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Final report on seed source evaluation
— Forest tree improvement project in Indonesia phase I* —

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Summary : This report reviewed major achievements and results of seed source evaluation conducted in the latter half of the technical cooperation project on tree improvement during the period from January 1995 until February 1997.

The two main frames of the current tree improvement program: reccurent selection with open pollinated mating and form of execution in cooperation with forestry companies, were reviewed to make clear the role of seed source evaluation activities.

Periodical measurements once per four months were conducted successfully in almost all the 33 orchards established until the end of 1996／97 fiscal year. All the data were checked and kept in a recently developed computerized data processing system; that includes field note preparation, data check, analysis of variance & covariance and family ranking by selection index (FTIP No.19).

Thinning (Within plot selection) was started in seven orchards at the end of 1995／96 fiscal year and expected to be finished in 17 orchards until the beginning of 1997／98 fiscal year. A manual was compiled for this operation in line with the above mentioned computerized data processing system. This system includes the map preparation for preliminary selection and an easy input-function on the results of the selection for the subsequent operations (FTIP No.48). The retrospective index selection was applied for evaluating the result of selection and the procedure was compiled in a manual for operational use (FTIP No. 56).

According to the results of the operations, trees in the orchards continue their growth irrespective of the season : rainy or dry. It was also found that the thinning should be conducted at the end of rainy season or early in the dry season to reduce wind damage.

Analysis on the results of within-plot selection revealed that the selection was practiced mostly on their form traits for *A. mangium*, while equal weight was allocated to the three traits examined ; height, d.b.h. and stem straightness for *Eucalyptus*. Family rankings at an early stage in the orchards of *A. mangium* were found to be similar between South Sumatra and South Kalimantan. Analysis on the volume productivity proved that the current populations of *A. mangium* tested in the orchards are more than 50% productive as compared to that of the locally selected plus trees. Regarding to *Eucalyptus*, more than 20% of increase was expected by the repeated thinnings in the orchard.

Expecting activities for the current tree improvement program were discussed with its short term schedule for implementation. Among those, family selection and plus tree selection would be started in the oldest orchards in 1997／98 and in 1998／99, respectively. It was suggested to examine the possibility to use／establish provenance resource stand or composite orchards along with the activities in the seedling seed orchards, when the project moves on to the second generation.

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1. Introduction of seed source evaluation

A role of seed source evaluation in the tree improvement program is defined as a set ofoperations to provide information in order to make accurate selections of individuals or families by analyzing data from field measurements in the seed sources. Thus the genetic gain by tree improvement is largely depend on the progress of this activity, however, the gain in general is also depend on the several factors in the whole process of tree improvement program. Among those, the following two factors seem to be essential in relation with the seed source evaluation ; (1) tree improvement strategy, (2) form of execution. For this reason, these two topics are described beforehand in order to make the role of seed source evaluationclear in the current tree improvement program.

1. 1 Tree improvement strategy applied to the current program

Tree improvement strategy applied to the current tree improvement project conducted under thetechnical cooperation may be defined as a recurrentselection scheme using seedling seed orchards withopen pollinated mating (Kurinobu 1993, See Fig.1). In forest tree improvement, a set of operations which is composed of selection, mating and propagation, is repeated by generation and the genetic gain by tree improvement is cumulative with this repetition (Zobel and Talbert 1984).

Major steps of operation in the on-going tree improvement program may be summarized as in the flow chart of Fig.1.1. The procedure to be taken at each generation is simple in practice (establishment of SSO with OP seed, roguing and seed production) and almost the same between the generations, however, there are several important features to be noted here ;

1) The seedling seed orchard established at each generation will have three purposes; it will be used as progeny test in the beginning then it will be used for seed production purpose after roguing. Finally it will be the base populations to select plus trees to be used in the next generation.

2) Use of open pollinated seed collected from plus trees is assumed to move on to the next generation.

3) In the beginning, the base population is made up of good provenances which were proved to be promising based on the previous trials, thenthe base population will be added by further collec-tion of seed in the second generation.

There are several options to repeat this cycle of operations and an appropriate choice of optionsare different depending on the species as well as techniques available (Wright 1976). The reason why the above mentioned strategy; seedling seed orchard with open pollinated mating, was adoptedto the current target species might be explained as follows ;

1) The first reason was due to the characteris-tics of target species. That is many of the tropical fast growing species tend to flower withina few years and are managed in a short rotation

Fig.1.1 Flow chart for the current tree improvement strategy using seedling seed orchard (SSO) with open pollinated mating

Components	First generation	Second generation	Further generation
Genetic variation	Choose good provenances	Add further seed collections	
(recombination)	↓	↓	
	Collect OP seed	→ Collect OP seed	→ Third generation
	↓	↓	
Selection	SSO(Progeny test)	SSO(Progeny test)	
	↓	↓	
	Roguing of SSO (Family + Individual)	Roguing of SSO (Family + Individual)	
	↓	↓	
Propagation	SSO (Seed orchard)	SSO (Seed orchard)	
	↓	↓	
	Plus Tree selection	Plus Tree selection	

Fig. 1.2 Sublining system by using seedling seed orchards with open pollinated mating

Generation	Breeding population			Production population
	Establish seedling seed orchards of around Fifty families of the same provenance			
First generation	SSO-SL1	SSO-SL2	SSO-SL3	→ Culled SSO
	↓	↓	↓	
	Cull SSOs then select plus-trees, collect OP-seed From each plus trees for the 2nd gen. SSOs.			
	↓	↓	↓	
Second generation	SSO-SL1	SSO-SL2	SSO-SL3	→ Culled SSO or Comp. CSO, SSO
	↓	↓	↓	
	Cull SSOs then select plus-trees, collect OP-seed From each plus trees for the 3rd gen. SSOs.			
	↓	↓	↓	
Later generation	Repeat the same procedure by generation.			

Note) Adopted originally from Nikles (1989) then modified to the current project (Kurinobu 1993).

cycles (Eldridge 1994). These two points will offsett he inherent disadvantages of seedling seed orchard; delay of seed production and poor accuracy of selection at an early stage. Thus the establish-ment of seedling seed orchard seemed to be the most realistic option to meet the immediate de-mand of improved seed.

2) The second reason was due to the limitationof available techniques for tree breeding. Reliable techniques for vegetative propagation and con-trolled pollination for the tropical species had notb een established as yet to be implemented on an operational scale. Thus more sophisticated options; such as clonal orchard or controlled pollination seemed to be inappropriate at the moment due to the concern of delay to turn over generation.

3) The third reason was due to the managementr eason on how to promote tree improvement pro-gra m. This combination of simple techniques ena-bled a large scale implementation of tree improve-ment in collaboration with forestry companies, because it does not require any further techniques other than silvicultural techniques for the planta-tion establishment.

Effectiveness of this strategy, especially in terms of gain per unit of time, had been already proofed by the successful result of four generationof improvement for *Eucalyptus* in Southern Florida (Franklin 1989, Reddy and Rockwood 1989). Now it has become a popular approach for the tropicaltr ee improvement programs. Tree improvement techniques for field design and selection method are rexamined for this approach recently (White 1996).

Another feature with the strategy of the current program was an introduction of the concept of subline system for the major target species ; *A. mangium* and *E. pellita* (van Buijitenen 1979, MacKeand 1980). With the use of sublining system, future increase of inbreeding would be minimized at least in the seed production popula-ti on, while maximzing short term gain by conducting intensive selections within the sublines (Matheson 1990). Each subline was made up of single or a few of the provenances which are closer in geographyic location with an expectation that their flowering time would be well overlapped (Nikles 1989). In addition to the above, the provenances used by the project are those which proved to be promising based on the previous trials with an intention to obtain a large gain from the beginning (Kurinobu and Soecipto 1993).

An outline of the tree improvement strategy with sublining system being applied to the major species of the project is shown in Fig.1.2. In the first generation, improved seed are supplied from the rogued seedling seed orchards. Genetic quality of improved seed would be increased greatly in the second generation, because the seed for opera-ti onal use would be supplied mostly from the composite orchards where the best individuals from the top ranked families are used with the aim to promote out crossed seed.

1.2 The form of execution for the current tree improvement program

In the current project, cooperative approach between the project, BP3BTH in later, and forestrycompanies was adopted from the beginning (Kurinobu and Soecipto 1992). It is well known that the cooperative approach will reduce risks of investment on tree improvement by each forestry companies, while ensuring the opportunity to get technical assistance, information and improved stocks for their seed sources (Zobel and Talbert 1984). This approach was especially adaptable to the present situation in Indonesia, because many of the forestry companies had just started their forest plantation programs (HTI), but they did not have experienced tree breeders or sufficient resources for the production of their planting stocks with a few exceptions.

Expected roles and benefits to be shared by the both organizations; forestry companies and FTIRDI is summarized in Table 1.1. Forestry companies will be responsible for the provision of land for the seed sources as well as the maintenance and measurement, while they will get the benefit to use seed for their plantation establishment. On the other hand, FTIRDI will be responsible for the supply of materials for seed source establishment and technical support, then the resulting information and materials could be used by FTIRDI for their research purposes as well as future deployment of tree improvement.

This type of collaboration will have further advantages other than those mentioned in the above.

1) The first advantage is that the genetic gain will become greater than those from the program conducted by single forestry company or government institute. In general genetic gain is proportional to the selection differential as well as the accuracy of selection, both of which are basically depend on the scale of the base population. Therefore the co-operative approach is essential to obtain a greater gain by establishing a large base population.

2) The second advantage is that this co-operative approach is suitable in the structure for a rapid realisation of the gain in the operational plantation establishment, because forestry companies; the user of the improved seed, will establish their seed sources. Therefore the problems with the technical extension might be minimised as long as the collaboration is conducted successfully.

To establish a successful collaboration, how to share in roles by both organisations need to be specified more in detail at each step of operations. Fig. 1.3 shows the current system of collaboration of FTIRDI with forestry companies. As it is easily understood by looking at the Fig.1.3, the major role of FTIRDI is to give guidance for each step of operations by using or analysing data obtained at the previous step of operations. Thus developing a well-organised information processing system is essential, because the data collected at each step of operation is used subsequently to give an appropriate guidance for the next step of operation.

1.3 Major components of seed source evaluation

As described in the beginning of this chapter, the role of seed source evaluation can be defined as a set of operations to provide information to conduct accurate selections by analyzing data from field measurements. To attain this purpose, seed source evaluation activities is made up of the following three components;

(1) To determine the practical procedures at each step of operation; measurement, roguing and plus tree selection, in line with the recurrent selection schemes using seedling seed orchards with open pollinated mating as described in 1.1.

(2) To establish／operate a computerized data processing system which is related to the subse-

Table. 1.1 Roles of Forestry companies and FRITRDI

Organization	Responsible roles	Expecting benefit
Forest companies	Provision of land Execution of field activities	Use of seed sources for their reforestation
FTIDRI	Supply of materials Technical support	Keeping improved stocks, Use of information for research purposes

Note) Originally prepared in 1993, then revised.

Fig. 1.3 Current system of Seedling Seed Orchard Management in co-operation with Forestry Companies

Operations in order	Forestry company	Forest tree improvement research and development institute
Establishment	Execution ← (land & labor) →	Deliver seed & technical support Recording information
Measurement	Execution ← (labor & staff) →	Technical support Guidance field-note & devices Recording & Analysis
Roguing	Execution ← (labor & staff) →	Technical support Guidance for thinning Recording & Analysis
Seed production	Commercial use ← [Monitoring] →	Technical support Recording & Analysis
Plus tree selection	Provision of labor →	Execution & propergation Supply the material for the next cycle of tree improvement

Note) Originally prepared in 1993, then revised to the present situation.

quent steps of operation; measurement, roguing and plus tree selection as given in Fig. 1.3 for the purpose to conduct selection work efficiently and correctly.

(3) To conduct analysis of data processed in the above mentioned system to predict possible outcomes of selection as well as to provide information in choosing more effective selection strategy.

Since the three components are closely related to each other, consistency of operational procedures as well as format of data is essential. The activitie s in (1) and (2) are regarded as a routine work to be repeated by time, location and even by spe cies. In this case, consistent procedure is not only advantageous in saving time and cost, but also effective to reduce mistakes that are unavoidable in this type of work with handling huge amount of data. Moreover, this consistency is also essential to conduct analysis mentioned in (3), because it is common for those study to combine d ata at different time of measurement or those from different locations.

2. Seed source evaluation activities conducted during this phase of the project

Seed source evaluation activities conducted as a routine work during this phase of the project are reviewed in this chapter. There are three major items on seed source evaluation ; (1) measurement, (2) thinning and (3) construction of computerized data processing system. Thus they are described in each sub-chapters separately by confining the contents mainly on an operational aspect. The results of analysis derived from those activities are reviewed in the next chapter.

2.1 Measurement

The project determined to conduct measurement periodically. Major purpose of periodical measurement are summarized as follows ;

(1) To get a growth trend of stand development in order to determine an appropriate timing for thinning in the orchards.

(2) To get a time trend of genetic parameters so that it could be used for estimating gains by tree improvement.

(3) To asses the quality of data obtained from each orchard as well as the potential of improvement on each of the target trait.

(4) To make sure the skills for computer operation by repeating the similar set of analysis.

2.1.1 Periodical measurement

Measurement has been conducted periodically (once per four months) in 33 seedling seed orchards as shown in Table 2.1. Until now, the measurement has been executed quite successfully in most of the seedling seed orchards owing to the positive supports of the relevant staff of the forestry companies. But in some of the orchards, the measurement was stopped due to its poor survival ; AM003, or the frequency of measurement was reduced due to the difficult accessibility ; AM010 and AM011.

Measured traits were height (h), diameter at breast height (d). multi-stem (m), stem straight ness (s) and bole length (b). Height was measured on all of the surviving trees from the beginning until now, while the measurement of dbh was started from one year after planting. Stem straightness was measured occasionally after one year for *Acacias* and *Eucalyptus*. On the other hand multi-stem and bole length were measured only for *Acacias*. Multi-stem was measured twice ; 4 months and 8 months after planting, then the trees were singled by leaving main stem.

Metric scales of the nearest 0.1m, 1.0cm and 0.1m were used for height, dbh and bole length, respectively. Multi-stem and stem straightness were scored subjectively using three classes grading systems ; 1 : necessary for singling, 2 : unknown, and 3 : no need for singling on multi-stem, 1 : very crooked, 2 : crooked, and 3 : straight on stem straightness. These three class grading system was adopted due to its simplicity and practical convenience, because most of the field labors were not familiar to use an elaborate scoring system.

2.1.2 Results of measurement

As mentioned in 2.1.1, the measurement had been finished almost completely as scheduled with a few exceptions. This indicates that the collaboration with forestry company is possible not only for the establishment but also the evaluation especially for the periodical measurement. However, the frequency of mesurement applied here might be too intensive as compared to the operational standard. Thus reduction of intensity of measure ment should be examined later in relation with the schedule of thinning.

This frequency of measurement proved to be quite adequate to catch the growth trend of stand development as well as the time trend of genetic parameters, because the future trend of stand growth and genetic parameters could be predicted by using the results of the measurement (See the topics in chapter 3). A periodical increment of height growth of 1.0 to 2.0 m between the measurements seems to be appropriate to make an acurate prediction, because there had been no data available for this purpose until recently.

One of the unexpected finding here was that the trees will continue their growth during the dry season or growing even better than those during the rainy season in most of the orchards. This result may not be applicable to all the plantation, because it will depend on the climatic condition, the timing of fertilizer application or the growth response on family level. However, the results here should be examined more in details. It should be noted that even a simple repetition of measurement, it will form a set of valuable information that was not clearly recognized before.

Bole length of *Acacias*, which seems to be one of the important traits in determining their commercial value, might be better to measure after the average height exceeded 7.0 to 8.0 m, because the differentiation of main stem and branches are not clear until that size. On the other hand, multi-stem scoring could be finished at an early stage in accordance with the operational singling schedule. One of the useful findings was that there existed a fairly strong correlation between both traits (See chapter 3). Thus it is recommended to use this relationship when determining the schedule of measurement on these traits.

