平成5年度

# 技術情報提供活動促進業務報告書

## ―林業分野プロジェクト国内委員会活動―

（上巻）

平成6年3月

国際協力事業団



平成五年度 技術情報提供活動促進業務報告書（上巻） 平成六年三月 国際協力事業団

# 序　文

本報告書は、平成５年度林業協力分野国内委員会における技術情報提供活動の内容を取り纏めたものです。

技術情報提供活動は、林業協力プロジェクト等からの技術質問を受け、国内委員会が回答を作成して迅速に現場にフィードバックし、プロジェクトの効果的な推進を図ることを目的としています。

本年度、プロジェクトから提出された質問事項は、13項目ありますが、これら質問事項は国内委員会の各委員の多大な御協力により回答が作成されました。本報告書はこの13の質問内容及びそれらに対する回答を合冊したもので、現地からの林業情報及び国内からの支援情報が夫々相当量盛り込まれており、それらが備蓄されていけば、開発途上国における林業技術情報の有用な集積になるものと考えています。本報告書が海外林業協力の関係者に、より広く活用されることを願っています。

本報告書を取り纏めるにあたり、委員その他関係者から賜った御支援と御協力に深く感謝申し上げます。

平成６年３月

国際協力事業団
林業水産開発協力部
部長　二澤　安彦

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登録番号　2601
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| | 6 | 農耕と牧畜農業と林業の結合（保護樹帯のその取り扱いを含む） |
| 質問内容 | 半乾燥地帯における薪炭林の造成 | |
| プロジェクト | 中央林業開発訓練センター計画 | |
| 地域：国名 | 東南アジア　：ミャンマー | |
| キーワード | 薪炭林　住民林業　林業普及　半乾燥地 | |
| 参考文献 | 熱帯林の造成技術：浅川澄彦：国際緑化推進センター<br>熱帯地域における森林の更新技術：ＪＩＣＡ<br>ナイジェリア半乾燥地域森林資源保全開発実証調査報告書：ＪＩＣＡ | |

| | | | |
|---|---|---|---|
| 質問者 | 森田一行 | 回答者 | 河原輝彦 |

# 個別技術情報支援のための質問書

1994年１月31日

プロジェクト名　ﾐｬﾝﾏｰ中央林業開発訓練
専門家名　森田 一行

質問技術テーマ；半乾燥地帯における薪炭林の造成，管理技術について

1．質問技術テーマの具体的背景及びそのプロジェクト活動での位置付け
2．質問の具体的内容
3．期待する回答の範囲

1．当国では，水源かん養，土壌保全とともに住民への燃料供給を目的として，国の中央部に広がる半乾燥地帯の造林が国家プロジェクトとして取り上げられ，当訓練センターにおいてもその対応が必要となっている。このため，他の半乾燥地帯における薪炭林造成の方法，管理手法についてご指導いただきたい。

2．
(1) 薪炭林造成の際の，気象条件と樹種選定，植栽本数，間伐（もし、行われているなら）の時期と強度，収穫期間，更新方法，期待収穫量（＝生長量）。
(2) 在来樹種を活用した薪炭林造成の例（樹種名，選定理由，外来樹種との比較など）
(3) 住民参加型で薪炭林造成を行っている例があれば，住民の組織化の方法，土地所有，費用負担，労力　提供，技術指導・普及などの方法，収穫時の分配などの具体的方法。

質問のキーワード；
薪炭林，住民林業，林業普及，乾燥地造林

| 希望資料名； | 希望指導委員名； |
|---|---|

注意事項　　等様式１枚に複数の質問技術テーマは記載しないこと。

ミャンマー中央林業開発訓練プロジェクトからの質問技術テーマ

「半乾燥地帯における薪炭林の造成・管理技術について」

＜質問１＞薪炭林造成法

気象条件と樹種選定、植栽本数等の育林・保育については、国際緑化推進センター発行の「熱帯林の造成技術」（浅川澄彦著）、ＪＩＣＡ発行の「熱帯地域における森林の更新技術」（昭和５３年）及びＪＩＣＡナイジェリア半乾燥地域森林資源保全開発実証調査報告書に詳しく書かれていますので参照ください。しかし、まだこれに関する研究やデータは十分とは言えません。今後とのデータを集積していく必要があります。プロジェクトからの成果を期待しています。

＜質問２＞在来樹種を活用した薪炭林の例

薪炭用としては、初期成長が優れた早生樹がよく、短伐期で萌芽更新出来ることが望ましいことから、ユーカリ類、Gmerlina arboreaなどが重要な樹種になっている。この事もあって、今のところ在来樹種の薪炭林の例を示した報告書は見あたらなかった。今後再度文献を捜してみたいと思います。

＜質問３＞住民参加型の薪炭林造成

このことについては、３月３日からそちらのプロジェクトに短期専門家として九州支所鶴室長が派遣される予定になっていますので、彼に質問の回答をもっていってもらうことにしてあります。

回答者

森林総研　河原輝彦

登録番号　2340
参照番号

| | | |
|---|---|---|
| ODC分類 | 2 | 造林 |
| | 3 | 林分の更新と造成 |
| 質問内容 | タイのローカル樹種育成について | |
| プロジェクト | 東北タイ造林普及計画 | |
| 地域：国名 | 東南アジア：タイ | |
| キーワード | Tectona grandis　発芽処理　発芽率 | |
| 参考文献 | Kuerkool,P.:Nursery produciton Techniques in Thailand ASEAN-Canada Forest Tree Seed Centre Project Tech.Publication No.2,5pp.1991 | |

| 質問者 | 大森慎一 | 回答者 | 浅川澄彦 |
|---|---|---|---|

# 個別技術情報支援のための質問書

1994 年1 月31日

プロジェクト名　東北タイ造林普及計画
専門家名　大森慎一

技術質問テーマ：タイ国のローカル樹種育成について

1、技術質問の具体的背景、及びプロジェクト活動の中での位置付け
2、質問の具体的内容
3、期待する回答の範囲

当、東北タイ造林普及計画プロジェクトは、タイ東北部の森林回復に向けて、大量の苗木の生産と配布の計画を実行中ですが、現在、配布を希望する樹種はユーカリが８割以上を占めます。しかし、地元在来の樹種の希望も根強く、とくにチークは、タイでも高級高価な樹種であることは農民レベルの者にも知られており、今後は配布の要請が増加するものと考えられます。

このことから苗木の生産にあたって、チークに関する発芽、育苗等のデータ、特にチークは発芽率が低く何か良い方法がないか思考しているところですが、良い方法がありましたらお知らせ下さい。

（タイ北部の育苗データでは３割以下の発芽率で非常に低いものといわれている。スタンプ苗が最も成育が良いようです。）

質問のキーワード：

| 希望資料名： | 希望指導委員名： |
|---|---|
| チークに関する発芽処理および発芽試験データ | とくに無し |

「チークの育苗とくにタネの発芽について」

東北タイ造林普及計画プロジェクトからの質問に対する回答

ご承知と思いますが、アセアン－カナダ林木種子センターの刊行物として下記が公刊されています。

Kuerkool, P.: Nursery production techniques in Thailand. ASEAN-Canada Forest Tree Seed Centre Project Tech. Publication No.2, 5pp. 1991

この著者は長年、育苗の実際に専念された方で、その経験をもとに、RFD の育苗マニュアルとして同センターから刊行されてものゝようです。その概要は小著「熱帯の造林技術」(1994)に紹介してありますが、残念ながら、この報告にはタネの取り扱い方が説明されていません。ご質問の中心はタネの取り扱い方のように思われますので、私が持ち合わせている文献は1970年代のものですが、とりあえずそれらを参考にしてお答えします。

---

チークの実には 4～6 個、普通には 4個のタネがはいっており、活力をもつタネの割合は高いようですが、とくに実験室で発芽させるのは難しいとされています。（なお別な文献では、含まれるタネは 1～3 個、まれに 4個とされています。）苗畑でも、これまでのところ、すべてのタネを発芽させることができるような促進方法はないとされています。実験的には、外果皮(exocarp) を機械的に外すといくらかの促進効果はあるようですが、この方法を事業的な規模で行うのは難しいと思います。量的に行う方法として、１日水に漬けた後、陽光で２日間乾燥する操作を繰り返すことが提案されており、その結果、外果皮に割れ目がはいり、発芽がよくなるとされています。この操作を５回繰り返し、68日間に 61%の発芽率を得たという報告があります。このような前処理がどのくらい実際に行われているか不明ですが、フィリピンでは、マニュアルには前記のような前処理をするとよいと書かれていながら、不可欠ではないとさ

れており、普通には水に漬けるだけで播いていたように記憶しています。その場合には、一晩よく水に漬け、播きつけた後は見え隠れ程度に土をかけ、床面を乾かさないように管理します。また、そこまで丁寧に播きつけることが可能かどうか、私は困難だと思いますが、果実のいわゆるヘソが下向きになるように播くと多少は発芽がよいとされています。

ちなみに、私のもっている文献にあげられている例でも発芽率は 40～46%という低さですが、FAO の資料によると、世界各地で得られている苗畑発芽率には 20～80%と大きな幅があります。なお多くの場合、発芽率は、播いた果実数に対する発芽した果実の割合ですので念のため申し添えます。

ある文献では、数か月貯蔵したタネのほうが新鮮なタネよりよく発芽したことから、後熟が必要だとしています。また、タイの文献によると、1～2週間アリに食わせる(？)と外果皮がいためられて発芽が速くなるとされています。あとの報告は Bull. Nat. Hist. Soc. Siam の No.21 pp.75～86, 1966に載っていますので、RFD で見られると思います。

以上、結論として、1980年代初期までのところでは、チークのタネの発芽を効果的に向上する方法はないようです。

私はかって、ランパンからチェンライにゆく途中で、一面にチークの苗木が育成されていた大きな苗畑を訪ねたことがありますが、おそらく今でも、あのあたりではチークが植えられているのではないかと思いますし、チーク改良センター(TIC) でも取り扱っているのではないかと思います。それらの活動は見ておられますか？　私が訪ねてからすでに15年以上経っていますから、かなりの進歩があるのではないかと思いますので、もしもまだでしたら、ぜひ近況を探訪して下さい。

なお、インドにはチーク造林のより長い歴史があり、文献も沢山ありますが、今回はとりあえずこの程度で回答とさせていただきます。

（浅川澄彦）

登録番号　1109
参照番号

| | | |
|---|---|---|
| ODC分類 | 1 | 環境因子　生物学 |
| | 1 | 立地因子　気象　位置　土壌　水文学 |
| 質問内容 | モデル展示林の植栽効果の指標及び測定方法について | |
| プロジェクト | 東北タイ造林普及計画 | |
| 地域：国名 | 東南アジア：タイ | |
| キーワード | モデル展示林　流出土砂の測定 | |
| 参考文献 | | |

| | | | |
|---|---|---|---|
| 質問者 | 谷口文敬 | 回答者 | 河原輝彦　梁瀬秀雄 |

登録番号　9404
参照番号

| | | |
|---|---|---|
| ODC分類 | 9 | 国家的に見た森林と林業　林業の社会経済 |
| | 4 | その他の森林政策を実行するための方策 |
| 質問内容 | モデル展示林の植栽効果の指標及び測定方法について | |
| プロジェクト | 東北タイ造林普及計画 | |
| 地域：国名 | 東南アジア　：タイ | |
| キーワード | モデル展示林　流出土砂の測定 | |
| 参考文献 | | |

| | | | |
|---|---|---|---|
| 質問者 | 谷口文敬 | 回答者 | 河原輝彦　梁瀬秀雄 |

# 個別技術情報支援のための質問書

1994年1月31日

プロジェクト名 東北タイ造林普及計画
専門家名(造林担当) 谷 口 文 敬

質問技術テーマ：

1．質問技術テーマの具体的背景、及びそのプロジェクト活動の中での位置付け

タイ国における森林率は、過去３０年間に５０％から３０％に激減し、特に東北タイでは農耕地の拡大等により１４％まで減少している。

このような中で、当プロジェクトは東北タイの森林回復、環境の保全そして地域住民自らによる生活の糧となる植林活動の推進を中心に、生活福祉の向上を目的に開始された。

このことは東北タイの植林活動の促進、特に地域住民自身の手による植林活動を推進する上で、重要な契機を与えるものである。

１９９３年度は、保全目的モデル展示林及び経済目的モデル展示林をそれぞれ３０ｈａづつ下記の目的で造成した。

記

保全目的モデル展示林は、森林の保全的効用を啓蒙普及することを目的として、郷土樹種を主な造林樹種として、原植生を回復させることにより環境保全土壌流出防止・水源確保の役割効果等を広く地域住民等に普及宣伝するために造成した。

経済目的モデル展示林は、森林の環境保全を前提に、経済的利用を啓蒙普及することを目的として、早生樹種を主な造林樹種とし、郷土樹種も混植し地域住民の生活に直接益し、収入確保ができるようにする施業方法を展示するために造成した。

また、両展示林は各苗畑センターが行う訓練活動の場として、訓練参加者に森林造成に関わる技術知見の拡大・深化をねらいとし、森林及び林業の重要性を認識してもらうために造成した。

質問のキーワード；

| 希望資料名； | 希望指導委員名； |
|---|---|
| | |

注意事項　　当様式１枚に複数の質問技術テーマは記載しないこと。

# 個別技術情報支援のための質問書

1994年 1月 日

プロジェクト名 東北タイ造林普及計画
専門家名（造林担当）谷 口 文 敬

このような背景の中で造成設定したモデル展示林は、その植栽効果を測定・検証することが大変重要な課題であると考える。

植栽効果の指標及び測定方法として、当面下記のとおり考えている。

記

保全目的展示林（樹種別、施業方法別による）

環境保全機能として、水質汚濁の調査

（水質・水量等の変化の測定）

土砂流出防止機能として、植栽箇所及び非植栽箇所における土砂流出量の測定

（簡易な土砂受け枡等設定して測定）

その他として、野生鳥獣、地中生物等の生息状況の調査

（調査区域の設定）

経済目的展示林（樹種別、施業方法別による）

成長量の調査、伐採（間伐）時期・更新方法・販売先・販売価格の検討

副産物の収穫・販売（果物等）の調査・検討

質問の主旨は、より適切な植栽効果の指標及び測定方法があるなら具体的にご教示願いたい。

| 質問のキーワード； | |
|---|---|
| 希望資料名； | 希望指導委員名； |

注意事項　　当様式１枚に複数の質問技術テーマは記載しないこと。

東北タイ造林普及計画プロジェクトからの質問技術テーマ

「モデル展示林の植栽効果の指標及び測定方法について」

保全目的展示林

①水質関係は経験がすくないので良い資料がありません。一応資料を付けて置きますので、参考にしてください。

②土砂流出防止効果を測定する項目として、流出土砂量の測定が入っていますので、その調査に関しての注意していただきたいことを簡単に記載しておきます。

なお、これに関するコメントは、染谷水土保全科長によるものです。

経済目的展示林

①調査項目は揚げられている項目でよい。

②対象展示林は、樹種別、施業方法別に造成されているが、生産目的をはっきりした展示林を造成する必要があると思います。たとえば、薪炭用か建築材用かなど（このことは施業法別に含まれているのかもしれなせんが）。生産目標がはっきりしていないと、多くの調査を行っても、その結果を整理したときにはっきりした結論がでない恐れがあるかもしれないからです。

生産目標がはっきりすれば、植栽本数や間伐、伐採の方法や時期あるいは更新方法は自然に決ってくると思います。

③成長量の測定は、毎年は必要ではなく、２～３年毎で十分であり、それよりも長期間測定が続けられるような体制を作ることが大切です。たとえば、試験地の区画や測定資料の管理・整理をしっかりしておくこと等があります。

回答者

森林総研　河原輝彦

質問回答：JICA・東北タイ

1994.2.10

流出土砂の測定

流出土砂測定法は目的、対象地などによって異なる。すなわち、地形、地質、林種等の違いによる流出土砂量の差異を流域単位で、または山地斜面を対象にして明らかにしなければならないのか、充分検討して計画しなければならない。勿論、その条件にかなう試験地の設定が可能でなければならない。流域を対象とした場合には量水堰堤等ダムに堆積した土砂を測定する方法が一般的であり、山地斜面を対象にした場合には斜面に目盛をうった杭を打ち込み、地表面の変動をその目盛によって把握する方法もあるが、一般的にはトレンチ法、プロット法を用い、土砂受けにたまった山地斜面から流出した土砂を測定することになる。測定した土砂の整理方法としては例えば土地利用形態の違いによる流出土砂の実態を明らかにする目的であれば森林からの流出土砂量を基準にして裸地、草地等からの流出土砂量を比較することが考えられる。調査目的を達成するための整理方法も吟味することが大切である。

登録番号　2338
参照番号

| | | |
|---|---|---|
| ODC分類 | 2 | 造林 |
| | 3 | 林分の更新と造成 |
| 質問内容 | フタバガキ科植栽のための山取り苗木養成技術 | |
| プロジェクト | サバ州造林技術開発訓練計画 | |
| 地域：国名 | 東南アジア：マレーシア | |
| キーワード | フタバガキ科　山取り苗　苗木の移送　蒸散コントロール　スタンプ苗　発芽 | |
| 参考文献 | 多　数 | |

| | | | |
|---|---|---|---|
| 質問者 | 酒井紀夫 | 回答者 | 佐々木恵彦 |

# 個別技術情報支援のための質問書

プロジェクト名　サバ州造林技術開発訓練計画
ﾁｰﾌｱﾄﾞﾊﾞｲｻﾞｰ/ﾘｰﾀﾞｰ名　酒　井　紀　夫

質問技術テーマ：在来樹種(ﾌﾀﾊﾞｶﾞｷ科)植栽のための山取り苗木養成技術の確立

1　当プロジェクトの主要植栽樹種であるアカシア・マンギウム(A.m) に将来的に代替えしうる高価値の在来種造林技術確立のため、A.m 下の樹下植栽や二次林下の線状植栽を小規模ながら行っているが、種子確保が不定期で苗木確保に問題の多いフタバガキ科樹種の山取り技術の確立に資するため、山取りを実施した。

2　1)実施状況

別添1．の「フタバガキ科パラショレア属の山取り木ポット移植の実施内容」のとおりである。

この試行上の問題点として

a)　山取り現地と当プロジェクトの距離があるため移送に長時間を要する。

b)　現地で山引き後すぐポット移植したものは高い生存率を保ったが、プロジェクトに移送後ポット移植したものは成功率が大変低い。

c)　この種（パラショレア・マラアノナン）の山引き苗の根系は頗る貧弱である。ちなみに、技術移転相手方であるSAFODAの研究部もフタバガキ科の調査研究に力を入れ始めており、特にパラショレア属に注目している。

