with professional inquiry when it is carried out in order to transform ideas into actions or to alter people's actions and environment.

In addition, learning different inquiry approaches, along with their benefits and limitations, is central to professional development. This involves acquiring new competencies and methodologies. It will also be important to understand the premises, as well as the procedures, associated with a given methodology so that it can be put into practice.

This chapter presents four key learning dimensions. It provides a model that is useful for thinking about learning patterns and processes. It also integrates learning concepts with inquiry approaches useful to professionals in food, agricultural, and natural resources situations. The chapter concludes with an overview of two of these inquiry approaches, basic science and applied science inquiry. Others are introduced in Chapter 3.

What Is Learning?

If you want to deal effectively with food, agricultural, and natural resource problems, then you must understand how you and other people learn about and act on situations in the real world. The mark of educated people is that they command not only information, but also productive ways to find out about and take action on a wide array of problems. Learning is the process people use to make sense out of and gain some control over the ever-changing world. This chapter

Appendix 19

May 4:30 - 5:30 EXERCISE - USING THE PRESSURE BOMB.

I. Introduction and Background:

Plant structure and function:

Roots - uptake,

Stem - transport,

Leaf - transpiration

Plant Water Potential -

solute - hydrostatic

II. Use of the Pressure Bomb -

cautions in use

Correcting for internal pressure

III. Interpreting the Results

Water use patterns:

Diurnal Cycle - interaction with stomatal function

Seasonal Pattern -

Interpretations:

Ecological: Examples

Physiological: Examples

IV. Summary

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LABORATORY EXERCISE

PLANT WATER POTENTIAL

PURPOSE: To gain experience in measuring plant water potential using a pressure chamber apparatus (pressure bomb) and to understand some of the capabilities and limitations of this kind of measurement.

PROCEDURE: Each team of 2 to 4 students will work together to conduct the measurements outlined below. It is very important that each member of the team operates the instrument sometime during the measuring session. Also, the procedures outlined in the attached reading should be studied carefully so that each team member understands what measurements are to be made and why.

MATERIALS: Plant materials (seedling and trees outside); pressure chamber apparatus; nitrogen tank.

REPORT: Each team member will complete and submit a report using the data collected by the team, present results of the experiments, and discuss those results.

EXPERIMENT 1: Variability of the end-point

Conduct a series of measurements on the plants provided or designated. Each member of the team conduct five measurements of plant water potential. Discuss reasons for the variability and for the differences (if any) between results of various operators.

EXPERIMENT 2: Effect of light on plant water potential

Conduct five measurements on two plants; one in the shade and one in the sun or bright lights (if inside the laboratory). Compare the results and explain any differences.

EXPERIMENT 3: Effect of crown position on plant water potential

Conduct five measurements on samples from various parts of a tree. Compare the results and explain any differences.

EXPERIMENT 4: Effect of drying the plant sample on plant water potential

Obtain a large branch from a tree. Conduct three measurements of plant water potential at times 0, 5, 10, 20, 30, and 60 minutes. Leave the branch lying on the table between measurements. Explain your results.

EXPERIMENT 5: Effect of excessive xylem protruding through the rubber seal

Insert a small twig into the chamber such that about half of the twig has been stripped of leaves and phloem and protrudes through the rubber seal. Make another measurement on a sample from the same twig which protrudes only about 1/4" through the seal. Repeat this comparison two more times. Explain any differences you observe.

EXPERIMENT 6: Effect of repeated measurements on the same sample

Prepare a sample for measurement and determine the endpoint. Exhaust the chamber slightly (about 50-100 psi below the endpoint) and pressurize the chamber again, making a second determination on the same sample. Repeat this procedure three more times (five measurements on the same plant sample). Remove that sample and repeat the procedure on two additional plant samples (total of 15 measurements). Discuss your results.

EXPERIMENT 7: Effect of water supply on plant water potential

Cut a branch from a tree (preferably in the sun) and immerse the cut end in water. Measure the plant water potential immediately (time 0) and at various times during the next hour. Make as many measurements as you think you need to describe the changes occurring during the subsequent hour. Discuss your results.

PRESSURE CHAMBER TECHNIQUE FOR MONITORING AND EVALUATING SEEDLING WATER STATUS

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Use of the pressure chamber to evaluate plant water status has increased dramatically during the past decade. First introduced in 1914 (Dixon, 1914), the technique was virtually ignored until 1965 when Scholander reintroduced it (Scholander et al., 1965). Since then, plant water status generally has been determined by the pressure chamber—or "pressure bomb"--technique. Beginning in 1968, foresters in the Pacific Northwest have used this method extensively to evaluate seedling water status (Cleary, 1968).

Comparisons between the pressure chamber method and other techniques of measuring plant water potential are numerous (Boyer, 1967; Kaufman, 1968; Ritchie and Hinckley, 1975) and have validated using the pressure chamber as both a research tool and practical device. Fast, reliable, and accurate measurements can be made easily in the laboratory or field. However, it is not our intent in this paper to review all the techniques for estimating plant water status (see Ritchie and Hinckley, 1975, for a summary of comparisons published up to 1974) but, instead, to discuss the merits and safe, effective use of the pressure chamber method.

The J-14 press has been suggested as a substitute for the pressure chamber[1]. Basically, this device uses a flexible membrane to apply pressure to a tissue sample. Observed through a plexiglass window, the sample will either exude water from its xylem elements or, at lower water potentials, change color as cells rupture. The pressure required to cause either of these changes is calibrated to some other measure of water potential, often a pressure chamber. Our attempt to calibrate the J-14 using the pressure chamber as suggested by Childs[1] gave an unusable calibration curve (Fig. 1). Even though the J-14 can make measurements rapidly and does not require a compressed gas supply, it has some serious disadvantages: (1) the endpoint is indefinite; (2) precision is low; (3) it requires calibration with a pressure chamber; and (4) different age foliage gives different results. A very large sample size would be required to overcome these shortcomings and achieve an acceptable degree of accuracy.

[1] S. Childs. 1979. Evaluation of a rapid technique to estimate plant water potential for applications in forests (unpubl.).

USING THE PRESSURE CHAMBER

Foliage cut from a branch (the sample, A) is placed in the chamber (B) with the cut end of the sample exposed through the chamber cover (Fig. 2). Chamber pressure is slowly increased with nitrogen from a high pressure tank (C) until water is forced back to the cut surface (D). That pressure, indicated on the pressure gauge (E), estimates water potential (Ψ_w). Scholander et al. (1965) proposed that this technique measures gravitational and functional potentials. Boyer (1969) demonstrated that xylem water potential is indeed equal to the combined gravitational and functional components plus a third component comprising xylem solute and matric potential. This third component is not measured with the pressure chamber technique. Because it is commonly either negligible or constant, this correction for matric potential is generally ignored and the pressure chamber measurement accepted as an estimate of (Ψ_w).

Safety Considerations

The pressure chamber apparatus is a potentially dangerous device which should be treated with great respect. It can be extremely useful but also can injure a careless operator. Because the device uses compressed inert gas (preferably nitrogen) as its pressure source, failure of the pressurized vessel may cause the sudden release of pressure similar to an explosion. Sudden failure of the connecting hose or tubing, though less serious, could result in a wildly thrashing hose or, possibly, flying parts.

To safely operate the pressure chamber, establish and use the following routine for applying pressure to the instrument:

(1) Turn the instrument's control valve to "off."

(2) Check the supply hose to see that it is connected properly. Check, by careful inspection and tugging, hose fittings and any other connections that might be loose.

(3) Open the valve on the supply tank slowly, not suddenly. If the system should fail anywhere, the more nearly closed this valve is, the less damage is likely to result. This same principle—open the valve slowly—also applies to filling a portable tank from a main supply tank.

(4) Do not turn the valve wide open! Instead, open it only wide enough to permit the chamber to be pressurized without a substantial drop in hose pressure. One-half turn is usually sufficient. Close the main tank valve at the end of the day to conserve gas in case a small leak develops.

(5) Test the instrument's safety equipment to help detect leaks and perform minor adjustments on valves. Clean and lubricate chamber seals because dirt and foliage cause wear and can even plug valves or tubing.

Following these safety guidelines will not only minimize the inherent hazards of the technique but will also improve the efficiency of collecting data.

Sample Preparation

Preparing a sample for the pressure chamber will most often involve removing a small lateral branch; very small seedlings may require using the entire top. Removing the sample with a sharp knife or razor blade eliminates needless recutting, which can introduce error in species with large xylem vessels (Scholander et al., 1965).

In woody species, the bark must be stripped back far enough to allow the woody portion to protrude through the rubber sealing gasket, where the cut surface can be observed. Failure to remove the bark may result in mistaking phloem exudate for xylem sap at the endpoint. Resin can also obscure the endpoint in species with resin tubes, particularly the pines. Resin usually forms bubbles which break and can be wiped away to allow observation of the xylem endpoint.

Approximately 90% of the sample should be inserted inside the pressure chamber to avoid introducing measurement error (Waring and Cleary, 1967). Additional error may result if large proportions of a small, succulent sample are squeezed by the gasket, a situation that must be carefully evaluated when the sample is a conifer needle. For example, Ψ_w can be successfully measured with a fasicle of pine needles, but substantial (5- to 8-bar) errors in measuring Douglas-fir [*Pseodutsuga menziesii* (Mirb.) Franco] needles can occur even with a gasket only 4 mm thick (Cleary, 1971). Samples from dormant seedlings can be stored for 20 minutes under humid, low-stress conditions with little error introduced; however, seedlings actively growing in hot, dry conditions can easily read 10 bar lower after the same 20-minute period. Therefore, standardizing measurement techniques based on sound physical and physiological principles is essential. Experience using the instrument is also helpful in obtaining dependable and accurate data.

Operation

1. Never place any part of the body—particularly the eyes--directly above the hole in the chamber cover. Because fairly high pressures are required to force a plant through the seal, such an event can occur unexpectedly and with considerable vigour. The endpoint can be observed just as easily from the side as from above.

2. Never leave the chamber cover or lid half on. It should always be either on and ready to be pressurized or completely off. A cover sitting on the chamber but not locked in place can form enough of a seal to withstand low pressure, but may blow off at higher pressure. Avoid this situation by always leaving the chamber cover all the way on or all the way off.

3. After completing the day's measurements, close the main tank valve and leave the control valve on off or exhaust. Again, leave the cover all the way on or all the way off. If removing the supply hose is necessary, ascertain that the hose is not pressurized before disconnecting it. Like the chamber cover, quick-disconnect fittings should be either completely connected or completely disconnected. Connections should be made only when the hose is not pressurized.