2.1.3 Practical considerations for the execution of measurement

1) Contact to the forestry company before the execution of measurement

According to the experience to conduct measurement, a preliminary notice to the forestry company is essential for the timely execution of measurement, because they need time for their preparation of the measurement ; weeding in the seed orchard area, arrangement of their labores and transportation. Thus the early notice should be sent at least two weeks before the visit. This is especially important, when some of the orchards area are going to be measured by FTIRDI. A few days before the departing date, sending a notice for confirmation is also recommended, because the preliminary notice from FTIRDI may not reach to the resopnsible section

Table. 2.1　Periodical measurement achieved as of January 1997

Location	SSO Code	Estab lished	1 (4)	2 (8)	3 (12)	4 (16)	5 (20)	6 (24)	7 (28)	8 (32)	F.com pany
Sum-sel	AM001	94.01	h,m	h,m	h,d,s	h,d,s	h,d,b	h,d,s,b	h,d	h,d,s,b	MHP
Sum-sel	AM002	94.01	h,m	h,m	h,d,s	h,d,s	h,d,b	h,d,s,b	h,d	h,d,s,b	MHP
Sum-sel	AM003	94.01	h,m	h,m	h,d,s	h,d,s	h,d,b				MHP
Sum-sel	AM004	94.01	h,m	h,m	h,d,s	h,d,s	h,d,b	h,d,s,b	h,d	h,d,s,b	MHP
Kal-sel	AM005	94.01	h,m	h,m	h,d,s	H,d,s,b	h,d,b	h,d	h,d	h,d,s,b	INH3
Kal-sel	AM006	94.01	h,m	h,m	h,d,s	H,d,s,b	h,d,b	h,d	h,d	h,d,s,b	INH3
Kal-sel	EP001	94.01	h	h	h,d,s	h,d	h,d,s	h,d	h,d,s	h,d,s	INH3
Kal-sel	EU001	94.01	h	h	h,d,s	h,d	h,d,s	h,d	h,d,s	h,d,s	INH3
Kal-sel	AM007	95.01	h,m	h,m	h,d,s	h,d,b	h,d,s				MHP
Kal-sel	AM008	95.01	h,m	h,m	h,d,s	h,d,b	h,d,s				MHP
Sum-sel	AC001	95.02	h,m	h,m	h,d,s	h,d,s	h,d,s				MHP
Sum-sel	AC002	95.02	h,m	h,m	h,d,s	h,d,s	h,d,s				MHP
Sum-sel	AC003	95.02	h,m	h,m	h,d,s	h,d,s	h,d,s				MHP
Sum-sel	EP002	95.02	h	h	h,d	h,d,s	h,d,s				MHP
Sum-sel	EP003	95.02	h	h	h,d	h,d,s	h,d,s				MHP
Sum-sel	EP004	95.02	h	h	h,d	h,d,s	h,d,s				MHP
Jav-tan	AM009	95.02	h,m	h,m	h,d,s	h,d,s					FTRD
Jav-tan	EP005	95.02	h	h	h,d,s	h,d,s					FTRD
Kal-bar	AM010	95.02		h,m			h,d,s,b				INH3
Kal-bar	AM011	95.02		h,m			h,d,s,b				INH3
Jav-tan	AR001	96.02	h,m								FTRD
Jav-tan	PF001	96.02	h								FTRD
Sum-sel	AM012	96.02	h,m	h,m							MHP
Sum-sel	AR002	96.02	h,m	h,m							MHP
Sum-sel	EP006	96.02	h								MHP
Kal-tim	EP007	96.02	h	h							IHM
Kal-tim	EP008	96.02	h	h							IHM
Kal-tim	EP009	96.02	h	h							IHM
Kal-tim	EP010	96.02	h	h							IHM
Riau	EP011	96.02	h	h							PSPI
Riau	EP012	96.02	h	h							PSPI
Riau	EP013	96.02	h	h							PSPI
Riau	EP014	96.02	h	h							PSPI

Note) Abbreviations used in SSO code; AM, AC, EP, EU, AR, PF denote *A. mangium*, *A. crassicarpa*, *E. pellita*, *E. urophylla*, *A. auriculiformis and P. falcataria*, respectively. Abbreviations used in Forestry companies; MHP, INH3, FTRD, MHP and PSPI are PT. Musi Hutan Persada, PT. Inhutani 3, Forest Tree Improvement Research & Development Institute, PT. ITCI Huntani Mannungal and PT. Perawang Sukses Perkasa Industri, respectively. Figures in the parentheses indicate months after establishment of SSO.

in the field or the schedule of preliminary notice had been changed. These contacts are some sort of prerequisit to work with collaborators, but it was not always realized due to the delay of final decision by FTIRDI or the troubles with communication line.

2) Season for the measurement

Measurement should be scheduled during the dry season in Indonesia, because the measurement under the heavy rain is sometimes impossible or tends to cause many mistakes even if it is conducted. Moreover transportation is not always working well due to the muddy road condition. However, many of the field activities had to be executed in the latter half of the fiscal year; the rainy season, due to the delay of available budget. Since the climate can not be changed by human being, the system of funding needs to be revised as long as the measurement could be carried out effectively.

2.2 Thinning

The primary purpose of thinning in seedling seed orchard is to improve the genetic quality of

Table. 2.2 Outline of an expecting schedule for thinning in seedling seed orchard

Years after the establishment	Operation	Type of selection	Types of use
1.5 - 2.0	First thinning ----- cull poorer trees in each plot	Within plot selection	Progeny test
2.5 - 3.0	Second thinning ----- leave best tree per plot	Within plot selection	Start seed production
3.0 -	Final thinning ----- leave better families in SSO	Between family selection	Managed as seed orchards
3.0 - 4.0	Select plus trees for OP seed collection	Individual + family selection	

Note) FTIP No.46.

the seed produced in the orchard. Thus the thinning will leave the best trees from the better families so that they can mate each other to produce genetically improved seed. For this reason, the thinningis regarded as a selection work and it is one of the essential activities in the initial phase of tree improvement program.

2.2.1 Outline of schedule for thinning in seedling seed orchard

For the currently established seedling seed orchards, thinning will be conducted by two types of different selection scheme; within plot selection and family selection. This is because multiple tree plot is used in the current seedling seed orchards (Kurinobu et al 1993 ; FTIP No.15). In case of the multiple tree plot, only the best individual is assumed to be retained per plot to avoid related mating with the neighboring half sibs. Thus the spacing between the trees within the same family was designed narrower than those between the trees of different families.

An expecting schedule for thinning for the seedling seed orchards is given in Table.2.2. The first two times of thinning are the within plot selections and the final one is the between family selection. An operational seed production will start after finishing the second thinning, because the possibility of related mating would be much reduced since only the best tree retained per plot. Between family selection will be conducted based on the family ranking derived from the previously collected data.

2.2.2 Procedure of thinning

Operational procedure for thinning, especially for within plot selection, was compiled as a manual of FTIP No. 48. Main steps of the procedure is summarized as follows ;

1) Measurement

Measurement is conducted before thinning. The purpose of the measurement is to collect data for preparing map of preliminary selection as well as to use it for family ranking and further analysis.

2) Preliminary selection

Preliminary selection is made using the data of the previous measurement then the result is printed out in a form of map. The purpose to prepare this map is to give a standard criterion for selection and to provide material to record the results of the actual selection.

3) Field selection

Final choice of trees for culling is made in the orchard by comparing trees in the same plot. Before the selection, red mark will be painted on the stem of every first tree in each plot to make this operation correctly. The result of selection is written on the map as described in the previous step.

4) Execution of thinning

Thinning itself will be made as an operational manner. The trees will be cut at around 1.0m above the ground to identify the culled trees easily at the next measurement.

5) Recording of the results

Recording the results of selection is made using the map with degitizer connected to PC. Thus the field note for the next measurement will be revised easily by the resulting file of the thinning.

2.2.3 Thinnings practiced in seedling seed orchards

Thinning to be practiced until the end of the

Table 2.3 Thinnings practiced in seedling seed orchards as of March 1997

Location	Code	Estab lished	1995		1996				1997		F.com pany
			Jul.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	
Sum-sel	AM001	94.01			wp-1					wp-2	MHP
Sum-sel	AM002	94.01			wp-1					wp-2	MHP
Sum-sel	AM003	94.01									MHP
Sum-sel	AM004	94.01			wp-1					wp-2	MHP
Kal-sel	AM005	94.01		wp-1					wp-2		INH3
Kal-sel	AM006	94.01		wp-1					wp-2		INH3
Kal-sel	EP001	94.01		wp-1					wp-2		INH3
Kal-sel	EU001	94.01		wp-1							INH3
Kal-sel	AM007	95.01					wp-1				MHP
Kal-sel	AM008	95.01					wp-1				MHP
Sum-sel	AC001	95.02							wp-1		MHP
Sum-sel	AC002	95.02							wp-1		MHP
Sum-sel	AC003	95.02							wp-1		MHP
Sum-sel	EP002	95.02								wp-1	MHP
Sum-sel	EP003	95.02								wp-1	MHP
Sum-sel	EP004	95.02								wp-1	MHP
Jav-tan	AM009	95.02									FTRD
Jav-tan	EP005	95.02									FTRD
Kal-bar	AM010	95.02							wp-1		INH3
Kal-bar	AM011	95.02							wp-1		INH3

Note) Abbreviations used in Code; AM, EP, EU, AC denote *A. mangium, E. pellita, E. urophylla* and *A. crassicarpa*, respectively. Abblibiations used in Forestry companies; MHP, INH3 and FTRD are PT. Musi Hutan Persada, PT. Inhutani 3 and Forest Tree Improvement Research & Development Institute, respectively.

fiscal year 1996／97 are shown in Table 2.3. Thinnings conducted until 1997 are all within plot selection. Bold letter shows the thinning already finished and normal letter shows that scheduled in near future.

Seven seedling seed orchards established in 1994 had been thinned once in 1996 and six of them will be thinned again 1997 fiscal year. They are all within plot selection at the moment. In case of the seedling seed orchards of *A. mangium*, operational seed production can be started in 1997／98, because only one tree per plot will be retained after the twice of the thinning.

Regarding the seedling seed orchards established in 1995, only two of them were thinned once, but the thinning rate was 25% ; one poorest tree was culled in each plot. Another seedling seed orchard will be thinned at the end of 1997 fiscal year. Delay of thinning in these orchards was mainly due to the concern to avoid wind damage that will frequently occur during the rainy season.

2.2.4 Practical considerations on the results of thinning

1) Schedule of thinning based on the stand height

Regarding to the indicator for thinning, stand height is better suited than stand age, because stand growth is different depending on the soil productivity. For this reason, schedule for thinning for the current seedling seed orchard of A. *mangium* is proposed as shown in Table 2.4. The schedule here is still tentative and subject to be revised. However, compilation of this type of tending regime might be necessary to meet the management demand under the diversified environments.

In case the orchard is managed for operational purpose under the favorable environment, the thinning with high intensity may be preferred. On theother hand, the thinning with low intensity would be suitable, when the orchard is managed for research purpose or it was established under the windy area. In any case, family selection might be better to conduct after average height reaches around 15 m, because the pattern of growth seems to be not clear until that size.

2) Thinning to reduce wind damage

When the thinning is attempted in seedling seed orchard, most serious concern might be the damages by wind. This is because the trees retained after the thinning are much susceptible to the wind damage. Moreover the thinning ratio is

Table 2.4 Schedule of thinning for the current seedling seed orchard of A. mangium

Average height (m)	Thinning (high intensity)	Thinning (low intensity)
4.0 - 5.0		Within plot selection (3/4)
6.0 - 7.0	Within plot selection (2/4)	
8.0 - 9.0		Within plot selection (2/3)
10.0- 12.0	Within plot selection (1/2)	
13.0 - 14.0		Within plot selection (1/2)
15.0 - 16.0	Family selection	Family selection

Note) Regarding to within plot selection, the numbers in the parentheses are trees to be retained and those of before thinning.

generally higher than that commonly applied to the ordinary plantation. Therefore a careful choice of measures to reduce the damage is necessary at the time of execution.

This concern is especially true to *A. mangium,* because their rooting system seems to be not enough to support their stems and crowns against the strong wind. The seedling seed orchards of *A. mangium* established in South Kalimantan has received a repeated damage by wind, because they are locating only ten kilometers from the sea. In case of the orchard testing families from PNG, 35% of the retained trees were fallen down two months after the thinning with the ratio of 50%. On the other hand, the damage of Queensland origin was only 5% then.

There are two possible measures to reduce the damage by wind. The first one is to reduce the intensity of selection as proposed in Table 2.4. The reduction of selection intensity will reduce the damage, because the number of trees that are standing alone is decreased. The second measure is to conduct thinning shortly after the windy season. In this case, retained trees will have enough time to adapt themselves to the new environment, thus they will be more tolerant in the next windy season. The end of the rainy season is probably the best time for thinning in Indonesia, because wind damage will occur during November until February. In practice, the combination of the two measures would probably reduce the wind damage to an acceptable level.

3) Considerations on the schedule of measurement in relation with thinning

As mentioned in 2.2.2, measurement and thinning are regarded as a set of activities conducted together. Thus it is possible to say that the minimum frequency of measurement is equal to the frequency of thinning from the operational point of view. Besides those measurements before thinning, a measurement at around half year after planting might be necessary for the initial assessment of orchards. Although this measurement will not give much information, the average growth, survivals and experimental precision will give a good prospect on how to manage each of the seedling seed orchard subsequently; timing and intensity for thinning.

One of the basic constraints with seedling seed orchard is a trade off relationship between the thinning and accuracy of family ranking. Statistical accuracy of family ranking will become poorer, when the number of trees per plot is reduced by the thinning. According to the results of first thinning, family heritabilities of *A. mangium* dropped by 20% as compared to the values before the thinning, while those of *Eucalyptus* were slightly increased (FTIP No. 49; Annual report 1996). This contrasting result was probably due to the difference in the number of trees retained per plot on both species; two for *A. mangium* and three for *Eucalyptus*. An application of the thinning with low intensity or five-tree plot as *Eucalyptus* may reduce this constraint slightly.

2.3 Computerized data processing system

A data processing system being described here is a set of procedures to handle data using computers for the purpose of seed source evaluation; measurement, thinning and finally plus tree selection. Until now, manuals of the procedure had been compiled for the first two activities; measurement and thinning, as FTIP No.19 and No. 48, respectively. These manuals are essential to carry out this job quickly with consistency in data handling, because they are regarded as a routine work repeated several times in each of the seedling seed orchard.

2.3.1 Data processing system for measurement

This system was prepared to process the data collected from periodical measurement. It includes (1) field note preparation, (2) data check and calculation of plot mean, (3) analysis of variance & covariance and finally family ranking by selection index (See Fig. 2.1). Although details of the operations were described in FTIP No. 19, main points of the operations at each step are reviewed here.

(1) Field note preparation

Field note is prepared semi-automatically with BASIC program by using two data files generated at the time of establishment for each seedling seed orchard (See FTIP No.15). The resulting file will be used in two ways ; field note for measurement in the field as well as files for data-input after measurement. Since the form of field note and that of the data input file is the same, it is effective to reduce mistakes at data-input. Moreover it will make the subsequent data handling much efficient, because the format of the data is the same between the measurement at different time and location.

(2) Data check and plot mean calculation

Since miss typing of data is unavoidable when handling a large amount of data, the program to check unusual data on the graphic display was developed. Data correction is made by looking at the graphic screen. The file for plot mean will be output after finishing the revision of the mistyped data. Although the data check procedure adopted here may not be complete, this laborious job can be finished quickly as well as intuitively by using this system.

(3) Analysis and family ranking

Analysis of variance and covariance on each of the measured traits are made by BASIC program using plot-means. This program will result three files ; analysis of variance and covariance tables, parameters file estimated by the analysis and least square estimates for each tested family in the orchard. The latter two files are used subsequently for calculating selection index for family ranking. The results obtained here might be sufficient to make a preliminary report on each of the periodical measurement.

2.3.2 Data processing system for thinning

This system was developed also to manage the operational thinning in the orchards. It includes three stages of operations ; (1) preliminary selection for thinning, (2) recording the results of selection and (3) assessment on the results of the selection. Since the thinning is practiced based on the data collected by the periodical measurement, this system is regarded as a continuing part of the previous data processing system described in 2.3.1.

A flow of the operation is shown in Fig. 2.2. The operational procedure is given in FTIP No.48. An outline at each step of operation is as follows ;

(1) Prepare a map for preliminary selection

A map showing the result of preliminary selection is prepared based on the data from the previous measurement. This map is exactly the same as the trees planted in the field. Trees to be culled and those to be retained are designated by black circles and white ones, respectively. Thus the map will be used as a guide line for selection in the field. Moreover it could be used as a field note to record the results of the actual selection.

(2) Recording the results of selection

The result of selection recorded on the map will be input to the computer by using digitizer. This result is used for two purposes; revision of field note and analysis for an assessment of the selection. The field note will be revised by adding "-1" to the culled trees for the convenience at the later measurement. For the purpose of assessment, the result of selection, which is designated as 1 for retained trees and 0 for culled trees, is combined with the previous individual data file.

(3) Assessment on the result ofselection

Initial assessment of the selection is made with using individual data file prepared at the previous step. Analysis of variance is conducted in two ways; before selection and after selection. With this procedure, the changes in the population mean as well as those of genetic parameters are obtained on each trait. The change of family ranking is also examined by using the two files of least square estimates for each family. Further analysis for the assessment could be made by applying a retrospective selection index (FTIP No. 56) and it will be described in the subsequent chapter.

