Genetic Improvement of Plantation Species in Indonesia
－Outline of Project Achievement－

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(JICA Forest Tree Improvement Project Phase II)

Summary: Major achievements that were attained during the ten years' technical cooperation project between Indonesia and Japan: started in June 1992 and terminated in November 2002, were reviewed. This project was initiated with an aim to support industrial reforestation program (HTI) in Indonesia by supplying genetically improved seed, hence it was conducted in cooperation with forestry companies that were involved in HTI program. During 10 years' technical cooperation, the project had realized a rapid diffusion of improved seed to the HTI program by establishing around 70 seedling seed orchards in 11 areas of Indonesia with open pollinated families from superior provenances of seven fast growing species. In the case of *Acacia mangium*, a higher priority species of the project, second-generation seedling seed orchards were established by completing the first cycle of tree improvement and then the realized genetic gains were confirmed in those orchards. The first generation tree improvement was completed in most of the other target species as well. Many useful findings such as differences in adaptability among provenances, genotype-environment interactions, mating systems and variation of seed viabilities among seed trees in the orchards, were obtained through the studies using data and samples collected from these seedling seed orchards. Studies on genetic variation as well as vegetative propagation for the indigenous tree species of Shorea were also conducted in the latter half of the project.

Overview of the technical cooperation

The Forest Tree Improvement project was started in June 1992 as a technical cooperation between Indonesia and Japan after the completion of grant aid that included building construction and installation of facilities and equipments for tree improvement at Purwobinangun in Yogyakarta province. The technical cooperation was conducted for ten years, which comprised of two phases of the five years' projects. During this period, over forty Indonesian staffs were assigned as counter parts to work together with the experts dispatched from Japan. Many of them also had opportunities of training in Japan to acquire knowledge and techniques in various fields of tree improvement.

The technical cooperation of forest tree improvement was proposed with the objective to support industrial forest plantation programs that had been started in the late 1980s'. Thus the fast growing species that were regarded as promising for plantation establishment were chosen as target species for the tree improvement project (Kurinobu and Soecipto 1992).

In the phase I project, more than 30 seedling seed

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orchards of seven species were established in seven locations of Indonesia (Hashimoto 1997). They were measured periodically and the results were recorded and analyzed with a computerized data processing system. Isozyme analysis was applied to evaluate genetic variations for some of the target species (Seido et al. 1993) and then the analytical method was replaced with DNA marker system in the latter half of the phase I. Vegetative propagation and seed production techniques were studied using the currently available materials. Most of the field works were done in collaboration with forestry companies, thus the technical extensions were conducted concomitantly with the seed sources establishment.

The second phase project was started in December 1997 with the purpose to strengthen the function of c/p organization to promote tree improvement (FTIP-P2 No.3 1998). A major activity in the phase II was the continuation of the phase I project to move on to the second generation by completing the first generation of tree improvement. In addition, information management and study on indigenous species were newly started. A role of information management has become important with the progress of tree improvement and the database recording information on 3,050 individual tree lots was established (Sutarman and Hashimoto 2002). The second-generation seedling seed orchards of *A. mangium* had been established in collaboration with eight forestry companies and they organized a tree improvement association to work together with c/p institute: Center for Forest Biotechnology and Tree Improvement (P3BPTH). A molecular genetic study has made an apparent progress by revealing genetic diversity of *shorea* as well as mating systems in the seedling seed orchards of *A. mangium*.

Owing to the current needs of tree improvement as well as the evident of progress of tree improvement, a counter part organization of the project had become Balai (BP3BTH) during the phase 1 and it further promoted its status as Pusat (P3BPTH) in the middle of the phase II. Thus the institute that had been initiated as a temporary project has now been authorized as a permanent institution to lead forest tree improvement in Indonesia. During these two phases of technical cooperation, five counterparts had successfully obtained scholarship from Japanese government and they are currently studying in various field of tree improvement at universities in Japan.

Current achievements during the technical cooperation

Applied strategy for tree improvement of fast growing species

Since this project was initiated with an aim to support industrial reforestation program (HTI) in Indonesia by supplying genetically improved seed, it was conducted in cooperation with forestry companies that were involved in HTI program. This type of tree improvement was advantageous not only due to an economical reasons to save project expenses but also effective for a rapid realization of genetic gain in the operational plantation establishment, because the real users of the improved seed are the forestry companies that are enthusiastic to increase productivities of their plantations.