EVALUATING WATER POTENTIAL IN SEEDLINGS

Field experience and research studies on the growth and survival responses of seedlings to different water potentials has led to establishing guidelines for conifer seedlings. These guidelines, based primarily on data collected for Douglas-fir and ponderosa pine (*Pinus ponderosa* Laws), generally have been applied to all Pacific Northwest conifers (Cleary and Greaves, 1978). We plan to conduct experiments that may refine these guidelines for other species, particularly western hemlock [*Tsuga heterophylla* (Raf.) Sarg.], western redcedar (*Thuja plicata* Donn), and true firs (*Abies* spp.).

Bare-Root Seedlings

Seedlings removed from a nursery bed should be watered immediately to reduce water stress. Maintain a Ψ_w level above -10 bar at all times thereafter. Ideally, bare-root seedlings should have a Ψ_w of greater than -5 bar; if Ψ_w decreases to -10 bar, the risk of planting a damaged tree is significant; if Ψ_w decreases to -20 bar, the likelihood of severe physiological damage to root tissue is so high that seedlings are probably best destroyed. A Ψ_w less than -50 bar is probably lethal for most seedlings. Because water potential can be raised immediately by adding water to seedlings in a packing bag, Ψ_w should be evaluated before water is added. The maximum observable value with the pressure chamber is -1 to -2 bar in Douglas-fir and slightly higher in ponderosa pine.

Planted Seedings

For seedlings planted in soil or other media, Ψ_w is not limiting for photosynthesis at levels above -10 bar (Cleary, 1971). In ponderosa pine, at Ψ_w levels between -10 and approximately -20 bar, seedling photosynthesis is slowed or stopped; between -20 and -50 bar, seedling vigor continually declines; and at levels below approximately -50 bar, seedlings die (Fig. 3). The lower the Ψ_w, the longer it takes for seedlings to recover after watering (Fig. 4). In Douglas-fir, lack of water does not limit photosynthesis above -10 bar; between -10 and approximately -30 bar, photosynthetic capacity of seedlings declines; and between -30 and -50 bar, seedling vigour drops. Death occurs at Ψ_w levels in excess of -50. Other species have similar responses but at different values of Ψ_w. An estimate of seedling vigour in response to Ψ_w is essential to interpret the effect of low water potential on seedlings.

Monitoring Bare-Root and Planted Seedlings: Two Example Studies

Two recent Oregon studies have demonstrated the usefulness of monitoring water potential at different stages of reforestation.

The first study examined the effects of winter Ψ_w on bare-root Douglas-fir seedlings during nursery lifting and processing (Daniels, 1978). Daniels evaluated three groups of seedlings each lifted at a Ψ_w of either -4, -12, or -20 bar during mid-February. Half the seedlings undercut at -12 and -20 bar were not watered after lifting (dry treatment). Water is seldom added at lifting in nurseries where dry conditions are not prevalent throughout most of the lifting season. The other half had shoots and roots directly sprayed with water immediately after lifting (wet treatment). It is significant that the dry-treated seedlings lifted at -12 bar had decreased to less than -20 bar Ψ_w within 2 hours after lifting. Thus, essentially no difference existed between the -12- and -20-bar dry-treated seedlings because of the nursery processing technique. Wet-treated seedlings grew significantly taller (9 cm compared with 8 cm) and produced more new foliage (5.7 g compared with 4.77 g) than dry-treated seedlings when grown free of competing vegetation in a nonstressed environment. Survival without competition was excellent for all treatments, ranging from 93 to 98%. In contrast, when outplanted on a stressed site with considerable competition between grass and seedlings, 43% of wet-treated seedlings survived compared with 23% of dry-treated seedlings. Wet-treated seedlings also grew taller (7.6 cm compared with 6.6 cm) and produced more new foliage (3.1 g compared with 2.6 g). Therefore, stock protected from desiccation during lifting and processing in accordance with the previously outlined guideline survived better and grew faster during the year after planting (Cleary and Greaves, 1978).

The second study involved irrigation scheduling at a major Oregon nursery. Lavender and Cleary (1974) outlined conifer seedling-production techniques to improve seedling establishment and identified the need to ensure that dormancy induction be initiated early (by mid-July) in the summer. Seedlings must encounter moderately low water potentials to induce dormancy (Lavender and Cleary, 1974). The key to doing so is having plants large enough early in the summer so that nurserymen are not forced to continue irrigation merely to attain some size objective. Oregon nurseries should seed early in the spring at a bed density low enough to ensure high growth rates early in the growing season. For the first year, irrigation must be frequent during the early growing season to maximize growth until approximately mid-July. After August 1, irrigation should be used only on extremely hot days (35°C) or when early morning Ψ_w is below -12 bar. After September 1, Ψ_w should be allowed to reach but not exceed -15 bar until fall rains begin. From August 1 to the fall rains, irrigation should be minimal or sufficient only to bring temporary relief of successively lower Ψ_w levels and should not saturate the soil profile. During the second growing season or the growing season of a transplant crop, schedules should be such that irrigation during the early part of the season is frequent enough to keep the soil profile near field capacity and yet not saturated until mid-June. Thereafter, early morning Ψ_w levels should be allowed to decrease to -15 bar; again, irrigations should be short so that Ψ_w will remain above -10 bar but frequent enough to prevent it from exceeding -25

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bar. The Ψ_w guidelines outlined previously are useful in implementing the techniques for improving seedling establishment.

SUMMARY

Seedling water status is a critical physiological function that can easily be measured with the pressure chamber. As with any device using highly pressurized gas, safe and careful operation is a must. High Ψ_w levels— determined by the pressure chamber—ensure vigorous seedlings and, thus, high survival potential. The measurement of Ψ_w is a point sample, however, and cannot detect previous desiccation damage in a plant rewatered after damage has occurred. Maintaining high Ψ_w levels between lifting and outplanting is an important part of producing high quality stock and is essential to maintaining high survival and growth rates of outplanted seedlings.

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ABSTRACT

Pros and cons of using the pressure chamber technique for evaluating seedling water status are presented. Safe use of the instrument, sample preparation, and proper operation to obtain the best possible data are emphasised. Guidelines for determining and interpreting water potential (Ψ_w) levels are given for bare-root and planted seedlings. Results from two Oregon studies concerning the effect of water potential on seedlings show the pressure chamber to be extremely useful in monitoring Ψ_w at different stages of reforestation.

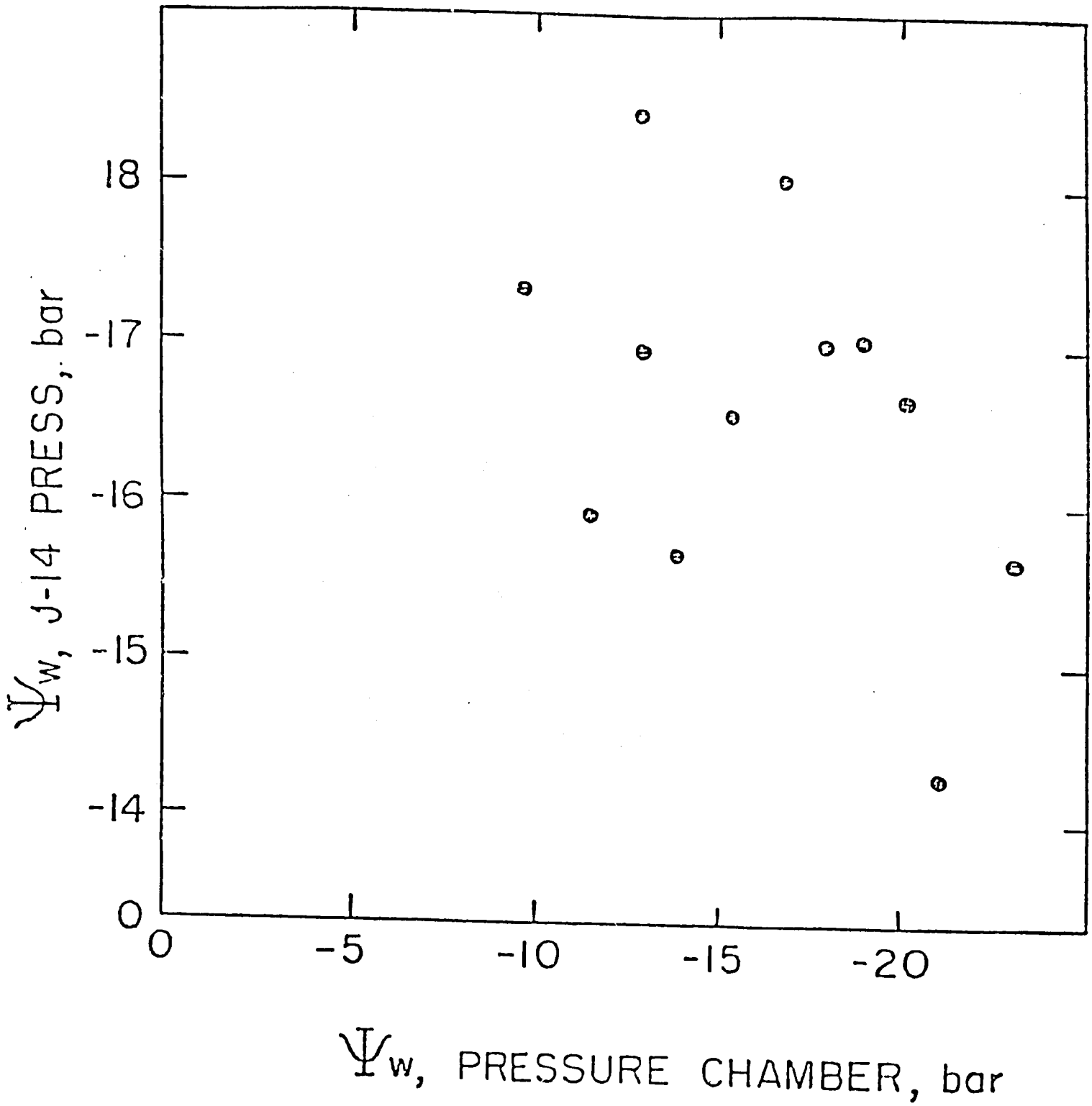

Figure 1. Calibration data for the J-14 press for 12 paired samples measured simultaneously with the J-14 press and pressure chamber techniques.