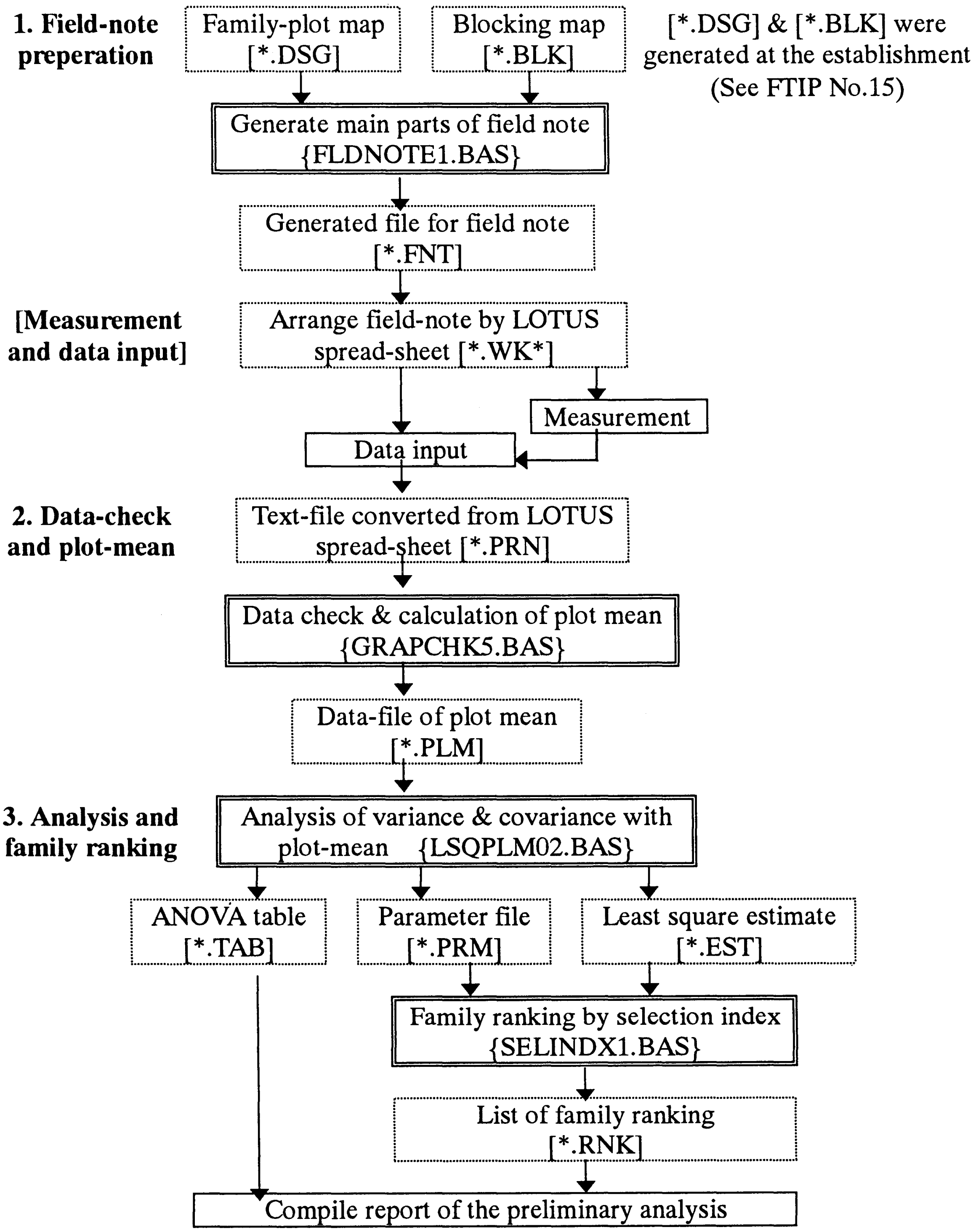
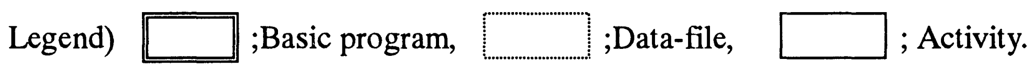


Fig. 2.1 Flow of the operations for the prekiminary analysis



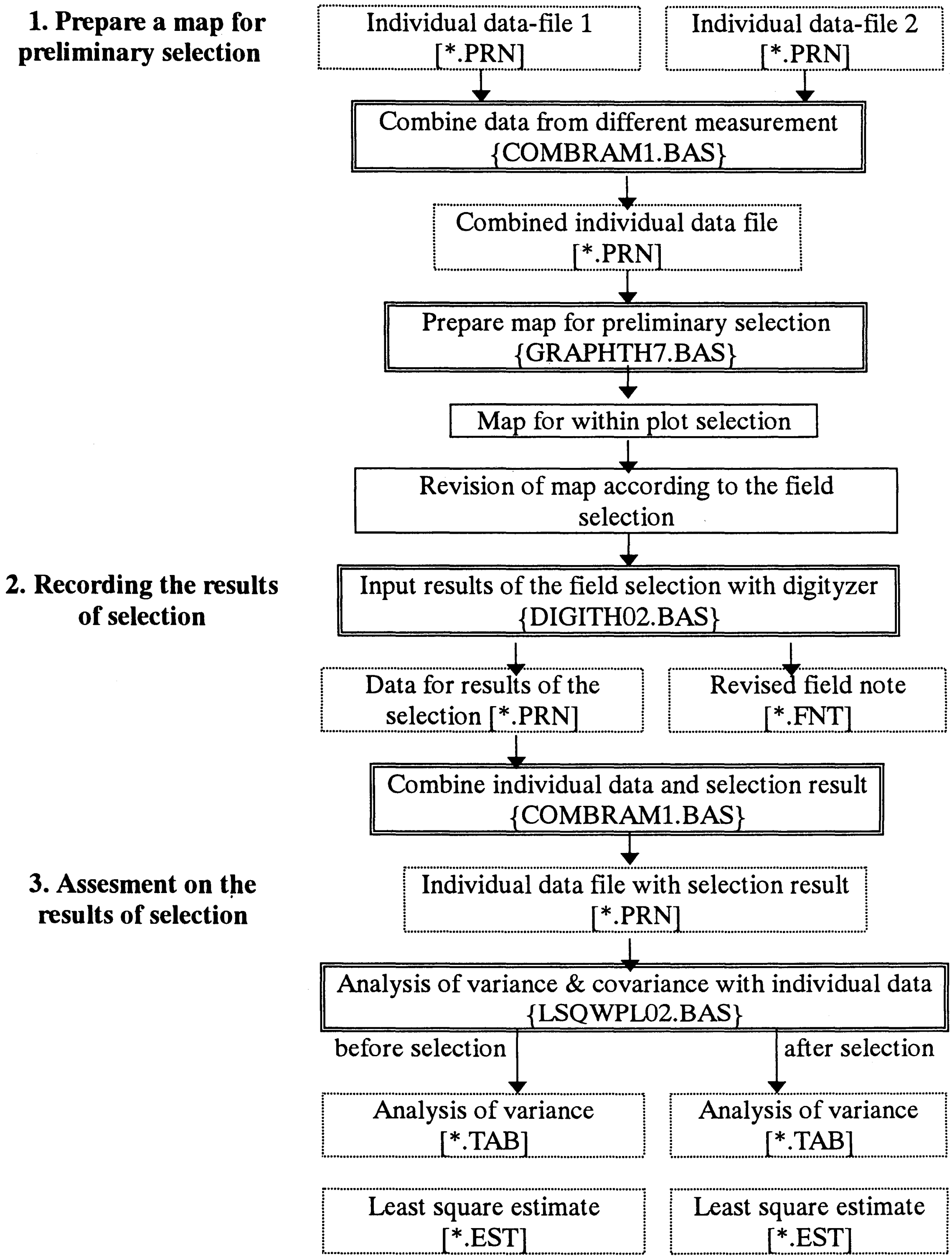


Fig. 2.2 Flow of the operations for data processing related to the thining

Legend) ;Basic program, ;Data-file, ; Activity.

2.3.3 Practical considerations on the computerized data processing system

(1) Data input and check

In the computerized data processing system, one of the essential parts but frequently neglected process is a data-input and data-check. It should be noted that most of the unusual results of the analysis are caused by a few of mistyped data or incompleteness of the data file. To reduce this type of mistakes, one program was prepared specifically for data-check (2.3.1-2), however, there are several different types of mistake that the program can not detect. Some of the typical examples are given as follows ;

1) Skipping of data due to an oversight at the measurement.
2) Inconsistency in the order of the measured traits.

These mistakes are detected frequently when the data at different times of measurement are combined. Thus it is recommended to give instructions to reduce this type of mistakes at the beginning of measurement. It is also necessary to let the technicians to know it when they are going to type data.

(2) Use of graphical aids

In this system, programs with graphic were adopted at several steps of operation; data-check and mapping for the preliminary selection, because it is intuitively easier to work with rather than those with row-column identification. This graphic system is controlled by the three values; row, column and position within plot as attached in the individual data file; "*.PRN". Thus it is a prerequisite to keep these three values to identify each individual in the orchards.

(3) Naming system for the file

One consistent procedure was used for the naming of files to understand the contents of files easily (See FTIP No.19 4.2). This naming system is composed of two parts; the part of 8 digit for name and 3 digits for extension. The 8 digit part is divided into three parts; the first 2 letters designates the species, next 3 digits is allocated to the serial number of the orchard of the species, then the last 3 is used to identify the months of measurement after planting (See Table 2.1). Regarding to the extension as indicated in Fig. 2.1 and Fig .2.2, "PRN", "TAB" and "EST" are individual data-file, result of analysis of variance and least square estimates of the families, respectively.

(4) Compatibility with IBM-PC

Since all the programs were coded initially by N 88-BASIC (Product of NEC corp.), compatibility of the programs to the IBM-PC is not enough (See FTIP No. 19 Appendix 2). All the programs using graphics have not been revised as yet applicable to IBM-PC at the moment. It may be necessary to revise those programs compatible to IBM-PC in the future.

2.3.4 Direction for the future development of the system

(1) Shortages with the current system and use of data base

There are two major practical shortages with the current system. The first one is that this system needs additional step to replace tentative code with FTIP code for family identification, when the analysis across the orchards is conducted. This is because the tentative code is only applicable within the respective orchards and it is not applicable across the orchards. Now the program to replace with FTIP code had been available, thus multiple site analysis is possible as long as the reference files are prepared from the seed information data base (FTIP No. 57 ; Agus and Hashimoto 1996). The second shortage is the lack of trait identification. As mentioned in 2.3.3, confusions of data with different traits sometimes occur during the data input process. If the trait identification is clearly defined, the frequency of this type of mistake may be reduced.

An introduction of data base function to the current system will probably solve above mentioned shortages. The introduction should be made step by step with retaining the basic properties of files in the current system, otherwise many of the practically important activities may be halted. This is because many of the convenient functions with the current system; data check, graphic function and statistical analysis, can not be replaced with the data base alone.

(2) Use of the popular soft-wares for analysis

In the research field of forest tree improvement, there are two soft-wares predominantly used for statistical analysis such as SAS or GENE-STAT. They are sufficiently flexible to analyze data with several different models, once the basic operational procedure is mastered. Moreover they will finish their computing much faster than those of ordinary BASIC programs. This is especially true when the model has become complex and it needs large size of matrices. Thus it is reasonable to use these soft-wares for the further analysis ; such as multiple site analysis.

An application of these soft-wares might be better to limit to the elaborate analysis, while the current system is used for the routine operation. This is because these soft-wares will not cover the entire operations that the current system is carrying out. Thus how to link the current system with these soft-wares would be a matter of consideration. Some of the programs that will prepare data files applicable to SAS were already compiled and they were put into practical use. In future, it seems to be necessary to develop this type of programs or procedures to meet the diversified needs of research.

(3) Use of the current system for another field of research

Now the seedling seed orchards established in the earlier phase of the project has reached the stage to provide materials for several different field of research. They are the research on growth, wood property, reproductive biology, vegetative propagation and molecular genetics. Although the procedures in each field of the research are different, the data in the current system will be the basis to choose materials or samples for their own research purposes. Moreover it is sometimes true that the procedures of analysis are directly applicable to some of the topics; such as those on growth, wood property, reproductive biology, because their ultimate purpose is tree improvement.

3. Major research results achieved during the current phase of the project

Major research results in the field of seed source evaluation are reviewed in this chapter. Since most of the topics here were already presented at several international conferences, it is suggested to refer to the original papers when further information is necessary. Original titles of the paper, authors, publications are given in the references.

3.1 Optimum design of seedling seed orchard to maximize gain

This study was conducted in 1993 when the project was going to start establishing seedling seed orchards. The original paper was presented at the workshop of BIO-REFOR held at Yogyakarta on September in 1993. The procedure to determine the design element for seedling seed orchard was given in FTIP No.15.

3.1.1 Purpose of the study

Purpose of this study was to establish theoretically derived criteria for designing seedling seed orchards to maximize genetic gains that are expected from the repeated thinning in the orchards. This is because the information on the optimum design for seedling seed orchard was limited when the project had started tree improvement by establishing orchards.

It should be noted that the design of the current seedling seed orchards was based on the results of this study. They are the choice on the number of trees per plot, number of families, initial density and size of the seedling seed orchard.

3.1.2 Outline of the procedure

Expected gains (ΔG) were calculated using the following formulae by changing several design elements of seedling seed orchard ; number of families, size of the orchard, number of trees per plot, replications, initial density and final density.

$$\Delta G = i_2 (1/4) \sigma_{A'}^2 / \sigma_2 + i_3 (3/4) \sigma_A^2 / \sigma_3$$

$$\sigma_2^2 = \sigma_t^2 / (n_2 r) + \sigma_P^2 / r + (1/4) \sigma_{A'}^2$$

$$\sigma_3^2 = \sigma_t^2$$

The key point in this study is to utilize the fact that the intensity of family selection will be calculated automatically once the number of trees per plot determined. A total selection ratio is calculated as n_f / n_i, when the initial density per hectare and that of the final stage are defined as n_i and n_f, respectively. When n_p is the number of trees planted per plot, the proportion of within plot selection is equal to $1/n_p$. This is because the within plot selection will leave only one tree per plot. Thus the proportion of family selection will become $n_f n_p / n_i$, because the total proportion of selection is the product of a ratio of within

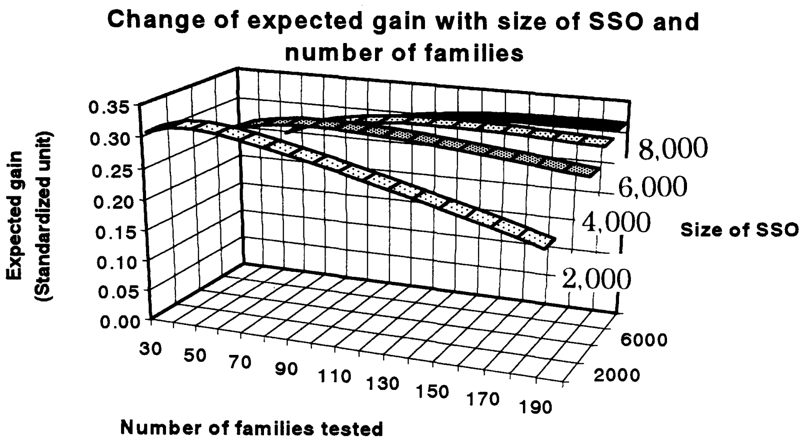


Fig. 3.1　Change of expected gains with size of SSO and number of families

plot selection and that of family selection.

The relative size of the three types of variances; family variance (σ_f^2), plot error variance (σ_p^2) and within plot variance (σ_w^2) were estimated from the regression equation derived from the trend of the variances on eight traits measured in provenance/progeny trials of *E. urophylla* in NTT (Oemi 1987).

3.1.3 Results

The results of this study were summalized in the following five items as follows;

(1) Number of families should match with the size of S.S.O. in order to attain maximum genetic gain.

Although the size of S.S.O. is not a primary factor to increase genetic gain, the optimum number of family does exist and it will increase in proportion to its size (Fig. 3.1). Thus the size of S.S.O. might be better to regard as a factor to be chosen depending on its purpose. If S.S.O. is established to supply seed to a wide range of environment, around hundred families with several thousands seedlings might be preferred to retain sufficient amount of genetic variation. On the other hand, when S.S.O. is established as a unit of subline (Nikles 1989), thirty to sixty families with few thousands of seedlings would be feasible.

(2) High initial density is recommended as long as the space for later evaluation is possible.

To adopt high initial density might be an effective choice to increase genetic gain. This is because the intensities of family selection and that of individual selection are primarily dependent on the ratio of the final density to the initial density (Fig. 3.2). Final density might be determined

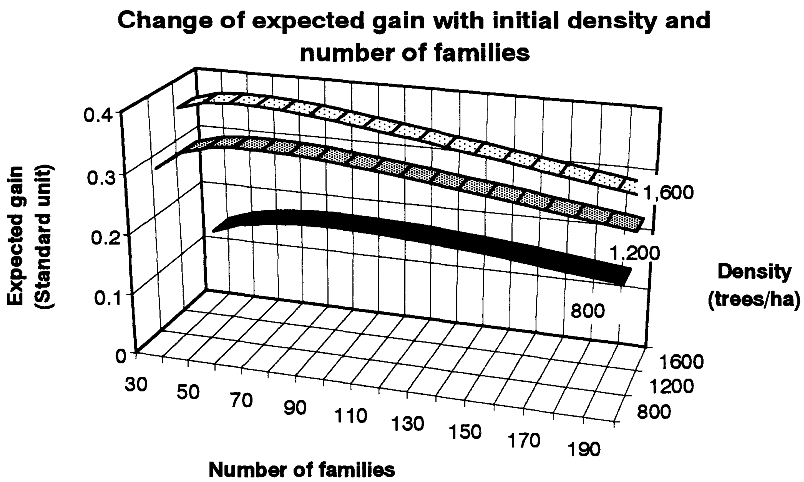


Fig. 3.2　Change of expected gains with initial density and number of families

Table 3.1 Optimum number of trees per plot under different number of replications and selection rate (%)

Number of blocks	Proportion of selection (%) 5.0	7.5	10.0	12.5	15.0	20.0	25.0
high heritability (0.24)							
6	8.34	6.42	5.31	4.58	4.05	3.34	2.88
8	7.68	5.92	4.93	4.28	3.80	3.16	2.73
10	7.16	5.58	4.66	4.06	3.62	3.01	2.62
12	6.82	5.31	4.46	3.89	3.47	2.91	2.53
low heritability (0.08)							
6	6.41	5.09	4.30	3.75	3.36	2.82	2.46
8	5.83	4.67	3.96	3.48	3.13	2.63	2.31
10	5.40	4.36	3.71	3.28	2.95	2.50	2.20
12	5.06	4.12	3.52	3.12	2.82	2.40	2.11

according to the biological characters of each species or it may be determined by the minimum requirement of seed production per unit area. On the other hand, the initial density can be increased as high as the space for the later evaluation is possible. A spacing of 3.0m × 1.5 m is recommended for several *Eucalyptus* species and *Acacia auriculiformis* (Harwood *et al.* 1993), which is twice of the density for the operational sylvicultural standard.

(3) The range of an appropriate choice of number of families becomes wider with the increase in the size of S.S.O. as well as the initial density.

The difference between marginal gains and the maximum will become smaller with the increase in the size of S.S.O.s as well as the increase in the initial density. This indicates that the choice of number of families becomes less important when S.S.O. is large with high initial density. On the contrary, when S.S.O. is small in size with low initial density, the number of families in S.S.O. should be determined with caution.

(4) Number of blocks may be determined based on an operational efficiency as long as testing and seed production purposes attained.

The increase in genetic gain with the increase in the number of replication was not large in this study. Thus it may be better to consider on an operational efficiency when we determine the number of replication in S.S.O. However, S.S.O.s has dual purposes; testing of family performances and seed production, both of which preferred many replications with smaller plots. It is generally accepted that less than six replications is not recommended even for a testing purpose (Bridgwater *et al.* 1983).

(5) Optimum allocation of materials would be determined by referring the two way table of total intensity of selection and number of replications.

As a result of this study, total intensity of selection and number of replications are regarded to be the main factors to affect genetic gain. Therefore, the two way table of the above mentioned two factors was prepared under the two contrasting heritabilities (Table 3.1). As the table will give an approximate estimate of an optimum number of families to maximize genetic gain, it would be possible to design S.S.O. adaptable to various situations.