In the technical aspect of tree improvement, the project chose an option to establish seedling seed orchards with open pollinated families collected from the provenances that were proved as promising based on the previous tests. This is because a good amount gain can be realized in a relatively short period with minimum techniques of plantation establishment; hence it is also suitable for the collaborative work with forestry companies (Kurinobu 1993).

In the case of major species, such as *Acacia mangium, Eucalyptus pellita,* and *A. crassicarpa,* sub-line system was applied for family groups of different provenances, while a single breeding population was used for the minor species: *A. auriculiformis*, *A. aulacocarpa, Paraserianthes falcata* and *E. urophylla.*

Selection and testing

By the end of phase I, 37 seedling seed orchards of seven species were established in six provinces (Hashimoto 1997). Then plus trees were selected for *A. mangium*, *E. pellita, A. crassicarpa* and *A. auriculiformis* after completing two to three stages of selections in the orchards (Chigira and Budi 2001). Among those species, 30 second-generation orchards of *A. mangium* were established in collaboration with eight forestry companies during the phase II. It should be noted that most of the orchards were designed and analyzed with a set of computer programs that had been developed with N88-Basic (Kurinobu et al. 1994) , and then it was converted to Visual Basic on Windows (Kurinobu et al.. 1998, Kawasaki et al. 1999, 2000). Thus a series of work that includes design with family adjustment, data-check, analysis, thinning and plus tree selection in SSO can be done with a minimum amount of labor and time in a fairly consistent manner.

Regarding to the growth and form traits, family variation of *A. mangium* seemed small except for the bole length (Kurinobu et al. 1996). This relatively narrow genetic variation was also confirmed with a phylogeny study on genus *Acacia* using RAPD markers (Anto 1998). Even with this limited genetic variation, fairly high heritability (> 0.30) was estimated in FNQ (Far North Queensland) population at age 2, while it reduced to less than 0. 30 at age 4. On the other hand, that of the PNG (Papua New Genie) was apparently low (< 0. 10) at age 2 and then it increased to 0. 20 at age 4 (Kurinobu et al. 2000). Heritabilities of *E. pellita* were variable depending on the population, while the estimates at an older age (h2 = 0. 19 at age 4. 8) were generally higher than those at age 2 (h2 = 0. 14). In the both stages of within plot selection, bole length was found to be the highest priority trait for *A. mangium* (Arif and Kurinobu 2002), while the growth represented by dbh received highest selection intensity for *E. pellita* (Budi and Kurinobu 2002).

The provenances of *A. mangium* procured by the project showed apparently better growth compared to the local selections in Subanjeriji and this might bring about 20% increase in stand volume at the eight years' rotation age (Arif et al. 2002). In addition, further possibility of improvement was also indicated in the second-generation seed orchards where percentage superiorities of progenies from the first generation plus trees over the unimproved population were 2. 2, 4. 1, 2. 6 and 3. 8% for height, dbh, stem form and multiple-stem, respectively (Budi et al. 2002). Wood properties were studied by collecting wood samples from plus trees as well as sample populations (Muji 2001).

Moderately high heritabilities on wood density: 0.20 for *A. mangium* (Susilawati 2002a) and 0.39 for *E. pellita* (Susilawati 2002b), also suggest a good possibilities of improvement on wood property.

Genotype by environment interaction seemed moderately strong between South Sumatra and South Kalimantan, although the magnitudes were variable depending on age, species and traits. The interaction on growth traits were generally small for *A. mangium* and *E. pellita* until two years old (Arif and Kurinobu 1996), while it become evident at four years of age where the average genetic correlation was estimated at around 0.60 for *E. pellita* (Budi and Kurinobu 2002). This amount of interaction might be regarded as marginal on how to deploy the breeding populations: to develop specific breeding population for each region or to develop single population across the regions. The latter choice would be economically feasible at the moment, although the loss of gain may not be a negligible amount. In the case of *A. mangium*, the magnitude of interaction at an older age has not been assessed in a conventional manner due to the high mortality of trials. However, it should be noted that the progeny of plus trees that were selected in South Sumatra performed better than the none-selected populations in South Kalimantan (Budi et al. 2002). Family performance of *A. auriculiformis* seemed fairly consistent between Central Java and South Sumatra, because any significant interactions were not found on height, dbh, stem form and bole length at five years of age (Noak et al. 2002).