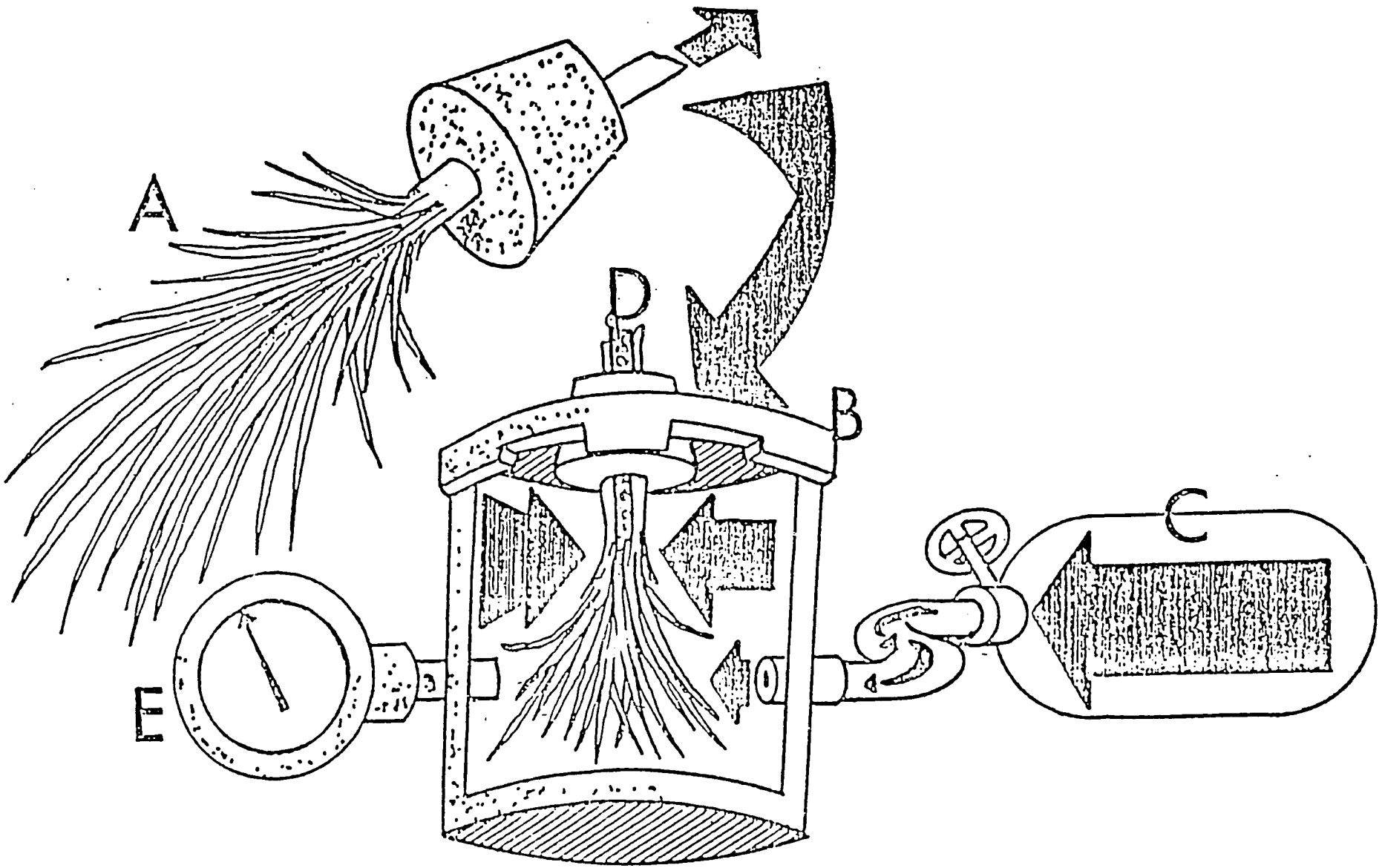

Figure 2. Measuring Ψ_w with a pressure chamber. A, sample; B, pressure chamber; C, pressure tank; D, water forced back to cut surface; and E, pressure gauge.

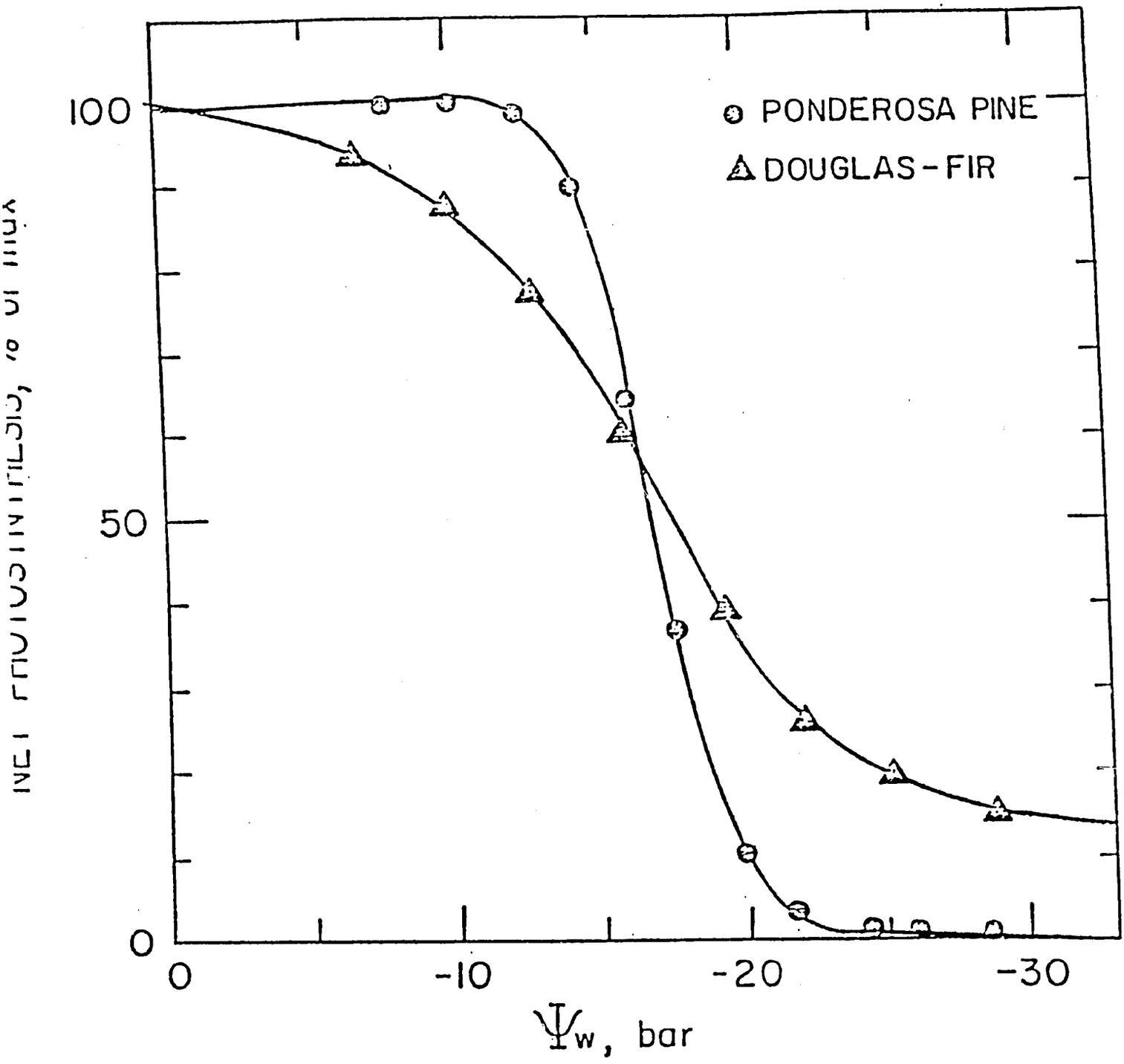

Figure 3. Photosynthetic response of Douglas-fir and ponderosa pine seedlings to decreasing Ψ_w (Cleary, 1971).

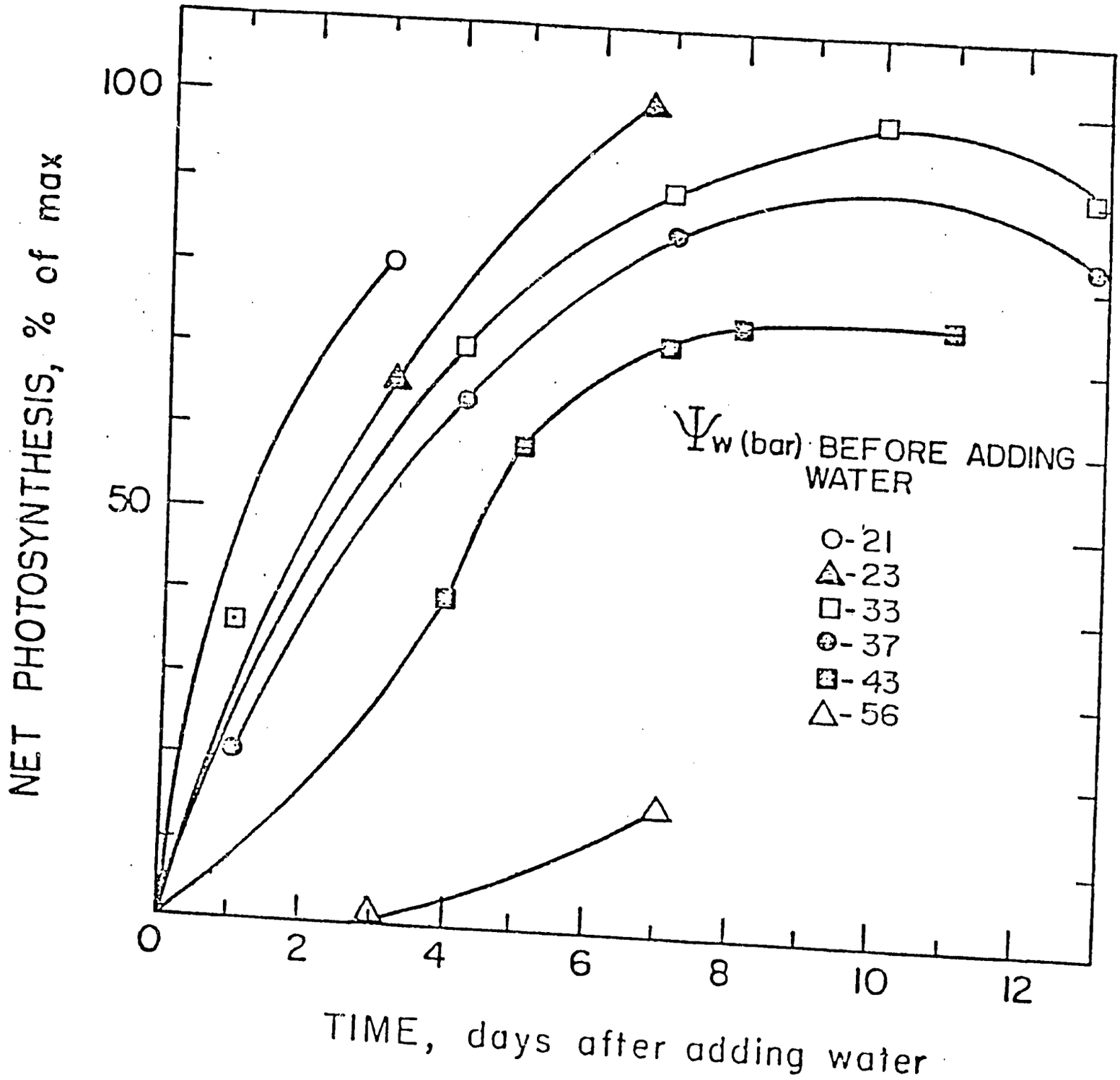

Figure 4. Photosynthesis of ponderosa pine seedlings as a function of time after watering (Cleary, 1971).