3.2 Thinning in seedling seed orchards

This study was conducted in 1996 after the first within plot selection at South Kalimantan. The original paper was presented at QFRI-IUFRO Conference held in Queensland, Australia on October in 1996. The procedure applied in the paper was compiled as a manual of FTIP No. 56.

3.2.1 Purpose of the study

The purpose of this study was to develop the procedure to evaluate the result of thinning practiced as a within plot selection in seedling seed orchard. Within plot selection is conducted widely as a first step of selection work in the orchard, however, an appropriate procedure for its evaluation has not been well established yet. This is because the choice of trees for culling is largely depend on the breeders' preference or their intuitions. In this study, retrospective selection index was applied to the results of within plot selection in the orchards to examine the trend of selection as well as to assess its applicability.

3.2.2 Outline of the procedure

Results of selection were assessed in four seedling seed orchards established at South Kalimantan : two of *A. mangium* (Group A and C) and one each of *E. pellita* and *E. urophylla.* Thinning was practiced at 22 months of age by removing 2 poorest trees in each plot. Data used to evaluatethe selection were height, dbh and stem form at 20 months after planting for *Eucalyptus.* In case of *A. mangium*, multi-stem at 8 months, height at 16 months, and dbh, bole length and stem form at 20 months were used for analysis

Analysis of variance and covariance were made using individual data for the above mentioned traits (Harvey 1979), then variance and covariance components were calculated to use for the matrix elements for the derivation of selection index. Genetic parameters ; individual heritabilities, genetic correlations were estimated according to the ordinary procedures (Zobel and Talbert 1984). Retrospective selection index was derived using the following formula (Yamada 1977) ;

$$b_t = P_w^{-1} \times \Delta p_t,$$

where b_t, P_w and Δp_t are vector of coefficient of weight, a within-plot variance covariance matrix and vector of selection differentials, respectively. Then the coefficients were used in simulated selection to calculate total selection differential on each trait. Biserial correlation (r_b) was calculated using the following formula (Yamada 1977) ;

$$r_b = (I_s - I)/(I_q - I),$$

where I, I_s, and I_q are average index value of whole population, that of actually selected individuals and that of individuals with higher indicies, respectively. Expected gains by within plot selection ; (Δg_w) were calculated by the following formula (Hazel 1943) ;

$$\Delta g_w = G_w \times b_w.$$

where G_w and b_w are matrix of genetic variance and covariance within plot and a vector of coefficient of weight derived from the total selection differentials of within plot selection calculated by the simulated selection. Expected gains by family selection were calculated by the ordinary formula using the two sets of coefficients ; (1) the one derived by the retrospective selection index and (2) that assuming relative economic weight is equal to the inverse of standard deviation of each trait.

3.2.3 Results

(1) Genetic parameters

Heritabilities of *Eucalyptus* were generally high on all traits, while those of *A. mangium* were variable between groups as well as among traits (Table 3.2). Heritabilities of *A. mangium* on growth traits were high in group C, but much lower in group A. On the other hand, those on form traits in group A were moderate and compa rable to those in group C except for stem form. Regarding to within plot variance, the size of *Eucalyptus* were greater than those of *A. mangium* on height and stem form, whereas those on bole length of *A. mangium* were the greatest and almost the same size in both groups.

Within plot correlations of *Eucalyptus* were all positive among the three traits, while those

Table 3.2 Parameters related to within plot selection in seedling seed orchards.

Parameters And Traits	Mean	Heritability ±s.e.	Within plot variance	Mean	Heritability ±s.e.	Within plot variance
A. mangium (A)				*A. mangium* (C)		
Height	5.79m	0.06±0.04	0.3328	5.54m	0.47±0.11	0.2214
D.B.H.	8.99cm	0.10±0.04	1.7528	9.37cm	0.34±0.08	1.9403
Bole length	5.58m	0.14±0.05	2.8387	5.27m	0.22±0.06	2.8972
Multi- stem*	1.73	0.15±0.04	0.5697	2.15	0.14±0.05	0.5822
Stem form*	2.52	0.07±0.03	0.2800	2.58	0.56±0.11	0.1260
E. pellita				*E. urophylla*		
Height	5.75m	0.47±0.07	1.0692	6.85m	0.54±0.08	2.0628
D.B.H.	5.30cm	0.28±0.04	1.8205	5.65cm	0.18±0.04	2.5737
Stem form*	2.39	0.38±0.05	0.3850	2.31	0.48±0.07	0.3823

Note: Traits with * were assessed by subjectively with three grades; 3 for no need of singling until 1 for necessary singling on multi stem, 3 for straight until 1 for very crooked on stem form.

Table 3.3 Correlations among traits in the four seedling seed orchards.

Species	Traits					Traits				
Traits	height	d.b.h	bole length	multi-stem	Stem form	height	d.b.h	bole length	multi-stem	stem form
A. mangium (A)						*A. mangium* (C)				
Height	-	0.45	0.11	-0.02	0.12	-	0.58	0.13	0.08	0.01
d.b.h.	0.79	-	-0.01	-0.07	-0.15	0.81	-	-0.04	0.08	-0.08
bole length	-0.06	0.06	-	0.10	0.03	0.16	-0.25	-	0.07	0.11
Multi stem	0.41	0.32	0.95	-	0.10	0.16	0.01	0.37	-	0.05
Stem form	0.98	0.45	0.63	0.73	-	0.04	-0.16	-0.06	0.37	-
E. pellita						*E. urophylla*				
Height	-	0.738	-	-	0.345	-	0.799	-	-	0.379
d.b.h.	0.932	-	-	-	0.341	0.830	-	-	-	0.327
Stem form	0.652	0.638	-	-	-	0.505	0.377	-	-	-

Note : Correlations above diagonals are within plot correlation and those below diagonals are genetic correlations.

of *A. mangium* were generally weak except for the ones between height and d.b.h. (Table 3.3). This positive relationship among the traits of *Eucalyptus* was remained the same in their genetic correlations. On the other hand, the trend of genetic correlationsof *A. mangium* was slightly different between thetwo populations. That is genetic correlations of almost all of the combinations of traits were positive in group A, while those of group C seemsto be weak just like the same as those of within plot correlations. However, multi stem seems to have positive correlations with other form trait ; bole length and stem form in both populations. It suggests that multi stem and other form traitsmight be controlled by similar set of genes.

(2) Results on the application of retrospective selection index

Results of the application of retrospective selection index to the within plot selection is shown in Fig. 3.3. In the actual selection, selection differentials were found to be positive on all traits, among which those of bole length were the greatest in *A. mangium*, while those of *Eucalyptus* seem to be more uniform among the traits. This trend was also the same in the coefficients of weight derived as retrospective indicies on both species, however, the stem form

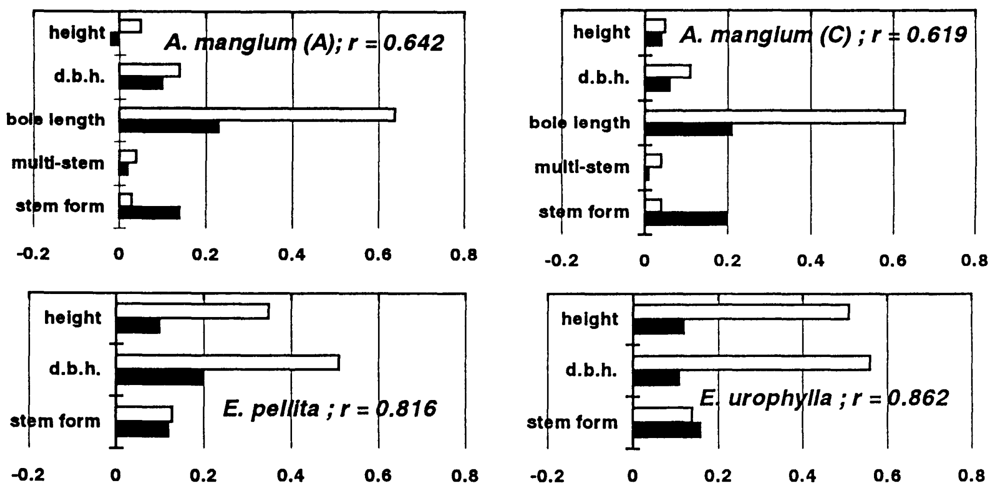


Fig. 3.3 Results from the application of retrospective selection index to within plot selection

Note) White bar shows the size of selection differential and the gray one shows the coefficients of weight in the index.

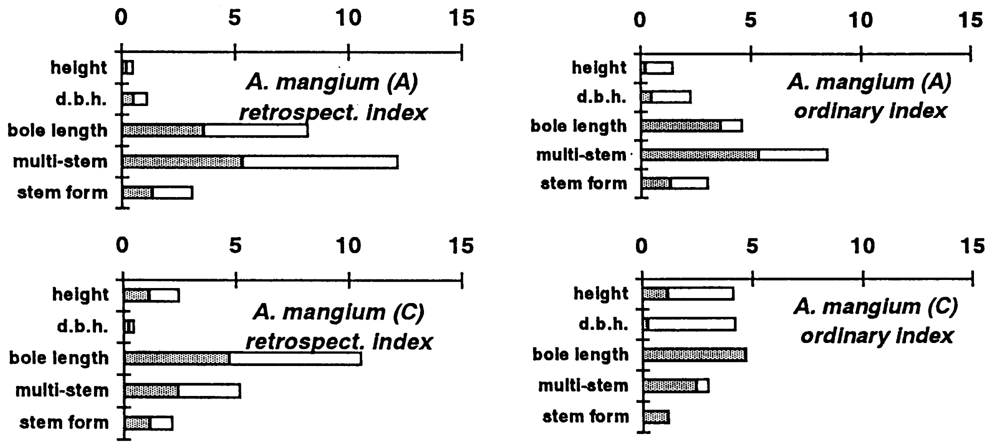


Fig. 3.4－a　Relative genetic gains (%) expected for *A. mangium*

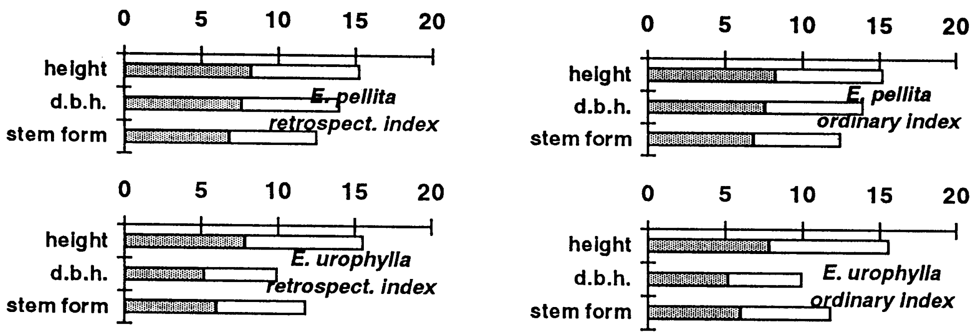


Fig. 3.4－b　Relative genetic gains (%) expected for *Eucalyptus*

Note) Gray colored parts indicate the gains by within-plot selection and white portions indicate gains by between-family selection.

received the second largest weight in *A. mangium*. It indicates that we put more emphasis on form traits rather than those of growth in the actual selection of *A. mangium*.

Biserial correlations of *Eucalyptus* well exceeded 0.8, while those of *A. mangium* were slightly above 0.6. It appears that the indices derived for *Eucalyptus* were well fitted to the results of actual selection, whereas those of *A. mangium* were not enough to explain the field selection completely. One of the causes of the incompleteness of those indices for *A. mangium* was due to the wind damage which occurred after the measurement, because some of the good trees had to be selected for culling due to their missing tops ; around 5% of trees were damaged by wind in both group A and group C.

(3) Expected gains

Expected gains for each of the seedling seed orchards are shown in Fig. 3.4. These are the relative gains from the total step of selection in the orchards; within plot selection and between family selection. Thus these gains will be expected additionally to the average values of original populations when the seedling seed orchards start seed production for operational use.

In case of *A. mangium*, improvement on the form traits is evident due to the intensive selection on bole-length and stem form at the stage of within plot selection (See Fig.3.4). This is especially true when the set of coefficients of retrospective selection index is applied also to the family selection. On the other hand, we can not expect much improvement for the growth traits. Improvement on growth traits seems to be less than 5 % even if family selection is practiced mainly on their growth performances.

Regarding to the gains in *Eucalyptus*, we can expect a more uniform improvement on the three traits (height, d.b.h. and stem form) regardless of the type of family selection. Moreover the relative amount of improvement are well exceeding 10 % on all traits, however, these expectation should be examined further from the aspect of out-crossing ratio of each species. This is because the estimates of genetic variances may be inflated due to the large difference in the out-crossing ratio between the families.

3.2.4 Conclusions

(1) An application of the retrospective selection index was proved to be useful for the assessment of within-plot selection. This is because the actual selection was quantified as a set of coefficient of weight for the previously measured traits.

(2) The gain of within-plot selection can be predicted by the retrospective selection index and it will be a basis for evaluating several alternatives of family selection in order to balance the total gain in the seedling seed orchards.

(3) In the actual selection of *A. mangium*, we found that the selection was practiced mostly on their form traits; bole length and stem straightness, while in case of *Eucalyptus* almost equal weights were allocated on three traits ; height, d.b.h. and stem form.

3.3 Gain predictions on stand volume productivity of improved seed produced in seedling seed orchard

This study was conducted in the late of 1996 after finishing the periodical measurement at 32 months of age in the oldest seedling seed orchards established in South Sumatra and South Kalimantan. The original paper for *A. mangium* was presented at the International Seminar held by FTIRDI and JICA at Yogyakarta on December in 1996, while that for *E. Pellita* has not been published.

3.3.1 Purpose of the study

The purpose of this study is to develop the procedure for predicting genetic gain on volume productivity at the end of rotation age using the currently accumulating data of measurement. In case of seedling seed orchard, it is impossible to measure the final volume gain in the trial, because the stand condition will be much different from the ordinary plantation after it is converted to the orchard for seed production purpose. Therefore rational procedure needs to be established to evaluate the potential of tree improvement to increase the forest productivity.

3.3.2 Outline of the materials and the procedure

The gain prediction was made in the following three seedling seed orchards ;

SSO of *A. mangium* : group A (PNG origin) with local selection in South Sumatra,

SSO of *A. mangium* : group C (QLD origin) in South Kalimantan,

SSO of *E. pellita* in South Kalimantan.

They were established on January in 1994. The data used for this study were the results of eight times of periodical measurements on height that were conducted at each four months until 32 months after planting.

Since the purpose of this study is to predict the gain in volume productivity at the harvest age, some sort of modeling work had to be done before the prediction. Main step of the modeling is summarized as follows ;

(1) Extrapolations of the height growth until the end of rotation age by growth functions which were derived from the data of periodical measure ment.

(2) Estimate time trend of genetic parameters on height by fitting regression equations to the estimates of variances and correlations using height as a independent variable.

(3) Calculate height growth of improved population as correlated responce using the equations obtained at step (1) and (2).

There are three types of improvement assumed in this study ;

1. Roguing in the seedling seed orchard,
2. Establish composite seedling orchard after selecting plus trees in the orchards,
3. Establish composite clonal seed orchards.

(4) Convert the height growth to the volume growth per unit area using previously published yield table for the two species.

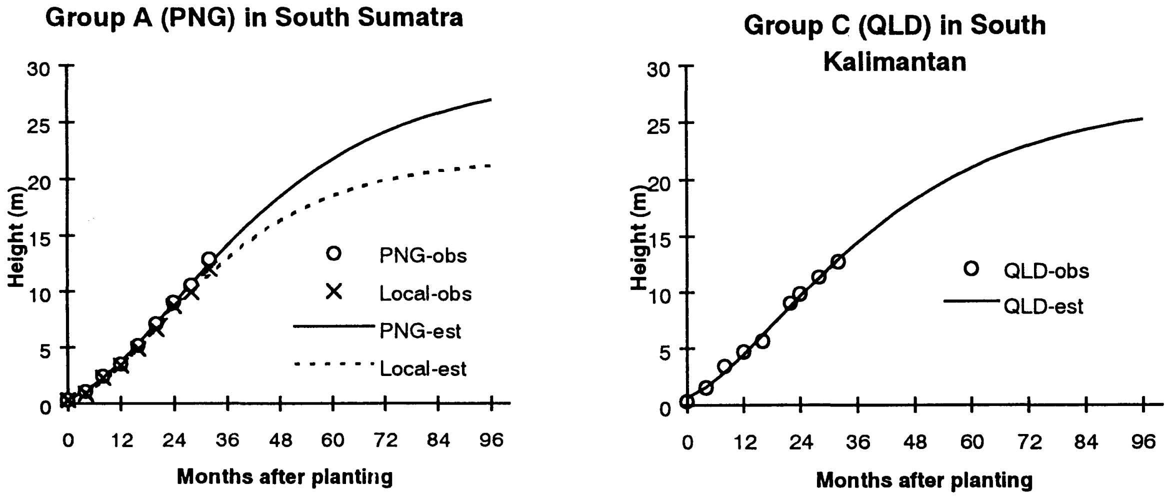


Fig. 3.5 Extrapolated height growth based on the results of periodical measurement

3.3.3 Predicted results on *A. mangium*

(1) An extrapolation of the height growth

The result of fitting growth curve and future projection is shown in Fig. 3.5. In South Sumatra, periodical increment of height growth had reached maximum at around two years of age and it is decreasing slightly, whereas the trend of periodical increment in South Kalimantan seems to be not clear until now. The growth in South Kalimantan was apparently faster in the past 2 years, however, the current height is almost the same due to the steady growth in South Sumatra. This is not due to the difference of seed origin, because another populations from PNG or QLD also showed the same trend of growth in both locations. Thus the trend of growth in the respective location might be better to regard as reflections of local environment on both locations ; climate, soil or sylvicultural treatment.

Expected height growth projected by Richard's function (Richards 1959) will reach around 25 m at age 8 for both South Sumatra and South Kalimantan, whereas the height of local selection will be slightly greater than 20m. According to the yield tables compiled in Malaysia (Inose 1992), expecting height of PNG and QLD used in the seedling seed orchards are the same or slightly above the first site class, while the one of local selection is almost the same as the second site class. Considering the past trend of growth obtained by the periodical measurements, difference in the height is getting greater now, thus the projected result here may be not far from the reality in the future.