2)　「山取→移送→ポット移植」の技術を確立し生存率を高めるため、改良すべきと考えられている点。（現地で山取り後、すぐポット移植する方法の場合、現地からの苗木の多量輸送が困難であり、「山取→移送→ポット移植」の技術を確立したい。）

a)　山取→ポット移植の時間を極力短縮する。

具体的：午前中の山取りは昼には移送を開始する。当日（山取）中に苗畑まで移送する。

b)　移送中の温度条件を良くするため、昼間の移送はランドクルーザーなど、温度をコントロールできる車を使い、その他の場合は夕方～夜間に移送する。

c)　山取りは、引抜きで実施しているが、根系を傷めないよう道具を使って行うものと比較してみる。ただし、現地の経験では、根系が貧弱なため、引抜きと道具による掘取りで根系の状態にそう差はないように感じている。

d)　移送後、ポット移植前に流水につけて、苗木の衰弱の回復を図る。

（これは、パンタバンガン・プロジクトの *Anisoptera* SPP の Wilding のマニュアル「Manual For Species Alteration　: Feb.1992」を参考としている。）

e)　蒸散コントロールの改良も実施してみる。

例：○　移送前・・・全葉を取り除いたものでも実施してみる。

○　移送中・・・全葉、半分葉の苗木を蒸散防止のためビニール袋で密封する。

○　ポット移植時・・・全葉取り除きでも実施してみる。

f)　苗長別の生存率を比較する。

3)　期待する回答の範囲

a)　これまでの試行（別添1）及び改良案（2の2)）についての指摘事項

追加指摘事項、問題点の指摘等。

b) フタバガキ科のこの種の試行に参考となるレポート、資料の送付。（日本文か英文に限る。）

3 その他：別添2として参考写真を添付した。

① 天然林*Parashorea malaanonan*(P.m)
（写真 Feb.16.1993）

② 山取り後プロジェクトに移送されポット移植前のP.m （30.Janu.1993）

2．2）　「山取－移送－ポット移植」の技術を確立し、生存率を高めるため改良すべきと考えられる点。（現地で山取り後、すぐポット移植する方法の場合、現地からの苗木の多量輸送が困難であり、山取り－移送－ポット移植の技術を確立したい）

a）山取～ポット移植の時間を極力短縮する。

具体的：午前中の山取りは昼には移送を開始する。

当日中に苗畑まで移送する。

（山取）

b）移送中の温度条件を良くするため、昼間の移送は、ランドクルーザーなど温度コントロールのできる車を使い。その他の場合は、夕方～夜間に移送する。

c）山取りは、引抜きで実施しているが、根系をいためないよう道具を使って行うものと比較してみる。ただし、現地の経験では、この種は元々、根系が貧弱なため、引抜きと道具による堀取りで根系の状態にそう差はないように感じている。

d）移送後、ポット移植前に流水につけて、苗木の衰弱の回復を図る。（これはパンタバンガンプロジェクトのAnisoptetr sppのWlldingのマニュアル「Manual Fn Species Alteratin:Flo.1992」を参考としている。）

e）蒸散コントロールの改良

例：・移送前……全葉をとり除いたものでも実施してみる。

・移送中……全葉、半分葉の蒸散防止のため苗木をビニール袋で密封する。

・ポット移送時……全葉取除きでも実施してみる。

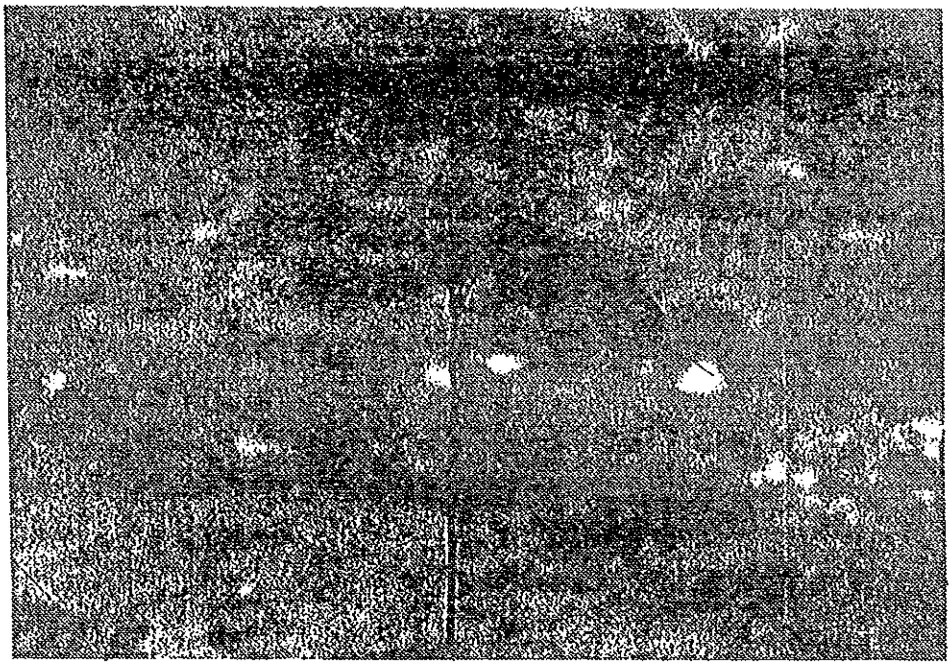
f）苗長別の生存率を比較する。

3）　期待する回答の範囲

a）これまでの試行（別添1）及び改良案（2の2）についての指摘事項、追加指導事項、問題点の指摘等。

b）ユタバガキ科のこの種の試行に参考となるレポート、資料の送付（日本分か英文に限る。）

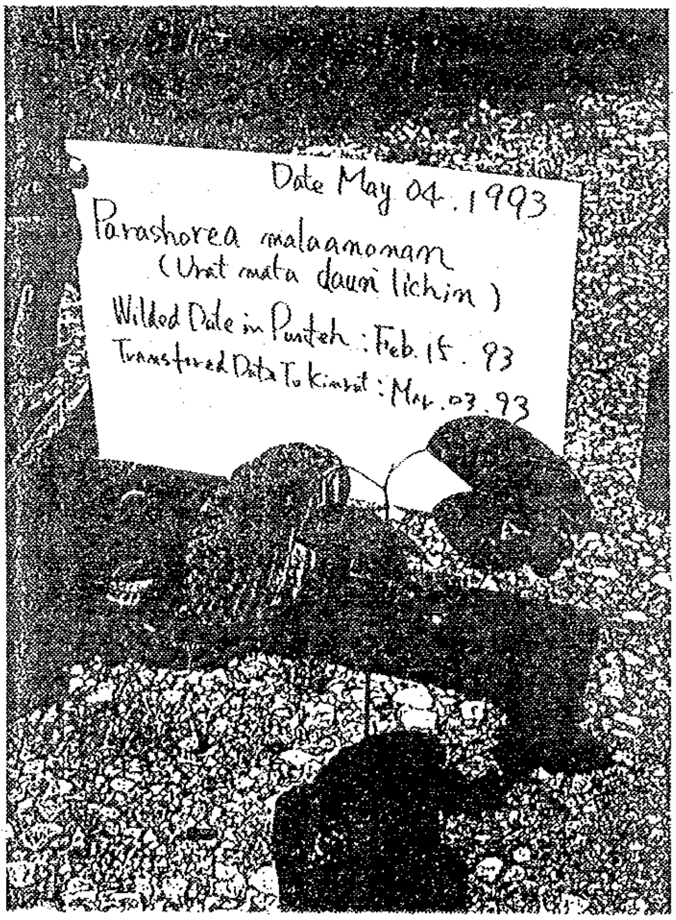
3．その他：別添2として参考等頁を添付した。



⑤　一度葉が枯れた後再生した葉の状況。

ポット移植後40日の状況。（前ページ参照）

（　12. March. 93　）




⑥

２月15日に山取り後現地で

ポット移植

約半月後（３月３日）プロジェクトに

移送

これはその２ヶ月後の５月４日に

とったもので、上部の２葉は、

移送後新出したもの。

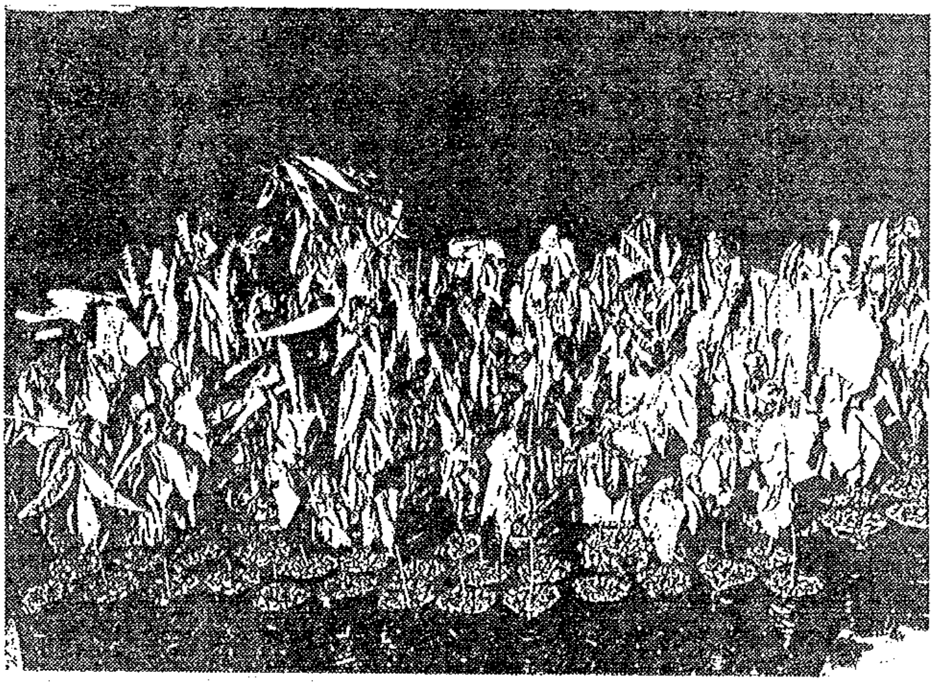
下方の葉は、山取り時に

蒸散抑制のため、半分

カットしている。

③　山取り－移送後　ポット移送中

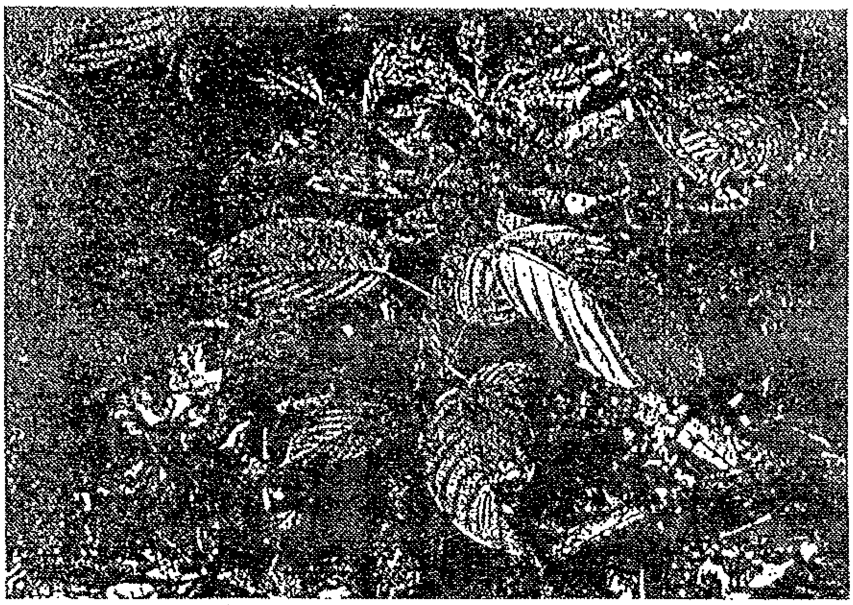
（ 30. January. 93 ）



④　ポット移送後（２日後）の葉のしおれの状況

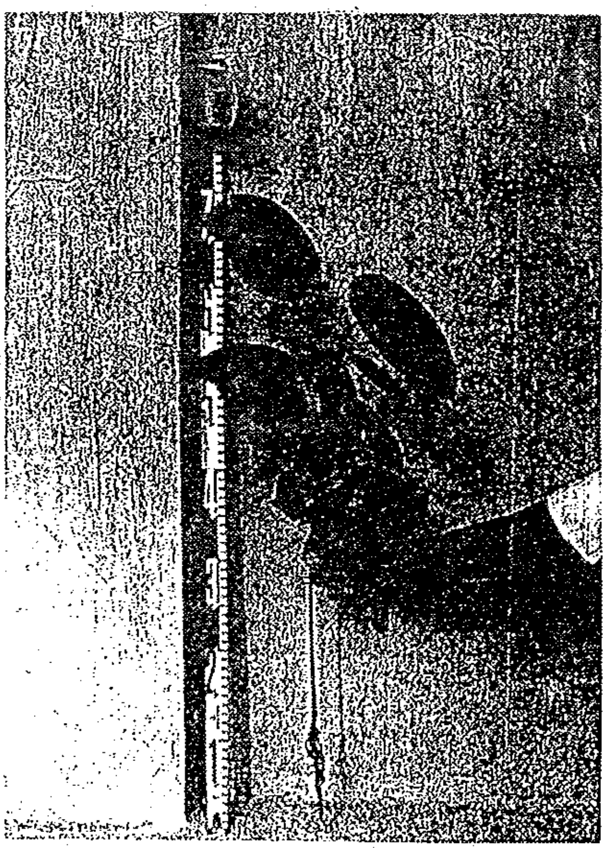
元気なものは、数本しかない。

（ 01. Feb. 93 ）



① 天然林床でのParashorea malaanouan (P.m)

（ 写 Feb.16.1993 ）



② 山取り後プロジェクトに移送され

ポット移植前のP.m

（ 30.Jaunary.1993 ）

Vol. 44 No. 1, 1981

# PHYSIOLOGICAL STUDIES ON GERMINATION AND SEEDLING DEVELOPMENT IN INTSIA PALEMBANICA (MERBAU)

*by*

S. SASAKI* AND F.S.P. NG**

Summary

The mature seed of *Intsia palembanica* has a moisture content of less than 10% of the seed dry weight, is protected by a hard seedcoat, and can be stored for a long time at room temperature. The seedcoat is impermeable to water and needs scarification to facilitate water imbibition. An effective method for scarification is to rupture the strophiole, which is a small protrusion located at the end of the seed opposite to the hilum. Seeds with abnormal shapes as well as small sizes often develop into albinos and dwarfs. An experiment involving cotyledon removal showed that cotyledon seed reserves contribute to seedling development up to the stage of development of the first pair of leaves. Direct sowing of seeds in fields is feasible, as the seed reserves alone are sufficient to establish the seedlings. However, a precaution is needed since the seedcoat is dehydrated by exposure to sunlight and this often interferes with the parting of the cotyledons and emergence of the epicotyl. To avoid this, the seeds must be planted vertically with hilum downward, so that the seedcoat is shed as the hypocotyl emerges from the soil.

The seedling growth under various field conditions was the fastest in the open and the slowest under closed canopy conditions, indicating that the species needs a high light intensity for growth. This was confirmed by light quality experiments. The species required red light for weight increment, but under closed canopy conditions, red light is scarce as the canopy layers absorb the red light spectra.

*Intsia palembanica* seedlings grow better in a soil with 25% sand mixed. Good drainage is important for the species to grow. Also, high air humidity may help to promote photosynthesis.

## Introduction

*Intsia palembanica* (Merbau) is a heavy hardwood timber of wide distribution in South East Asia (Whitmore, 1972). In recent years it has become very popular for a wide range of uses and has fetched very high export prices. The species is on the preferred list for forest regeneration in Peninsular Malaysia (Anon, 1975) but is reputed to be slow-growing and difficult to manage silviculturally. These studies were carried out to develop better methods of growing Merbau.

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Seeds

The mature seed is very hard and dry, with its moisture content less than 10%. The seed is covered by two layers of hard seedcoat, under which are two large cotyledons, attached to a radicle and plumule. Other legume seeds such as *Parkia javanica*, *Sindora coriacea*, and *Dialium maingayi* have similar hard seedcoats. The outer seedcoat is impermeable to water and scarification is needed to promote germination. Among the methods of scarification, immersion of the seed into concentrated sulphuric acid, scratching of the seedcoat by a handsaw or a file, and scraping off the small swelling (strophiole) of the seedcoat on the opposite side of hilum are effective to promote water imbibition for *Intsia palembanica* (Sasaki, 1980). Particularly, the last method is easy and quick, and applicable for field work where no other facilities are available. Also, this method can minimize injury and exposure to microbial infections. Scarified seeds absorb water within an hour and start shedding off the outer layer of the seedcoat. The imbibed seed is markedly swollen and the cotyledons become soft (Fig. 1). The radicle protrudes from the hilum 3 to 5 days after imbibition.

Various shapes are found in *Intsia* seeds (Fig. 2). Seeds with odd shapes are generally correlated with abnormality of seedlings such as albinos and dwarfs. The average weight of the seed is more than 5 grams. Initial growth of *Intsia palembanica* seedlings is impressive as the seedlings grow up to 25 cm high on the strength of cotyledon reserves (seed reserves) alone within 2 weeks of sowing.

Seedling Development

*Importance of the seed reserves (cotyledon reserves) to seedling establishment*

To study the contribution of seed reserves to seedling development, cotyledons were excised at various stages of germination. Scarified seeds, soaked in water overnight, were sown in regular nursery plastic bag-pots 5 – 7 cm deep so that the hard seedcoat could be shed while the cotyledons were emerging. Most of the seedlings emerged within 9 days. Emerged cotyledons were excised 9, 10, 11, 12, 13, 16, 19 and 25 days after the seeds were sown. The shoots were measured 78 days after sowing, and the results are shown in Table 1.

The seedlings with cotyledons removed in the early stages were stunted, with the first pair of foliage leaves, and subsequent leaves if any, and their stems, reduced in size. The reduced size in leaves in turn appeared to slow down further development of the seedlings because of reduced photosynthetic areas. A preliminary trial suggested that the seeds of over 7 grams by dry weight performed better than those of 5 grams or below. Also, it appeared that abnormal seedlings such as albinos, deformed leaves, and short internodes, were more frequently associated with small sized seeds.

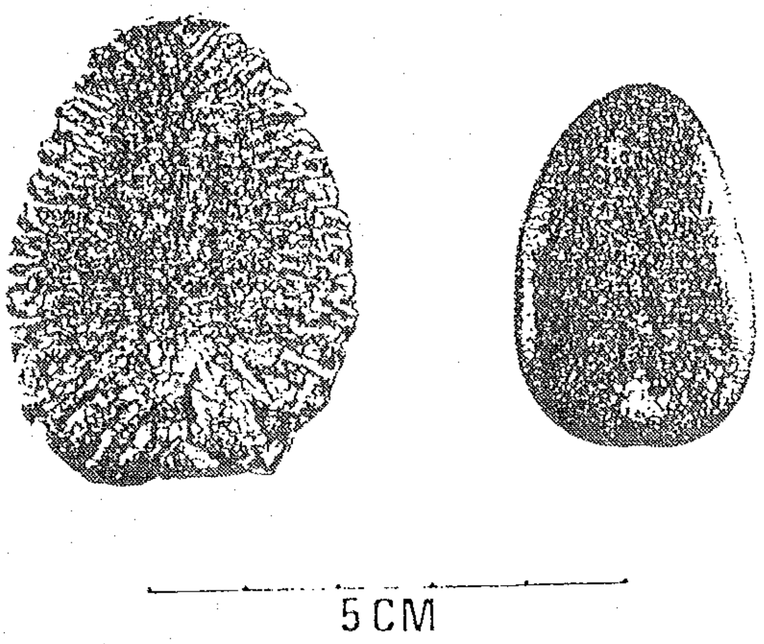


Figure 1. Imbibed Intsia palembanica seed (left) compared with dry seed (right). The imbibed seed is markedly swollen and the cotyledons become soft.

Figure 2. Various shapes of Intsia palembanica seeds. Seeds with odd shapes often are associated with abnormality of seedlings.