PROCEDURES FOR MITOTIC INDEX DETERMINATION:
(adapted from procedures by W.C. Carlson)

A. Sample collection

1. Remove terminal buds plus 1 to 2 cm of shoot from tree using a scalpel. The portion of shoot below the bud is used for handling the apical meristem (AM) during dissection. To minimize variation, it's best to sample at the same time of day for each sampling period. Sample more shoot tips than necessary to complete a final mitotic determination because mistakes do happen during dissection, processing, and squashing.

2. Trim needles off terminal shoot using scissors or scalpel. If you tear needles off with fingers, be careful not to damage/rip the shoot or terminal bud. Any damage might make apical meristem dissection more difficult.

3. Place shoot tips in McClintock's Fixative. It's best to have a large volume of fixative relative to the number of shoot tips.

   CAUTION: All solutions used in mitotic index determination are damaging to skin and are noxious to breath. Be sure to use gloves, lab coats, and fume hood when preparing samples.

4. Bring samples to the laboratory and place the shoot tips under vacuum for 15-20 minutes. To ensure fixation shoot tips, or dissected AM's should remain in McClintock's fixative for a minimum of 24 hours. Once the tissue is fixed, the buds can be stored at room temperature in McClintock's for up to several months.

B. Apical Meristem Dissection and Squash Preparation

Dissection

1. Dissect apical meristems under a dissecting microscope, using forceps and a scalpel fitted with a curved No. 12 blade, or a straight No. 11 blade, whichever is easier for you to use. Transfer, to a petri dish, enough McClintock's solution to keep the AM moist during dissection. Do not let the AM dry out during processing! Dissect the AM by holding the shoot tip under the scope with forceps and, using the scalpel, pull away the bud scales. I find it best to cut the base of the bud scales and then work the remaining scales back and forth with the scalpel until they are gone. Once the bud scales are removed, slice the AM off the shoot tip using the scalpel (Do not remove any stem material along with the AM). Make the same type of cut on each AM you dissect. It's important to be consistent and to keep AM

damage to a minimum. The dissected AM's can now be prepared for squashing or placed back into McClintock's solution for storage until further processing. I find it easiest to transfer the dissected AM's among the different solutions using a disposable Pasteur pipette (Please don't throw them away, though; the pipettes can be washed and reused).

Squash Preparation

2. Transfer AM to vial containing Warmke's solution then to Carnoy's solution using Pasteur pipettes. The AM should remain in the Warmke's solution for a minimum of 15 minutes (20 minutes optimum) and in the Carnoy's solution for a maximum of 15 minutes (10 minutes optimum). Tissue left in Carnoy's too long hardens excessively resulting in a poor squash. Transfer as little as possible of one solution to another during the preparation process.

3. Place AM on a microscope slide using a Pasteur pipette. Allow excess Carnoy solution to evaporate (but do not let the AM dry out) and then add a drop or two of the orcein stain. If the buds have too much Carnoy's solution remaining, the AM's will repel the orcein. Use a flat level surface when staining and cover slides with petri dishes to prevent dust contamination. Allow stain to set for 10-15 minutes before gently placing coverslip over the AM. Add additional drop or two of stain, if necessary, before adding coverslip. Be sure to place coverslip so AM is located in the middle.

4. Secure the coverslip with one hand and squash the AM/coverslip with the other using the flat, wooden end of a dissecting needle. Apply firm, rapid pressure directly over the AM. Remove excess stain using Kimwipes. Try not to move the slide across the AM as this may ruin the tissue. After allowing the AM to sit for a few minutes, use the needle end of the dissecting needle to further squash the bud to a unicellular thickness. Press the needle across the coverslip to disperse the cells from the center of the AM to the edges. Firm pressure is used to squash the bud and this may sometimes produce small cracks in the coverslip. While this is not ideal, the squash should usually remain useable. After squashing, warming (not to the boiling point) the slide over a bunsen burner will help stain the AM more thoroughly.

C. Mitotic Index Determination

1. Mitotic index determination should be made immediately after squashing. Squash slides can be stored for short periods of time if the squash is kept moist with stain solution. Use a bright-field microscope with a 10X ocular lens and a 40X objective. A 10 x 10 counting grid is used in an ocular yepiece to assist in counting cells. Scan the entire M to find the three regions of highest mitotic activity.

For each active region, mitotic index is determined as:

$$\frac{\text{No. of actively dividing cells}}{\text{Total No. of cells within counting grid}} \times 100 = \text{MI\%}$$

Any cell within, or touching, the grid is included. Use a hand tally meter to assist in counting cells.

NOTE: Please wash and reuse slides and coverslips unless broken or badly scratched or stained.

Solutions:

	Volume Ratio
McClintock's Fixative	
100% ethyl alcohol (95% acceptable)	3 parts
Glacial acetic acid	1 part
Warmke's Solution	
95% ethyl alcohol	1 part
Concentrated hydrochloric acid	1 part
Carnoy's Solution	
100% ethyl alcohol (95% acceptable)	6 parts
Glacial acetic acid	1 part
Chloroform	3 parts

Orcein Stain

-1 g orcein into 100 ml of boiling 45% acetic acid
-cool and decant
-let stand for 12 hours
-filter and store in refrigerator

Changes in mitotic index during onset of dormancy in Douglas-fir seedlings

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Received November 20, 1979[5]
Accepted April 17, 1980

CARLSON, W. C., W. D. BINDER, C. O. FEENAN, and C. L. PREISIG. 1980. Changes in mitotic index during onset of dormancy in Douglas-fir seedlings. Can. J. For. Res. 10: 371–378.

A method is presented for rapid determination of the mitotic index in terminal buds of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco. Fertilization at planting increased mitotic index but fertilized seedlings entered dormancy at the same time as unfertilized seedlings. Cold storage, prior to dormancy, reduced mitotic index rapidly and was related to reduced height growth the following year. The effects of moderate moisture stress and seed source on mitotic index were slight.

CARLSON, W. C., W. D. BINDER, C. O. FEENAN et C. L. PREISIG. 1980. Changes in mitotic index during onset of dormancy in Douglas-fir seedlings. Can. J. For. Res. 10: 371–378.

Une méthode est présentée pour la détermination rapide de l'index mitotique dans les bourgeons terminaux du sapin de Douglas, *Pseudotsuga menziesii* (Mirb.) Franco. La fertilisation effectué lors de la plantation a augmenté l'index mitotique mais les semis fertilisés sont entrés en dormance en même temps que les semis non fertilisés. L'entreposage au froid avant la dormance a réduit rapidement l'index mitotique en plus d'être relié à une réduction de la croissance en longueur l'année suivante. Les effets de stress modérés en humidité et la provenance des graines n'ont eu que peu d'effet sur l'index mitotique.

[Traduit par le journal]

Introduction

Growth potential of planted tree seedlings can be greatly reduced by improper coordination of cultural and outplanting practices with the physiological condition of the tree. One important and often mismanaged aspect of nursery production is conditioning of seedlings to promote completion of successive stages of dormancy.

Stages of dormancy have been discussed in detail by Samish (1954) and Romberger (1963), while Lavender and Cleary (1974) described them in terms of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) nursery management. Owens (1968) and Owens and Molder (1973) have described the annual growth cycle in terms of bud development, defining dormancy as the absence of cell division in the bud. These general dormancy classifications are compared with periods of susceptibility to transplanting shock (Fig. 1). The expansion of preformed stem and leaf primordia occurs during the bud scale initiation phase. Free growth (Jablanczy 1971) can occur during the early rapid leaf initiation phase followed by a return to bud scale initiation. Vegetative bud set occurs at the end of scale initiation (Sterling 1946).

Knowledge of progression of dormancy stages is very important to management of nursery crops. Managers must be able to determine the dormancy status of crops in order to properly schedule cultural and outplanting activities. One method to evaluate seedling dormancy status requires up to 30 days of observation (Lavender and Hermann 1970). This time period is too long for effective decision making by nursery management. Use of an oscilloscope and square wave generator to measure electrical resistance reduces the time necessary to determine dormancy status (Ferguson et al. 1975). Unfortunately, electrical resistance and impedance are more directly related to cold hardiness and stress than bud dormancy and growth (van den Driessche 1969; Wargo and Skutt 1975; Askren and Hermann 1979).

Owens (1968) and Owens and Molder (1973) have utilized mitotic frequency, i.e., the number of dividing cells in five median longitudinal sections, to monitor onset of bud dormancy. This procedure gives a very precise indication of the end of cell division activity which coincides very closely with the time when Lavender and Cleary (1974) noted the beginning of deep dormancy (Fig. 1).