One important finding for *A. mangium* that might have practical implication is the provenance by site interaction on wind tolerance (Arif et al. 2002). This interaction was observed in seedling seed orchards after 50% of thinning had been practiced. PNG provenance that is known as most productive was found to be prone to wind damage, while FNQ provenance was fairly tolerant probably due to the natural selections repeated by generations at its original location. This provenance difference in wind firmness was evident at the coastal area in South Kalimantan, while there was no provenance difference in South Sumatra. Since the current breeding population of *A. mangium* is made up of each two sub populations from PNG and FNQ provenance, it is recommended to choose appropriate sub populations when the plantations is established for timber production at a location prone to wind damage.

Propagation and production

With the completion of two to three stages of thinning, seed production was started in seedling seed orchards. In the case of *A. mangium*, 20 to 40 kg of seed are produced per one hectare of the orchard annually, while its maximum production potential was estimated around 100 kg (Yamada et al. 2001). Seed production of *A. auriculiformis* had started in seedling seed orchard in Central Java at age 4 and the amount of seed ranged from 10 to 50 grams per tree with an apparent difference between the provenances (Tajudin 2000). Seed production of *E. pellita* is still an increasing phase, a maximum potential of seed production with 5 to 10% of fruiting trees was estimated around 5 kg of seed per hectare (Yamada et al. 2001) and the production is likely to reach around 10 kg at the full production stage.

Studies to improve the quality of seed from the seedling seed orchards of *A. mangium* were also conducted by examining seed viability as well as using DNA markers. According to the comparative study on field germination rate and surrounding density of seed trees in the orchards, it was suggested that an optimum density to maximize seed viability is likely existent (Rina 2002) . The molecular genetic study using micro-satellite DNA markers revealed that 80% of pollen came from the seed trees within the range of 40m radius by identifying paternal contribution of all seed trees in the orchard (Vivi and Isoda 2002). These findings would be utilized to compile a guideline for managing the seed orchards.

Vegetative propagation and tissue culture studies were conducted with an aim to establish clone bank of plus trees as an immediate objective, while in the medium term these techniques would be utilized to establish clonal seed orchards as well as breeding orchards for controlled pollination and hybridization. An experimental clone bank of *A. mangium* was established within the site of the institute with air-layered plus tree clones selected in the seedling seed orchard in Central Java. They are currently under multiplication using tissue culture that had successfully multiplied three out of the seven clones up to the acclimation stage (Nishikoori 2000, Toni 2002). Regarding the clonal propagation of *E. pellita*, side grafting seemed promising, because 29 out of 42 plus trees were successfully multiplied (Chigira and Hamdan 2002) . However, the transportation of scion from distant location is still an unresolved problem for an operational application (Moko et al. 2001).

Controlled pollination was made for intra-species (*Pinus merkusii*) and inter-species hybridization (*A. mangium and A. auriculiformis*). Although the controlled pollination of *Pinus merkusii* was not new in Indonesia, control pollinated seeds were obtained in 17 crosses out of 20 crosses of 4 by 5 factorial mating (Fasis et al. 2002). One of the interesting results with this experiment was that the sound seed per cone with controlled pollination (20 seeds / corn) was greater in number than that of open pollinated cone (3. 3 seeds / cone). The species hybridization between *A. mangium* and *A. auriculiformis* had obtained the seed in all of the nine cresses of 3 x 3 factorial mating design and they are under the investigation at the nursery (Fasis et al. 2002).

Indigenous species

Research topics on indigenous species were newly added to the phase II project and most of the subjects were conducted in a form of collaborative study with another on-going projects; ITTO project for ex-situ gene conservation of *Shorea leprosula* and Komatsu project for vegetative propagation of Meranti. Genetic diversity of *S. leprosula* was studied with DNA markers (RAPD and micro satellite) using seedlings collected by ITTO project and it revealed the relative size of genetic diversities of natural populations in Jambi and East Kalimantan as well as some findings to improve sampling method for gene conservation (Anto et al. 2001, Istiana et al. 2001). Genetic variation in hedged orchards of *Shorea leprosula* that is currently used for rooted cutting production in East Kalimantan was found to be almost the same as the natural population, and thus the plantations established with these materials would have sufficient genetic diversity (Isoda et al. 2001)