Table 1. Effect of cotyledon excision on shoot growth, as measured 78 days after sowing of imbibed seeds

| Day of cotyledon excision | Total shoot | Average length (cm) Hypocotyl | Epicotyl | Post-epicotyl shoot |
|---|---|---|---|---|
| 9 | 15.8 | 6.5 | 6.4 | 2.9 |
| 10 | 19.6 | 8.6 | 9.2 | 1.8 |
| 11 | 21.3 | 9.4 | 11.1 | 0.8 |
| 12 | 25.2 | 10.9 | 14.3 | 0 |
| 13 | 26.7 | 11.8 | 15.0 | 0 |
| 16 | 26.6 | 10.7 | 15.9 | 0 |
| 19 | 28.4 | 10.7 | 15.2 | 2.5 |
| 25* | 38.3 | 11.4 | 17.0 | 9.9 |

* At 25 days the cotyledons were about to be shed naturally.

*Growth of Intsia palembanica under various field conditions*

An *Intsia* seedling with the first pair of leaves fully expanded reaches 26 cm in height within 15 days after sowing. Therefore, the species may be suitable for direct sowing in the field. A preliminary experiment was conducted to evaluate direct sowing methods and growth performance under various canopy conditions. The seeds were scratched by a handsaw at both flat sides of the seed. These scarifed seeds were soaked in water for 5 minutes. After water was drained out, the seeds were divided into two groups; one was treated with daconil powder (a wettable powder fungicide) and the other served as control. These seeds were directly sown in four different sites.

The seed is a large flat bean (average size: 5 x 4 x 1 cm) which needs strong force to emerge from the soil in germination. Placing arrangement may have an influence on germination. Therefore, treatments included horizontal (flat) placement and vertical placement with the hilum downward. The summary of treatments and experimental sites are shown in Table 2.

The seeds sown directly in the field germinated very well, with germination percentages over 90% in all sites. This indicates the possibility of direct sowing for *Intsia palembanica*. However, several precautions are needed before putting the method into practice, as the experimental results indicated probable animal, fungal and mechanical damages during germination (Table 2).

The site I (open field) is located in a heavy soil with poor drainage. A few seeds tailed to emerge from the heavy soil and their hypocotyls were broken because the elongating force of the hypocotyls could not lift the seeds. Particularly, horizontally placed seeds were affected by soil pressure more than those vertically sown.

Table 2. Site conditions for Merbau direct sowing, and survival

| Site Number & Canopy condition | Light intensity (lux) | Soil condition | Seed treatment | Seed placement | Number of seeds | Damages (%) | | | Survival (%)* | Final survival** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Rodent | Fungus | Breakage (soil weight) | | |
| (1) Open | Full sunlight 100,000 | Heavy, water logged, gley soil | Fungicide | Vertical | 20 | — | — | 5.0 | 95.0 | 85.0 |
| | | | | Horizontal | 20 | — | — | 5.0 | 95.0 | 90.0 |
| | | | Control | Vertical | 20 | — | — | 5.0 | 95.0 | 90.0 |
| | | | | Horizontal | 20 | — | — | 15.0 | 85.0 | 80.0 |
| (2) Diffused light and open line (N – S) | Diffused light 800 – 1,000 | Yellow forest soil | Fungicide | Vertical | 20 | 10.0 | 5.0 | — | 85.0 | 80.0 |
| | | | | Horizontal | 20 | 20.0 | 5.0 | — | 75.0 | 70.0 |
| | | | Control | Vertical | 20 | 10.0 | 35.0 | — | 55.0 | 55.0 |
| | | | | Horizontal | 20 | — | 40.0 | — | 60.0 | 60.0 |
| (3) Diffused light and closed canopy | Diffused light 200 – 400 | Yellow forest soil | Fungicide | Vertical | 20 | 70.0 | — | — | 30.0 | 0 |
| | | | | Horizontal | 20 | 100.0 | — | — | 0 | 0 |
| | | | Control | Vertical | 20 | 30.0 | 15.0 | — | 55.0 | 45.0 |
| | | | | Horizontal | 20 | 40.0 | — | — | 60.0 | 35.0 |
| (4) Diffused light and closed canopy. Side light from the west. | Diffused light 300 – 600 | Yellow forest soil | Fungicide | Vertical | 20 | — | 5.0 | — | 95.0 | 95.0 |
| | | | | Horizontal | 20 | — | — | — | 100.0 | 100.0 |
| | | | Control | Vertical | 20 | — | 7.5 | — | 92.5 | 80.0 |
| | | | | Horizontal | 20 | — | 12.5 | — | 87.5 | 80.0 |

* 16 days after sowing.
** 143 days after sowing.

The hard seedcoat that softened during imbibition must be completely shed before cotyledons emerge. If not, the seedcoat is dehydrated again when lifted above ground by the elongating hypocotyl and hardened under the strong sunlight, to constrict the cotyledons. This prevents the cotyledons from opening. As a result, epicotyls were often trapped and twisted between the cotyledons in the site 1 (Fig. 3). To avoid such a situation, the seeds may be buried vertically 5 to 7 cm deep so that the seedcoat can be shed off completely before the cotyledons emerge from soil.

Rodent damages were observed in sites 2 and 3, with particularly heavy damages in site 3 (Fig. 4). This may be controlled by planting the seed inside a bamboo column.

Fungus infection often occurred on the injured cotyledons after scarification. This can be controlled to some extent by dusting the seeds with fungicide. A new scarifying method, scraping the swelling point of the seedcoat can minimize injuries (Sasaki, 1980).

Figure 3. Intsia palembanica seedling with distorted epicotyl. Redehydrated seedcoat pinched cotyledons, resulting in abnormal growth of epicotyl inside of cotyledons.

Figure 4a & b. Rodent damages of Intsia palembanica.

Although the site 1 (open field) consisted of heavy poor soil, leaf production of the seedlings markedly surpassed that under canopy conditions, as more internodes were counted in the open grown seedlings (Table 3).

Within the experimental period, the height of seedlings does not show significant differences between sites (Table 3). One of the reasons is that the seedlings in the open site had short internodes. In contrast, the seedlings under heavy canopies at the sites 2, 3, and 4 showed epinasty symptoms, with hypocotyls and epicotyls excessively elongated. However, those seedlings in sites 2, 3, and 4 almost stopped growing after expansion of the first pair of leaves. The seedlings under heavy canopy conditions probably remain stagnant after exhausting the reserve food in the cotyledons.

Because of the poor soil conditions in site 1, the experiment was abandoned after assessment at 143 days. However, seedlings in the open are expected to grow far better than those in the forests, provided that soil conditions are the same. This statement is supported by evidence from other experiments in which the seedlings were grown in the open.

*Responses to light quality*

Further experiments were conducted to evaluate the light spectral requirements for seedling growth of *Intsia palembanica*.

After scarification, seeds weighing over 7 grams each were sown in pots filled with 3 parts of forest top soil mixed with one part of sand. The pots were placed in colour chambers with specific spectral compositions (Table 4 and Fig. 5 a – f). Seedlings were harvested one month and also six months after sowing the seeds. The results are shown in Table 4.

Control seedlings under transparent white vinyl film showed smallest height growth, but weight increment during the six month period was the largest. The seedlings grown under the light with little red spectra such as the dark red film (CF 112 – 2) and blue film (CF 112 – 5) showed height growth equivalent to those with the red spectra such as yellow (CF 112 – 1) and orange (CF 112 – 3). However, the weight increments were the smallest under the light without red spectral regions. Probably the height increment was enhanced by the far red light as seen in the field experiments.

Root growth between one month and six months was more pronounced than shoot growth, as a decline in shoot/root ratios was distinct after six months. This is partly attributed to upward development of root zones in the hypocotyl observed at 6 months (Table 4).

The elimination of the red light spectra appeared to reduce weight increments, but not height growth. This may be confirmed by the following experiment.

**Table 3. Shoot growth of Merbau under various conditions, 143 days after sowing imbibed seeds**

| Site No. & Light intensity (lux) | Treatment | Seed Placement | Whole shoot | Average lengths (cm) Hypocotyl | Average lengths (cm) Epicotyl | Post-epic. shoot | Maximum internodes* |
|---|---|---|---|---|---|---|---|
| 1 (100,000) | No fungicide | Vertical | 36.4 | 9.6 | 15.8 | 11.0 | 6 |
| | | Horizontal | 37.4 | 10.0 | 16.5 | 10.9 | 7 |
| | Fungicide | Vertical | 37.6 | 9.9 | 17.6 | 10.1 | 5 |
| | | Horizontal | 40.4 | 10.5 | 18.3 | 11.6 | 6 |
| 2 (800 – 1,000) | No fungicide | Vertical | 38.2 | 15.9 | 18.6 | 3.7 | 3 |
| | | Horizontal | 36.9 | 16.4 | 19.0 | 1.5 | 3 |
| | Fungicide | Vertical | 38.0 | 16.1 | 20.4 | 1.5 | 3 |
| | | Horizontal | 37.4 | 17.3 | 19.6 | 0.5 | 2 |
| 3 (200 – 400) | No fungicide | Vertical | 38.2 | 18.1 | 19.4 | 0.7 | 2 |
| | | Horizontal | 36.6 | 16.1 | 20.4 | 0.1 | 2 |
| | Fungicide | Vertical | 34.2 | 16.7 | 17.0 | 0.5 | 3 |
| | | Horizontal | No measurement | | | | |
| 4 (300 – 600) | No fungicide | Vertical | 34.9 | 14.6 | 19.1 | 1.2 | 2 |
| | | Horizontal | 36.6 | 16.4 | 18.9 | 1.3 | 4 |
| | Fungicide | Vertical | 38.0 | 16.3 | 20.5 | 1.2 | 4 |
| | | Horizontal | 39.5 | 17.9 | 20.1 | 1.5 | 4 |

* Maximum number of internodes observed among seedlings of the sample, counting the epicotyl as internode 1.

Table 4. Shoot growth of Merbau in colour chambers

| Film colour; spectra eliminated: Light intensity (lux)* | Age (months) | Average length (cm) | | | | Maximum** No. of Internodes | | Average weight (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Shoot | Root | Hypocotyl† | Epicotyl | | Total | Shoot | Root | S/R |
| CF 112 – 4 Violet 500 – 600 nm | 1 | 50.0 | 15.5 | 18.9 | 20.7 | 4 | 3.8 | 3.2 | 0.6 | 5.3 |
| 14,000 | 6 | 70.3 | 28.1 | 14.9 | 21.5 | 9 | 20.0 | 15.7 | 4.3 | 3.7 |
| CF 112 – 2 Dark red Below 600 nm | 1 | 59.1 | 16.3 | 19.5 | 23.9 | 4 | 3.4 | 2.8 | 0.6 | 4.7 |
| 11,000 | 6 | 73.9 | 24.1 | 16.1 | 24.3 | 10 | 13.0 | 10.5 | 2.5 | 4.2 |
| CF 112 – 5 Light blue 600 – 700 nm | 1 | 45.7 | 16.1 | 18.3 | 18.7 | 5 | 3.7 | 3.0 | 0.7 | 4.9 |
| 32,000 | 6 | 75.7 | 25.6 | 13.8 | 23.6 | 10 | 17.5 | 13.6 | 3.9 | 3.5 |
| CF 112 – 1 Yellow Below 500 nm | 1 | 56.6 | 15.8 | 20.2 | 21.7 | 5 | 4.1 | 3.4 | 0.7 | 4.6 |
| 30,000 | 6 | 72.6 | 31.4 | 15.0 | 22.3 | 9 | 18.2 | 14.0 | 4.2 | 3.3 |
| CF 112 – 3 Orange 400 – 500 nm | 1 | 51.1 | 15.8 | 19.8 | 19.6 | 5 | 4.3 | 3.5 | 0.8 | 4.4 |
| 30,000 | 6 | 73.3 | 26.3 | 15.3 | 23.0 | 10 | 20.0 | 15.9 | 4.1 | 3.9 |
| Transparent — White — | 1 | 49.2 | 15.0 | 17.4 | 19.8 | 5 | 4.5 | 3.8 | 0.7 | 5.5 |
| 50,000 | 6 | 63.0 | 27.8 | 13.6 | 23.0 | 8 | 21.1 | 16.4 | 4.9 | 3.5 |

* Compared to open light of 80,000 lux.

** Epicotyl counted as internode 1.

† The hypocotyl is apparently shorter at 6 months than at 1 month because of upward initiation of new roots.

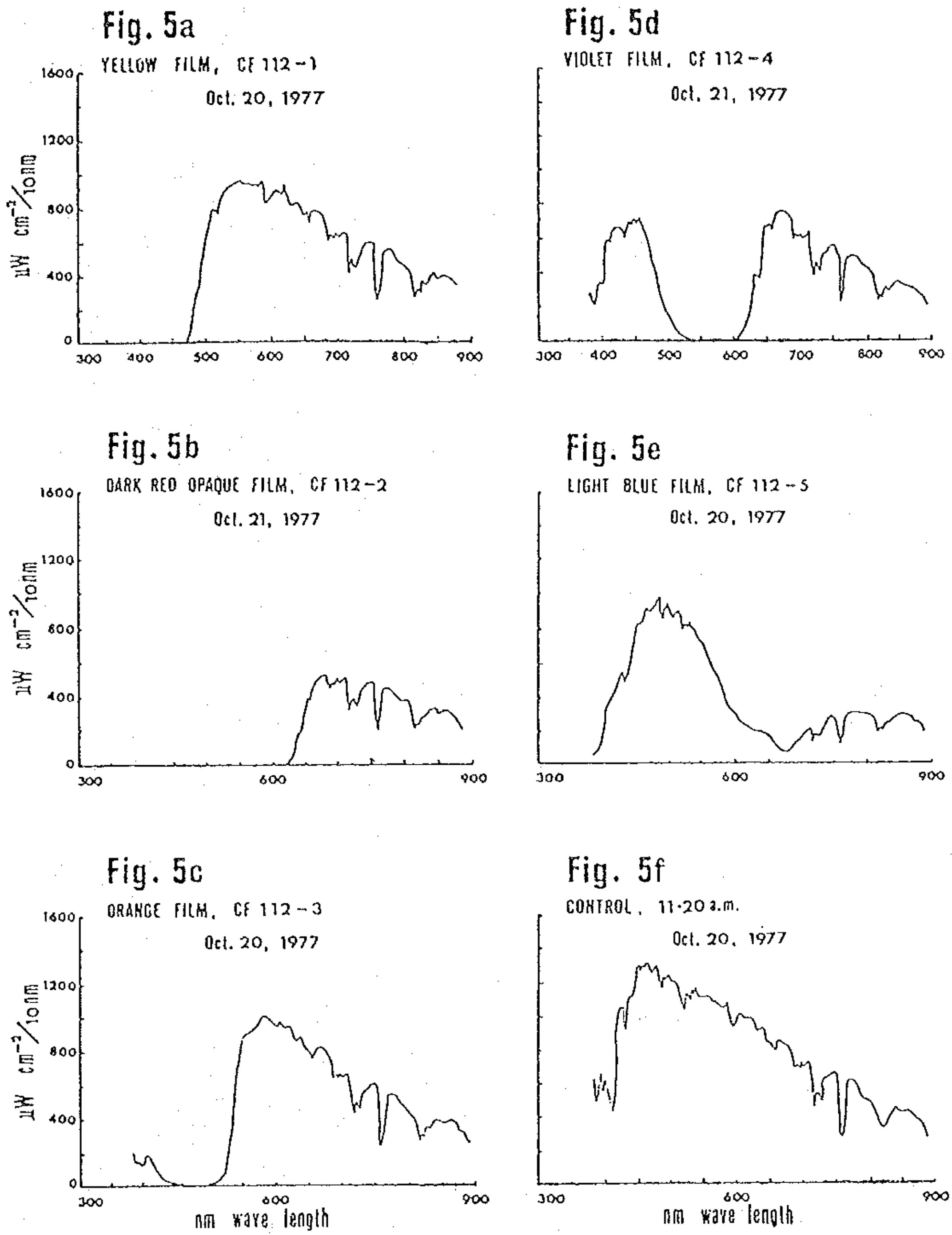


Figure 5. Spectral composition of light transmitted by various vinyl films used in colour chamber experiments.

With the same acryl colour films, colour chambers were made, but in addition, aluminium foil was used to cover a half side of the top of each chamber, so that total light intensity under the aluminium cover was less than that in the other half of the box. Also, cotyledons of six seedlings in each treatment were excised immediately after germination in order to study effects of cotyledon reserve on initial growth of *Intsia* seedlings. This was necessary to observe growth contributed by photosynthesis alone. The seedlings were harvested 45 days after the experiment was initiated. The results are shown in Table 5 and Fig 6

The seedlings without aluminium cover showed no significant differences in weight between the treatments (Fig. 6). In contrast, when the light intensity was reduced by the aluminium cover, a significant reduction in weight increment was observed in the blue light and dark red light chambers which eliminated the 600 to 700 nm spectral region (red light region). These results indicated that *Intsia palembanica* needs the red light spectra for growth. Under the field conditions, sufficient red light can only be obtained through sunflecks or the direct sunlight. As indicated earlier, the diffuse light under the canopy does not contain strong red light spectral energies. Therefore, the growth of *Intsia palembanica* may reach the maximum at fairly high light intensities, although full sunlight (vinyl film with no cover) reduced height growth. Elimination of the spectra between 400 and 500 nm did not influence the growth of *Intsia palembanica*. However, elimination of the spectra above 500 nm reduced numbers of internodes under the aluminium cover. Where the light intensity was higher (no aluminium cover) no effects of the light, particularly above 500 nm, were observed.

All the treatments with cotyledons removed reduced height growth as well as weight increments. Reduction in leaf size was significant, indicating that reduced photosynthetic areas further affected growth of seedlings. However, at the time of measurements (45 days after sowing the seeds), promotive effects of the red light were not clearly shown yet for the seedlings without cotyledons.

*Soil mixture requirements*

Judging from the field experiments, *Intsia* seedlings prefer fertile soil with good drainage, for their growth. An experiment was conducted to determine suitable soil mixtures for *Intsia* seedlings.