The methodology of Owens (1968) for determining mitotic frequency is laborious. The use of a squash technique rather than sectioning, and determining mitotic index (the percentage of cells in division) (J. N. Owens and M. Molder, personal communication) rather than mitotic frequency allows comparatively rapid assessment of dormancy status. Use of mitotic index is more precise than mitotic frequency for estimating dormancy via bud squashes, where the number of cells in the grid field is a function of the pressure used in preparing the

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0045-5067/80/030371-08$01.00/0
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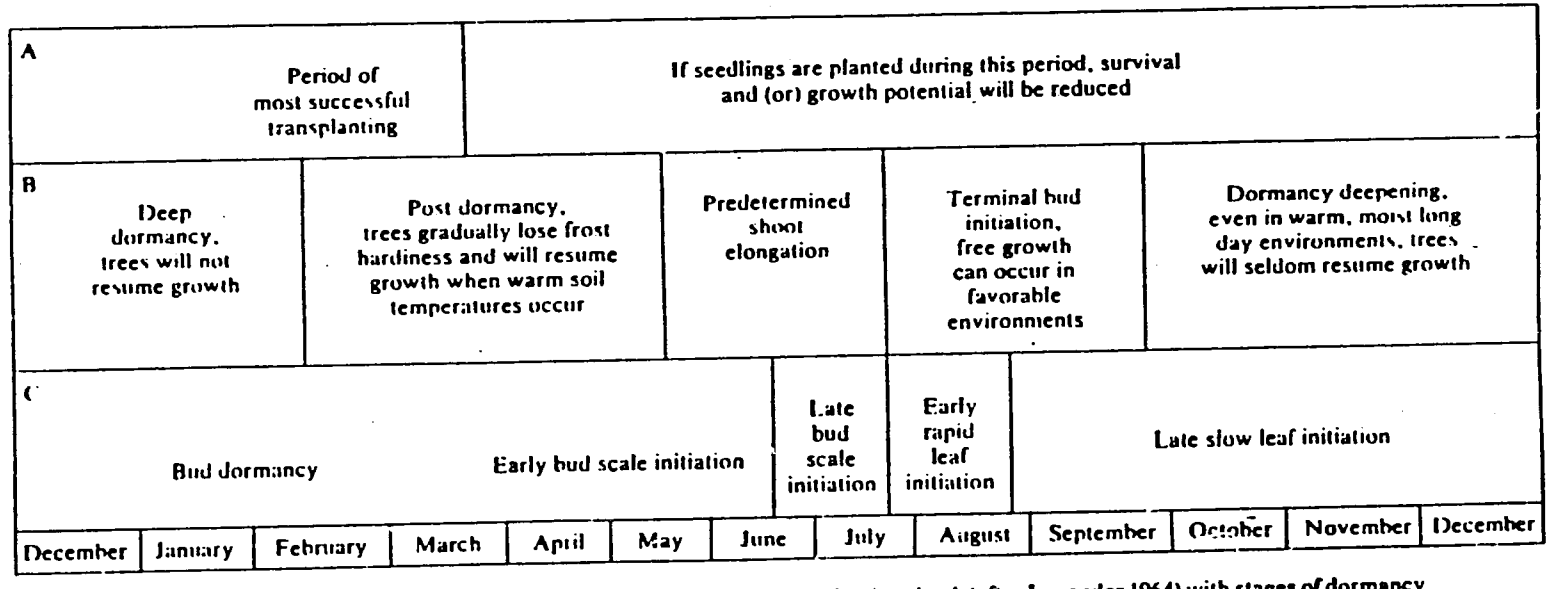

FIG. 1. A general comparison of (A) periods of susceptibility to transplanting shock (after Lavender 1964) with stages of dormancy as determined by (B) observing vegetative growth patterns in a favorable environment (after Lavender and Cleary 1974), and (C) by following bud development anatomically and noting the rate of cell division (after Owens 1968).

squash. This paper presents the results of monitoring mitotic index in the terminal bud of Douglas-fir seedlings during onset of bud dormancy.

Materials and methods

During the 1st year of the study, buds were sampled from a greenhouse experiment concerning the effect of periodic moisture stress on induction of vegetative bud set in container cultured Douglas-fir seedlings. A nutritional regime similar to that utilized by the British Columbia Forest Service was used. The schedule was described in general by Brix and van den Driessche (1974) and specifically by Carlson (1978). These early tests of the mitotic index method established the basic pattern of dormancy onset in 1st-year Douglas-fir seedlings. During the 2nd year, the effect of various outplanting strategies on mitotic frequency was evaluated. An experimental plantation was established adjacent to greenhouse facilities used in the study near Aurora, OR, U.S.A. Outplanting strategy included (1) time of outplanting, (2) whether seedlings were extracted from containers 2 days before planting and wrapped in Saran in 25-tree bundles or were planted directly from Styroblock 4 containers in which they were cultured, and (3) whether or not seedlings were fertilized with a 22-8-2 NPK Agriform forest starter pellet in the planting hole.

Sampling

Bud sampling was done between midmorning and midafternoon. Diurnal fluctuation in mitotic index was small (W. C. Carlson, W. D. Binder, and C. O. Feenan, unpublished data). In 1977, eight terminal buds were collected at random from the two blocks for each treatment (seed source and moisture stress level). Two seed lots were used: Seaside, OR (elevation 500 ft (1 ft = 0.3048 m)) and Sekiu, WA (elevation 1000 ft). Weekly sampling continued from July 29 (before bud set) until December 22.

In 1978, 53 terminal buds were collected at random from the greenhouse population on August 18, before outplanting began. Subsequently eight buds were sampled from the greenhouse populations immediately before each outplanting, and another eight buds were sampled from the residual populations 2-5 days after establishment of each portion of the plantation. During and immediately following the period of vegetative bud set, the greenhouse population was sampled frequently to define the mitotic index peak. Bud samples were taken at random from the entire population 48 h after the establishment of each portion and at additional dates as shown in Results. Predawn moisture stress was measured on excised stems on each field sampling date using a pressure bomb. The outplanting dates were August 23-24, October 2-3, October 13, and December 11. From 100 to 300 trees were planted per treatment (fertilization × extraction) on each planting date in a completely randomized single tree plot design.

Bud squash techniques

After removal of scales, the embryonic shoot (bud) was removed from the stem and fixed in McClintock's fixative (Johansen 1940) for a minimum of 6 h.

After fixation, buds were placed in Warmke's solution for 10-25 min to dissolve pectin material in the middle lamella (Johansen 1940). In order to counteract the softening of the cell that was caused by Warmke's solution, buds were transferred to Carnoy's solution for 5-20 min (Johansen 1940).

The buds were then placed on slides and stained with orcein or acetocarmin, the latter with iron added (Johansen 1940). The buds, including the stem apex and leaf primordia, were stained for 10-20 min, time being proportional to size. Half way through the staining period, a cover slip was placed gently on top of the bud and stain. The weight of the cover slip flattened the bud slightly. At the end of the staining time, the bud was crushed by applying pressure to the cover slip directly above the bud. After crushing, the slide was warmed, without boiling, over an alcohol lamp until it was almost too hot to hold.

Immediately after staining, cells were counted using a Leitz Diavert microscope equipped with a 12.5× ocular, a 40× objective, and an ocular counting grid. All of the stages of karyokinesis were counted as dividing except interphase (Fig. 2). To determine the onset of bud dormancy more precisely, the least dormant area of the squash was counted. Areas under mitotic index curves were determined by weight.

Results

Analysis of variance in the 1977 mitotic index indicates that there was a comparatively weak effect of seed source (α = 0.47) on mitotic index and no effect of moisture stress treatment (α = 0.70), the experimental error mean square being greater than the treatment mean square. Therefore data were pooled over seed source and moisture stress level (Fig. 3). Seedlings cold stored in late October showed a more rapid decline in mitotic activity than did seedlings which remained in the greenhouse until December (Fig. 3). Decrease in area under the mitotic index curve due to early storage was approximately 7%.

Outplanting in August 1978 lowered the mitotic index; however, the October outplantings raised the mitotic index (Fig. 4*a*). Mitotic index was affected within 2-5 days after outplanting, and the effect continued until the final drop in December, which occurred at the same time in both field and

TABLE 1. Analysis of variance in 1978 mitotic index

Source of variation	Degree of freedom	Mean square	Probability of a greater F
Planting date	4	27.47	0.0223
Error	904	9.58	
Fertilization	1	94.97	0.0009
Extraction	1	0.01	0.9686
Fertilization extraction	1	1.46	0.6793
Error	496	8.51	

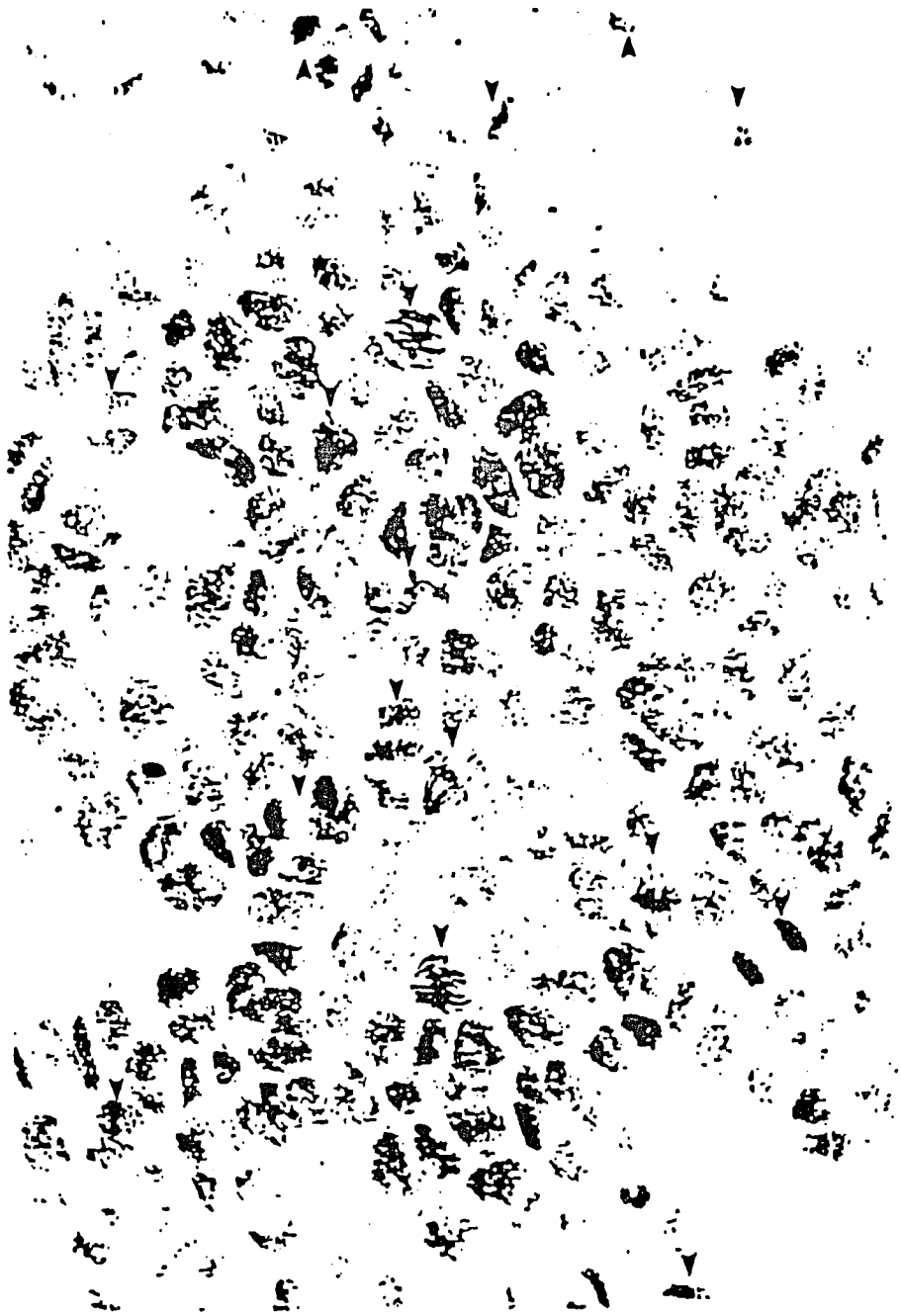

FIG. 2. A typical Douglas-fir bud squash showing (▶) cells which would be counted as dividing. While the photograph shows ıly one focal plane, the actual counting of the squash is done with slight focal adjustment to facilitate decisions based on cell ructure. The mitotic index of the area shown is 4.5%.