(2) Time trend of genetic parameters

The four types of variances (total phenotypic variance, within plot variance, family mean variance and family variance) were regressed to the average height. All linear equations between the average height and the square root of the variances were fitted well, showing their correlation coefficients exceeding 0.95. Regarding to the family-mean correlation, trend of the decline was well expressed by the function using height ratio as independent variable (Kurinobu and Arif 1996). Therefore all the genetic parameters can be re-estimated by these equations using height as an independent variable.

Time trend of genetic parameters assuming 8 years of rotation were drawn as in Fig. 3.6. Although there are minor differences in both populations at the initial stage, four genetic parameters seem to follow the same trend of change. That is (1) the correlation increases rapidly in the beginning starting from around 0.5 then it exceeds 0.9 at around 3 years before the final age, (2) relative order of three types of heritabilities is the same ; family mean heritability is around 0.5 then followed by within plot heritability ranging around 0.4 and individual heritability is settled at around 0.3. The trend of heritability estimated here may be slightly optimistic in terms of the absolute size, but the trend is well agreed to the actual result of Loblolly pine (Balocchi *et.*

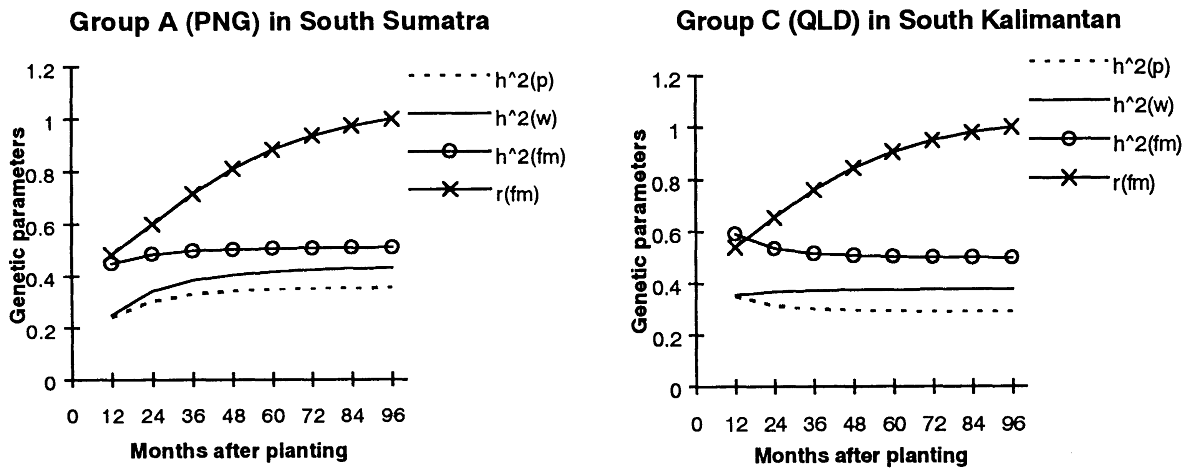


Fig. 3.6 Time trend of genetic parameters assuming 8 years of rotation

Note) h^2(p), h^2(w), h^2(fm) and r(fm) are heritabilities for single tree, within plot, family mean and family mean correlation coefficient, respectively.

al. 1993).

(3) Expected volume productivity by improved seed in the seedling seed orchard

A summarized result of volume prediction is given in Table 3.4. According to the realized selection differentials in the first roguing, selection intensity on height was estimated 0.11 and 0.20 for group A and group C, respectively. Thus the expected selection differentials by the three stages of selection in those orchards will amount to 1.2 m in both populations and it will bring around 0.5 m of net increase in height for the improved seed. Therefore the effort of improvement in the currently established orchards would bring 5% of increase in volume productivity as compared to the productivity of non selected populations in the orchards.

A potential gain by choosing good provenances proved to be quite large when the diffrence in the height growth between the local selection and PNG population in South Sumatra was converted to the stand volume (Table 3.4 and Fig. 3.7). PNG population was estimated to be 70% greater than the local selection in volume productivity at age 8. According to the trial in Riam Kiwa, Claudi River in Queensland was 60% to 100% greater than Subanjeriji (≃ Local selection) in volume productivity at age 5 (Vuokko 1992). In this study, the superiority of PNG population at the same age is around 40%, then the relative productivity is getting greater until the assumed rotation age (See Fig. 3.7). Therefore the gain in volume productivity projected here seems to be realistic and it indicates the tremendas importance to choose good provenance as a base population for tree improvement.

(4) Potential gains for the next step of tree improvement

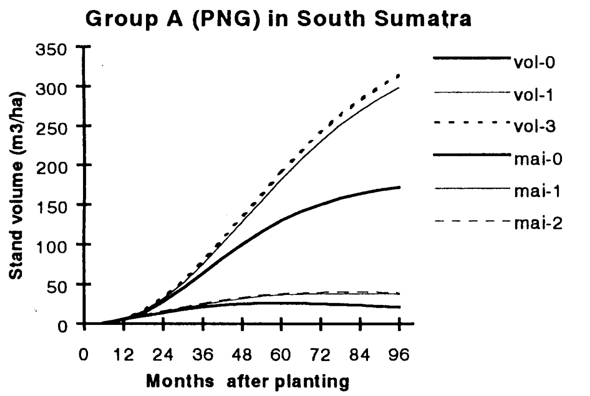
Repetitions of breeding cycle; selection, seed production and mating, is essential to enlarge the gain by tree improvement, because the gain obtained by each generation is accumulative even after most of the potential provenances have been exploited for tree improvement. This is especially true for the tropical fast growing species, because a rapid turn over of generation (3 to 5 years per generation) is possible for many of these species due to their early flowering habit. For this reason, expecting gains to be realized in near future by our current tree improvement program was estimated with some of the realistic assumptions (Table 3.4).

Expecting gains given in Table 3.5 are those to be realized when seed production population is established as a composite seedling seed orchards (Comp.-SSO) or composite clonal seed orchard (Comp.-CSO). In these orchards, open pollinated seed or vegetative propagules collected from the best plus trees from the top 10 families in each of the subline will be used together to produce

Table 3.4 A summary of the stand volume prediction after roguing in the two seedling seed orchards

Location / Population	Height at 32 months	Selection in SSO: Intensity	Selection in SSO: Differential	Estimate at 8 years old: Height	Estimate at 8 years old: Volume	Estimate at 8 years old: MAI	Gain (%): Rate	Gain (%): Total
South Sumatra	(m)			(m)	(m^3/ha)	(m^3/ha/year)		
Local selections	12.01			21.2	172	21.5		
Group A (PNG)	12.87	i_1=0.11, i_2=0.5, i_3=0.7		26.9	298	37.3	73.3	
Group A after roguing		26.8 m → 28.0 m		27.4	314	39.2	5.2	78.5
South Kalimantan								
Group C (QLD)	12.73	i_1=0.2, i_2=0.5, i_3=0.7		25.2	255	31.9	48.3*	
Group C after roguing		25.1 m → 26.3 m		25.7	268	33.4	4.9	53.2*

Note) *; Ratio calculated by assuming the volume productivity is the same in both orchards.



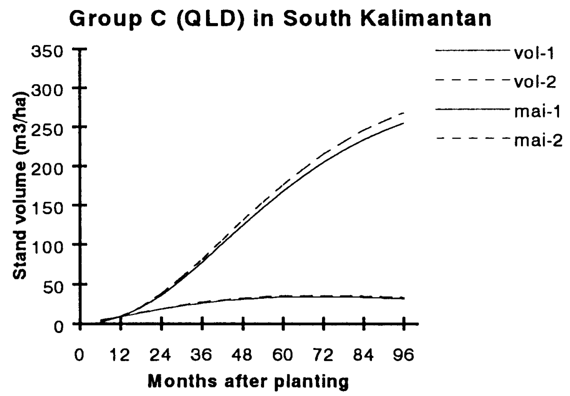


Fig. 3.7 Expected stand volume growth and mean annual increment of improved seed

out crossed seed.

The amount of improvement compared to the initial population of the current seedling seed orchard is around 15% for clonal seed orchard, while the gain in seedling seed orchard would be slightly lower as 12% on account to the smaller selection intensity on male parents (Shelbourne 1992). Additional gain is still possible due to the three reasons. The first one is the increase in the chance of out crossing. The second reason is the roguing based on the progeny trials in breeding population or forward selections in seedling seed orchards. In addition to these posibbilities, intensity of individual selection could be increased also, because each subline is tested in several locations. Therefore the expecting gains given in Table 3.5 is better to regard as conservative estimates going to be realized in these ten years, if the current tree improvement program is continuing successfully.

(5) Conclusion on the expecting volume productivity of improved seed for *A. mangium*

1. Provenance populations currently used in the seedling seed orchards proved to be much productive; more than 50% to 70% greater in stand volume as compared to that of the local plus trees selected in Subanjeriji.
2. Roguing in the orchard before the seed production will add another 5 % of increase in volume productivity.
3. Continuation of tree improvement by establishing composite seedling seed orchard or clonal seed orchard will bring 12 to 15 % of additional increase in volume productivity.

3.3.4 Predicted results on *E. pellita*

E. pellita is a relatively new species being recognized as one of the most promising *Eucalyptus* for industrial plantation programs in the low-land tropics (Eldlidge 1994). For this reason, yield table for this species has not been compiled yet due to its short history of domestication. However, the result of the spacing trial of *E. urophylla* in Brazil is now available (Laercio *et al.* 1977). Thus the prediction was made based on the result of that trial with the data of periodical measurement in South Kalimantan.

Table 3.5　Expecting gains to be achieved in the next step of tree improvement

Options	South Sumatra (PNG) height (m)	Stand-vol. (m^3/ha)	MAI (m^3/ha/yr.)	South Kalimantan (QLD) height (m)	Stand-vol. (m^3/ha)	MAI (m^3/ha/yr.)	Remarks
Original-SSO	26.9	298	37.3	25.2	255	31.9	Initial pop. Before roguing
Comp.-SSO	28.1 4.5%	333 12.4%	41.7	26.4 4.8%	285 13.1%	35.6	best ind. from top 10 family
Comp.-CSO	28.4 5.6%	342 15.5%	42.8	26.6 5.6%	291 15.6%	36.4	best ind. from top 10 family

(1) An extrapolation of the height growth

The result of fitting growth curve by Richard function (1959) and its extrapolation is shown in Fig. 3.8. Average height in the orchard had exceeded 10 m at 32 months after planting. Although the trend of decline in the height growth has not been clear until now, their periodical increment reached the maximum at around two years of age then it is declining slightly. According to the projected growth, average height is expected to reach 20 m at the end of rotation age.

(2) Estimated time trend of genetic parameters

As in the case of *A. mangium*, time trend of genetic parameters was derived from the results of analysis of variance and covariance which were made at each of the periodical measurements (Fig. 3.9). In case of *E. pellita*, coefficient of relationship for open pollinated family was set to be 2.5 instead of 4.0 due to their low out crossing rate (House and Bell 1996). Three types of heritability were higher than those of *A. mangium* in spite of the smaller coefficient of relationship. Moreover the family-mean correlation is higher also as compared to that of *A.mangium*. This indicates that the tree improvement is quite effective in improving the growth for *Eucalyptus*.

(3) Relationships for stand volume prediction derived from spacing trial of *E. urophylla*

As described in the above, some of the essential relationships for stand volume prediction were derived from the spacing trial of *E. urophylla* in Brazil (Laercio et al 1977). They are the relationships on height-d.b.h., d.b.h.-density and single-tree volume. Height-d.b.h. relationship was expressed successfully by linear regression equation with correlation coefficient of 0.987. Another two relationships were also derived successfully as shown in Fig. 3.10. However, the equations here are better to regard as tentative ones for the convenience of prediction in this study.

(4) Expected gain on volume productivity by improved seed of *E. pellita*

Height of improved seed in the seedling seed orchard of *E. pellita* is expected to increase by 13.5% due to the three stages of selection, which is 2.6m increase from 19.6m on absolute scale (Fig. 3.11). This amount of improvement is much greater than that of *A. mangium*. There are three reasons to support this result of prediction. The first one is due to the higher heritabilities and age-age correlations as observed in (2) of 3.3.4. The second one is that more intensive selection is likely to be practiced on growth trait at the within plot selection as found in 3.2. The last one is due to the higher selection intensity in the orchard ; selection rate is 9 % for *Eucalyptus* while 12% for *Acacias*.

This amount of increase in height will bring around 26% of increase in stand volume for the improved seed in the seedling seed orchard of *E. pellita* (Fig. 3.11). This means that the currently expected volume of 137㎥/ha will be increased up to 173㎥/ha after finishing the thinning in the orchard. However, the stand volume for *E. pellita* estimated here is far below the expected amount of *A. mangium* planted under the similar environment ; 268㎥/ha (See Table 3.4). Thus it may be concluded that *E. pellita* has a good potential to increase in volume productivity by tree improvement, but it is not so much productive as compared to that of *A. mangium* at the moment.

3.4　Analysis on G × E interaction for family evaluation

There were two papers studying on this topic, both of which were prepared by Ir. Arif ; the counter part of seed source evaluation. The first one was conducted in 1994 after finishing the

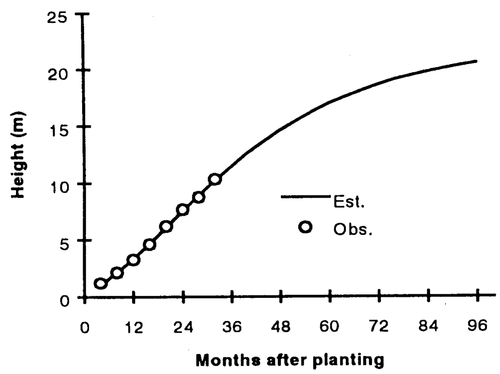


Fig. 3.8 Projected height growth based on the results of periodical measurement in South Kalimantan

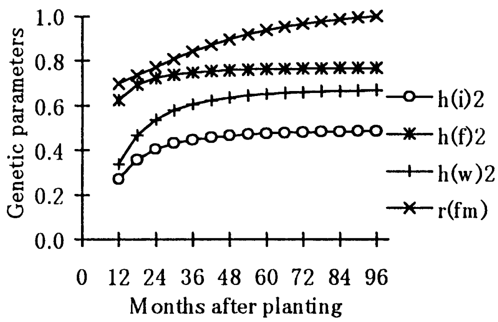


Fig. 3.9 Time trend of genetic parameters assuming 8 years rotation in South Kalimantan

measurements in three provenance／progeny trials of *E. urophylla*, then the result of the analysis was presented at QFRI-IUFRO Conference in 1996. The second one was conducted in 1996 after collecting data in seedling seed orchards of *A. mangium* established in South Sumatra and in South Kalimantan. It was presented at the Inter National Seminar held by FTIRDI and JICA at Yogyakarta in 1996.

3.4.1 Purpose of the study

The purpose of this study is to assess the magnitude of genotype by environment interaction to the expected gain by selection. This is because the result of selection at certain environment is not applicable to another environment when this type of interaction is large (Zobel and Talbert 1984). In that case, stratification of the testing environment or an application of selection that includes stability parameter would be preferred instead of using the selection under the single environment (Shelbourne 1972). Thus results of this study would be an essential information in determining seed transfer zones or plus tree selection being conducted in near future.

3.4.2 Outline of the procedure

A basic procedure applied in both of the studies is almost the same and it is summarized as follows ;

(1) To conduct analysis of variance using plot-mean at each of the test as well as across the test to estimate family variance components and family×site interaction variances.

(2) To calculate type B correlations (Burdon 1979), then they were used to derive covariance elements of the off-diagonal blocks (G_{f12}) in the variance covariance matrix across the tests.

(3) To derive coefficient of weight for selection index for single test as well as those for across the tests using the following formulae ;

selection index for single test ;

$b_s = P_f^{-1} \times G_f \times a_s$.

selection index for across the tests ;

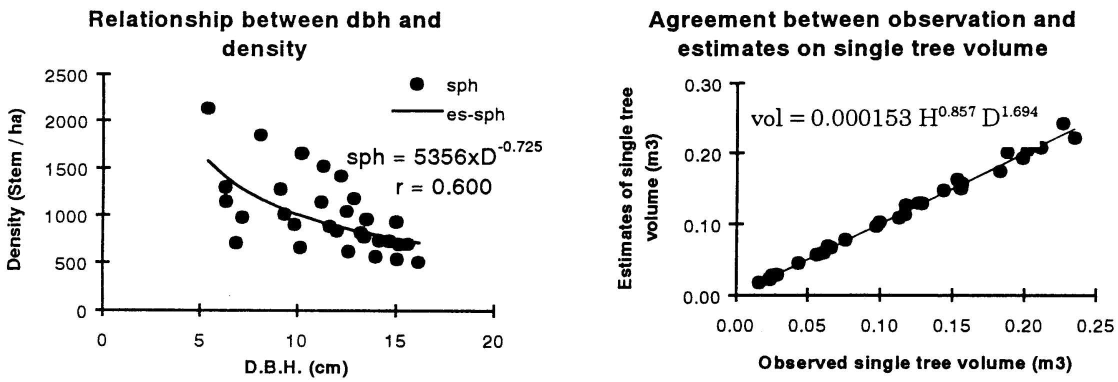
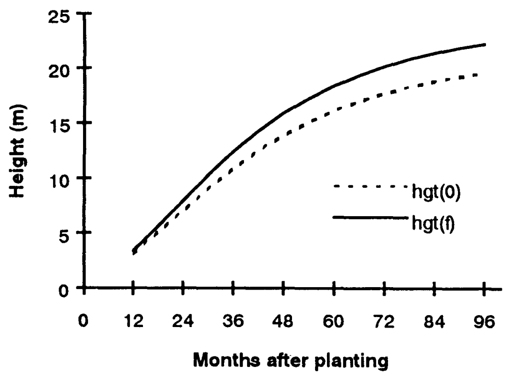
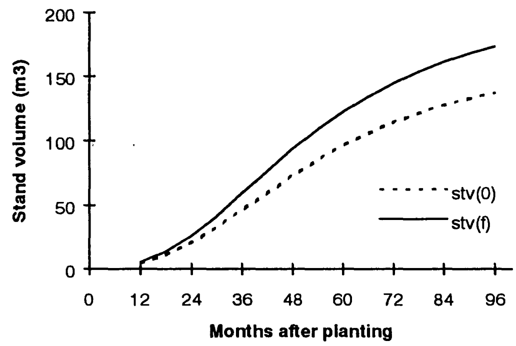


Fig. 3.10 Relationships for stand volume prediction derived from spacing trial of *E. urophylla*



Height growth



Volume growth

Fig. 3.11 Expected growth of improved seed in seedling seed orchard of *E. pellita*

$$b_m = \begin{vmatrix} P_{f1}\cdot & G_{f12} \\ G_{f12}\cdot & P_{f2} \end{vmatrix}^{-1} \times \begin{vmatrix} G_{f1} & G_{f12} \\ G_{f12} & G_{f2} \end{vmatrix} \times \begin{vmatrix} a_1 \\ a_2 \end{vmatrix}$$

(4) To predict genetic gain in each of the test as well as those of across the tests by selection indicies ;

$$\Delta g = G_f \times b / (b' \times P_f \times b)^{1/2}$$

(5) To calculate actual family ranking in order to check the conclusion derived from the results of gain prediction.