Yellow top soil of the forest was mixed with white quartz sand to make 100, 75, 50, 25 and 0% of soil mixtures. These soil mixtures were used to fill plastic bags in which scarified seeds soaked in water overnight were sown. One half of the soil mixture series was fortified with super phosphate of lime (7 g/pot). Replications of ten pots per soil mixture were

Table 5. Growth of Merbau seedlings in the colour chambers after 45 days; Experiment II

| | | | Average length (cm) Shoot | Root | Hypo. | Epic. | Post-epic. | Maximum No. Internodes |
|---|---|---|---|---|---|---|---|---|
| CF 112-4 Violet 500-600 nm eliminated | Top open 14,000 lux | Cotyledon removed | 22.9 | 9.5 | 13.3 | 8.9 | 0.7 | 2 |
| | | Cotyledon intact | 46.6 | 13.2 | 15.4 | 16.2 | 15.0 | 6 |
| | Top closed 8,000 lux | Cotyledon removed | 23.9 | 8.8 | 14.0 | 9.1 | 0.8 | 2 |
| | | Cotyledon intact | 41.5 | 13.8 | 15.3 | 15.9 | 10.3 | 3 |
| CF 112-2 Dark red 600 nm below eliminated | Top open 11,000 lux | Cotyledon removed | 25.2 | 8.4 | 13.2 | 10.0 | 2.0 | 2 |
| | | Cotyledon intact | 48.2 | 13.8 | 17.1 | 18.3 | 12.8 | 4 |
| | Top closed 2,200 lux | Cotyledon removed | 27.3 | 8.8 | 14.8 | 12.2 | 0.3 | 2 |
| | | Cotyledon intact | 47.3 | 13.4 | 16.5 | 19.3 | 11.5 | 4 |
| CF 112-5 Blue 600-700 nm eliminated | Top open 32,000 lux | Cotyledon removed | 23.8 | 9.7 | 13.5 | 9.9 | 0.4 | 3 |
| | | Cotyledon intact | 46.8 | 13.4 | 16.2 | 17.9 | 12.7 | 5 |
| | Top closed 6,000 lux | Cotyledon removed | 24.8 | 10.5 | 13.9 | 10.6 | 0.3 | 2 |
| | | Cotyledon intact | 44.9 | 16.0 | 15.7 | 19.8 | 9.4 | 4 |
| CF 112-1 Yellow 500 nm below eliminated | Top open 30,000 lux | Cotyledon removed | 25.3 | 10.4 | 13.1 | 10.9 | 1.3 | 3 |
| | | Cotyledon intact | 51.7 | 13.9 | 16.1 | 17.9 | 17.7 | 6 |
| | Top closed 20,000 lux | Cotyledon removed | 28.4 | 8.7 | 14.8 | 11.8 | 1.8 | 3 |
| | | Cotyledon intact | 54.2 | 14.8 | 16.0 | 18.0 | 20.2 | 6 |
| CF 112-3 Orange 400-500 nm eliminated | Top open 30,000 lux | Cotyledon removed | 24.6 | 9.7 | 13.2 | 10.1 | 1.3 | 3 |
| | | Cotyledon intact | 49.2 | 15.3 | 16.4 | 17.6 | 15.2 | 6 |
| | Top closed 26,000 lux | Cotyledon removed | 26.2 | 9.1 | 14.1 | 11.3 | 0.8 | 2 |
| | | Cotyledon intact | 52.3 | 14.1 | 17.1 | 19.3 | 15.9 | 6 |
| Vinyl film White Transparent | Top open 50,000 lux | Cotyledon removed | 22.0 | 8.9 | 12.2 | 7.2 | 2.6 | 4 |
| | | Cotyledon intact | 42.8 | 13.8 | 14.3 | 16.4 | 12.1 | 6 |
| | Top closed 40,000 lux | Cotyledon removed | 24.0 | 9.9 | 12.7 | 10.4 | 0.9 | 2 |
| | | Cotyledon intact | 54.5 | 14.1 | 15.4 | 16.1 | 23.0 | 5 |

NOTE: The top closed or open refers to whether the plants were grown under an aluminium foil cover or not, in addition to being enclosed in a vinyl film chamber. The light intensity figures given are in comparison to open sunlight measured at 80,000 lux.

Table 6. Growth of Merbau seedlings in various soil mixtures

| Soil mixtures | Growth period (days) | Average shoot length (cm) | | | | Average No. of internodes | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Super-phosphate | | Control | | Super-phosphate | | Control | |
| | | Shade | Open | Shade | Open | Shade | Open | Shade | Open |
| 100% Soil | 47 | 37.0 | 39.1 | 34.3 | 35.3 | 2.7 | 3.0 | 2.8 | 2.5 |
| | 88 | 40.8 | 43.6 | 37.8 | 37.6 | 3.7 | 3.9 | 3.4 | 2.8 |
| 75% | 47 | 42.2 | 36.9 | 37.8 | 39.1 | 3.3 | 2.8 | 3.0 | 3.0 |
| | 88 | 48.8 | 43.2 | 43.7 | 39.0 | 4.6 | 4.2 | 4.4 | 3.8 |
| 50% | 47 | 35.9 | 35.8 | 34.7 | 35.8 | 2.5 | 2.8 | 2.7 | 2.7 |
| | 88 | 43.5 | 43.1 | 38.4 | 37.2 | 4.4 | 4.4 | 3.6 | 3.1 |
| 25% | 47 | 35.9 | 36.7 | 35.4 | 37.3 | 2.9 | 2.7 | 2.7 | 2.8 |
| | 88 | 40.1 | 41.3 | 39.0 | 38.8 | 4.3 | 4.0 | 3.4 | 3.3 |
| 0% | 47 | 29.9 | 31.8 | 30.8 | 34.9 | 2.3 | 2.4 | 2.4 | 2.7 |
| | 88 | 35.0 | 34.7 | 35.9 | 37.1 | 3.1 | 3.6 | 3.4 | 3.4 |

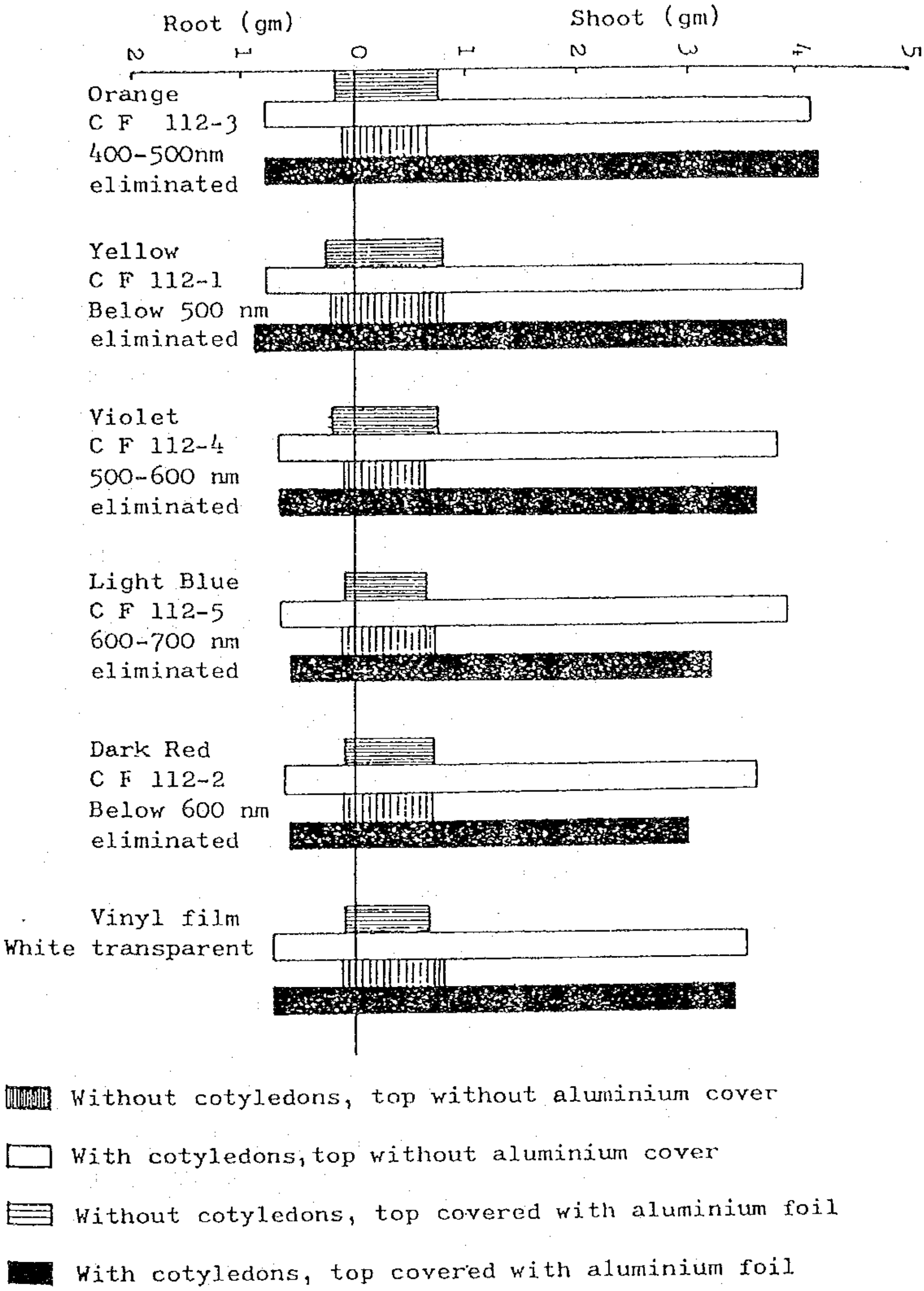


**Figure 6. Dry weight of Merbau seedlings after 45 days, under various treatments.**

placed in the open and also under *Nypa* palm shade in the nursery. Height and internode measurements were taken 47 and 88 days after imbibition of the seeds.

The results are shown in Table 6. Average height growth and average number of internodes indicate that 75% soil mixture is suitable for *Intsia* growth. Also, it appears that the soil mixture 50% is better than 100% soil alone. Addition of super-phosphate of lime promoted the growth of seedlings slightly. These differences may become more distinct in a later stage of seedling development, as the early development is more dependant on the seed reserves. Further study is needed to clarify nutrient requirement and suitable soil conditions for optimal growth of *Intsia palembanica* seedlings. This area of study is important to understand specific sites for *Intsia palembanica*, as most trees of *Intsia palembanica* in forests grow in rich soil.

Judging from the drooping of leaf petioles under direct sunlight, *Intsia* seedlings may grow better under high humidity conditions. Seedlings in the colour chambers where high humidity was maintained performed better than in the open. The seedlings in the chambers showed turgid petioles during the daytime, whereas the seedlings in the open nursery had drooped petioles under strong sunlight. It is assumed that *Intsia* seedlings often grow slowly because of the limited photosynthetic rates under water stresses. As basic data, we need to obtain photosynthetic rates under various water stresses.

Observations in the field and nursery suggest that genetic variations are great in the species. Occurrences of albinos, deformed leaves, abnormal seed forms as well as great variations in growth rates in the field suggest that detailed study is needed for selection of seed trees.

## Conclusions

From the experiments conducted, the following suggestions can be made for handling *Intsia palembanica*.

1. Direct sowing with scarified seeds can be done. One of the best methods to scarify the seed is to scrape off the small swelling point of the seed-coat on the opposite side of the hilum. If the rodent population is high in the planting site, protection of the seed by a bamboo column may be helpful.

2. The seed should be placed 5 – 7 cm under the soil surface in vertical position with the hilum down to promote shedding of the seedcoat during seedling emergence.

3. Good fertile and well aerated soil is needed for plantation.

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# GROWTH AND STORAGE OF BARE-ROOT PLANTING STOCK OF DIPTEROCARPS WITH PARTICULAR REFERENCE TO SHOREA TALURA

*by*

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# GROWTH AND STORAGE OF BARE-ROOT PLANTING STOCK OF DIPTEROCARPS WITH PARTICULAR REFERENCE TO SHOREA TALURA

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S. SASAKI*

Summary

Transpiratory water loss from seedlings appeared to be the most serious problem in transplating of Dipterocarp seedlings, particularly for bare-root planting. To minimize the water loss from the seedlings, tissues such as all the leaves and young portions of stem were removed from the transplants of *Shorea talura*. Such heavily pruned seedlings survived in the open and developed axillary buds, with the uppermost bud taking over the role of the leader shoot. Therefore, the seedlings seldom developed multileader shoots. With these pruned seedlings of *Shorea talura*, and *Hopea odorata*, bare-root transplanting resulted in almost perfect survival. The growth of bare-rooted seedlings, however, was accelerated 10 months after transplanting. The pruned seedlings could be stored in a polyethylene plastic bag at least for several months, particularly *Shorea talura* and Hopea *odorata seedlings* which could remain viable for more than 7 months. In addition, the pruned seedlings of *Shorea talura* were propagated vegetatively by laying down the pruned leafless seedlings horizontally. Axillary buds developed into several plantlets growing vertically with their individual root system initiated. These results suggest that some of Dipterocarp species have a potential as species for artificial regeneration.

## Introduction

Drooping of the leaves is common in many broad leaf species under direct sunlight during midday. The phenomenon is particularly distinct in Dipterocarps with long petioles. This suggests that water loss by transpiration during the day-time may be a serious problem in transplants. Leaves are needed for growth, but may be detrimental temporarily at the time of transplanting, even for transplanting of potted seedlings. The problem may be further aggravated by the traditional nursery practice of raising seedlings under heavy shade which tends to produce very tall seedlings with large thin tender leaves but little root system. Therefore, experiments were conducted to observe the effects of leaf removal on survival of transplants and the feasibility of bare-root planting of Dipterocarp seedlings without leaves.

## Experiment I. Effects of leaf removal on growth of seedlings

Seedlings of *Shorea talura* grown in the open in the nursery bed for 15 months were pulled out and used for the experiment. Treatments con-

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sisted of (1) all leaves removed and the leader shoot and tap root trimmed; (2) the leader shoot and tap root trimmed, but a few leaves left intact; (3) no treatments on the shoot but tap root trimmed. Each treatment consisted of 20 replications. After these treated seedlings were transplanted, they were not watered except for natural rains. One week after transplanting, buds were observed to expand from the axils of leaf scars of the seedlings. Also, fine lateral roots were regenerated. The seedlings with a few leaves intact delayed new bud development until those leaves had fallen off. In contrast, the seedlings with all leaves intact showed symptoms of desiccation and die-back from the top. After leaves were shed off by desiccation, a new flush of growth started from the lower portion of the stem, but there was a delay of one month's growth compared with the seedlings without leaves.

A new axillary shoot, generally the uppermost one, took over the leader shoot role (Fig. 1), as the previous leader shoot was trimmed off or died back. None of the seedlings developed multiple leaders (Fig. 2).

Measurements on diameters, total shoot growth and new leader growth were taken 15 months after transplanting (Table 1). These results indicated that the seedlings with their roots and shoot trimmed as well as all the leaves stripped off were best suited for transplanting. For practical work, these trimmed and stripped seedlings are easily handled in the field.

Table 1. Growth response in Shorea talura seedlings after bare-root transplanting*

| Treatment | Average diameter of (cm after 15.5 months) | | Average height of (cm after 15.5 months) | | |
|---|---|---|---|---|---|
| | Root collar | New leader shoot | Total shoot | New leader shoot | Old stem† |
| 1. Shoot and root pruned<br>All leaves removed | 2.60* | 1.57 | 128.0 | 96.1 | 31.9* |
| 2. Shoot and root pruned<br>A few leaves intact | 1.79* | 1.15 | 86.7 | 60.9 | 25.8* |
| 3. Shoot intact, but root pruned<br>All leaves intact | 1.87* | 1.11 | 75.1 | 50.4 | 24.5* |

* Seedlings used for this experiment were 50 to 60 cm in height and 0.8 to 1.0 cm in diameter at the time of treatments.

† Old stem means original stem left and new leader shoot is axial stem regenerated after treatment. Length of old stem in Treatment 3 indicates reduction of axial stem by dieback.

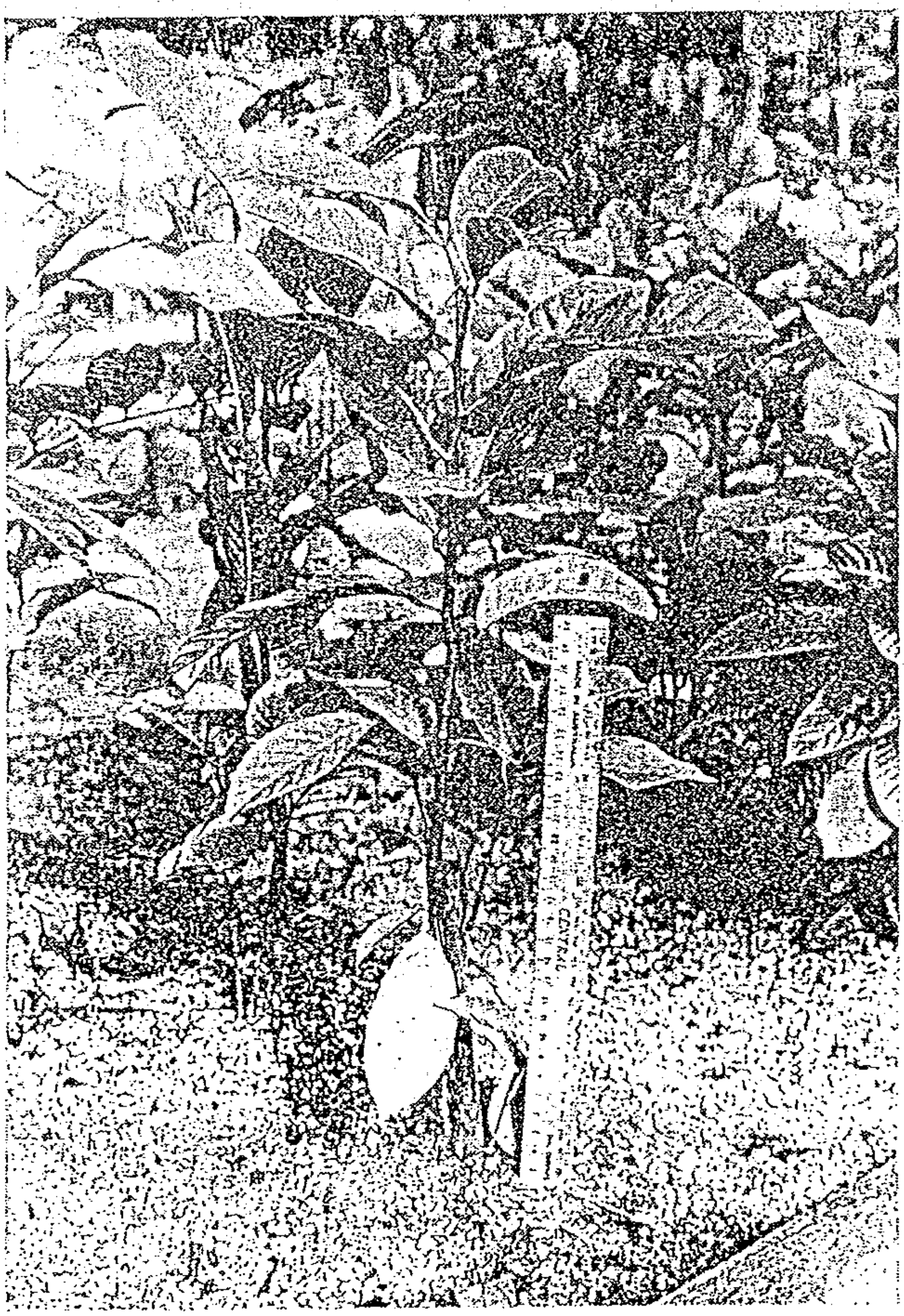

Figure 1. A new leader shoot development from the uppermost axillary bud (Shorea talura).

Figure 2. Establishment of single leader trees of *Shorea talura* bare-root transplants. The photo was taken 14 months after transplanting.

Experiment II. Effects of stem length on shoot regeneration

Since the uppermost leaf axil generally produced the new leader shoot, an experiment was carried out to determine the optimal number of nodes (leaf scars) to be left on the prunned stem in order to obtain robust regeneration of new leader shoots. In addition, effects of organic fertilizers on shoot development were tested. *Shorea talura* seedlings of 1.5 years age were pulled out from the nursery bed. Roots were trimmed and leaves were all removed. Then shoots were cut off: (1) just above the first node*, (2) above the third node, (3) above the fifth node, and (4) above the ninth node. Seedlings with shoots left intact were used as controls.

A nursery bed filled with sandy soil was partitioned into 4 sections which received different soil treatments. Into each section, ten seedlings per treatment were transplanted. The soil treatments consisted of (1) mulching with 2 gallons of sawdust compost, (2) mulching with 2 gallons of sawdust compost plus 28.4 grams of organic fertilizer, (3) 28.4 grams of organic fertilizer alone, and (4) control with no treatment.