·eenhouse seedlings. Analysis of variance (Table ı indicated that planting date had a significant ef- :ct on the mitotic index in the terminal bud.

Summarizing outplanting treatments over plant- ıg date (Fig. 4*b* and Table 1), fertilization at time f planting increased mitotic index: however, there 'as no consistent effect of extraction from containers. Measurement of the areas under mitotic index curves (Table 2) confirmed the effects of fertilization and outplanting. The interactive effect of fertilization and extraction treatments was comparatively weak (Table 1).

In 1978, seedlings in the greenhouse and field sel dom reached 12 bars (1 bar = 10^5 Pa) moistur

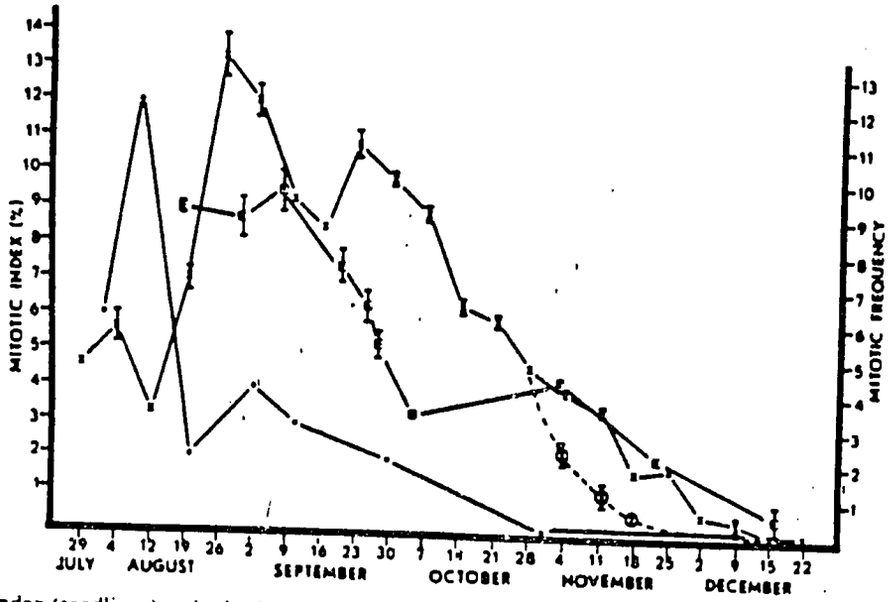

FIG. 3. Mitotic index (seedlings) and mitotic frequency (mature trees) of Douglas-fir during the dormancy cycle: 1-0 seedlings in the greenhouse: x, 1977; ■, 1978; ⊗, seedlings put into cold storage on October 28, 1977; ●, mitotic frequency of a mature tree near Victoria, B.C. 1968; redrawn from Owens and Molder (1973).

stress because the weather was cool and rainy during the end of August and September (W. C. Carlson, unpublished data).

Discussion

Several features of the mitotic index curve during the onset of dormancy period in 1st-year Douglas-fir seedlings are similar to those of the mitotic frequency curve for mature Douglas-fir (Fig. 3) (Owens and Molder 1973). There is a peak at the end of bud scale initiation followed by a sharp drop in mitotic index, a smaller peak, and finally a gradual decrease in mitotic index to zero through the fall. The curve for mature Douglas-fir was shifted so that maximum mitotic frequency occurred 2 weeks to 1 month earlier. There was relatively little activity by early November (Owens and Molder 1973). The amount of cell division at bud set was very similar for mature Douglas-fir on Vancouver Island (Owens and Molder 1973) and 1977 greenhouse seedlings; however, the 1978 seedling peak was substantially lower. Mitotic frequency and mitotic index were found to be comparable estimators of cell division in longitudinal sections (Owens and Molder 1973). Since the longitudinal section method samples only a portion of the tissue, while the squash method samples the apex and all of the leaf primordia, it is expected that the latter method yields higher estimates of mitotic index. This would be most apparent late in the season since the apex ceases division earlier than leaf primordia and internodal tissues (Owens 1968 and personal communication (1979)).

TABLE 2. Mean areas under mitotic index time curves: 1978 greenhouse and field by treatment and over date of planting

	Area unit* ± SE
Greehouse	49.9566 ± 0.3163
Planted	
Fertilized	
Extracted	59.9375 ± 0.5369
Not extracted	61.4592 ± 0.6173
Not Fertilized	
Extracted	53.4477 ± 0.0701
Not extracted	53.0893 ± 0.0650

*One area unit = 1.0% mitotic index per 10 days.

The earlier peak in mature material could indicate a basic difference between mature trees that have only predetermined growth and seedlings that exhibit free growth. Mature trees support early production of the bud to be overwintered, while seedlings maintain free growth for a longer time and then produce the overwintered bud in a shorter period of time. Area under the curve during onset of dormancy is an indicator of the accumulated effect of cell division (the number and (or) size of the leaf primordia and stem units in the overwintering bud). This area was substantially less for mature trees than for seedlings and could indicate a combination of higher division rates in seedlings related to free growth. It is unlikely that differences were due to seed source since seedling populations from north-

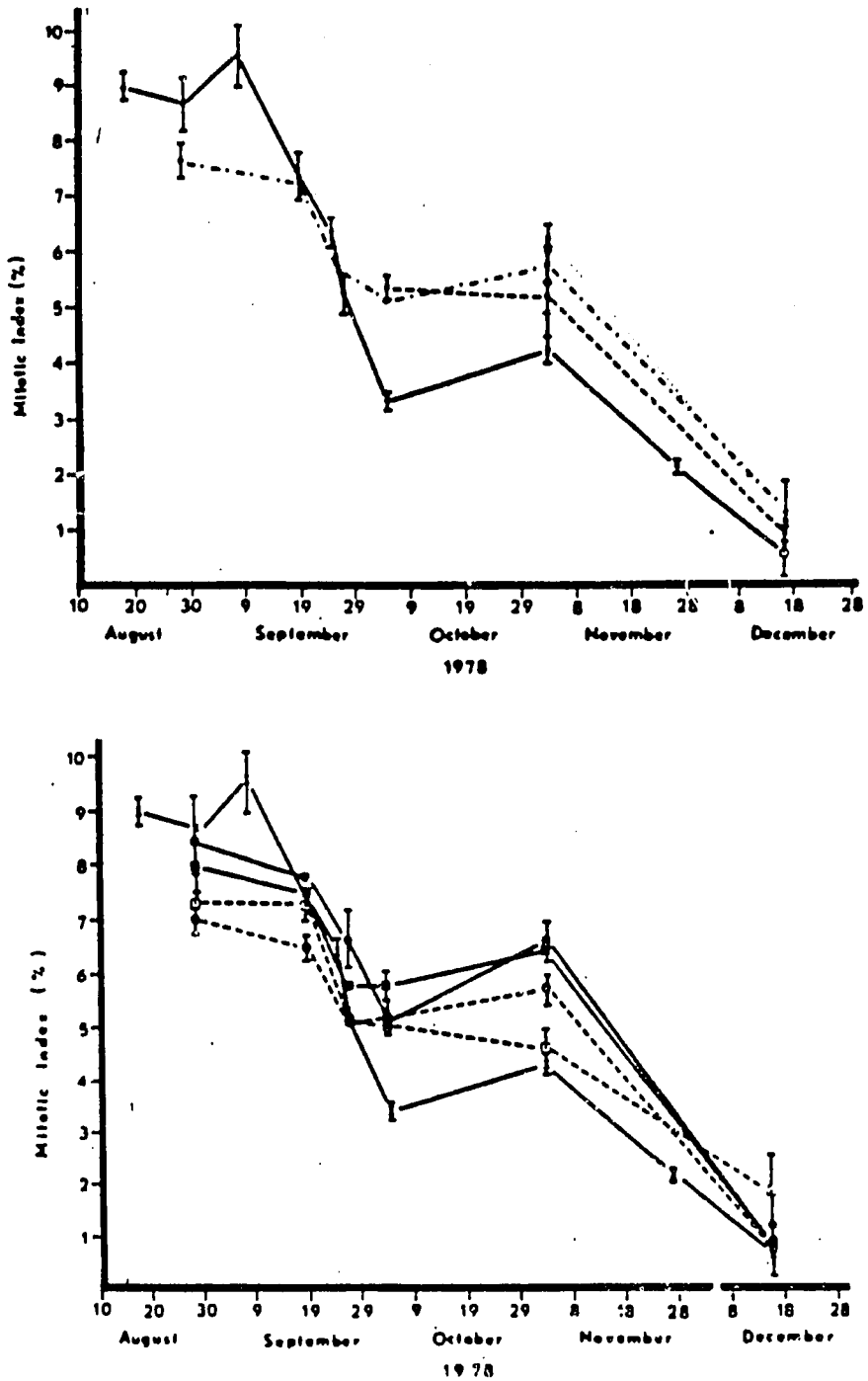

FIG. 4. Mitotic index of 1-0 Douglas-fir seedlings in 1978. (A) In the greenhouse and outplanted by date: ——, greenhouse; ··· August 23-24; —·—, October 2-3; ·, October 30-31; ⊃, December 11. (B) In the greenhouse and outplanted by treatment and over planting date: x, greenhouse; ⊙, no fertilization and no extraction; ⊡, no fertilization and extraction; ⊗, fertilization and no extraction; ■, fertilization and extraction.

west Oregon and the northwest tip of Washington (very close in latitude to Victoria, B.C.) did not differ in cell division patterns when greenhouse cultured in 1977. It is, however, possible that differences between squashing and sectioning procedures, year of sampling and (or) local weather conditions also affected differences in mitotic activity.

The importance of differences in the area under the curve is not clear. If a greater number of cell

divisions indicates a greater number of cells in the stem internode, then an increase in area under the curve would indicate increased height growth the following year (Cannell et al. 1976). Mitotic index is an indication of number of cells produced: however, it is not precise unless the length of time spent in each phase of the cell cycle in each generation is known. It is probable that mean cell generation time increased with decreasing temperature late in the season (Grif 1963). This would result in fewer cells being produced per unit time per unit of mitotic index. Seedlings of all seed source × moisture stress treatments had the same mitotic index curve during onset of dormancy and there was no difference between treatments in 1st year height growth in the field the following year (Carlson 1978).