3.4.3 Results on the provenance progeny trial of *E. urophylla*

(1) Provenance progeny tests analyzed in this study

The provenance-progeny tests used in this study were established in 1983 at Central Java and in 1984 at Nusa Tenngara Timur. Around 100 open-pollinated families from five provenances were tested at each trial, among which 98 families were common to both trials. At around ten years after the establishment, measurement was conducted on three traits: height, d.b.h. and bole length, in both tests.

(2) Outlines of the results

Family heritabilities at each test were moderately high on all traits, whereas those on growth traits across the tests were lower ; less than 0.5 (Table 3.6). This is due to the strong family × site interactions, the magnitudes of which were almost twice of the family variance components. However, the interactions estimated heremight be inflated by large differences in the size of genetic variances between the tests (Yama da 1962), because family variances at Central Java were five times greater than Nusa Tenngara Timur.

Phenotypic correlations among the traits were all positive and type B correlations were moderately high. The type B correlations on height, bole length, and d.b.h. were 0.52, 0.61, and 0.49, respectively.

Table 3.6 Estimates of variance component and family heritability by single test and across tests

Locations	Traits		
	Height (m)	bole length (m)	d.b.h. (cm)
Nusa Tenngara Timur			
Mean	10.03	3.83	11.16
Family var. components	0.978	0.540	1.182
Family-mean heritability	0.681	0.706	0.612
Central Java			
Mean	16.70	7.13	17.50
Family var. components	5.239	0.986	5.527
Family-mean heritability	0.675	0.410	0.612
Across locations			
Family var. components	0.757	0.607	1.088
Family x site interaction	1.901	0.211	1.755
Family-mean heritability	0.331	0.620	0.405

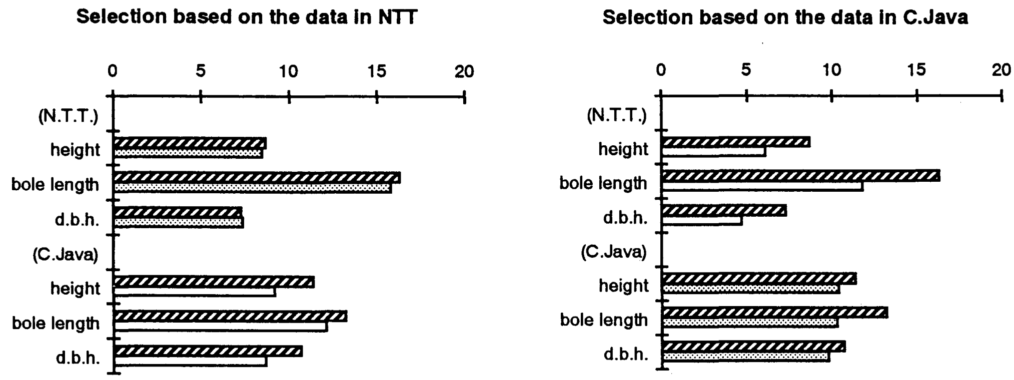


Fig. 3.12 Relative gains predicted by selection index across tests (bar with slanting lines) and those at each test (bar colored with gray). White bars are correlated responses at another test.

Genetic correlations derived from the type B correlations were sufficiently high to indicate an effective application of selection index to combine information from both tests. As a result, relative gains predicted by the selection index across the tests were slightly greater than those of the indices at each test on almost all the traits (Fig. 3.12).

Therefore it might be concluded that data from the two tests would be better to be used together in the form of selection index to conduct more accurate family selection. This conclusion can be partially confirmed by the fact that around eighty percent of the top forty families ranked by the index across the tests were also selected by the indices at each test. 35 families and 30 families were selected in common at Nusa Tenngara Timur, and at Central Java, respectively.

3.4.4 Results on the seedling seed orchards of *A. mangium*

(1) Seedling seed orchards analyzed in this study

The four seedling seed orchards analyzed here are two sets of orchards: namely group A

Table 3.7 Eatimates of variance components and family heritabilities by single orchard and across orchard

Location	Group A (PNG) height (m)	Group A (PNG) d.b.h. (cm)	Group A (PNG) stem straightness	Group D (QLD) Height (m)	Group D (QLD) d.b.h. (cm)	Group D (QLD) stem straightness
South Sumatra						
Mean	5.11	5.87	2.67	5.05	5.56	2.68
Fam.var.component	0.0226	0.1036	0.0132	0.0053	0.1367	0.0059
Family-mean heritability	0.467	0.620	0.337	0.069	0.424	0.182
South Kalimantan						
Mean	5.78	6.605	2.458	5.22	6.28	2.56
Fam.var.component	0.0045	0.0188	0.0045	0.0470	0.0548	0.0148
Family-mean heritability	0.184	0.344	0.472	0.554	0.445	0.540
Across the orchards						
Fam.var.component	0.0036	0.0255	-	0.0235	0.0245	0.0134
Family × site interaction	-0.0012	0.0084	0.0100	0.0091	0.0259	-0.0017
Family-mean heritability	0.248	0.480	-	0.809	0.270	0.638

(PNG seed origin) and group D (QLD seed origin). Each set was established in South Sumatra and in South Kalimantan. Around 60 families were tested in these orchards, among which 58 families were used in common for group A and 54 families for group D. Measurements were conducted at 16 months after planting on three traits; height, d.b.h. and stem straightness.

(2) Outline of the results

Single-site family heritabilities on d.b.h. were moderately high in both orchards, while those on height and stem straightness were variable depending on the group and the orchard (Table 3.7). Family heritabilities across the orchards are also variable ranging from high (0.809 on height in group D) until negative (stem straightness in group A).

Estimated family site interactions were smaller on four traits out of the six analyzed here. Negative estimates of the interactions (height in group A and stem straightness in group D) may be due to the large experimental errors, because family heritabilities at each one of the orchard were extraordinary low (0.184 on height at S. Kalimantan of group A and 0.182 on stem straightness at S. Sumatra of group D). On the other hand, family heritabilities on the traits showing relatively large interaction are moderately high (stem straightness in group A and d.b.h. in group D).

Although differences in the heritabilities could not be explained clearly, each two trait was arbitrary chosen to calculate selection indices so that any of the family correlation among the selected traits will not exceed 1.0. This is because poor estimates of genetic parameters, especially the covariances will be a cause of unrealistic prediction result (White and Hodge 1989). Traits used for the selection index are height and d.b.h. for group A and d.b.h. and stem straightness for group D. The results of gain prediction for each group were shown in Fig. 3.13.

Expected gains by selection indices across the orchards are slightly smaller (group A) or even

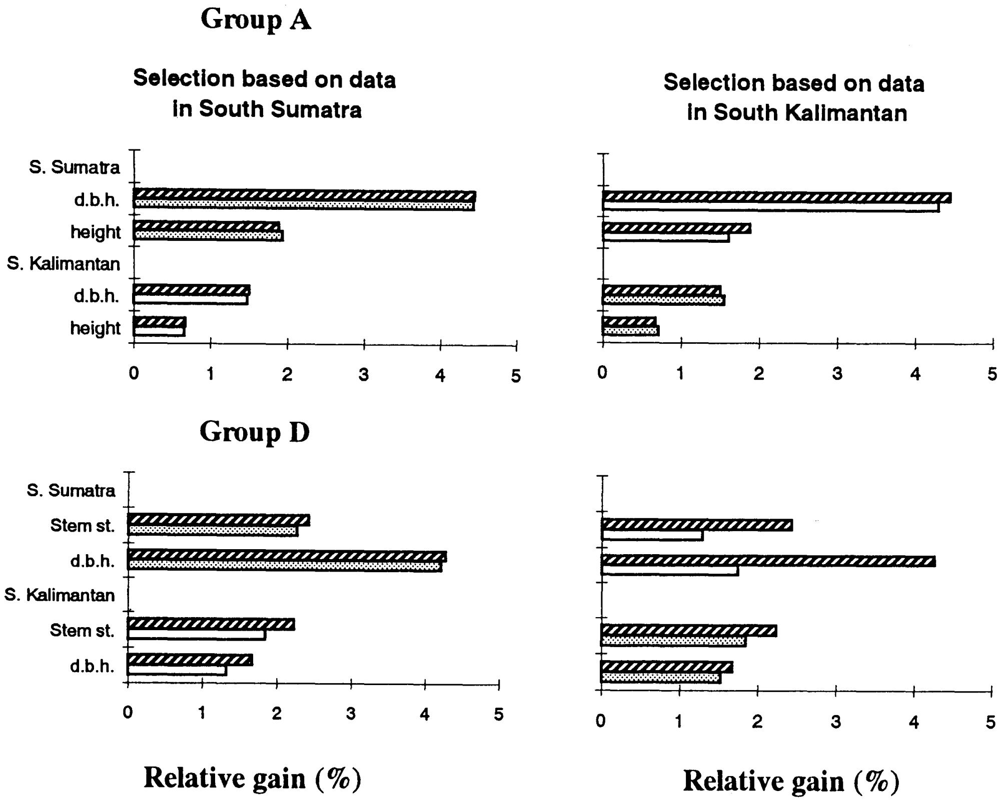


Fig. 3.13 Relative gains predicted by selection index across tests (bar with slanting lines) and those at each test (bar coloered with gray). White bars are correlated responses at another test.

greater (group D) than the gain by direct selection in each of the orchards (Fig. 3.13). This indicates that the family × site interaction between South Sumatra and South Kalimantan is not so strong that it will reduce the effectiveness of selection indices across the orchards.

To check the results of predicted gain, two types of indices; index of the respective orchards and that of across the orchards, were calculated for each family. In group A, the correlation coefficients between the indices across the orchards and these at each orchard were 0.921 for South Sumatra and 0.702 for South Kalimantan. The correlations in group D were slightly lower as 0.813 for South Sumatra and 0.652 for South Kalimantan. Thus the indices across the orchards seem well reflect the results in South Sumatra but less agreed with those in South Kalimantan, even though the expected gains are almost the same.

Regarding to an application of multiple-site selection index, further investigation is necessary for *A. mangium*. This is because the results of predicted gain here did not clearly support the advantages of multiple-site index selection. This is also true in the result of correlation analysis, because the correlations were not sufficiently high to guarantee the similar result of family ranking in both of the orchards. It may be better to apply single-site selection index for each of the orchards to maintain wide genetic variation, because more families would be retained than those by multi-site selection index. From the technical point of view, more clear results might have been obtained if genetic parameters were estimated by pooling the results of analysis in the two populations.

3.5 Choice of selection strategies

This study was conducted in 1994 when the project was establishing seedling seed orchards extensively under the scheme of recurrent selections with open pollinated mating as described in 1.1. The original paper was presented at CRC-IUFRO Conference held at Hobert in Australia on February in 1995.

3.5.1 Purpose of the study

The purpose of this study is to evaluate possible options of selection strategies by their cumulative gains and inbreeding which are obtained by simulations on five generations of selection and mating. Recurrent selection with open pollinated mating is widely applied to the tree improvement programs for the tropical fast growing species due to its practical feasibility (Franklin 1989).

Table 3.8 Type of selections examined in the simulation study

	Type of selection	Selection method and its intensity: Female parent	Selection method and its intensity: male parent
1	Mass selection with CSO	Mass selection [p / (40×p)]	same as female
2	Within family selection with CSO	within family selection [1 / 40] per each family	same as female
3	Mass selection in SSO without family selection	Mass selection [p / (40×p)]	within plot selection [1 / 8] per plot
4	Mass selection in SSO with family selection	mass selection with [1/20] for top 50% families	within plot selection with [1/4] per plot for top 50% families
5	Index selection in SSO with family selection	index selection with [1/20] for top 50% families	within plot selection with [1/4] per plot for top 50% families
6	Within family selection in SSO with family selection	within family selection with [1/20] for each top 50% families	within plot selection with [1/4] per plot for top 50% families
7	Simple mass selection in seed stand	Mass selection [p / (40×p)]	mass selection with [1 / 8] per site

Note) Selection ratios are given in [ ] as a form; number of selections / population for selection in which p is the number of plus trees per generation.

Table 3.9　Simulation model used in the study

Values generated in the simulation	Formulae to generate values
Mating and selection in the first generation	
Breeding value of plus tree;	$G_0 = g[i\times h^2, \sigma_A{}^2]$
Breeding value of the progeny;	$G_1 = G_0/2 + g[0, (3/4)\times\sigma_A{}^2]$
Phenotypic value of the progeny;	$P_1 = G_1 + e[0, 1 - h^2]$
Mating and selection in the successive generations	
Breeding value of the progeny;	$G_{n+1} = (G_{nf} + G_{nm})/2 + g[0, (1-F)/2\times\sigma_A{}^2]$
Phenotypic value of the progeny;	$P_{n+1} = G_{n+1} - b\times F + e[0, 1 - h^2]$

Note) g[ ] and e[ ] are the random values generated by normal distribution having mean and variances given in the [ ]. b is the coefficient for inbreeding depression. 2.0 is used as b by assuming 25% as coefficient of variation in progeny population and 5% reduction with the increase of 0.1 of F.

However, there is a serious concern with this selection strategy, because the progress of inbreeding is regarded to be much faster than that of the strategy with controlled pollinated mating (Griffin 1989). Therefore relative merits of several selection options should be examined in relation with its expected gain as well as expected progress of inbreeding before the actual execution of the selection strategy.

3.5.2 Outline of the procedure

In this study, seven selection options were examined assuming heritability of 0.20 at three levels of population size ; 20, 40 and 60 plus trees per generation. The seven options of selection are given in Table 3.8. To obtain a comparable result among the option, the selection rate of plus trees are set to be 2.5% through out of the seven options, whereas intensities of selection on pollen parents were different between options with CSO and that with SSO ; 2.5% for CSO and 12.5% for SSO.

(1) Selection options examined

The first two options assume plus trees will mate each other in CSO to produce the same number of open pollinated progeny. They are planted in the field with no family identification (Option 1) or as family blocks (Option 2). Then plus trees will be selected in the plantation with ignoring their parentage (Option 1) or the best one per each family block (Option 2). They are vegetatively propagated to establish CSO for the next generation. For the purpose of comparison with another option, number of progenies per plus tree assumed to be forty, however, it might be possible to increase the number in practice because of their simplicity of operation.

The next four, 3 to 6, are the options with seedling seed orchard (SSO). Selection in SSO is generally composed of between family selection and within family selection. The rate of between family selection was assumed to be 0.5 in option 4 to 6. About the option 3, which is the one without family selection, the rate of within family selection was set to be halved; one out of eight trees per plot, to equalize the total selection intensity. The difference among options of 4 to 6 was the form of plus tree selection ; mass selection for option 4, index selection for option 5 and within family selection for option 6. The last option of 7 is a simple repetition of seed stand establishment by mass selection with open pollinated seedling. The same with another option, number of progeny per each plus tree was set to be forty and one out of eight trees assumed to be retained in seed stand as pollen parent. This is also an option with good potential to get larger genetic gain by increasing the number of progenies without spending much effort.

2) Simulation model

The simulation model used in this study is a parameter based model in which genetic and environmental deviations were generated from independent normal distributions having pre-assigned means and variances. The simulation was made twenty times for each option. The heritability was assumed to be 0.2 and its phenotypic variance was set to be one by letting environmental varians $1 - h^2$.

The common part of the model throughout the seven options is given in Table 3.9. At each generation, plus trees mate with randomly assigned

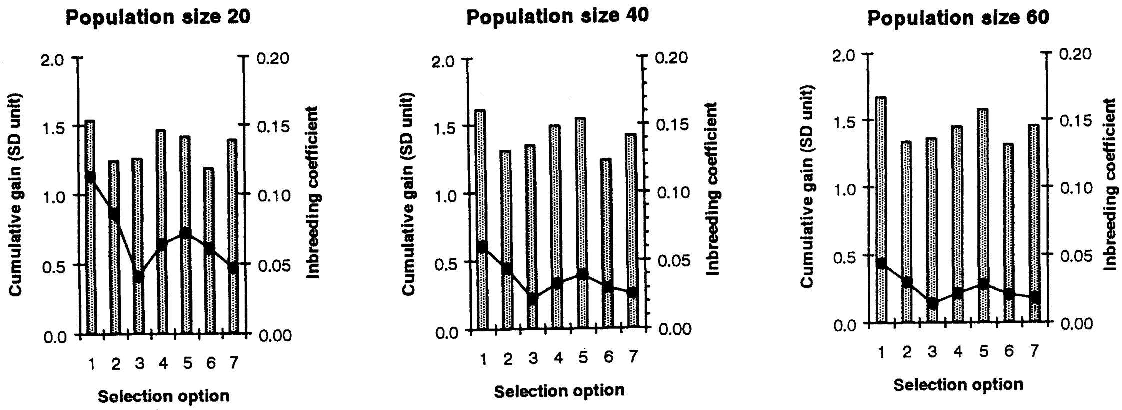


Fig. 3.14 Cumulative gains and inbreeding coefficients at the fifth generations for the seven types of selection options with different population size.

pollen parents. Inbreeding coefficient is calculated at each mating by using pedigree line method to impose inbreeding depression on a phenotypic value of each progeny (Abe and Nishida 1971). It is also used to make approximate reduction in the size of additive genetic variance (Falconer 1981).