Bud expansion was vigorous in the compost and in the compost plus the organic fertilizer. In the early stages of growth, multiple leaders developed but later one of the new shoots took over as the dominant leader shoot. The recovery of apical dominance is probably a natural phenomenon in young seedlings of *Shorea* species. Similar trials on *Shorea ovalis*, *Hopea odorata*, and *Dryobalanops aromatica* showed development of new robust leader shoots. Also, in the forest, there were many saplings with good leaders which developed from axillary buds. Therefore, there is no fear that multiple leaders will result from shoot trimming.

Growth of the seedlings was assessed 290 days after the experiment was initiated (Table 2). The results showed that the compost plus the fertilizer mulching definitely promoted new shoot development, followed by the compost alone and the fertilizer alone respectively. This may be due to the fact that the nursery bed was filled with quartz sand, which contains little nutrients. The physical properties of the soil might be also improved by mulching with organic matter. Shoot pruning appeared to enhance the new shoot development, as control seedlings showed less development of new shoots than those top-pruned. For practical purposes, the number of nodes left on the stem did not influence the new leader shoot development much. Therefore, the exact position of shoot trimming is not important, provided that a few leaf scars are left on the stem. Transplanting of pruned and bare-rooted seedlings is very practical because of easiness of handling, and better survival due to minimisation of desiccation problems.

* The first node or node 1 is taken as the node of the first foliage leaf. The cotyledonary node in *Shorea talura* is at ground level (hypogeal germination) and is not counted.

Table 2. Effects of compost and organic fertilizer on development of shoots in bare-rooted and pruned *Shorea talura* seedlings 290 days after transplanting

| Soil treatment | | Position of shoot pruning at: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | above node 1* | | above node 3* | | above node 5* | | above node 9* | | unpruned | |
| | | Total seedling | New leader | Total seedling | New leader | Total seedling | New leader | Total seedling | New leader | seedling Total | New leader |
| Compost | Diameter (cm)† | 1.15 | 0.50 | 1.09 | 0.62 | 0.94 | 0.56 | 1.10 | 0.60 | 1.12 | 0.53 |
| | Height (cm) | 28.8 | 24.2 | 37.1 | 28.8 | 35.7 | 28.4 | 39.9 | 27.3 | 45.7 | 25.9 |
| Compost + organic fertilizer | Diameter (cm)† | 1.47 | 0.86 | 1.19 | 1.80 | 1.20 | 0.70 | 1.20 | 0.80 | 1.46 | 0.67 |
| | Height (cm) | 51.4 | 46.1 | 56.2 | 47.0 | 48.4 | 37.8 | 68.4 | 48.4 | 59.1 | 30.9 |
| Organic fertilizer | Diameter (cm)† | 0.93 | 0.50 | 1.10 | 0.54 | 1.15 | 0.62 | 0.90 | 0.47 | 1.22 | 0.53 |
| | Height (cm) | 35.3 | 24.1 | 37.6 | 26.6 | 43.9 | 30.7 | 38.1 | 19.3 | 47.1 | 24.2 |
| Soil alone | Diameter (cm)† | 1.08 | 0.57 | 0.94 | 0.49 | 1.01 | 0.47 | 1.19 | 0.44 | 1.21 | 0.45 |
| | Height (cm) | 37.8 | 28.8 | 33.8 | 22.8 | 32.8 | 19.1 | 29.4 | 15.9 | 41.9 | 10.8 |

* Node count started from the first node above the cotyledonary node.
† Diameter measurements were made at the root collar and the basal end of new leader shoot.

Experiment III. Storage of bare-root planting stock

The bare-root planting method discussed in the previous experiments needs to be extended to a method for seedling storage.

*Shorea talura* seedlings, with their roots and shoots trimmed as well as all leaves stripped off, were stored under various conditions. For this experiment, the seedlings were graded into large-sized seedlings with root collar diameter over 1.0 cm, and small-sized seedlings with the root collar diameter below 0.5 cm.

In order to study the effect of moisture contents on survival of stored seedlings, the seedlings were stored in open bags as well as in closed plastic bags. Also, optimum temperature ranges were surveyed by storing the seedlings at 4 17, and 25°C. To avoid premature bud expansion due to excess of moisture in the bag, the roots were not washed. All the treatments are shown in Table 3. Five seedlings from each treatment were taken out periodically and transplanted to the nursery bed in the open.

Survival percentages are shown in Table 4. Apparently, large-sized seedlings showed better survival percentages than small ones, possibly due to larger available reserves of water and food in the tissues. The open bags could not keep the seedlings alive. This suggests that the maintainance of moisture content in the tissues is important for the seedlings to survive.

Table 3. Storage treatments of pruned and bare-rooted Shorea talura seedlings

| Temperature | Size of seedling | Number of seedlings | Stored in |
|---|---|---|---|
| 4°C | Small | 5 | Open plastic bag |
| | Small | 25 | Closed plastic bag |
| | Large | 5 | Open plastic bag |
| | Large | 25 | Closed plastic bag |
| 17°C | Small | 5 | Open plastic bag |
| | Small | 25 | Closed plastic bag |
| | Large | 5 | Open plastic bag |
| | Large | 25 | Closed plastic bag |
| 25°C | Small | 5 | Open plastic bag |
| | Small | 25 | Closed plastic bag |
| | Large | 5 | Open plastic bag |
| | Large | 25 | Closed plastic bag |

Table 4. Survival % of Shorea talura seedlings after storage

| | Temperature stored | Seedling size | Storage period (weeks) 1 | 2 | 3 | 4 | 10 |
|---|---|---|---|---|---|---|---|
| | | | % Survival | | | | |
| Open bag | 4°C | Small | 80 | | | | |
| | | Large | 60 | | | | |
| | 17°C | Small | 0 | | | | |
| | | Large | 0 | | | | |
| | 25°C | Small | 0 | | | | |
| | | Large | 40 | | | | |
| Closed bag | 4°C | Small | 100 | 100 | 40 | 20 | 0 |
| | | Large | 100 | 100 | 100 | 80 | 0 |
| | 17°C | Small | 100 | 100 | 40 | 80 | 40 |
| | | Large | 100 | 100 | 100 | 100 | 100 |
| | 25°C | Small | 100 | 100 | 100 | 100 | 100 |
| | | Large | 100 | 100 | 100 | 100 | 100 |

Storage at low temperature appeared to be detrimental to seedlings. In the case of small seedlings, even in closed bags, a gradual decline in survival was evident. Although the large-sized seedlings were still surviving after 3 weeks at 4°C, their bud development was markedly delayed.

Growth measurements were taken 15 months after the experiment was initiated (Table 5). The growth of large-sized seedlings was far better than that of the small ones. For up to 2 weeks of storage at 4°C, the seedlings were not affected by the low temperature. However, storage at 4°C for more than 3 weeks caused retardation of growth. Storage at 17°C for more than 3 weeks may also retard seedling growth. In contrast, storage at 25°C in an airconditioned room appeared to be promising for a long term storage, as the seedlings stored for 10 weeks showed considerable growth during a 390 day-experimental period.

Since the results indicated that storage at 25°C was promising, a storage trial was conducted to estimate maximum longevity of seedlings at 25°C. *Shorea talura* seedlings with their roots and shoots trimmed and all the leaves stripped off were stored in polyethylene plastic bags at 25°C. These seedlings survived at least for 7 months and were successfully transplanted in the nursery. Similarly, *Hopea odorata* seedlings survived for 7 months or more (Table 6). On the other hand, *Shorea ovalis*, one of the Red Merantis, suffered loss of viability to 60% after storage for 2 months. Further technical refinements for other species may be necessary for a large scale application.

A field trial by bare-root planting by the Silviculture Section in Sungei Buloh Forest Reserve, showed encouraging results for *Shorea talura*. More trials including various species are needed to further evaluate the method. At present, it is noted with confidence that the method is applicable at least for White Meranti species of *Shorea* and *Hopea*.

Table 5. Growth of stored seedlings of Shorea talura, after transplanting

| Storage period (week) | Seedling size | Storage temp. (°C) | Diameter (cm) | | Height (cm) | | Growth period (days) |
|---|---|---|---|---|---|---|---|
| | | | Root collar | New shoot | Total | New shoot | |
| 1 | Small | 4 | 1.73 | 1.20 | 70.5 | 59.2 | 453 |
| | | 17 | 1.34 | 0.95 | 54.5 | 47.3 | |
| | | 25 | 1.34 | 1.17 | 46.9 | 41.2 | |
| | Large | 4 | 2.36 | 1.49 | 96.9 | 74.1 | |
| | | 17 | 2.44 | 1.23 | 82.6 | 64.4 | |
| | | 25 | 2.27 | 1.70 | 93.0 | 80.9 | |
| 2 | Small | 4 | 1.08 | 0.46 | 26.0 | 19.5 | 446 |
| | | 17 | 1.51 | 0.81 | 48.2 | 39.7 | |
| | | 25 | 1.96 | 1.12 | 70.7 | 54.3 | |
| | Large | 4 | 2.40 | 1.26 | 89.9 | 63.4 | |
| | | 17 | 2.26 | 1.32 | 79.0 | 62.6 | |
| | | 25 | 2.52 | 1.33 | 91.4 | 65.5 | |
| 3 | Small | 4 | 0.89 | 0.44 | 24.3 | 13.8 | 439 |
| | | 17 | 0.95 | 0.50 | 29.8 | 19.8 | |
| | | 25 | 1.10 | 0.51 | 37.9 | 20.4 | |
| | Large | 4 | 1.78 | 0.92 | 59.8 | 48.1 | |
| | | 17 | 2.43 | 1.08 | 68.9 | 54.0 | |
| | | 25 | 2.72 | 1.36 | 93.8 | 71.2 | |
| 4 | Small | 4 | 0.94 | 0.62 | 38.5 | 32.5 | 432 |
| | | 17 | 1.54 | 0.75 | 56.8 | 37.5 | |
| | | 25 | 1.66 | 0.91 | 54.8 | 44.4 | |
| | Large | 4 | 1.68 | 0.78 | 39.9 | 33.0 | |
| | | 17 | 2.33 | 1.63 | 100.5 | 80.0 | |
| | | 25 | 2.62 | 1.24 | 95.8 | 67.8 | |
| 10 | Small | 4 | No survival | | | | 390 |
| | | 17 | 0.73 | 0.25 | 15.3 | 7.5 | |
| | | 25 | 1.27 | 0.68 | 40.1 | 25.9 | |
| | Large | 4 | No survival | | | | |
| | | 17 | 1.51 | 0.87 | 55.5 | 45.4 | |
| | | 25 | 1.45 | 1.07 | 64.2 | 54.1 | |

## Experiment IV. Growth pattern of bare-rooted transplants

The bare-root planting method described above showed high survival percentages in the open. However, establishment of the leader shoot and acceleration of the leader shoot growth appeared to suffer a certain time lag.

Growth parameters were plotted against the time after transplanting. Total height growth, new leader shoot elongation, root collar diameter, and new leader shoot diameter all showed significant increases 10 months after transplanting (Fig. 3 to 6). Thereafter, the growth is accelerated and bare-root seedlings of *Shorea talura* can grow as tall as 200 cm within 1.5 years after transplanting. However, the bare-root seedlings may take at least one year for firm establishment.

Table 6. Survival of long-term stored seedlings

| | % survival of one-year old seedlings | | | | |
|---|---|---|---|---|---|
| | Storage period | | | | |
| | 1 month | 2 months | 3¼ months | 4 months | 7 months |
| *Shorea talura* Stored in closed bag at 25°C | 100 | 100 | 100 | 80 | 80 |
| *Hopea odorata* Stored in closed bag at 25°C | | 100 | | | over 50 |
| *Shorea ovalis* Stored in nursery office at room temp. | 80 | no data | | | |
| Closed bag. Stored in closed bag at 25°C | 80 | 60 | | | |
| *Shorea assamica* Stored in closed bag at 25°C | over 50 | | | | |

**Experiment V. Vegetative propagation using bare-root planting stock**

Plantlet development was from axillary buds of horizontally laid bare-root planting stock.

The prospects of vegetative propagation for Dipterocarps have been explored by Momose (1978) who succeeded in rooting of cuttings of *Shorea* (White Meranti), *Vatica*, and *Anisoptera* species. According to his data, Red Meranti was difficult because of poor callus formation. Results from bare-root planting in this study also suggest that White Meranti and *Hopea* have strong regenerative ability.

In the forest, it was often observed that there was vertical sprouting from fallen tree trunks. Therefore an experiment was conducted to induce upright growth of new shoots from axillary buds of seedlings placed in a horizontal position. Rooting of the new shoots was also tested.

*Shorea talura* and *Shorea ovalis* seedlings were used for the experiment. All the leaves were removed and the shoot tips were trimmed to release axillary bud development. These seedlings were horizontally placed on the nursery bed and covered lightly with soil.

Although all *Shorea ovalis* seedlings failed to develop new shoots under the ground, *Shorea talura* seedlings initiated new shoot growth vertically, (Fig. 7). Roots began to form within 10 months after the experiment was initiated.

This experiment suggests a possibility for vegetative propagation with a higher percentage of success. The method can be improved by exposing the seedlings to light to stimulate bud development, and then by burying in soil to stimulate root formation. Further experiments are urgently needed to develop the method for other species. If the bud development is first promoted, even Red Meranti species might possibly be propagated vegetatively by the method.

All the results and other observations suggest that White Merantis, particularly *Shorea talura* are the easiest species for silvicultural handling. Therefore, *Shorea talura* should be given more attention in regeneration programes.

Recommendations

1. To promote lateral root development, tap roots may be pruned.

2. It is necessary to grow seedlings with a well balanced shoot/root ratio. *Shorea talura* seedlings should be grown in the open or in a high light intensity area to promote root growth. Seedlings that have been grown in shade may easily be desiccated after transplanting probably because their transpiration rates are high.

3. Concrete seedling beds are detrimental to root development, particularly in the open. Root development is hindered physically and the heat on the concrete may cause root growth to slow down. It is better for seedlings to be grown on the ground with their root system penetrating into it. When the seedlings are due to be transplanted elsewhere, the roots can be pruned.

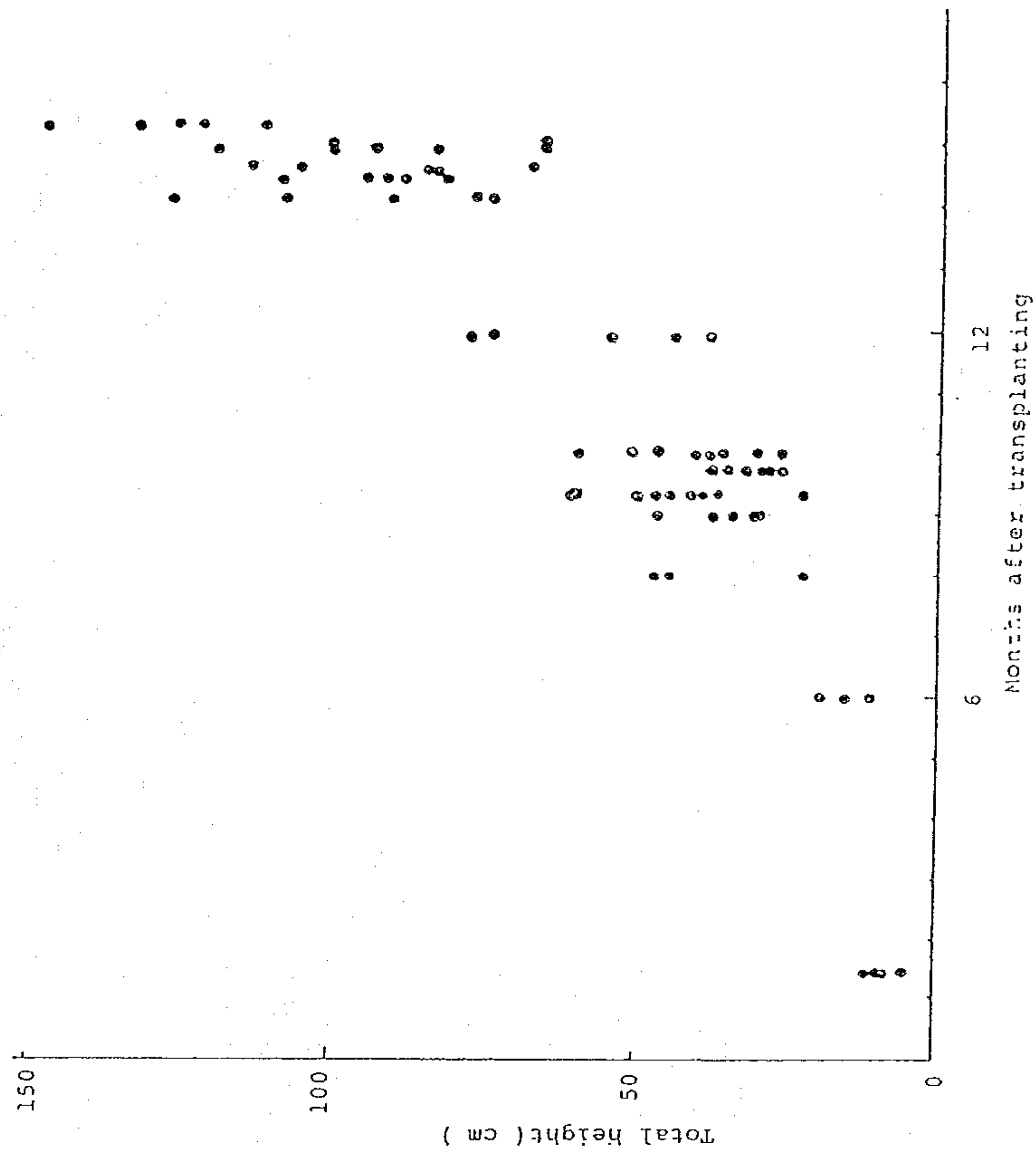


Figure 3. Height growth of bare-root transplants of Shorea talura.