Early cold storage, which reduced area under the curve by 7%, resulted in a 23% reduction in height growth the following year. Since the reduced mitotic activity occurred during late, slow leaf initiation, at which time division is slower and contributes to leaf primordia and internodal development (Owens and Molder 1973), decreased height growth could have resulted from a decreased number of cells, leaf primordia and (or) stem units in the overwintered internode. Other physiological factors such as reduced food reserves due to early cold storage could also have affected reduced height growth.

Outplanting involved physical disruption and possible changes in temperature regimes, moisture levels, and (or) nutrient levels. The practice of extracting and packaging seedlings in Saran wrapping material rather than transporting them to the field in containers could disrupt physiological processes, and therefore direct transplanting is preferred (Hahn and Hutchison 1978). Although our results indicate this disruption did not affect the mitotic index in the developing bud, it could affect changes in other physiological functions, e.g., extraction could affect the development of growth potential in root tips and reduce their ability to quickly egress from the plug after planting (Hahn and Hutchison 1978).

There was a substantial effect of planting date on mitotic index, which was not related to physical disruption during extraction. Outplanting in August temporarily decreased mitotic index in all treatments, while all outplanted seedlings had an increased mitotic index throughout the rest of the fall. During August and early September cold rainy weather reduced field temperatures, and, although the greenhouses were maintained with open walls and cooling fans running, it is possible that the greenhouse environment was warmer. During the period from October through December, it is likely that container media temperature decreased faster and fluctuated to greater extremes because of its small mass than soil temperatures in the field. Such decreased temperatures would reduce mitotic index (Grif 1963).

A separate study (W. C. Carlson and C. L. Preisig, unpublished data) showed that controlled release fertilization at planting increases both the number of needles and the length of their associated stem units formed after fertilization, overwintered in the bud, and elongated the following growing season. Increases in mitotic index due to fertilization could result in an increased rate of production of leaf primordia and (or) numbers of cells per stem unit since the date of dormancy in fertilized and unfertilized seedlings was the same.

Acknowledgements

We thank Drs. J. N. Owens, D. Lavender, and J. B. Zaer for helpful comments on the manuscript and G. D. Shaw, R. Shuren, and O. Horvath for technical assistance. We also thank Crown Zellerbach, Northwest Timber Division, for providing facilities and equipment necessary to begin research in 1976.

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Appendix 20

DISTRIBUTION OF WORKSHOP MATERIAL BY U.S. CONSULTANTS

During the Workshop at KAU-Trichur, one copy each of the following publications were distributed by the U.S. Consultants to each participant :

1.	Forest Nursery Manual	O.S.U
2.	Seedling Nutrition & Irrigation	U.S.D.A
3.	The Biological Component : Nursery Pests & Mycorrhizae	U.S.D.A
4.	Ornamentals : Northwest Newsletter, Nov. - Dec. 1991	O.S.U.
5.	Equipment for Containerized Tree Seedlings	U.S.D.A
6.	Hand Planting Tools	
7.	Nursery Technology Cooperative Annual Reports	

One copy each of the following reference materials were also provided to each of the workshop participants .

1.	Effects of Soil Compaction on Seedling Growth	O.S.U.
2.	Catalog of Nursery Equipment - Oct. 1976	U.S.D.A
3.	Mineral Nutrition and the Target Seedling	
4.	Care & Planting of the Southern Pine Seedlings	U.S.D.A
5.	Starch Analysis Procedures	
6.	Nursery Technology Cooperative Annual Reports	
7.	Technical Guide for Forest Nursery Man in Caribbean & Latin America	

In addition to the above referred list of publications. a large carton containing 'Irrigation Systems' with a total cost of US $ 265.28 was brought in by the U.S. Consultants as accompanied baggage from the U.S.A., for demonstration purposes and distribution to the Agroforestry Researchers in India as per details given below :

1. Three demonstration irrigation systems were built and left with select workshop participants.

2. The College of Forestry, Kerala Agricultural University, Trichur, received both of the PVC Pipe Irrigation Systems with assorted nozzles.

3. Dr. M.G. Dastagiri from TNGNDAU, Mettupalayam (Tamil Nadu) received the trickle irrigation demonstration.

4. Dr. L.N. Harsh. Scientist, CAZRI. Jodhpur (Rajasthan) received the Styroblocks and the Battery Powered Programable Water 'On/Off' Valve.

5. The College of Forestry, Kerala Agricultural University, Trichur also received one set of publications except for the Technical Guide for Forest Nursery Manual in the Caribbean & Latin America.

6. Winrock-Delhi office received a set of publications from the Consultant, Dr. Robin Rose, as donation to the Library.

7. All of the Workshop participants received OSU Baseball caps.

8. All of the Workshop participants received Diplomas.

PROBLEMS AND QUESTIONS

Monday, May 6, 1991

Overview of world reforestation

1. Name several problems that each country or region of the world have in common.

2. . State the role of the forets nursery in solving reforestation problems.

3. Are reforestation problems solvable by scientific means alone?

Bareroot Nursery Development

1. (Ch. 2, FNM) State why soil workability and drainage, water supply, and soil texture are important to a bareroot nursery. ... a container nursery.

2. (Ch. 6, FNM) State the relationship among pressure, soil moisture content, and soil bulk density.

3. (Ch. 7, FNM) Assume you have a nursery 10 kilometers away from another nursery with similar soil characteristics. Will your fertilizer regime be the same as the other nursery? Explain your answer.

4. (Ch. 8, FNM) State why it is important to monitor soil fertility every year.

5. (Ch. 9, FNM) State the benefits of organic matter in soil.

6. (Ch. 10, FNM) State the advantages and disadvantages of covering cropping. ...leaving land fallow vs. continuous cropping.

7. (Ch. 16, FNM) State the primary advantage of transplanting plug seedlings.

8. Which is better...a containerized seedling or a bareroot seedling? Or does it matter? Explain.

Wednesday, May 8, 1991

Seed/Genetic Variation/Source/Seed Physiology

1. (Ch. 4, GNM) State why seed maturation at the time of collection is so important.

2. (Ch. 4, FNM) State why seed moisture content is so important.

3. (Ch. 5, FNM) Find Bunting's account of the dilemma of bed density.

4. (Ch. 17, FNM) Define directional selection.

5. Should cull plants be planted in order to maintain biodiversity? Yes or no? Explain.

6. (Ch. 19, FNM) State what IPM (Integrated Pest Management) is.

7. (Ch. 20, FNM) State the difference between an ectomycorrhizal fungus and an endomycorrhizal fungus.

8. (Vol. V, The Bio Comp) State how a manager can best manage for disease.

9. Name several ways to inoculate soil or media with mycorrhizae.

Thursday, May 9, 1991

1. Define the Target Seedling Concept.

2. (Ch. 8, FNM) State the advantages of tissue analysis over soils analysis.

3. State the several ways nutrition data can be analyzed.

4. (SNI) State why water quality is so important.

5. What is nutrient concentration?

6. What is nutrient content?

Monday, May 13, 1991

1. (Ch. 14, FNM) State how physiology and morphology work together to help a seedling grow.

2. Does a seedling survive to grow or grow to survive? Explain (have to pick one).

3. Define dormancy.

4. (Ch. 15, FNM) State how nursery cultural practices impact seedling quality. (Keep to ≤100 words!)

5. (Ch. 17, FNM) State how nursery practices alter the population structure.

6. Why do seed orchards tend to produce better quality seed and seedlings than wild collected seed in some areas of the world?

7. (Ch. 6, ESQ) Name 20 morphological parameters that can be measured in a seedling.

8. Name 10 physiological parameters that can be measured in a seedling.

9. State how apressure bomb works. Use a diagram if you wish.

10. State the advantages and disadvantages of using RGP test results.

11. Frost hardiness may not apply directly to your situation. So, what is the difference between quiescence and rest?

Appendix 20-B

NURSERY MANAGEMENT WORKSHOP

Drs. R. Rose, W. Emmingham, L.N. Harsh

PRE-WORKSHOP PROFORMA

Your Name:

Name and Address of Your Institution:

Your Present Position and Title:

Your Job Description:

1. Please describe your present work:

2. If there is any information about your present or future work-related responsibilities that you think will help make this course more useful to you, please explain below:

Your Academic Training:

1. What is the highest degree you have earned?

2. Date earned?

3. Name of Institution granting the degree?

4. Major or Specialty:

Nursery Experience

1. Have you taken 1 or more courses at the post-graduate level in:

- Soils _____ Yes _____ No
- Plant Physiology _____ Yes _____ No
- Ecology _____ Yes _____ No
- Horticulture _____ Yes _____ No
- Agroforestry _____ Yes _____ No
- Others: _____

_____

_____

2. Have you had training in Nursery Management?

_____ Yes _____ No

If yes, please describe that training.

3. Please describe your experience in Nursery Management:

_____

_____

_____

In what climatic region and with what species:

_____

_____

_____

_____

_____

Please list information needs, or questions that you would like to have addressed in this workshop.

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

INSTRUCTORS

1. Name of First Instructor: Robin Rose

Rate this instructor in the following areas (please circle the appropriate number):

	Poor				Excellent			
Knowledge of Subject?	5	4	3	2	1	20	1.70	.84
Presentation of Material?	5	4	3	2	1	20	1.90	.94
Ability to Relate Material to Nursery Management?	5	4	3	2	1	20	1.55	.58
Encourages Participants to Discuss Material?	5	4	3	2	1	20	1.85	.96

What, if anything, would you suggest this instructor do to improve?

2. Name of Second Instructor: Wm. Emmingham

Rate this instructor in the following areas (please circle the appropriate number):

	Poor				Excellent			
Knowledge of Subject?	5	4	3	2	1	20	1.10	.30
Presentation of Material?	5	4	3	2	1	20	1.10	.30
Ability to Relate Material to Nursery Management?	5	4	3	2	1	20	1.10	.30
Encourages Participants to Discuss Material?	5	4	3	2	1	20	1	0

What, if anything, would you suggest this instructor do to improve?

3. Name of Third Instructor: L.N. Harsh

Rate this instructor in the following areas (please circle the appropriate number):

	Poor				Excellent			
Knowledge of Subject?	5	4	3	2	1	19	2.10	1.02
Presentation of Material?	5	4	3	2	1	19	1.94	0.94
Ability to Relate Material to Nursery Management?	5	4	3	2	1	19	2.21	1.01
Encourages Participants to Discuss Material?	5	4	3	2	1	19	1.73	0.96

What, if anything, would you suggest this instructor do to improve?