3.5.3 Results of the simulation

Cumulative gains and inbreeding coefficients resulted from the five generations of simulation are shown in Fig. 3.14. The cumulative gains in each of the selection options are almost the same among the three different population sizes due to the same selection intensity. On the other hand, inbreeding coefficients were apparently smaller when the population size is large. However, it should be noted that the relative size of inbreeding coefficient among the seven selection options seems to be almost consistent among the three levels of population size.

Mass selection with CSO (Option 1) is the largest in cumulative gain as well as its inbreeding coefficient. This might be due to the result of complete selection of pollen parents in CSO where both female parents and male parents are plus trees only. This nature of CSO is still evident in the second highest inbreeding coefficient of option 2 of within family selection, even though its cumulative gain is apparently smaller than those of options with SSO.

The second largest group in cumulative gains is the options with family selection in SSO (Option 4 and 5). Index selection option seems to be slightly better than the mass selection when population size is large, however, its inbreeding coefficient is generally higher. Among the options with family selection, that of within family selection for plus tree (Option 6) is the smallest in cumulative gain, even though its inbreeding coefficient is moderately high.

The simple mass selection in seed stand (Option 7) may have practical potentials because of its comparable cumulative gain to the options with family selection in SSO as well as its relatively low level of inbreeding coefficient. The option of without family selection in SSO (Option 3) gave the lowest inbreeding coefficient. Thus it seems to be suitable to maintain genetic variability.

The options with SSO appeared to be more effective than those with CSO in reducing the progress of inbreeding provided that the equal chance of mating among seed parents in SSO is realized. This might be due to the milder selection of pollen parents. Therefore the result here suggests that the progress of inbreeding may be minimized by using options of SSO with a moderate population size, 40 to 60.

On the contrary to the advantage of minimizing inbreeding coefficient, the option of SSO seems to be less efficient in accumulating genetic gain until the fifth generations compared to that of CSO with mass selection. However, the generation interval of SSO option might be much shorter than that of CSO that involves two stages of plantation establishment; clonal breeding orchard and plantation for plus tree selection. Thus in practice, the options of SSO with family selection are likely to bring greater gain per unit time.

4. Subjects to be done in the consecutive tree improvement

Expecting activities of seed source evaluation to move on to the second generation tree improvement are described in this chapter. As mentioned in the preceding chapter, current tree improvementwork is still a half-way in the first generation. Thus the succeeding activities, such as family selection, plus tree selection then establishment of second generation population, are expected to be done in the next three to five years. For this reason, an outline of the strategy toward second generation tree improvement is presented first, then followed by specific topics; family selection and plus tree selection, and finally a short term implementation schedule was proposed.

4.1 Outline on future deployment of the current tree improvement

When the current tree improvement program is going to move on to the second generation, several new elements should be examined to include along with the main line activity of seedling seed orchard. They are plus tree selection in provenance resource stands or use of untested seedlots when forming the second generation population. The establishment of base population and composite orchards are the new elements to be examined after moving on to the second generation tree improvement (See Table 4.1).

(1) Seed to form second generation population

As mentioned in the above, it is better to consider the three populations to form second generation population. They are the breeding population in the current seedling seed orchards and additionally, provenance resource stands and untested seed by the current exploration (Fig.4.1). These additional inputs are expected to ensure the genetic variability as well as to increase genetic gain in the breeding population.

Regarding to the current breeding population, open pollinated seed will be collected from plus trees after finishing the roguing in the orchards (Fig. 4.1). This group of the plus trees will be the main part of the second generation population. The number of plus trees selected in each of the orchards will be determined basically by the number of individuals to meet the criteria for plus trees. However, the criteria could be revised according to the number of families available from the additional sources.

Provenance resource stands of *A. mangium* were once established by FTIRDI in cooperation with some of the forestry companies. This type of plantations was established also by different organizations, such as BTR in South Kalimantan (Nikles 1991, 1992). As mentioned in the simulation study of 3.5, gain by simple mass selection in the seed stand (option 7) proved to be sufficiently high as long as the intensive thinning had been practiced. Thus there is a good possibility to select genetically superior individuals especially when the population size is large. For this reason, it is recommended to collect current information on the availability of the seed from those sources as well as their seed origin, because this seed could be used together with those of the sub-line of the same provenance in the second generation.

Untested seed-lot collected by the current exploration might be worth trying in the second generation, if they are collected from the promising provenances. This is not only because the seed currently under testing did not cover the whole families in the promising provenances, but also because some of provenances found to be promising recently based on the new trials in Indonesia. *A. mangium* from Bupul-Muting had found to be quite productive according to the provenance trial in Riaw (Budi *et al.* 1996), thus it is recommended to form new sub-line for this provenance. In case of *A. crassicarpa*, some of the Queensland provenance should be selectively included in the current sub-line of Queensland, because their performances were almost the same as those of PNG (Budi *et al.* 1996).

(2) The three populations in the second generation

In the second generation of tree improvement, the needs and possibilities to establish additional populations should be examined by species. They are provenance resource stand, seedling seed orchard and composite orchard, functions of which are the supplemental population for plus tree selection, breeding population, and seed production population, respectively.

In case of the major species, provenance resource stand will be established in pair with each of the sublines by using bulked seed of

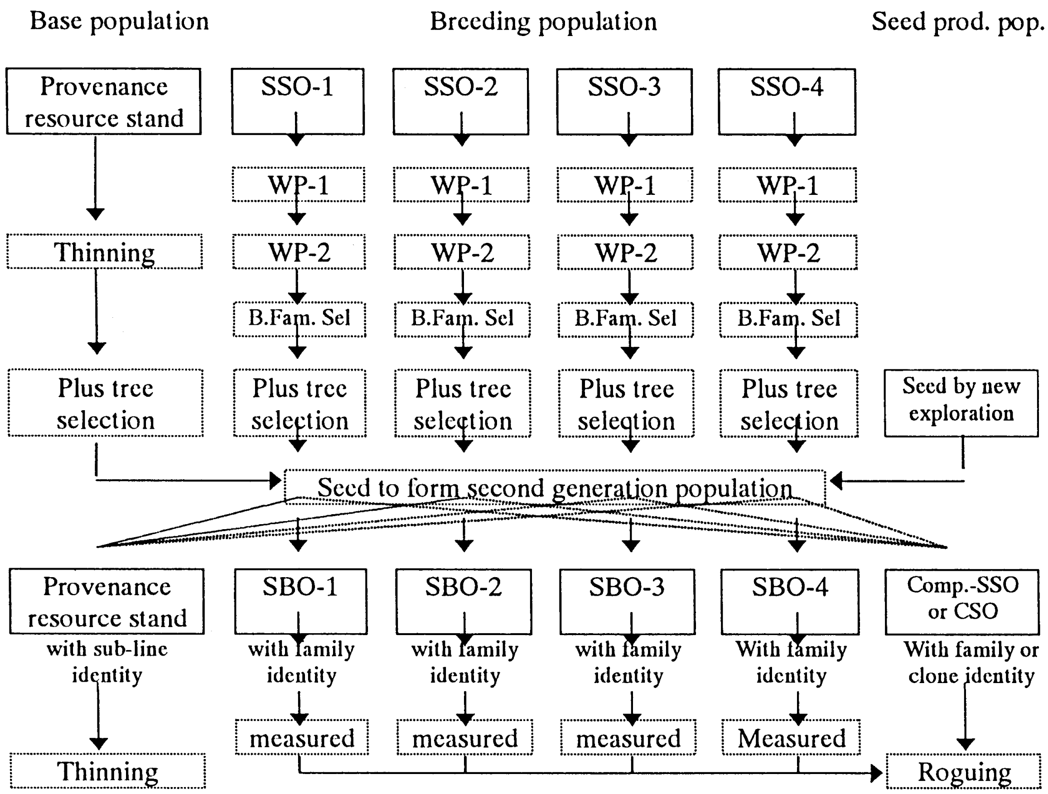


Fig. 4.1 Outline of the current tree improvement to move to the second generation for the major target species

corresponding subline. The composite orchard will be established by using open pollinated seed or clones of the top ranked plus trees in each of the sublines as mentioned in 1.1. On the other hand, composite orchard is not necessary for the species with single breeding population.

The function of seedling seed orchard of the second generation for the major species will be sifted to the breeding purpose. This is because the orchards especially for the seed production purpose would be established separately in the second generation. However, there would be still a possibility to be used for seed production purpose, when specific provenances are proved to be much productive or adaptable. These orchards may be better to be established earlier than composite orhards so that the results of family ranking can be used for the roguing in composite orchard (Fig. 4.1).

Provenance resource stand is better to be established corresponding to each of the sublines. The primary function is to provide supplemental plus trees to the breeding population by using a large selection differential that is difficult to realize in the seedling seed orchard. However, the stand will have a function to maintain genetic variation when they are established in large size at several locations.

Regarding to the major species, composite orchard can be established for seed production purpose using ranking of plus trees. It might be better to use many families or clones so that the later roguing in the orchard is possible. This is because the rankings in the first generation materials are regarded to be not reliable because of the great variation in out-crossing ratio or neighborhood inbreeding (Harwood 1996). If the orchard can be established in many locations, the orchards could be used as a range-wide test before the seed production. There is a good possibility to use them for this purpose, because many of the forestry companies probably want to establish this type of orchard due to the demand of further improved seed.

4.2 Family selection

Between family selection will be conducted at around three to four years of age based on the family ranking as described in 2.2. Then the orchards will start seed production on an operational scale. This selection is expected to be practiced at the end of the 1997／98 fiscal year in the oldest seedling seed orchards.

Although the manual for family selection has not been compiled yet due to time limitations, family ranking for the selection can be made by following the manual of preliminary analysis (FT IP No.19). Besides these matters, there are several factors that should be examined before the practical execution. They are the problem with family ranking peculiar to the first generation, selection intensity, choice of traits for selection and the relation with the results of multiple-site analysis. Therefore technical suggestions are given on those issues.

(1) Family selection in the first generation

Some sort of combination between simple mass selection and between-family selection might be preferred rather than a strict application of between-family selection in the first generation. This means that good individuals should be retained, even though they are the progenies belonging to the lower ranked families. This is because average family performance is not always a good indicator of genetic worth of family due to the great variation of out-crossing ratio and neighborhood inbreeding among families (Harwood 1996). For this reason, index selection combining family information and individual performance may be a realistic option, when greater weight is intentionally imposed on the individual performance.

(2) Intensity for family selection

Intensity for family selection is automatically calculated once the final density in the orchard is determined as described in 3.1 (Table 4.1). Final density was assumed as 150 trees per ha at the establishment, however, the intensity of family selection can be altered by changing the final density. Although the final density would be determined based on the optimum spacing for flowering as well as pollination for each of the species, it may be possible to reduce the rate of family selection due to the unreliability of family ranking as mentioned in (1). In that case, it should be noted that the reduction in the intensity of family selection will bring reduction in expected gain in the orchard.

(3) Traits included in family selection

As indicated in (1) of 4.2, an application of index selection combining family information and individual performance seems to be the most realistic option as long as greater weight is intentionally allocated on individual performance. In case of 50％ of selection rate, this selection index will be expected to retain around 60 to 70 ％ of families regardless of their individual numbers. Moreover the indices can be used to choose candidates of plus trees also. The function of site-adustment among the replication should be included in this selection index in order that the retained trees should be distributed equally in the orchard.

It might be better to allocate more weight on growth traits at the time of family selection. This is because family selection is regarded as useful to improve the traits with low heritability such as growth traits (Zobel and van Buijitenen 1989). This is especially true for *A. mangium* as found in 3.2 ; form traits received more weights at the stage of within plot selection. Another point of consideration would be a pattern of growth, even though juvenile-mature correlation seems to be strong as predicted in 3.3. It is reported that the selection at an early stage of growth tends to alter the improved population to an early growing type. Thus it is necessary to

Table 4.1 Relationship between the final density and rate of family selection

Species	Optimum number per plot	Adopted number per plot	Initial spacing per tree	Final density (trees / ha) 150 T. rate	150 F.rate	100 T. rate	100 F.rate	200 T. rate	200 F.rate	300 T. rate	300 F.rate
Acacia	4.06	4	8	0.12	0.48	0.08	0.32	0.16	0.64	0.24	0.96
Eucalyptus	4.66	5	6	0.09	0.45	0.06	0.30	0.12	0.48	0.18	0.72

Note) Optimum number is a number of trees per plot and the values were from Table 3.1. T.rate and F. rate are total rate of selection and rate of family selection, respectively.

examine the possibility to include current periodical increment as one of the factors of selection criteria. Regarding to the wood property, it will be discussed more in detail at the next sub-section of plus tree selection.

As described in 3.4, further investigation is necessary to the application of multiple-site selection index. This is due to the concern that the simple application of this index may lose many of the potentially better families because of their low out-crossing rate or heavy neighborhood inbreeding. For this reason, the application would be restricted only for improving the accuracy of family ranking obtained in the orchards with poor experimental precision.

4.3 Plus tree selection

Most of the plus trees will be selected from the current seedling seed orchards after finishing their between-family selection. This means that the plus tree selection will start in the beginning of 1998/99 fiscal year in the oldest seedling seed orchards. However, the establishment of the second-generation population will start after completing seed collection from plus trees in the younger seedling seed orchards. Thus it will take another one or two years to start establishment of the second-generation orchards.

There are several factors to be examined regarding to the plus tree selection. Some of the essential issues will be discussed briefly here from a technical aspect as well as an operational aspect.

(1) Time for plus tree selection

Due to the concern on the unreliability of family ranking, there is an idea that the plus tree selection and its open pollinated seed collection should be practiced before the family selection to insure pollen contribution from potentially better families (Dr. Eko personal communication 1997). This idea may be advantageous to turn over of the generation rapidly besides its main objective. However, the primary concern with this option might be the proportion of flowering trees at the time of seed collection. In case the flowering trees are not enough, seed collections have to be postponed until the full flowering stage. As a result, it will bring some amount of reduction in genetic quality of the improved seed due to the delay of final thinning in the orchard.

An application of the selection index proposed for family selection (index selection combining family information and individual performance in 4.2) might reduce the above mentioned concern of unreliable family ranking. In addition it will avoid the problem with flowering age also. Moreover, the expected gain in the second generation will be greater than that of the previous option due to the completion of the final selection in the orchards.

In any case, the study on flowering phenology in seedling seed orchards is strongly requested. This is because practical procedures of seed collection can not be well established without basic information on flowering, such as the increase in the rate of flowering trees with age, family variation in flowering time and quantity. This type of data can be easily incorporated into the computerized data processing system and used effectively for operational purposes as long as the data collection is conducted in line with the current system as described in 2.3.

(2) Number of plus trees

Number of plus trees per generation is around 50 per subline for the major species with multiple breeding population and around 100 for the secondary species with single breeding population. These population sizes should be better to be maintained by selecting the same number of plus trees to move on the second generation. Regarding to the minimum population size to obtain continuous gain, it was proposed 25 parents per sub-group for multiple populations and 50 parents for single population (Namkoong et al. 1980). This population size is supported by some of the studies that simulate the progress of inbreeding (Mahalovich 1989, Kurinobu 1995; see 3.5). Therefore the current size of the population would be probably large enough to expect continuous gains, even though some amount of bias may occur in mating among the plus trees.

It may be better to select plus trees twice as many as the current number of families due to the practical reasons. This is a protection measure against the reduction of an available number of plus trees due to the none flowering trees or those with low germination rate. Thus it is generally recommended that the establishment of the second-generation orchards should be started soon after the seed from target number of plus trees are collected.

(3) Method of plus tree selection

Since plus trees will be selected in each of the orchards, the results of selection index used for family selection might be utilized directly for the preliminary screening of candidate plus trees. Then the candidate trees will be examined one by one in the observations in the field. It would be necessary to set certain restrictions not to select too many plus trees from few of the best-ranked families.

An application of BLP seems to be desirable to rank plus trees across the orchard, because almost every set of families are tested in two to three locations. The ranking result will be used to establish composite orchards.

(4) Measurement of wood property

Regarding to the wood properties, census survey is necessary for all the plus tree candidates. Increment cores should be collected by increment borer with diameter size of 10 mm from the standing trees, because this type of non-destructive sampling method is necessary in the orchard due to the later use for seed production. Wood specific gravity, fiber length and possibly moisture content will be the traits to be measured from the sample of increment cores.

If sufficient labor is available for sampling and later measurement, it may be better to collect wood samples from all the seed trees retained in the orchard. The data will be used for two purposes ; estimation of family variation as well as grading of seed trees on wood properties. Family level information would be used to make accurate ranking of candidate plus trees as well as seed trees on wood property. In this case, selective seed collection would be possible according to the grade derived from the ranking of seed trees in the orchard.

It should be noted that the data on wood property should be incorporated with another result of measurement, because data on wood property is only a part of the total information to evaluate plus trees or seed trees. Thus the whole process of measurement and analysis should follow the procedure of computerized data processing system described in 2.3, otherwise effective use of data on wood property would be much diminished.

4.4 Short-term schedule for implementation

Two years short term schedule is proposed for the expecting operations in the current seedling seed orchards (Table 4.2). Operations scheduled in the table are measurement, thinning (within plot selection and family selection), and plus tree selection. However, sampling of wood for analysis on wood properties and monitoring on flowering are not included here.

(1) Measurement

Measurements are scheduled twice per year until the end of within-plot selection (3 years of age). After finishing the within plot selection, the frequency is once per year before the family selection. An exception is the measurement in the oldest seedling seed orchards (1993／94 establishment), in which twice of measurement is planned after the within plot selection. This is due to the two reasons ; to get more detailed trend of growth for the prediction purpose and to use data for investigating the procedure for family selection.