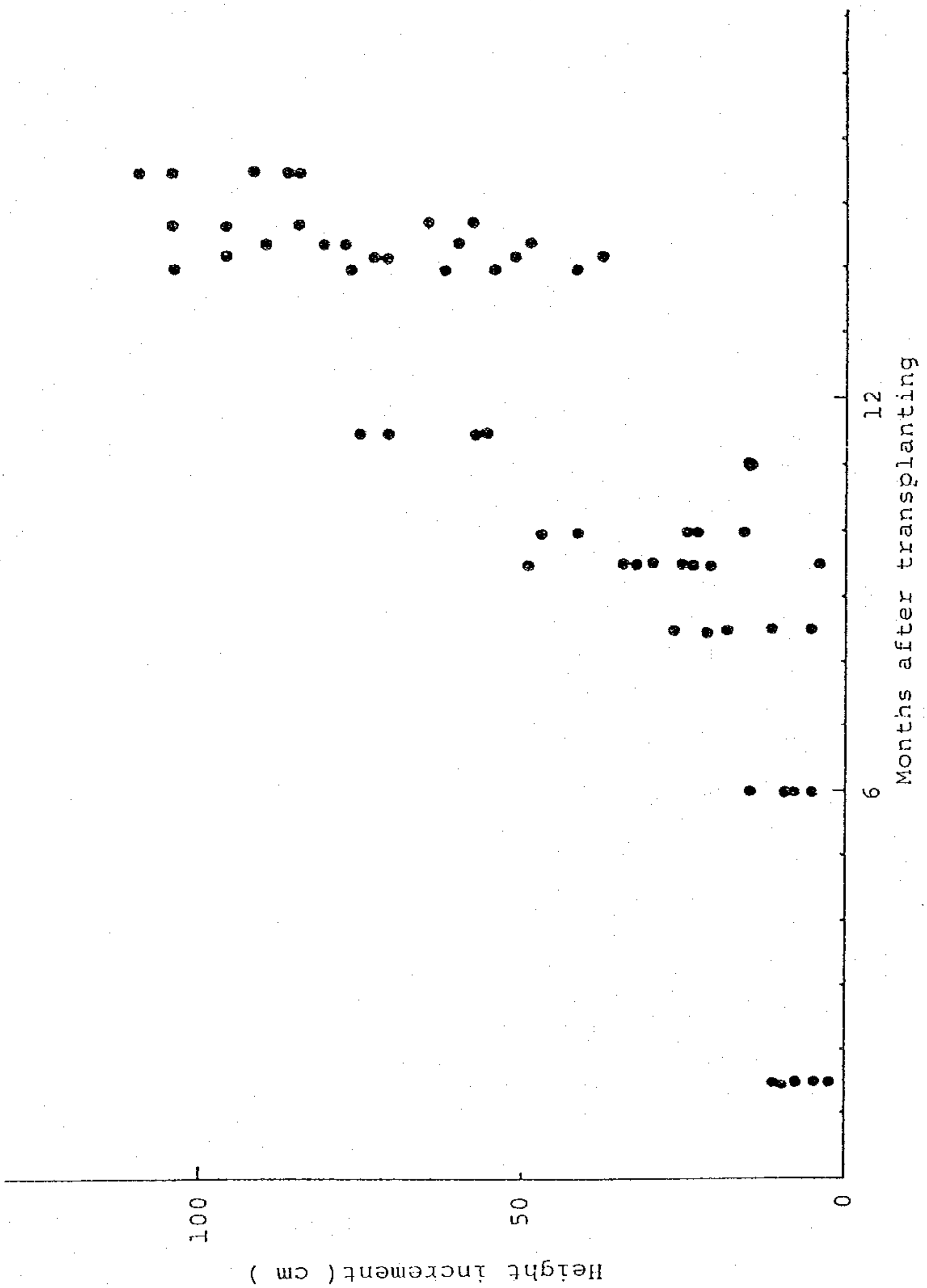


Figure 4. Height increment of bare-root transplants of Shorea talura.

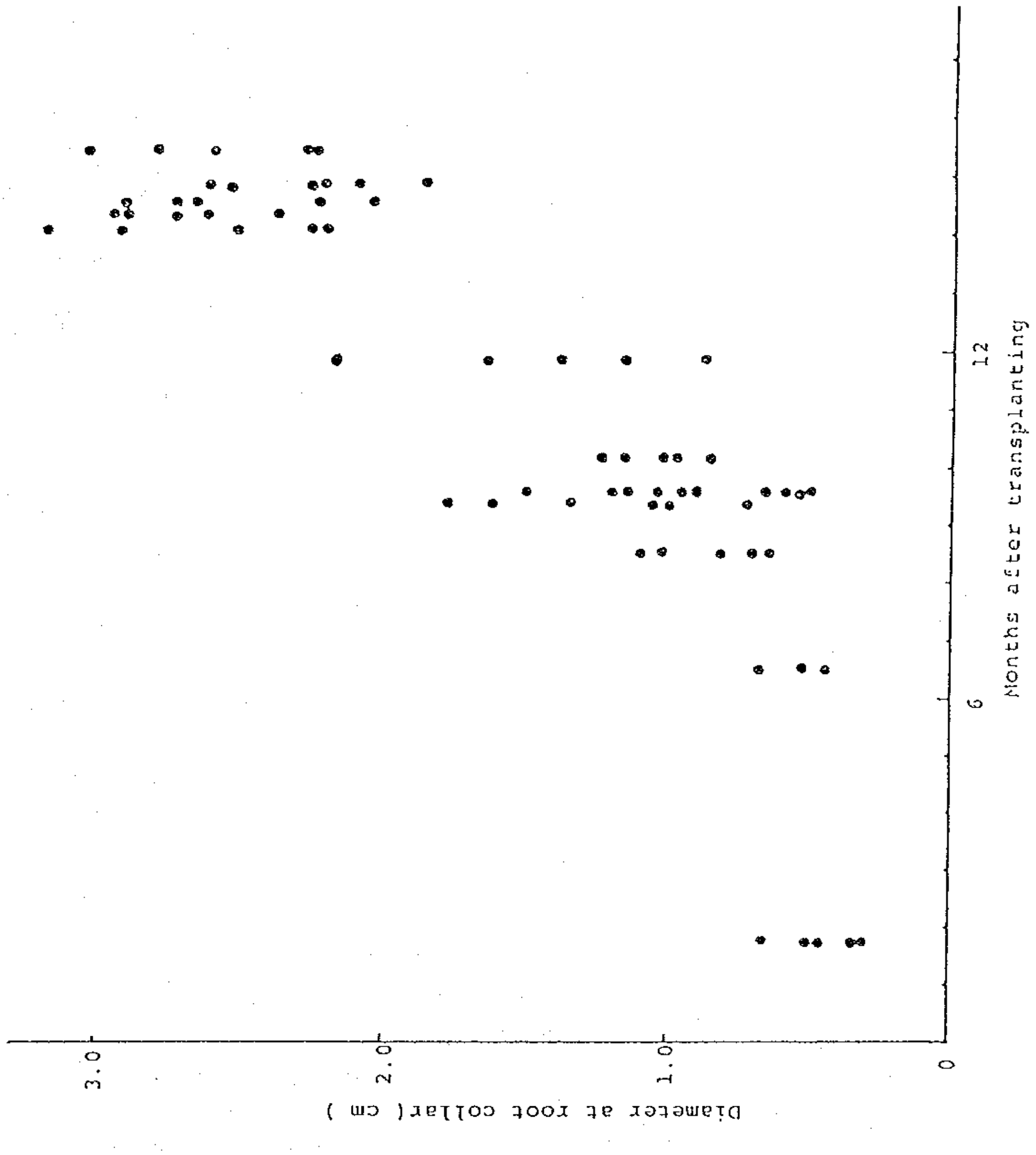


Figure 5. Diameter growth of bare-root transplants of Shorea talura.

Figure 6. Diameter growth of new shoot in bare-root transplants of Shorea talura.

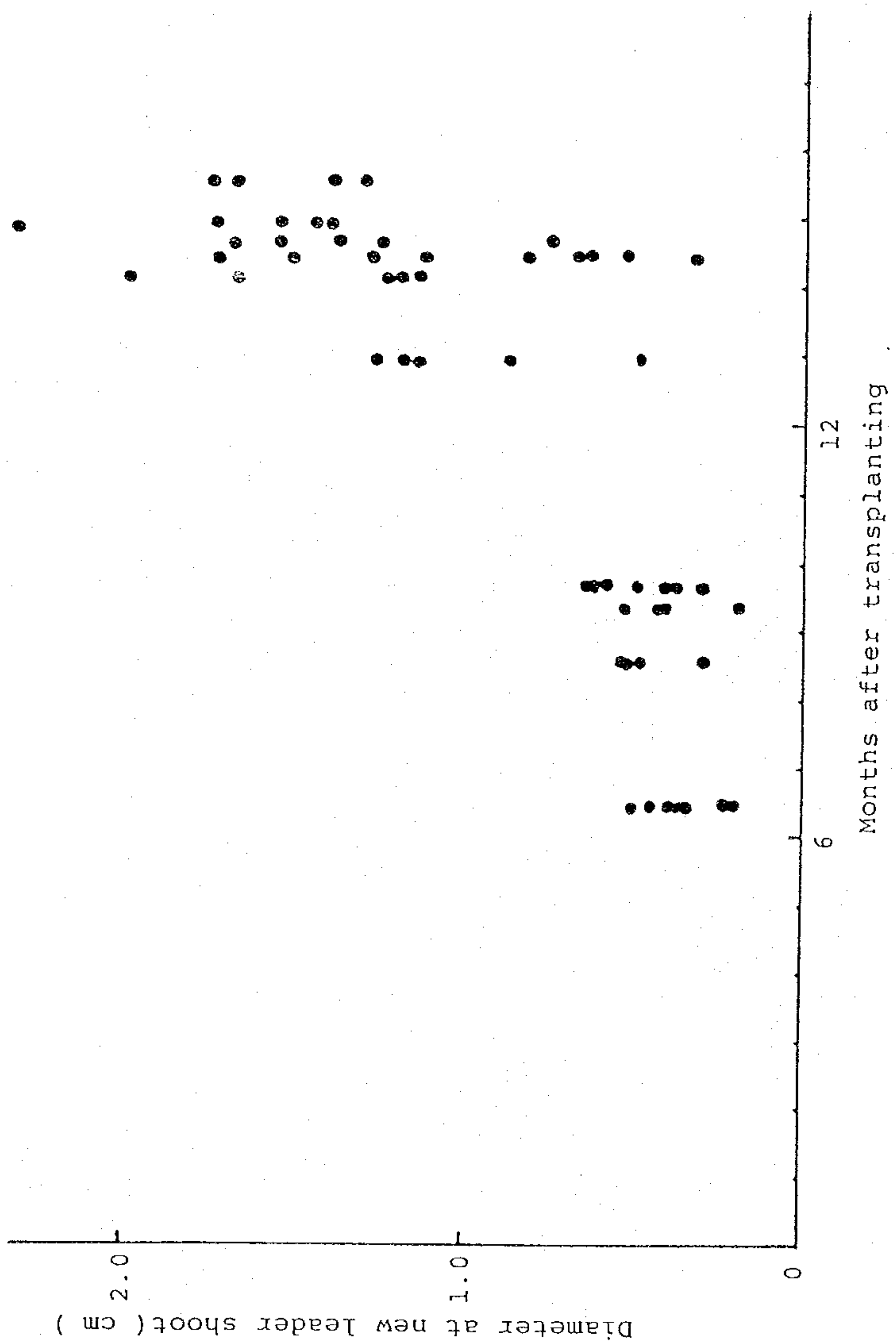

Figure 7. Seedlings placed in a horizontal position. Vegetative propagation can be done by developing individual seedlings from axillary buds. Root formation can be seen in the photograph at right.

4. Bare-root planting can be used for *Shorea talura*. To avoid transpirational loss of water by leaves, all leaves of the seedling should be stripped off and the upper part of the shoot should be trimmed. The root system also can be trimmed. Provided a few leaf scars are present on the stem, new buds start developing after transplanting. New leader shoots should develop among the activated buds, and very rarely do the seedlings form multiple leaders.

5. In the field the acceleration of growth in bare-root transplants takes at least 10 months. Therefore, weeding of planting lines may be required. Survival of the bare-rooted seedlings is quite high and handling is easy.

6. The bare-rooted stock can be stored in plastic bags. If the moisture content of the seedlings is maintained at a high level in air tight conditions, the seedlings can be stored for more than 7 months at 25°C room.

7. *Shorea talura* seedlings can be propagated vegetatively. Cuttings are successful. Also, using seedlings with all the leaves stripped off and apexes trimmed, a new method for vegetative propagation has been developed, by placing the seedlings in a horizont position to stimulate vertical shoot development from dormant axillary buds to make new individual plantlets. The method needs further refinement to promote early root formation.

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Momose, Y. (1978) Vegetative propagation of Malaysian trees. Malay. For. 41: 219–223.

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# STORAGE AND GERMINATION OF DIPTEROCARP SEEDS

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# STORAGE AND GERMINATION OF DIPTEROCARP SEEDS

*by*

S. SASAKI*


## Summary

Maturation, storage, and germination of several Dipterocarp seeds were studied. As Dipterocarp seeds matured, they reduced moisture contents to 50 to 60% of the dry weight. The mature seeds germinated faster, and their percentage of germination was higher than that of the immature seeds. Therefore, timing of seed collection is very important for practical silviculture.

Dipterocarp seeds lost viability at low moisture contents below 20 to 30% of the dry weight. For the storage of Dipterocarp seeds, the moisture content must be maintained above the critical level in each species. In order to maintain the moisture content, seeds may be stored in a plastic bag or a closed container to keep the relative humidity above 95% at 25°C. The relative humidity can also be maintained at over 95% by circulating air bubbled through water or 11% $H_2SO_4$.

Dipterocarp seeds may be classified by their degree of tolerance of low temperatures. Most of White Meranti seeds survived at 4°C for at least 2 months, whereas those of Red Meranti and Balau needed temperatures above 15°C for survival. Some *Hopea* and *Dipterocarpus* seeds also survived at 4°C for at least a month. Of all the seeds tested, seeds of *Shorea talura* were the best in terms of storage, showing ability to survive for more than 6 months at 4°C.


## Introduction

Typically non-dormant Dipterocarp seeds have high moisture contents and continue to be very active biologically even after maturation (Sasaki, 1977; Sasaki and Mori, 1978). The seeds of *Dryobalanops aromatica* have been observed to germinate on the mother tree before they are shed (Sasaki *et al.*, 1979). Therefore, storage of Dipterocarpaceae seeds is more difficult than that of typically dormant seeds (Jensen, 1971; Tamari, 1976; Tang, 1971; Tang and Tamari, 1973).

Dipterocarpaceae consists of several genera and subgenera (Symington, 1941). Preliminary experiments showed some physiologically characteristic differences in the seeds between genera or subgenera. With respect to the survival of seeds at low temperatures, in particular, Dipterocarp seeds can be classified into two groups, with those in the first being able to tolerate

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temperatures as low as 4°C, and those in the second being unable to tolerate temperatures below 15°C.

**Species with seeds possessing the ability to survive at 4°C**

*(a) Shorea talura (White Meranti Group)*

*Maturation:* In 1975, *Shorea talura* trees at Field 19 of the Forest Research Institute, Kepong fruited at the end of March and subsequently shed all the seeds at the end of April. Maturation, germination and storage of these seeds were studied.

The percentage of germination of *Shorea talura* seeds showed a significant increase as the seeds matured. Germination tests in the laboratory as well as in the seed bed in the nursery showed that the percentage of germination of the seeds increased in a relatively short period toward the end of seed development which is close to the stage of seed shedding (Fig. 1). The moisture content[1] of the seeds has an inverse relationship to the percentage of germination, with a gradual decline of the moisture content as the seeds mature (Fig. 2). Similarly, the time lag between the start of water imbibition and the emergence of radicles became shorter in seeds collected later (Fig. 3). Mature seeds were able to be stored for the longest period (Table 1). Therefore, it is important to collect competely mature seeds for storage for long periods.

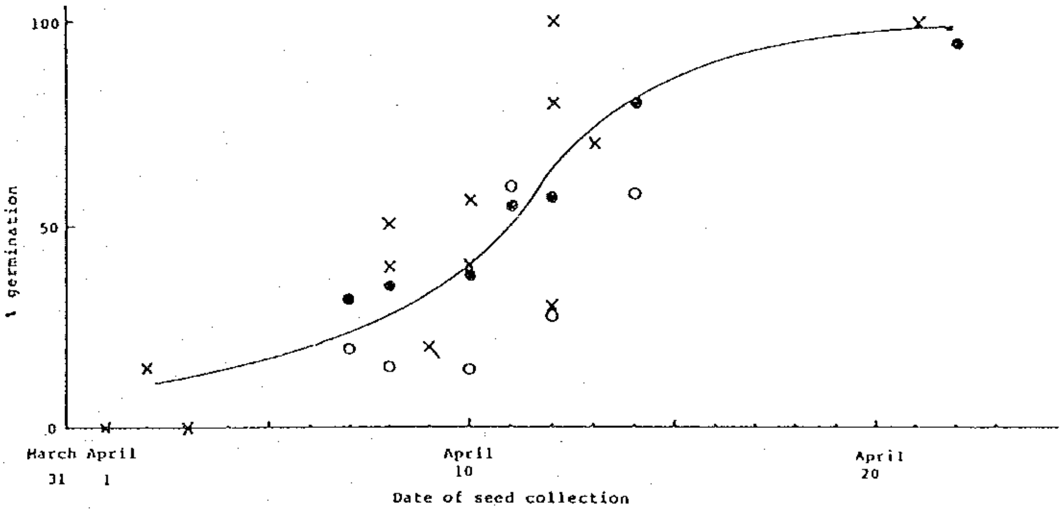


**Figure 1. Increase in percentage germination of Shorea talura seeds corresponding to maturation stages.**
Germination percentages for large size seeds (●) and small size seeds (o) in the nursery bed, as well as those in Petri dishes (x), are shown.

[1] In the present experiments, moisture content is given as a percentage of the dry weight of seed.

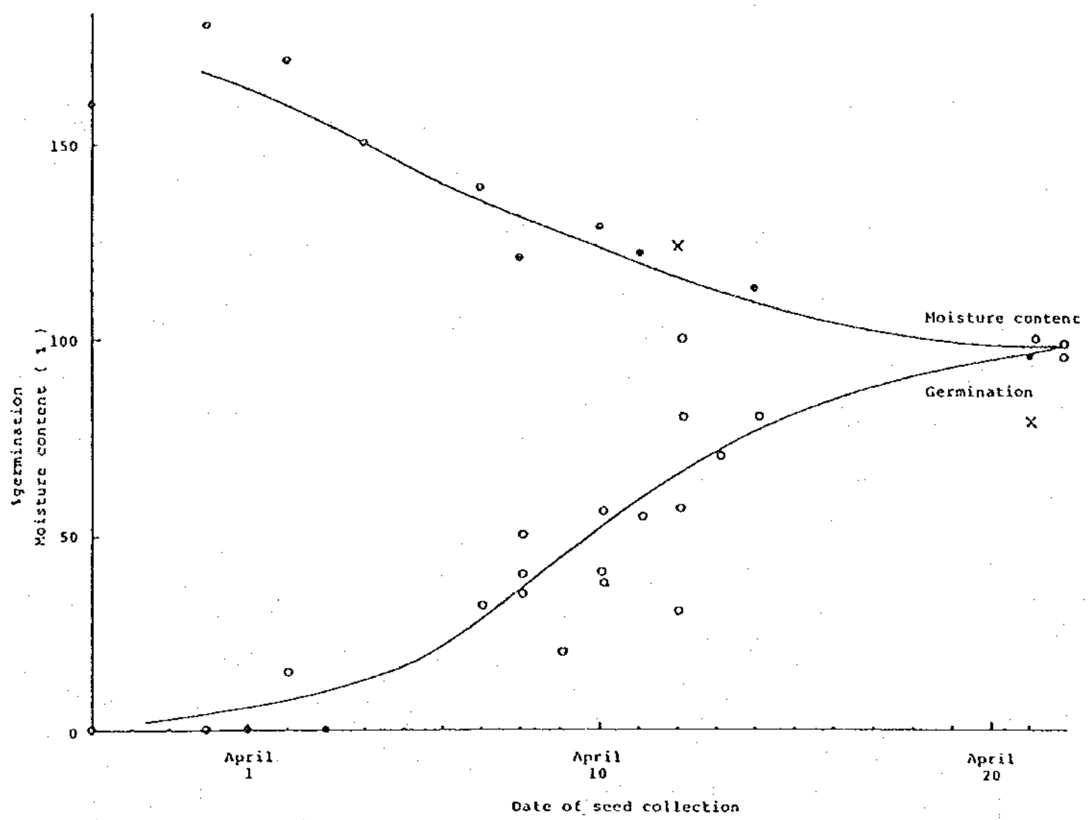


**Figure 2. Changes in moisture content and percentage germination of Shorea talura seeds in relation to maturation.**

Moisture contents of seeds collected from the ground (●) and those collected from the tree (x) are shown.