OVERALL WORKSHOP SATISFACTION

1. Would you recommend this course to other individuals with a background similar to yours?

   19 Yes 1 No

   Please explain why or why not:

2. In general, how confident are you that you can apply the skills learned during this workshop to your work activities (please circle the appropriate number)?

Not at all				Extremely	N	$\bar{X}$	Std
5	4	3	↑ 2	1	20	2.35	1.06

3. Specifically, which topics do you feel you will be able to apply?

4. Please make additional comments you would like to about this workshop.

4. For each of the following course topics, please indicate whether they should be expanded, shortened, omitted, or left as is:

	Expand	Shorten	Omit	Leave As Is
Overview of World Reforestation	10	2		7
Bareroot Nursery Development	8	5		7
Container Nursery Development	11	4		5
Seeds/Genetics/Physiology/Handling	8	2		10
Target Seedling Concept	6	3		10
Seedling Nutrition & Fertilization	11		1	7
Irrigation Systems	6	1	1	8
Seedling Quality	10	4		5
Vegetation Management	9	1		10
Technology Transfer	7	2	1	12
Field Trips	12	4		3

5. What topics would you recommend be added to the workshop?

COURSE DESIGN AND DELIVERY

1. During the course, was the daily schedule:

   1 Too short? 11 About right? 8 Too long?

2. Was the overall length of the course:

   2 Too short? 13 About right? 4 Too long?

3. Indicate how helpful you found each of the following teaching methods to be (please circle the appropriate number):

	Not at all Helpful				Extremely Helpful	n	$\bar{x}$	sd
Lecturers?	5	4	3	2	1	20	2.05	0.6
Large Group Discussions?	5	4	3	2	1	20	2.35	1.01
Small Group Discussions?	5	4	3	2	1	20	2.20	1.16
Exercises?	5	4	3	2	1	20	2.65	1.31
Individual consultations with instructors?	5	4	3	2	1	20	1.60	0.73
Field trips?	5	4	3	2	1	19	2.0	1.21

4. How useful were the following types of materials (please circle the appropriate number):

	Not at all Helpful				Extremely Helpful			
Course Outline?	5	4	3	2	1	20	1.70	0.71
Handouts?	5	4	3	2	1	20	1.60	0.80
Reading Assignments/, Exercises?	5	4	3	2	1	20	2.10	0.99
Audiovisual Materials?	5	4	3	2	1	20	1.95	0.65

Comments on instructional materials:

Appendix 20-C

NURSERY MANAGEMENT WORKSHOP

Drs. R. Rose, W. Emmingham, L.N. Harsh

POST-WORKSHOP PROFORMA

PRE-WORKSHOP INFORMATION

Did you receive pre-workshop information?

19 Yes 0 No

If yes,

1. How clear were the course objectives? (please circle the appropriate number)

N	$\bar{x}$	sd
19	2	0.85

Unclear 5 4 3 2 1 Very Clear

2. How clearly were workshop arrangements (date, place, travel) communicated?

N	$\bar{x}$	sd
19	1.94	1.35

Unclear 5 4 3 2 1 Very Clear

COURSE ADMINISTRATION/LOGISTICS

Please indicate your satisfaction with the following support arrangements (please circle the appropriate number):

	Not at all Satisfied				Extremely well Satisfied	N	$\bar{x}$	Standard Deviation
Training Facilities?	5	4	3	2	1	20	2.3	0.71
Housing Accommodations?	5	4	3	2	1	18	2.8	1.19
Logistical Support?	5	4	3	2	1	19	2.7	0.92
Food?	5	4	3	2	1	20	3.2	1.15

Comments:

FIELD TRIP

1. Did the pre-field trip briefings adequately explain why you were going on the trip and what you would see?

15 Yes 4 No

2. Were you given adequate opportunity afterwards to discuss the field trip?

15 Yes 4 No

N = number of delegates that answered
$\bar{x}$ = mean sd = standard deviation

3. Please indicate how relevant the field trips were to the following (please circle the appropriate number):

	Not at all Relevant				Extremely Relevant	N	$\bar{x}$	sd
Course information & activities?	5	4	3	2	1	19	2.26	0.71
Research needs & situations?	5	4	3	2	1	19	2.57	1.13
Personal interests?	5	4	3	2	1	18	2.61	0.95

COURSE CONTENT

1. At the beginning of the course or during the course, did you discuss with the instructors how the course content would meet your specific needs?

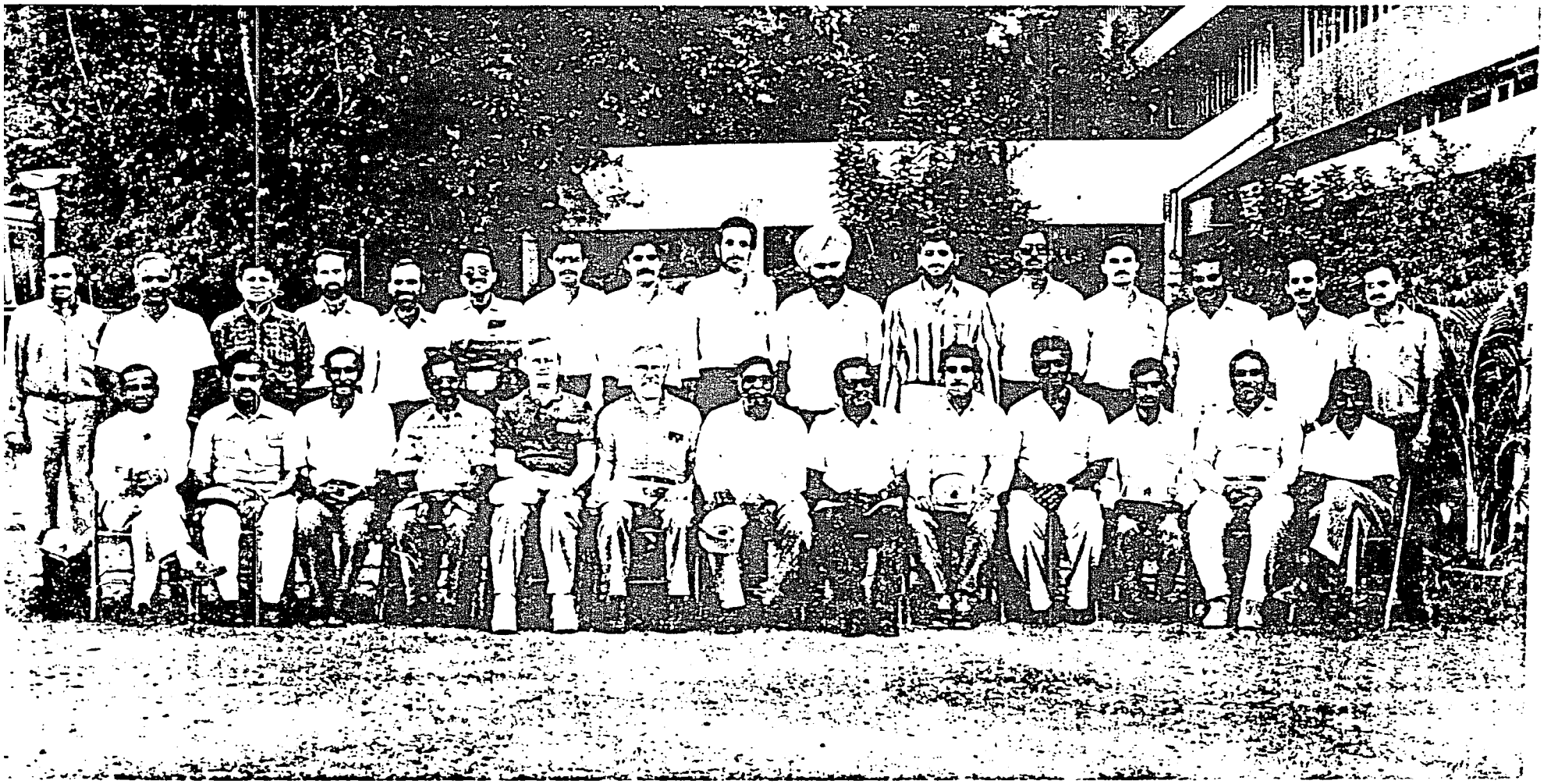
15 Yes 4 No

2. Was the level of presentation of the subject matter:

4 Too simple? 15 About right? ____ Too complex?

3. Rate the usefulness of each of the course topics in terms of being able to use the ideas, materials or skills in your work (please circle the appropriate number):

	Not Useful				Very Useful	N	$\bar{x}$	sd
Overview of World Reforestation	5	4	3	2	1	20	1.95	1.2
Bareroot Nursery Development	5	4	3	2	1	"	1.45	0.7
Container Nursery Development	5	4	3	2	1	"	1.90	0.7
Seeds/Genetics/Physiology/Handling	5	4	3	2	1	"	2.05	0.9
Target Seedling Concept	5	4	3	2	1	"	1.75	0.9
Seedling Nutrition & Fertilization	5	4	3	2	1	"	2.25	0.9
Irrigation Systems	5	4	3	2	1	"	2.45	1.2
Seedling Quality	5	4	3	2	1	"	1.75	0.9
Vegetation Management	5	4	3	2	1	"	2.1	1.1
Technology Transfer	5	4	3	2	1	"	1.5	0.9
Field Trips	5	4	3	2	1	"	2.3	1.05



Sitting left to right

M/s P. KUPPUSWAMY; K.A. DORAISAMY; K.V. SUBRAMANIAM; DR.L.N. HARSH; DR. ROBIN ROSE; DR.W.H. EMMINGHAM; DR.S. CHINNAMANI; DR.C.C. ABRAHAM; V.K. SHUKLA; A.K. SAMANTHA; DR.J.V. RAO; DR.M.G. DASTAGIR; DR.K. SUDHAKARA

Standing left to right

M/s DR.K. GOPIKUMAR; S.B. DEVARANAVADGI; DR.K.A. SINGH; A.B. DESAI; DR.B. MOHAN KUMAR; R.W. GAWANDE; B.B. DASH; S. SHEIK HYDER HUSSAIN; DR.P.K. ASOKAN; AVTAR SINGH; G. RAJESWAR RAO; THOMAS MATHEW; SONNEY GEORGE; K.V. SURESH BABU; T. PREM KUMAR; DR.J.C. TEWARI

Appendix 21

Certificate of Completion

Awarded to:

THE NURSERY MANAGEMENT WORKSHOP
Trichur, India

May 6-18, 1991

Robin Rose, PhD

Wm. H. Emmingham, PhD

Appendix 2