(2) Thinning

Thinnings are scheduled once per year after two years of age. The timing of thinning is set at the beginning of dry season (March until May) except for the case that the within plot selection is planned three times (South Kalimatan AM007, AM008). In almost all the cases, measurement is scheduled before the thinning. Collection of wood samples (disks of the culled trees) should be planned according to the schedule of thinning.

Family selection will include the following activities ;

1. preliminary selection using selection index,
2. field selection using the result of preliminary selection.
3. recording the result of the final selection.

(3) Plus tree selection

Plus tree selection is scheduled after the family selection is finished, thus the selection will be practiced around four years of age. This operation will include the following activities;

1. preliminary screening of candidate plus trees by the indices for family selection,
2. to determine plus trees by field observation.
3. collection of wood samples (increment cores) for further evaluation and ranking of plus trees.

Table 4.2 Schedule of operations in current seedling seed orchards until June 1999

Location	SSO Code	Established	1997 Jan	Apr	Jul	Oct	1998 Jan	Apr	Jul	Oct	1999 Jan	Apr	For. comp
Sum-sel	AM001	94.01	m37	wp2	m44		m48	fms	Pls				MHP
Sum-sel	AM002	94.01	m37	wp3	m44		m48	fms	Pls				MHP
Sum-sel	AM003	94.01											MHP
Sum-sel	AM004	94.01	m37	wp2	m44		m48	fms	Pls				MHP
Kal-sel	AM005	94.01	wp2	m42		m46	fms	pls					INH3
Kal-sel	AM006	94.01	wp2	m42		m46	fms	pls					INH3
Kal-sel	EP001	94.01	m36	wp2	m44		m48	fms	Pls				INH3
Kal-sel	EU001	94.01	m36	wp2	m44		m48	fms	Pls				INH3
Kal-sel	AM007	95.01	m24	m30	wp2		m36	wp3			M48	fms	MHP
Kal-sel	AM008	95.01	m24	m30	wp2		m36	wp3			m48	fms	MHP
Sum-sel	AC001	95.02	wp1		m32		m36	wp2			m48	fms	MHP
Sum-sel	AC002	95.02	wp1		m32		m36	wp2			m48	fms	MHP
Sum-sel	AC003	95.02	wp1		m32		m36	wp2			m48	fms	MHP
Sum-sel	EP002	95.02	m24	wp1	m32		m36	wp2			m48	fms	MHP
Sum-sel	EP003	95.02	m24	wp1	m32		m36	wp2			m48	fms	MHP
Sum-sel	EP004	95.02	m24	wp1	m32		m36	wp2			m48	fms	MHP
Jav-tan	AM009	95.02	m26		wp1		m36		wp2		m48		FTRI
Jav-tan	EP005	95.02	m26		wp1		m36		wp2		m48		FTRI
Kal-bar	AM010	95.02	wp1			m34	wp2			m46	fms		INH3
Kal-bar	AM011	95.02	wp1			m34	wp2			m46	fms		INH3
Jav-tan	AR001	96.02	m12		m18		m24	wp1	m30		m36	wp2	FTRI
Jav-tan	PF001	96.02	m12		m18		m24	wp1	m30		m36	wp2	FTRI
Sum-sel	AM012	96.02	m12		m18		m24	wp1	m30		m36	wp2	MHP
Sum-sel	AR002	96.02	m12		m18		m24	wp1	m30		m36	wp2	MHP
Sum-sel	EP006	96.02	m12		m18		m24	wp1	m30		m36	wp2	MHP
Kal-tim	EP007	96.02	m12		m18		m24	wp1	m30		m36	wp2	IHM
Kal-tim	EP008	96.02	m12		m18		m24	wp1	m30		m36	wp2	IHM
Kal-tim	EP009	96.02	m12		m18		m24	wp1	m30		m36	wp2	IHM
Kal-tim	EP010	96.02	m12		m18		m24	wp1	m30		m36	wp2	IHM
Riau	EP011	96.02	m12		m18		m24	wp1	m30		m36	wp2	PSPI
Riau	EP012	96.02	m12		m18		m24	wp1	m30		m36	wp2	PSPI
Riau	EP013	96.02	m12		m18		m24	wp1	m30		m36	wp2	PSPI
Riau	EP014	96.02	m12		m18		m24	wp1	m30		m36	wp2	PSPI

Note) Abbreviations used in SSO-Code; AM, AC, EP, EU, AR, PF denote *A. mangium*, *A..crassicarpa*, *E. pellita*, *E. urophylla*, *A. auriculiformis and P. falcataria*, respectively. Abbreviations used in the table; m-, wp-, fms, pls, are measuremant, with-in plot selection, between-family selection, and plus-tree selection, respectively. Abblibiations used in Forestry companies; MHP, INH3, FTRI, MHP and PSPI are PT. Musi Hutan Persada, PT. Inhutani 3, Forest Tree Improvement Research & Development Institute, PT. ITCI Huntani Mannungal and PT. Perawang Sukses Perkasa Industri, respectively.

4. collections of open pollinated seed from the plus trees.

(4) Monitoring of flowering

This observation is better to be conducted at least once before the plus tree selection during the flowering season.

5. Considerations on supporting elements for the seed source evaluation activities

Some of the suggestions are given in this chapter to promote seed source evaluation activities successfully. These are the comments what I came to have during these two years work as a long term expert on seed source evaluation.

(1) Collaboration with forestry companies

Current project scheme is heavily depend on the collaboration with forestry companies as descriebed in 1.2. Until now the collaboration seems to be going well, however, the company staff are proposing several requests in return for their efforts. They are feed back of the results of measurement, further technical guidance or opportunities to receive training or exchange information on tree improvement. Therefore the FTIRDI should pay attention to meet those requests as long as the institute wants to keep current collaborative activities continuously.

According to my experiences working at several sites of forestry company, the company staff had become quite supportive for field operations after they finishing the training course. This is probably because they came to have a good understanding on the idea of collaborative activity that is not only useful for FTIRDI but also beneficial to the forestry company. In forestry companies, however, the staff responsible to research and development will change frequently. Therefore it is recommended that FTIRDI should organize the training curse continuously in combination with seminar or meeting to conduct collaboration successfully.

(2) Budget allocation

The budget that is available from the beginning of fiscal year seems to be essential for seed source evaluation. This is because the first quarter of the fiscal year is regarded as the best season for thinning as well as measurement as described in 2.1. and 2.2. For this reason, it is necessary to look for an appropriate fund to carry out evaluation activities effectively, because climatic factor or tree growth are hard to change.

It seems necessary to use attractive titles that sounds like scientific to get budget for this activity, because the name of periodical measurement may not be appealing to the staff at the Agency. However, it should be noted that outcomes of the periodical measurement are more than a well-known title of genetic parameter estimation. That is the estimated parameters were already put into practical use for the selection purposes, moreover they are sometimes predicted in the topics presented in chapter 3.

(3) Staff assignment

In the beginning, staff (researchers) may be better to assign to the research on each of the target species. This way of sharing research topic is clear and convenient for the researchers to conduct their research programs by collecting specific information on each of the assigned species. When the activity is developed, a matrix form of job assignment (data management or wood property analysis) could be considered to meet the diversification and specialization of the research contents.

It is important to give fair opportunities to each of the researchers for their publication according to their previous contribution. A special consideration is necessary on how to reward the effort on non-scientific type of work ; such as budget planning or coordination with forestry companies that is essential to conduct operational tree improvement successfully.

A frequent change of the staff should be avoided, once the assigned staff proved to be potentially capable. Misunderstanding on the assignment of the staff seems to be still common due to its simplicity of the activity in this field. However, an appropriate staff is limited in number, because it requires abilities in several different fields of operation; computer operation, sense on statistical analysis, planning and decision making in the field. Moreover it should be remembered that the collaboration with forestry company is sometimes maintained on the personal level.

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I would like to give my acknowledgement to Dr. Furukoshi, JICA team leader, and Dr. Hendi, director of FTIRDI, for giving me an opportunity to compile this report. My special thanks· are also given to my colleagues; Mr. Hashimoto, Mr. Kondo and Mr. Takahashi for their suggestions, encouragement and support to conduct my duty.

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I greatly appreciate hearty collaborations with the forestry companies : PT. Musi Hutan Persada, PT. Inhutani 3, PT. Perawang Sukses Perkasa Industri and PT. ITCI Hutani Mannungal. Among those, my special thanks are given to Mr. Hardjono in PT. Musi Hutan Persada and Ir. Yudianto in PT. INHUTANI 3 at Banjarbaru Unit for their constant supports throughout my duty

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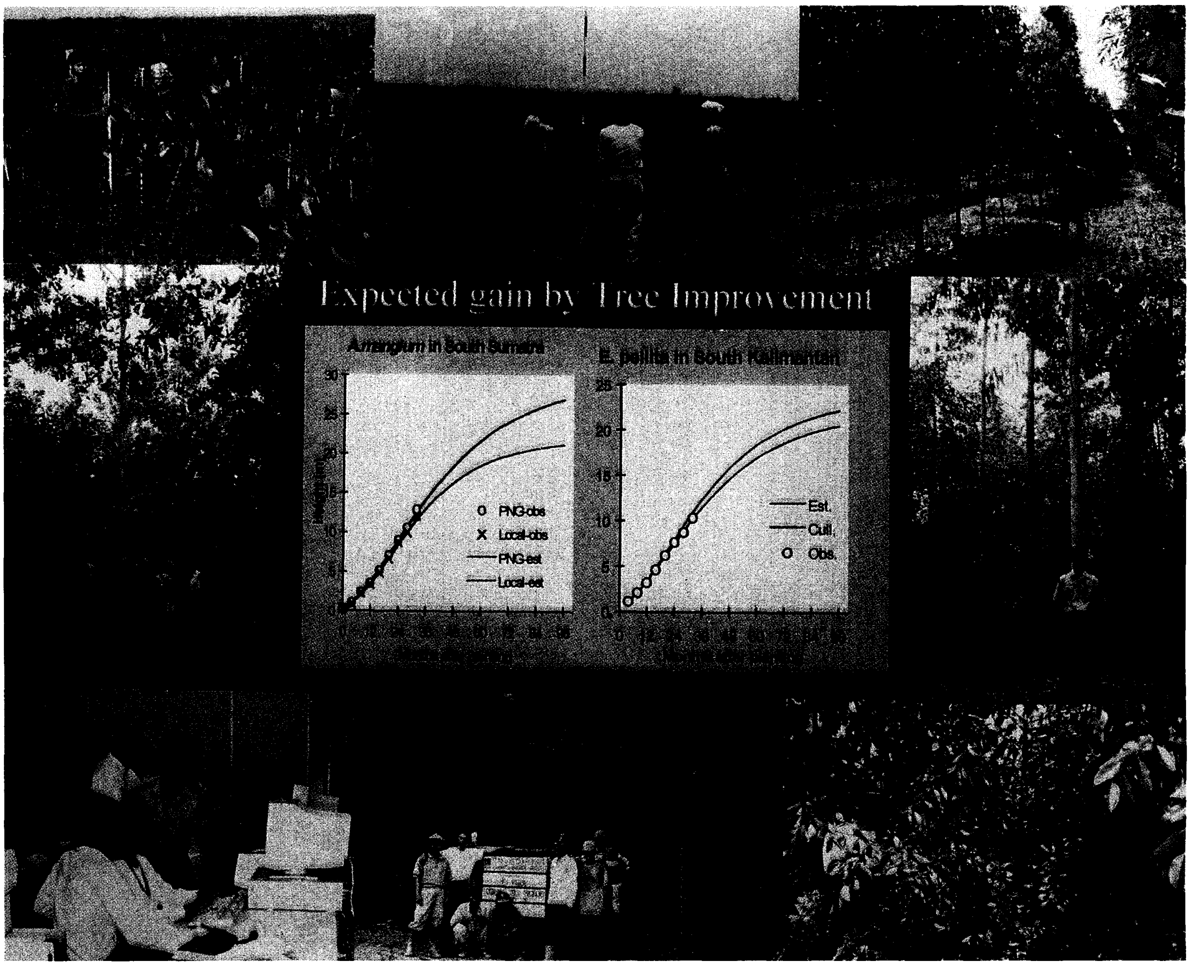
Photos and Chart summarizing Seed Source Evaluation.



2. Measurement in young SSO of *A. mangium*	1. Field survey for establishing SSO	3. Trees growing in SSO of E. *pellita*
4. Measuring tree height in SSO of *A. mangium*	Expecting gain by current tree improvement	5. Well growing *Eucalyptus* in SSO
6. Computer operation and Training	7. Skilled labor force at PT. Musi Hutan Persada	8. Early flowering of *E. pellita* in SSO

1. **Field survey for establishing SSO ;**
taken by Dr.Eko in South Sumatra on September in 1993. Successful trial starts from a good choice of the site. I conducted field survey for SSO when I came here as a short-term expert. This site was used for SSO of *A. mangium* ; group A. The current performance is shown in the middle chart and it is reported in 3.3.3. The design of SSO is discussed in 3.1.
2. **Measurement in a young SSO of *A. mangium*** ;
at Wonogiri on May in 1995. Periodical measurement had been conducted at each four months in almost all the seedling seed orchards. This is the first measurement in SSO established at Wonogiri. Measurement conducted during this phase of the project is summarized in 2.1.
3. ***E. pellita* growing in SSO ;**
in South Kalimantanon October in 1995. This is a picture of *E. pellita* at 22 months after planting. The growth of *E. pellita* is shownin the middle chart and reported in 3.3.4.
4. **Measuring tree height in SSO of *A. mangium;***
in South Kalimantan on January in 1997. Measurement of tree height is getting difficult with its growth, even though the first thinninghad been finished. Growth of *A. mangium* in South Kalimantan is reported in 3.3.3 and 3.4. Result of the first thinning is reported in 2.2 and 3.2.
5. **Superior individuals of *Eucalyptus* in SSO ;**
in South Kalimantan on January in 1997. Average growth of Eucalyptus is apparently behind that of *A. mangium*, but there is a good possibility to improve its volume productivity by selecting those excellent individuals. A potential of the improvement for *Eucalyptus* is reported in 3.3.4 and future strategy is discussed in 4.1.
6. **Computer operation and Training ;**
taken by Ir. Budi at BP3BTH on November in 1995. Now, the FTIRDI (BP3BTH) have a computerized data processing system that can follow the whole process of field activities. Counter-parts are able to organize computer training course for the forestry company staff to promote tree improvement together. The computerized data processing system is explained in 2.3.
7. **Skilled labor force at PT. Musi Hutan Persada ;**
in South Sumatra on January in 1996. Skilled field labor is quite helpful to carry out measurement, because they were involved in the activities from the beginning such as tree planting at the establishment of SSO. BP3BTH is now conducting tree improvement in cooperation with several forestry companies. The schemeof the collaboration is explained in 1.2.
8. **Early flowering of *E. pellita* in SSO ;**
in South Kalimantan on May in 1995. Only one year after planting, some of the trees started flowering in SSO. This indicates a good possibility to increase genetic gain with a rapidturn over of generations. Tree improvement strategy using this property is explained in 1.1 and related simulation study is given in 3.5.

Expecting gain by current tree improvement

Gain prediction has become possible based on the result of periodical measurement. The choice of provenance proved to be important for *A. mangium*, whereas an ordinary improvement procedure would bring sufficient amount of gain for *E. pellita*. See 3.3 for further details.

Photos except for No. 1 and No. 6 were taken by the author.

種子源評価最終報告
－インドネシア林木育種計画 フェーズⅠ－

栗延　晋

要旨：この報告では，海外林業技術協力プロジェクトとして実施されたインドネシア林木育種計画フェーズIの後半期間（1995年1月～1997年2月）における種子源評価に関する活動成果をまとめた。1章では，現在進めている育種プロジェクトにおける種子源評価の役割を明らかにするために，自然受粉種子を用いた循環選抜を骨子とする育種計画と林業会社と共同で進める林木育種の実施形態を説明した。

2章では，種子源評価の実行面の成果である実生採種林における定期調査と間伐の実施状況ならびにデータ処理システムについて述べた。定期調査は，1996年度までに設定した33ヶ所の実生採種林のほとんどで，4ヶ月に1度の頻度で実施した。収集したデータは派遣期間中に構築したデータ処理システムによってチェックした後，所定の様式で保存した。このデータ処理システムでは，採種林の設計，調査野帳の作成，データのチェック，分散共分散分析，選抜指数による家系の順位付けまでの作業を一定の手順で行なうことができる。1995年度末までに7ヶ所でプロット内間伐を終了し，1997年度初頭には延べ17ヶ所で実施予定である。この間伐作業を容易にするために作図機能を備えた間伐プログラムを作成するとともに，その事後評価には実現選抜指数を適用する手法を開発した。これらの作業は，先に述べたデータ処理システムの延長上で実行できる。集積されたデータや経験から，林木は雨季・乾季の別なく成長することや，間伐は風害を避けるために雨季の終わりに実施するのが望ましいことが明らかとなった。

種子源評価の実行成果を分析した結果を3章にまとめた。プロット内選抜について，*A. mangium* では幹曲りや分岐性を重視した選木が行われたのに対して，*Eucalyptus* では成長と形態の両方を配慮した選木がなされたことが明らかとなった。南スマトラと南カリマンタンに設定された *A. mangium* の試験地では，家系順位はかなり類似することが確められた。また，本プロジェクトで導入した *A. mangium* の系統は，インドネシアで従来使用されてきた系統に比べて収穫時の林分材積で約50％上回るとの見通しを得た。*E. pellita* に関しても，採種林の間伐によって元の集団よりも20％程度の収穫量の増加が期待できるとの試算結果を得た。

4章では，次世代へ向けての全体的な育種計画を提案するとともに，個々の採種林についても実施計画を作成して検討した。実生採種林の家系選抜は1997年度，プラス木の選抜は1998年度に着手可能と考えられた。また，第2世代では従来の実生採種林に加えて，産地別選抜母集団や混合採種林の造成を検討する必要があることを指摘した。