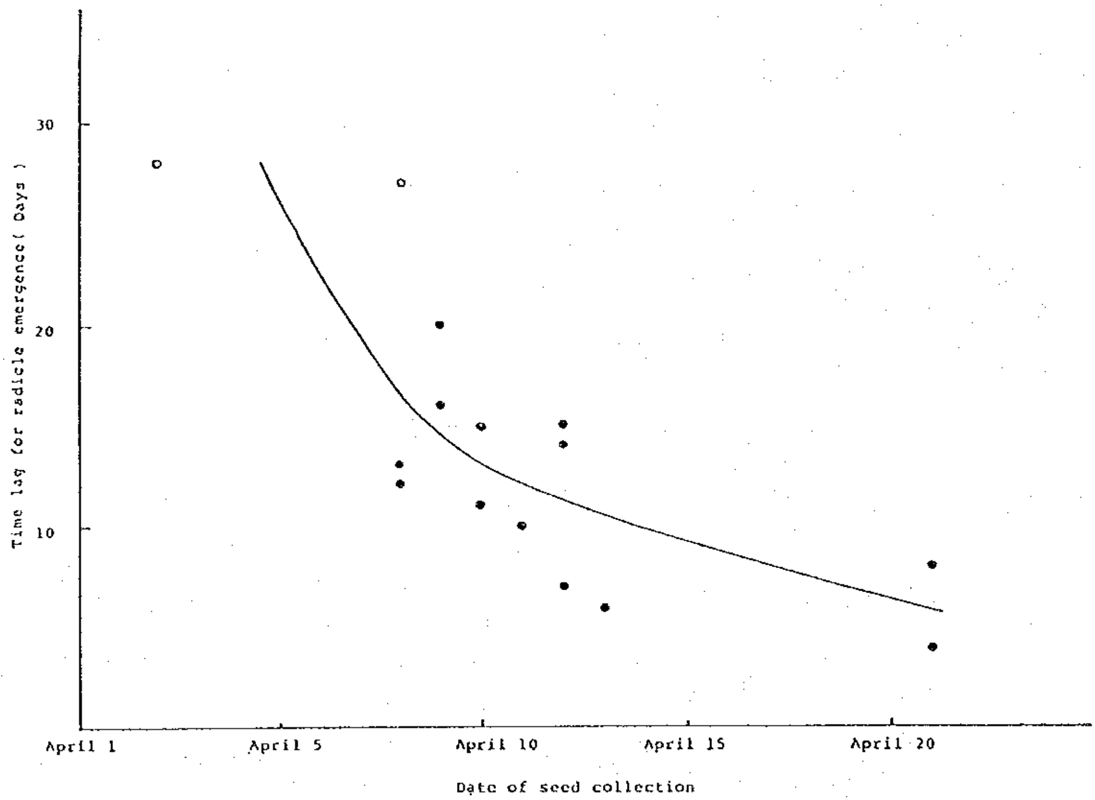


**Figure 3. Water imbibition period for Shorea talura seeds.**

**Table 1. Storage of Shorea talura seeds collected at various stages of maturation**

| | Original germination | Moisture content | Maximum storage | germination |
|---|---|---|---|---|
| Date of collection | % | (%) | days | % |
| April 8, 1975 | 50 | 120.0 | 84 | 50 |
| April 12, 1975 | 80 | 105.9 | 145 | 30 |
| April 21, 1975 | 95 | 68.1 | 182 | 69 |

Fifty percent of the less mature seeds collected on April 9, 1975 germinated initially, but one month after they were stored at 4°C, germination increased to 100%. This suggests after-ripening of the seeds during storage at 4°C. Similar trends were observed in *Hopea odorata* and *Hopea helferi* (Tamari, 1976).

A prechilling effect was observed in *Shorea talura* seeds, and this was probably related to the after-ripening phenomenon. The seeds stored at 4°C in a closed polyethylene plastic bag germinated very quickly after prolonged storage (Fig. 4). Further experiments were therefore conducted to examine the effect of prechilling on *Shorea talura* seeds. The seeds were placed on moist paper in Petri dishes and kept in a cold room at 4°C. At various intervals, the prechilled seeds were taken out from the cold room and germinated at 25°C. The rate of germination of the prechilled seeds was markedly accelerated as the prechilling treatment was prolonged, whereas the seeds kept at 25°C showed a gradual decline in the germination rate (Fig. 5). The results indicate that a certain degree of the prechilling effect is present for *Shorea talura* seeds. However, extremely prolonged prechilling may be detrimental to the seeds, because slow infection of fungi and bacteria deteriorates the seeds.

*Critical moisture content for survival of seeds:* *Shorea talura* seeds kept at 25°C in an open plastic bag showed a decline in the moisture content by natural desiccation. These seeds lost viability when the moisture content declined to a level of 20% (Table 2a). In a similar experiment, the seeds kept at 21°C showed loss of viability at 20% of the moisture content (Table 2b). Also, quick desiccation of the seeds killed the seeds. Therefore, the critical moisture content for the survival of *Shorea talura* seeds falls in a range between 20 and 25%.

*Tolerance of low temperature:* Temperatures below the freezing point killed *Shorea talura* seeds. However, one remarkable phenomenon was the survival of *Shorea talura* seeds at 4°C. As shown in Table 3, the seeds stored at 4°C survived for more than 5 months, provided that the moisture

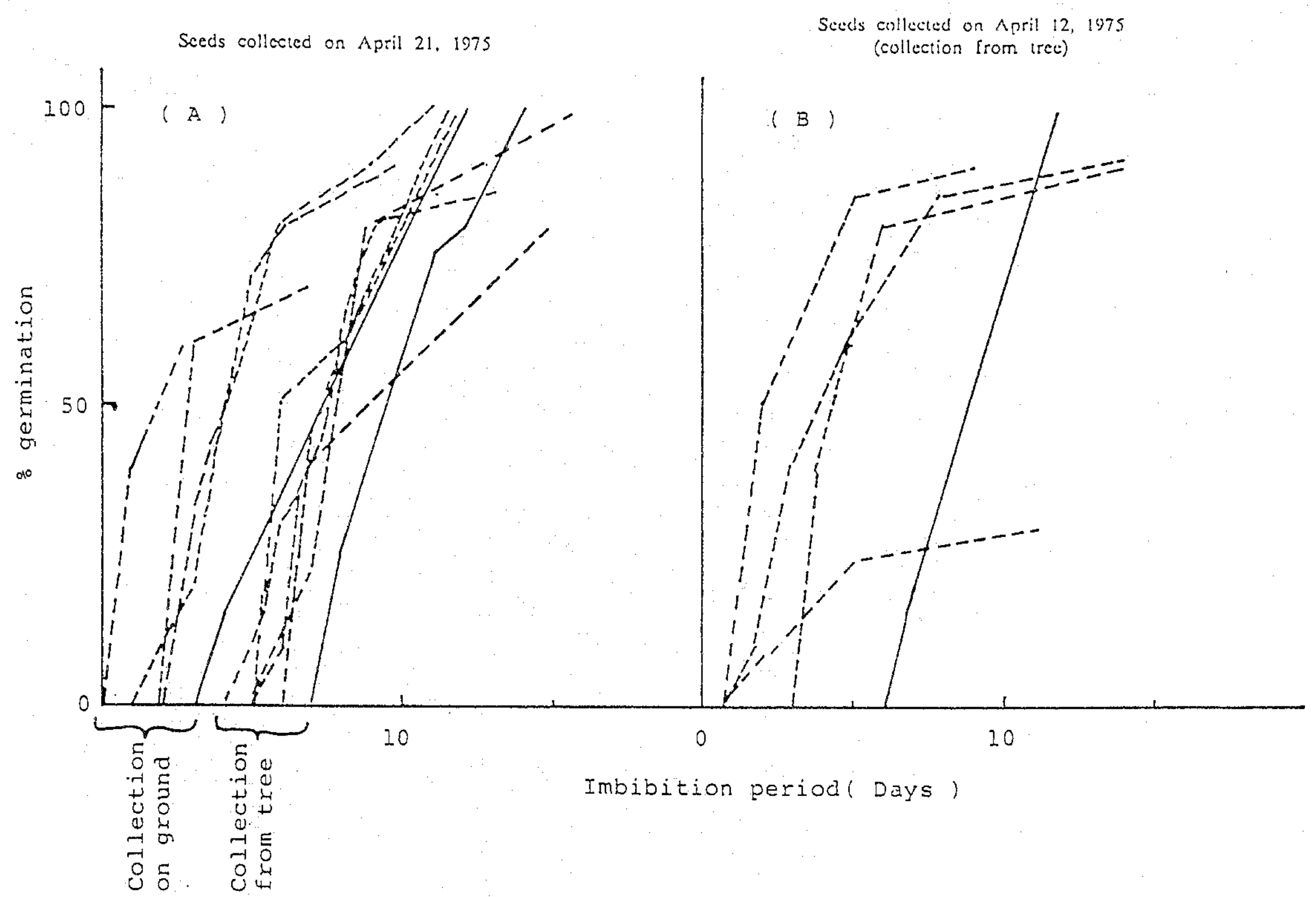


**Figure 4. Promotion of germination rates of *Shorea talura* seeds stored at 4°C.**
Solid lines indicate original germination rates, and broken lines indicate germination rates after various periods of storage.

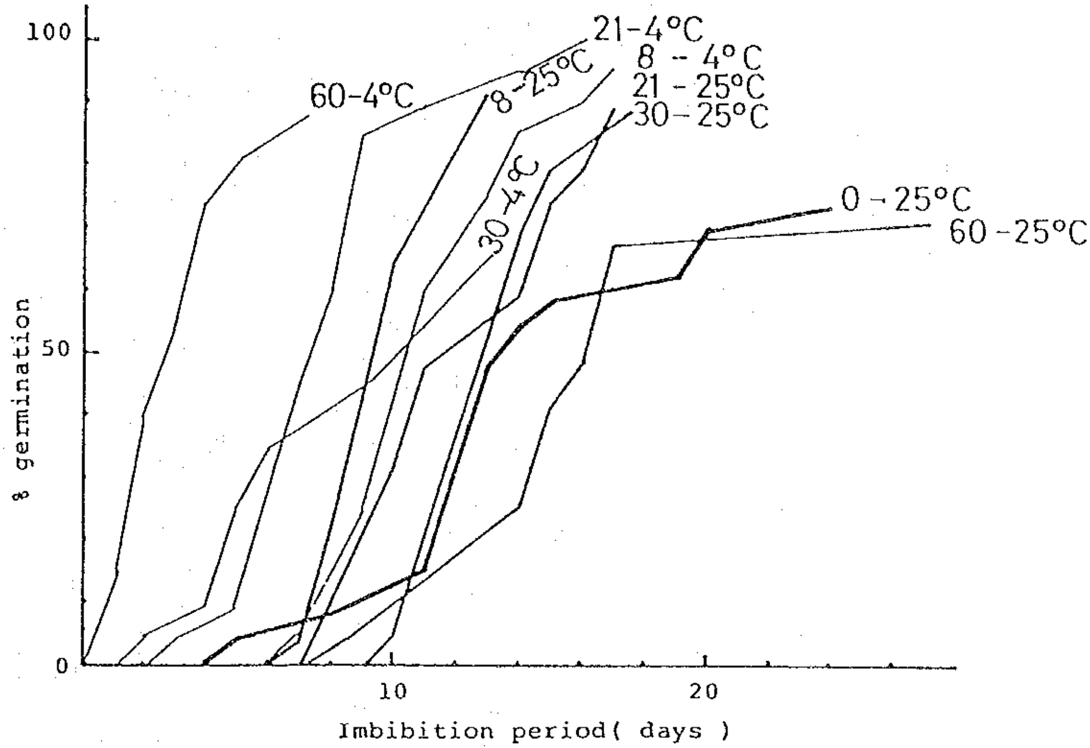


**Figure 5.** Effect of prechilling on *Shorea talura* seed germination.
First numbers indicate the duration of treatment, in days at the specified temperatures.

**Table 2a. Effect of moisture content on viability of *Shorea talura* seeds stored at 25°C**

| | Seeds collected on April 12, 1975 | | | | Seeds collected on April 21, 1975 | | | |
|---|---|---|---|---|---|---|---|---|
| Days | 24 | 31 | 37 | 62 | 0 | 15 | 30 | 40 |
| Germination (%) | 60 | 10 | 5 | 0 | 95 | 90 | 0 | 0 |
| Moisture content (%) | 41.2 | 22.5 | 20.4 | 16.0 | 68.1 | 45.6 | 20.9 | 18.1 |

**Table 2b. Effect of moisture content on viability of *Shorea talura* seeds stored at 21°C**

| | Seeds collected on May 19, 1977 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Days | 0 | 7 | 20 | 32 | 46 | 69 | 88 | 122 |
| Closed bag | | | | | | | | |
| Germination (%) | 100 | 92 | 87 | 64 | 82 | 87 | 95 | 97 |
| Moisture content (%) | 55.0 | 55.5 | 55.3 | 50.8 | 52.7 | 50.4 | 50.7 | 48.9 |
| Open bag | | | | | | | | |
| Germination (%) | 100 | 97 | 86 | 85 | 84 | 48 | 21 | 0 |
| Moisture content (%) | 55.0 | 51.9 | 50.8 | 44.6 | 36.4 | 32.0 | 28.3 | 25.7 |

**Table 3. Storage trials for Shorea talura seeds**

| Storage temperature | Treatment | Maximum duration (months) | Final germination (%) | Final moisture content (%) |
|---|---|---|---|---|
| 25°C | Closed bag | 3 | 64 | 29.5 |
| 21°C | Closed bag | 7¼ | 90 | 45.9 |
| 10°C* | Closed bag | 5 | 5 | 62.5 |
| 4°C* | Closed bag | 5 | 32 | 60.3 |
| | Desiccator | 5 | 42 | 55.7 |
| | Closed bag | 5 | 58 | |

Seeds collected in Perlis on April 20, 1977. Original seed germination 93%. Original seed moisture content 56.7%.

| Storage temperature | Treatment | Maximum duration (months) | Final germination (%) | Final moisture content (%) |
|---|---|---|---|---|
| 25°C | Closed bag | 2¼ | 70 | 25.7 |
| 21°C | Closed bag | 10 | 33 | 46.2 |
| 17°C* | Closed bag | 3 | 43 | 25.6 |
| 10°C* | Closed bag | 3 | 75 | 47.6 |
| 4°C* | Closed bag | 4 | 79 | 46.8 |

Seeds collected in Perlis on May 19, 1977. Original seed germination 100%. Original moisture content 55.0%.

* Power failure and mechanical problems caused the deterioration of the seeds stored.

content was maintained at a level above the critical moisture content. Even after 6 months in storage at 4°C, the seeds did not develop chilling injury symptoms. The adaptation of *Shorea talura* seeds to the low temperature appears to be unique among Dipterocarp seeds.

*Storage trials:* Storage experiments were carried out with a large quantity of *Shorea talura* seeds. Due to mechanical problems in the cold room, the seeds stored at 4°C lost viability and the results of the 4°C-storage could not be assessed fully. However, judging from the other tests (Table 1), the seeds can probably be stored more than 6 months at 4°C. For practical purposes, storage at 21°C would be the best among the storage treatments (Table 3). As suffocation causes fermentation of the seeds and secondary fungus infections, a ventilation system without reducing the moisture content needs to be developed. For this purpose, the plastic bag with slight ventilation through a chimney at the top of the bag was effective in preventing the seeds from suffocating.

*(b) Other species of White Meranti Group*

Seed maturation of other White Meranti species appears to follow a pattern similar to that of *Shorea talura*. Seeds with a high moisture content of above 100% did not survive a long-term storage. *Shorea assamica*, *Shorea bracteolata*, *Shorea hypochra*, *Shorea resinosa*, and *Shorea sericeiflora* survived at 4°C, although the duration of survival at 4°C varied among species (Table 4). One of the factors for seed survival may be the state of maturation of the seeds, as fermentation and suffocation were often caused in relatively immature seeds.

*(c) Hopea species*

*Hopea ferrea*, *Hopea latifolia*, *Hopea odorata*, *Hopea nervosa*, *Hopea subalata*, and *Hopea wightiana* survived at 4°C for various periods (Table 4). However, the duration of survival at 4°C did not exceed 3 months. Also, *Hopea helferi* has been shown to be tolerant of low temperatures (Tamari, 1975).

Some of the *Hopea nervosa* seeds stored at 21°C survived for more than 10 months in a preliminary experiment (Table 5a, 5b). In the experiment, some of the seeds were suffocated and infected by fungi, but some seeds were kept intact. During the storage, some seeds germinated, but their growth was arrested in the storage chamber. These germinated plantlets resumed growth on wet paper in a Petri dish, and were finally transplanted to pots in the nursery. The germinated plantlets can, therefore, be used as planting stock. This indicates that long-term storage is possible for some species of *Hopea*, provided that suffocation and fungus infection are prevented.

*(d) Dipterocarpus species*

*Dipterocarpus oblongifolius* seeds survived at 4°C for at least 2 months. Other unidentified species also showed a similar tendency.

*(e) Yellow Meranti species*

*Shorea resina-nigra*, *Shorea multiflora*, *Shorea faguetiana*, and *Shorea hopeifolia* seeds survived at 4°C for about a month. However, slow development of chilling injury symptoms finally killed the seeds.

*(f) Vatica species*

Only two species, *Vatica lowii* and *Vatica cinerea* were tested. These two species showed some degree of tolerance to low temperatures, but the degree of the tolerance could not be evaluated fully because of immature seed sources.

*(g) Dryobalanops, Balanocarpus, and Parashorea species*

The seeds of *Dryobalanops aromatica*, *Dryobalanops oblongifolia*, *Balanocarpus heimii*, *Parashorea densiflora*, and *Parashorea maluanonan*

Table 4. Survival of Shorea (White Meranti) and Hopea seeds stored at 4°C

| Species | Date of collection | Original % germination | Original % moisture | Storage period (months) | Storage % germination | Storage % moisture |
|---|---|---|---|---|---|---|
| Shorea talura | Apr. 21. 75 | 95 | 68.1 | 6 | 69 | 68.6 |
| Shorea assamica | Apr. 13. 77 | 86 | 38.1 | $3\frac{1}{4}$ | 50 | — |
| Shorea hypochra | May 19, 77 | 73 | — | 2 | 10 | — |
| Shorea bracteolata | Jun. 29, 76 | 50 | 48.2 | 2 | 4 | — |
| Hopea latifolia | — | — | — | $2\frac{3}{4}$ | 10 | 32.6 |
| Hopea odorata | May 13, 75 | 81 | 113.0 | $1\frac{1}{2}$ | 5 | 114.0 |
| Hopea wightiana | Aug. 16, 75 | 100 | — | 2 | 5 | 100.5 |
| Hopea subalata | Aug. 27, 75 | 100 | 77.4 | $1\frac{3}{4}$ | 40 | 46.8 |
| Hopea ferrea | May 19, 77 | 90 | 54.7 | 2 | 2 | 49.2 |
| Hopea nervosa | Jul. 29, 76 | 100 | 95.0 | $\frac{3}{4}$ | 15 | 76.0 |

survived at a temperature below 10°C for one or two weeks. However, survival at 4°C did not exceed a month. Some *Parashorea* may need to be re-examined on their tolerance to low temperatures as the species involved in this study showed a wide variety of physiological characteristics.