The vegetative propagation of *Dipterocarps* has been studied for more than a decade by many research organizations in Indonesia, because it is regarded more practical and promising propagation method rather than the seedling production which is always hampered by unstable fruiting habit as well as rapid reduction in seed viability of the species. It was experimentally confirmed that hedged stock should be kept around 0. 2 m in height to obtain scions with high rooting ability for *Shorea javanica* and *Hopea odorata* (Hamdan 2002a and 2002b). With the introduction of Komatsu fogging system, clonal propagation for *Dipterocarp* species will be further improved (Sakai 2002) and it would be used for establishing clonal trials that will provide individual tree variation on economically important traits for future tree improvement.

Future directions for tree improvement

First generation tree improvement has been completed for most of the major fast growing species; however, the second-generation improvement has just started for *A. mangium*. Thus it is recommended to start second-generation improvement for other species as well. This is not only to enlarge the genetic gain that might be cumulative by generation, but also to identify the outstanding genotypes with sufficient accuracy by backward selection that could be practiced only after the second generation. Those genotypes would be used to establish clonal seed orchard and possibly hedged orchard for the production of clonal planting stocks. For this reason, vegetative propagation techniques including tissue culture need to be further developed as reliable tools to be applied operationally.

Regarding the indigenous species, gene conservation for future utilization would be a more realistic approach rather than a hasty start of intensive tree improvement that is currently conducted for the fast growing species. This type of approach should be done to cover wide range of potential species that are exposed to a rapid depletion of the resources in Indonesia. Although an immediate contribution in the field of gene conservation might be a continuation of the study on genetic diversity that had been done during the technical cooperation, it would be necessary to develop gene conservation program by focusing on several potential species that are not covered by the on going project. Nevertheless, it should be noted that this type of program is hard to be accomplished without a close linkage with the administrative sections of the ministry and forestry sectors.

Advanced technologies; such as techniques using DNA markers, tissue culture and possibly gene fusion should be introduced to enhance the current tree improvement program as long as the appropriate fund is available. Although these technologies are regarded as crucial for the future development of the program, it might be better to start applying those techniques to solve the practical problems in the on going program. It should be emphasized that benefits with the application is largely depend on the quantities and qualities of information and materials of excellent genotypes that are currently generated by the on going tree improvement program.

Besides the technical aspect, management and coordination of tree improvement network that had been organized during the phase II project is of crucial importance to ensure the future development of tree improvement in Indonesia. This is because the network is not only a bases for the implementation of tree improvement, but also a group of users of the improved seed for their own purposes as well as to meet the outside demands. Thus P3BPTH is expected to lead this network by publishing newsletters and organizing periodical meetings to enhance the exchange of information and materials. In order to derive its full potential of the network, it is also expected for P3BPTH to take initiative actions by proposing and conducting collaborative research works that have not been achieved by a single tree improvement program of forestry sectors; provision of information on genotype by environment interaction, cost intensive study such as those using DNA markers and risk sharing operations such as seed exploitation for potential species.

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インドネシアにおける造林用樹種の育種
－JICA林木育種計画プロジェクト・フェーズ２の成果の概要－

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要旨：1992年６月から2002年11月末まで実施した国際協力事業団のインドネシア林木育種計画プロジェクトにおける成果の概要をまとめた。このプロジェクトでは，その発足当時に始まった産業造林に用いるアカシアやユーカリ等の早生樹種を対象にして，林業会社と連携した林木育種を進めた。優良産地の自然受粉家系を用いた実生採種林は，７樹種について11地域で70箇所余りを造成し，育種事業の広範な地域展開と成果の早期普及を実現した。アカシア・マンギュウムでは第１世代の育種を完了し第２世代の実生採種林を造成して実現された選抜効果を確かめるとともに，その他の樹種もプロジェクト終了までに第１世代の育種をほぼ完了するに至った。これらの実生採種林における調査分析や試験の結果から，樹種・産地別の適応性の違い，採種林内での交配実態，種子の品質，栄養繁殖技術等に関する知見を得た。また，プロジェクト後半には，郷土樹種メランティについて遺伝変異の評価や栄養繁殖技術の開発も行った。

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