**Table 5a. Survival assessment of the seeds stored for 10 months at 21°C**

| | No. of seeds | Percentage |
|---|---|---|
| Seeds decayed including seedling decayed | 141 | 19 |
| Germinated seeds alive | 413† | 56 |
| Sound ungerminated seeds | 188* | 25 |
| Total seeds | 742 | 100 |

The seeds used in the experiment were collected on 29th, July, 1976 and their survival was assessed on 27th, May, 1977.

* These seeds showed 73% germination at 10 months and 75% germination at 11 months. Percentage germination in Table 5b at 10 and 11 months were calculated.

† Radicles have a potential to grow. These seedlings were able to grow in Petri dishes. Also, radicles can be prunned to promote lateral root development. The seedlings were successfully planted in the nursery.

**Table 5b. Storage of Hopea nervosa seeds in the closed bag at 21°C**

| Initial germination | Germination after storage for (months) | | | |
|---|---|---|---|---|
| | $\frac{2}{3}$ | 1.5 | 10 | 11 |
| | Germination percentage | | | |
| 100 | 100 | 50 | 19* | 19* |

Among the species tested, *Shorea talura* seeds showed the highest tolerance to low temperature, and other White Meranti seeds appeared to have this capacity too. *Dipterocarpus* seeds also tolerated storage at low temperature. These two groups have a common physiological distinction in that the main seed reserve consists of starch.

The tolerance of the seeds to low temperature needs to be studied in detail. Since after-ripening and prechilling effects have been demonstrated in *Shorea talura* seeds, the tolerance is probably physiologically related to the dormancy processes. Also, the fact that seeds tolerant of low temperatures may be stored for a long term compared to the non-tolerant seeds indicates that dormancy is a related process.

**Species with seeds not possessing the ability to tolerate temperatures below 15°C**

Two subgroups of *Shorea*, Red Meranti and Balau, have been shown to be highly susceptible to low temperature damage at 4°C by Tang (1971). In that study, the seeds of the two groups developed chilling injury symptoms within 2 hours. The cotyledonous tissues lost elasticity and became brittle. The color of cotyledons changed from green or white to water-soaked necrotic brown. The development of symptoms in the radicles was delayed, but followed a pattern similar to that of the cotyledons. The color changes in the tissues did not take place when the seeds were placed in a freezer at -20°C, but the seeds lost viability nevertheless. This indicates that enzyme systems that cause brown staining, probably polyphenol oxidases, are also susceptible to the subzero temperatures. Microscopic observations suggest that brown staining is present on the cell wall and that cell membrances are ruptured by chilling injury.

*(a) Shorea ovalis (Red Meranti Group)*

The seeds were collected from an isolated tree. No other trees were fruiting nor flowering in the vicinity. The first collection of the seeds was made on Aug. 14, 1975. Thereafter, the seeds were collected on Aug. 18 and 29, and finally on Sept. 8, 1975. Immediately after the last collection, all the remaining seeds on the tree were shed and the development of new leaves was observed.

*Seed maturation:* Although germination rates were high, even in the earlier collections, other factors indicated that maturation processes were progressing until the seeds were shed from the tree (Table 6). For example, the moisture content declined from over 100% to 53%. Also, the time for radicle emergence after imbibition was shortened in the seeds from the last collection. The decline in the moisture content appeared to prolong the viability of the seeds during storage, as fermentation and fungus infection

**Table 6. Date of seed collections in relation to maturation of Shorea ovalis seeds**

| Date of collection | Aug. 14 | Aug. 18 | Aug. 29 | Sept. 8 |
|---|---|---|---|---|
| Germination (%) | 100 | 100 | 100 | 100 |
| Moisture content (%) | 138.7 | 144.9 | 55.2 | 53.2 |
| Duration of imbibition for seed germination (days)* | 8 | 8 | 4 | 3 |

* The time lag between the start of imbibition and the first radicle emergence was expressed in days.

are suppressed in the drier seeds. However, artificial drying of the seeds could not substitute for natural drying processes associated with maturation. When the seeds were dried artificially for various durations, germination rates immediately after the treatment were reasonably high, depending on the degree of desiccation. However, storage for 30 days after artificial drying caused complete deterioration of the seeds except for those dried only for a day (Table 7). Such results illustrate that natural drying during maturation involves physiological processes more complex than simple desiccation.

**Table 7. Effect of artificial drying on the viability of Shorea ovalis seeds**

| Drying period | Immediately after treatment | | After 30 days storage | |
|---|---|---|---|---|
| | Germination (%) | Moisture content (%) | Germination (%) | Moisture content (%) |
| Air dried for 1 day | 100 | 96.1 | 75 | 74.8 |
| Air dried for 2 days | 85 | 47.4 | 0 | 32.5 |
| Air dried for 3 days | 40 | 39.2 | 0 | 19.7 |
| Air dried for 4 days | 10 | 15.1 | 0 | 11.7 |

A typical pattern of increase in the percentage of germination with decline in the moisture content was noted in *Shorea dasyphylla* seeds (Fig. 6). The moisture content declined sharply as the percentage of germination increased. Biological dehydration is probably associated with the initial rapid drop of the moisture content, whereas physical desiccation may be the main cause for the later slow decline.

The moisture content of the seeds is a good indicator for seed maturation in the laboratory. However, the measurement of moisture content in the field is impossible. Even in the laboratory the measurement is tedious and time consuming. Therefore, moisture content as an indicator of maturation is impractical for silvicultural use. A good indicator for judging seed maturation is to examine browning and drying of the seed wings. The wings of typically mature seeds are brown in color down to the base of the wing. Only the constricted bottom part of the wing base remains green and the portion immediately above the green tissue is distinctly demarcated with dark stain. The dark stain resembles a paper chromatographic front. The seeds with such wings have moisture content of about 50%. The demarcation by the dark stain cannot be observed in the seeds desiccated artificially after shedding from the tree. Therefore, wing browing is the most useful indicator for seed maturation and it can be used as a criterion in seed collections

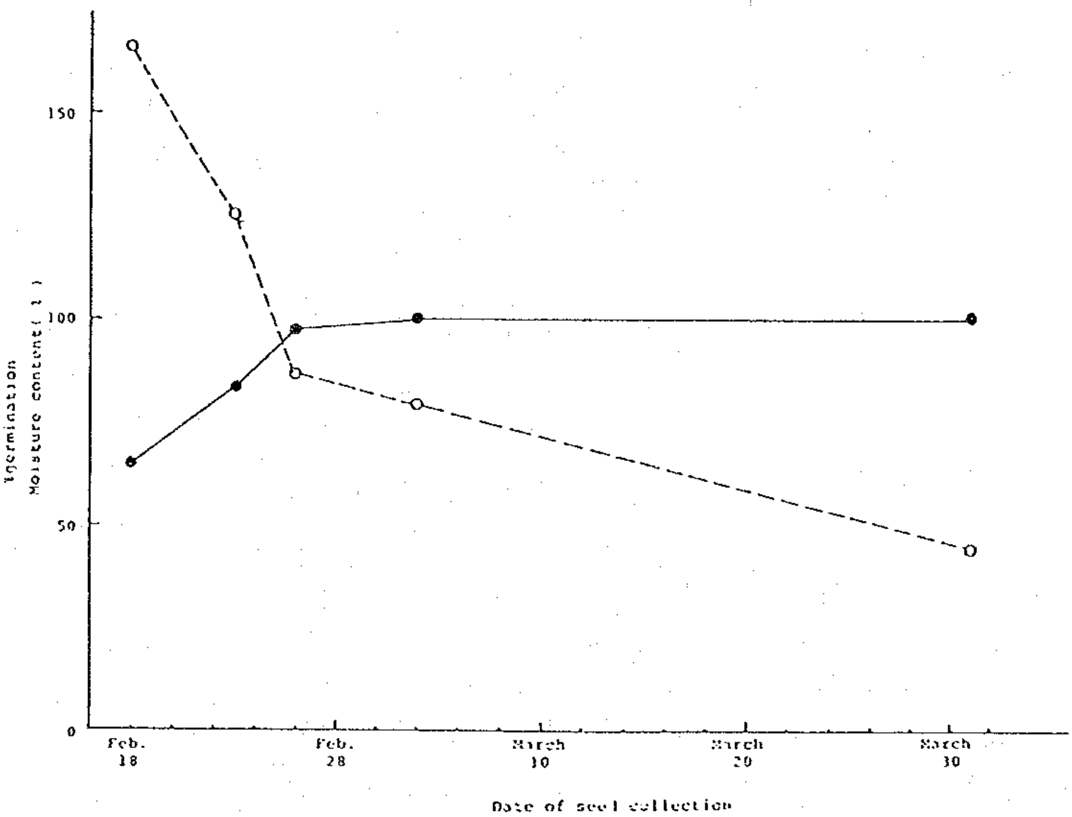


Figure 6. Changes in germination rates and moisture contents during the maturation of Shorea dasyphylla seeds.

*Storage trials:* As indicated earlier, *Shorea ovalis* seeds can neither tolerate desiccation below 20% (Table 8) nor temperatures below 15°C. Also, seeds have to be mature to undergo successful storage. The best results of more than 50% of the seeds surviving for 60 days were obtained at 21°C in a closed polyethylene plastic bag. Although fungus infection was serious in the moist conditions, 10% of the seeds still survived at 21°C even after 4 months (Table 9). Fungicide dusting may be helpful for protecting the seeds from infection.

Since the seeds cannot survive below 15°C, the optimum temperature for storage of *Shorea ovalis* seeds should be examined in a range between 16 and 25°C. Temperature fluctuation in the temperature controlling device should be considered when the seeds are stored at critical temperature.

*(b) Other Shorea species of the Red Meranti and Balau Group*

Most of the seeds in the group performed best in storage at 21°C, with the maximum storage period not exceeding 3 months (Table 10). However, original moisture contents suggest that some seeds were collected prematurely. Although these seeds cannot survive at a low temperature

**Table 8. Critical moisture contents for the survival of Shorea ovalis seeds**

| Stored at | | Duration of storage (Days) 0 | 3 | 8 |
|---|---|---|---|---|
| 25°C Closed bag | Germination (%) | 100 | 100 | 90 |
| | Moisture content (%) | 53.2 | 48.2 | 52.1 |
| 25°C Open bag | Germination (%) | — | 85 | 0 |
| | Moisture content (%) | — | 36.9 | 18.1 |

| Stored at | | Duration of storage (Days) 4 | 15 | 22 |
|---|---|---|---|---|
| 21°C Closed bag | Germination (%) | 100 | 90 | 80 |
| | Moisture content (%) | 57.9 | 54.5 | 45.4 |
| 21°C Open bag | Germination (%) | 100 | 35 | 0 |
| | Moisture content (%) | 41.1 | 23.6 | 20.4 |

below 15°C, the duration of the survival at 4°C varies among species. For example, *Shorea dasyphylla* survived for slightly longer at 4°C than other seeds, with 15% survival after 3 days at 4°C.

The moisture content of *Shorea curtisii* seeds dropped to 8.9% one month after the seeds were left in the airconditioned room. In contrast, seeds kept in the closed bag maintained the moisture contents at 54%, with 17% of the seeds being viable. These results indicate that the moisture content of the seeds can be maintained in the closed polyethylene plastic bag, but not in the open. When the seeds are placed in contact with constant atmospheric conditions for a sufficiently long period of time, the moisture contents of the seeds come into equilibrium with the atmospheric conditions. At normal atmospheric pressures, the moisture contents are mainly dependent on relative humidity (Nellist and Hughes, 1973). Although the equilibrium reached varies among species depending on their seed properties, plots of the equilibrated moisture content against relative humidity produce a sigmoid curve (Hubbard *et al.*, 1957). According to their results, the moisture content at a level above 20% has an equilibrium with a relative humidity of 90% or over. Therefore, a preliminary experiment was conducted to observe the effect of relative humidity on the survival of the seeds. Relative humidity at 25°C was controlled by $H_2SO_4$ following a prescription by Lange (1961). *Shorea curtisii* seeds were placed in containers with controlled relative humidity at 80%, 85%, 90% and 95%, as well as in a container saturated with water vapor. The seeds placed in the containers with 95% relative humidity or more maintained the moisture contents above

Table 9. Storage trials for Shorea ovalis seeds

| Date of collection | Site | Original % germ. | Original % moist. content | Storage temperature | Storage treatment | Maximum* duration (days) | % germ. | % moist. content |
|---|---|---|---|---|---|---|---|---|
| Aug. 29, 1975 | Kuala Pilah | 100 | 55.2 | 21°C | Closed bag | 168 | 10 | 34.4 |
| | | 100 | 55.2 | 21°C | Tin can | 168 | 15 | 64.8 |
| Sept. 8, 1975 | Kuala Pilah | 100 | 53.2 | 21°C | Closed bag | 127 | 10 | 37.3 |
| | | 100 | 53.2 | 21°C | Aluminium foil wrapped | 92 | 87 | 58.2 |
| Nov. 5, 1975 | Gombak | 95 | 83.5 | 21°C | Closed bag | 100 | 30 | 71.7 |
| | | 95 | 83.5 | 21°C | Tin can | 100 | 60 | 69.4 |
| Nov. 11, 1975 | Gombak | 90 | 43.9 | 21°C | Closed bag | 98 | 5 | 28.9 |
| | | 90 | 43.9 | 21°C | Tin can | 98 | 25 | 42.4 |
| | | 90 | 43.9 | 21°C | Tin can with daconil dusting | 171 | 16 | |

* All the treatments showed more than 50% survivals at 60 days.

Table 10. Maximum storage period for various Red Meranti and Balau seeds

| Species | Date of collection | Original % germ. | Original % moist. | 25°C Days | 25°C % germ. | 25°C % moist. | 21°C Days | 21°C % germ. | 21°C % moist. | 17°C Days | 17°C % germ. | 17°C % moist. | 4°C* Days | 4°C* % germ. | 4°C* % moist. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S. platyclados | Nov. 26, 76 | 86 | 59.0 | | | | 40 | 20 | 46.3 | 40 | 10 | 36.2 | | | |
| S. curtisii | Sep. 30, 76 | 90 | 64.1 | 35 | 5 | 21.6 | 30 | 78 | 72.7 | 14 | 15 | 73.1 | | | |
| | | | | | | | 67 | 83 | 70.8 | | | | | | |
| | Oct. 10, 76 | 100 | 54.5 | | | | 60 | 13 | 38.1 | | | | | | |
| | Oct. 1, 76 | 95 | 52.8 | 75 | 13 | 31.6 | 75 | 7 | 44.2 | | | | | | |
| | | 100 | 59.1 | 30 | 17 | 54.3 | 67 | 14 | 54.5 | | | | | | |
| | | | | 37 | 67 | 56.4 | | | | | | | | | |
| S. acuminata | Aug. 11, 76 | 95 | 75.3 | | | | 30 | 70 | 61.6 | 14 | 24 | 92.9 | | | |
| S. pauciflora | Jul. 29, 76 | 100 | 103.6 | 45 | 67 | 61.8 | 45 | 55 | 76.5 | 30 | 25 | 91.8 | | | |
| S. argentifolia | Jul. 30, 76 | 100 | 84.0 | 51 | 30 | 50.2 | 45 | 60 | 64.1 | 45 | 10 | 68.9 | | | |
| S. parvifolia | Mar. 31, 76 | 100 | 40.1 | | | | 21 | 43 | 34.5 | | | | | | |
| | Aug. 12, 76 | 95 | 94.3 | | | | 30 | 24 | 70.8 | | | | | | |
| | Mar. 4, 76 | 100 | 66.7 | 21 | 14 | 60.1 | 45 | 53 | 51.5 | 45 | 14 | 46.0 | | | |
| | Mar. 23, 76 | 100 | 83.0 | | | | 30 | 35 | 56.7 | 27 | 5 | 64.3 | | | |
| S. dasyphylla | Feb. 18, 76 | 65 | 166.6 | 18 | 0 | 126.6 | 35 | 0 | | 14 | 35 | | 2 | 63 | 118.7 |
| | Feb. 23, 76 | 83 | 125.5 | 14 | 0 | 88.8 | 14 | 0 | | 14 | 20 | 93.8 | 3 | 15 | |
| | Feb. 26, 76 | 97 | 86.9 | 8 | 48 | 55.3 | 14 | 24 | 68.0 | 8 | 48 | 68.0 | | | |
| | Mar. 31, 76 | 100 | 44.5 | 21 | 20 | 30.4 | | | | 21 | 5 | 30.3 | | | |
| S. leprosula | Mar. 23, 76 | 100 | 49.5 | | | | 30 | 47 | | 27 | 17 | 31.4 | 4 hours | | |
| | Aug. 16, 76 | 100 | 53.2 | | | | 30 | 45 | 40.4 | | | | | | |
| S. ovalis | Aug. 14, 75 | 100 | 138.7 | 18 | 53 | 150.6 | | | | | | | | | |
| | Aug. 18, 75 | 100 | 144.9 | 44 | 95 | 174.6 | | | | | | | | | |
| | Aug. 29, 75 | 100 | 55.2 | 25 | 37 | 40.9 | 42 | 80 | 58.6 | | | | | | |
| | Sep. 8, 75 | 100 | 53.2 | 30 | 50 | 34.4 | 120 | 10 | | | | | | | |

* All Red Meranti and Balau seeds tested were killed at 4°C, but *Shorea dasyphylla* seeds survived at least for 2 days.

the critical level and kept viable. In contrast, the seeds in the containers with the relative humidity at less than 95% lost viability and dried to a level below the critical point within a few days. Table 11 shows that 95% relative humidity at 25°C enables the moisture content of the seeds to be retained at over 20% for a long period. The aeration through 11.02% of $H_2SO_4$ (95% relative humidity at 25°C) is also effective in keeping the seeds viable for at least over a month with the moisture content unchanged. This indicates that an aerated storage chamber with controlled relative humidity can be developed in the future. The aerated storage chamber may be effective in preventing the seeds from suffocating and fermenting.

**Table 11. Moisture contents of Shorea curtisii seeds in chambers with 95% relative humidity at 25°C**

| Seed source<br>Treatment | | Initial stage | Placed in 95% relative humidity for | |
|---|---|---|---|---|
| | | | 18 days | 38 days |
| Tree No. 1 | | % | % | % |
| R.H. 95% | Moisture content | 59.1 | 53.5 | — |
| Sealed | Germination | 100 | 95 | — |
| Tree No. 1 | Moisture content | 59.1 | — | 56.4 |
| Aerated with | | | | |
| R.H. 95% | Germination | 100 | — | 67 |
| Tree No. 1 | | | | |
| R.H. 95% | Moisture content | 52.8 | 44.3 | 31.6 |
| Sealed | Germination | 95 | 80 | 13 |
| Tree No. 2 | | | | |
| R.H. 95% | Moisture content | 64.1 | 40.2 | 21.6 |
| Sealed | Germination | 90 | 60 | 5 |

These results show that relative humidity is important for the survival of Dipterocarp seeds, since at least 95% relative humidity is required for the seeds to survive. Such evidence may be further extended to relative humidities in natural conditions. Seeds fallen on various forest floors are subjected to a wide range of relative humidities, with only the seeds under a relative humidity of over 95% surviving. Probably heavy canopy layers, litter and humus promote high humidity conditions, whereas bare land creates low humidity conditions. At least, high moisture conditions are prerequisite for natural regeneration of Dipterocarps.