GROWTH PERFORMANCE AND MORPHOLOGICAL VARIATION INCLUDING SEX RATIO IN *CALAMUS SUBINERMIS* PROVENANCE *CUM* PROGENY TRIALS IN SABAH

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SCHOOL OF INTERNATIONAL TROPICAL FORESTRY
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ABSTRACT

GROWTH PERFORMANCE AND MORPHOLOGICAL VARIATION INCLUDING SEX RATIO IN *CALAMUS SUBINERMIS* PROVENANCE *CUM* PROGENY TRIALS IN SABAH

Survival percentage and growth performance of *Calamus subinermis* at different sites with different soil types, terrain, climate, canopy opening and espacement was investigated in the 14 years old provenance *cum* progeny trial located at Sook, Segaliud Lokan and Kolapis A. These studies indicated that the survival and growth rate of *C. subinermis* varied between sites and provenances. High survival percentage was observed in Sook's plot while Kolapis A and Segaliud Lokan plots had high mortality percentage. However, the growth rate was significantly higher in Kolapis A and Segaliud Lokan compared to Sook's plot. The growth performance of *C. subinermis* was highly affected by surrounding environment. This was indicated by the different growth increment of different trait at different sites which shows the interaction between genotype and environment. However, provenance site interaction only occurred in stem diameter and number of suckers. Thus selection for stem diameter and number of suckers traits are not restricted to planting site. The non-significant difference in provenance site interaction indicated that total stem length and internode length traits are site specific. Therefore, the best provenance for breeding in total stem length were provenance Kota Marudu, Lawas and Tandek in Sook; provenance Tamparuli, Tuaran and Penampang in Segaliud Lokan and provenance Tuaran, Pulau Tigaand Kota Belud in Kolapis A. Morphological variation in *C. subinermis* was evaluated in the provenance *cum* progeny trial in Kolapis A. Variations were occurred among provenances of this species. It was noted that stem diameter and internode length had a high provenance, family and individual heritability value as compared to other traits. The superior morphological trait like thornless leaf sheath had a low heritability value. The thornless leaf sheath trait was highly correlated to stem diameter. To complement the future breeding program, the sex ratio and the occurrence of andromonoecius individual of this species were determined in these trials. The female bias was observed in *C. subinermis* population in fertile site like Kolapis A and Segaliud Lokan. The observed andromonoecy individual in Kolapis A indicates possible natural and artificial pollination in this species. The morphological variations among provenances indicated that future improvement program should concentrate on the provenances which geographically far away as some of these families are suspected to be full-sib.

ABSTRAK

Kajian mengenai peratusan hidup dan pertumbuhan Calamus subinermis *di kawasan-kawasan yang berbeza dari segi tanah, kecuraman, cuaca, pembukaan kanopi dan jarak tanaman telah dijalankan di plot provinan* cum *progeni yang berumur 14 tahun yang terletak di Sook, Kolapis A dan Segaliud Lokan. Hasil kajian menunjukkan peratus hidup dan kadar pertumbuhan* C. subinermis *adalah berbeza di antara kawasan tanaman dan provinan. Plot di Sook menunjukkan peratusan hidup yang tinggi manakala plot di Kolapis A dan Segaliud Lokan mempunyai peratusan mati yang tinggi. Akan tetapi, plot Kolapis A dan Segaliud Lokan mempunyai kadar pertumbuhan yang jelas lebih tinggi daripada plot Sook. Kadar pertumbuhan* C. subinermis *adalah sangat dipengaruhi oleh keadaan persekitaran. Interaksi di antara genotip dan persekitaran ini telah ditunjukkan melalui perbezaan pertumbuhan di antara parameter yang di kaji di kawasan-kawasan tersebut. Tetapi, analisa statistik menunjukkan hanya parameter diameter batang dan jumlah anak dalam rumpun yang mempunyai interaksi diantara provinan dan kawasan tanaman. Sehubungan itu, spesis ini adalah di anggap sebagai memilih kawasan untuk bertumbuh bagi parameter kepanjangan batang dan panjang antara tunas. Pemilihan untuk membaikbiak diameter batang dan jumlah anak dalam rumpun boleh dilakukan di mana-mana kawasan. Justeru itu, provinan yang dipilih untuk pembaikbiakan kepanjangan batang di Sook adalah Kota Marudu, Lawas dan Tandek; untuk Segaliud Lokan, provinansi Tamparuli, Tuaran dan Penampang dipilih manakala provinansi yang dipilih di Kolapis A ialah Tuaran ,Pulau Tiga dan Kota Belud. Variasi morfologi dalam* C. subinermis *telah di kaji di plot provinan* cum *progeni di Kolapis A. Hasil kajian menunjukkan variasi wujud di antara provinan dalam spesis ini. Didapati provinan-provinan ini hanya dibezakan melalui kedudukan geografi. Didapati diameter batang dan panjang antara tunas mempunyai nilai heritabiliti provinansi, keluarga dan individu yang tinggi berbanding dengan sifat-sifat lain. Sifat morfologi yang baik seperti pelepah batang tidak berduri dan pelbagai batang dalam satu rumpun menunjukkan nilai heritabiliti yang rendah. Sifat pelepah batang tidak berduri didapati berkaitrapat dengan diameter batang. Demi untuk kegunaan program pembaikbiakan yang akan datang, nisbah jantina dan kewujudan pondan dalam populasi telah dikaji di plot-plot tersebut. Populasi* C. subinermis *didapati mempunyai nisbah betina yang lebih tinggi di plot-plot yang mempunyai tanah yang subur sperti Kolapis A dan Segaliud Lokan. Kewujudan individu pondan menunjukkan kemungkinan pendebungaan secara semulajadi atau pembuatan dalam sepsis ini. Variasi morfologi antara provinan menunjukkan provinan-provinan ini adalah berkait rapat antara satu sama lain dan mungkin berasal dari baka yang sama. Justeru itu adalah disyorkan supaya provinan yang yang jauh dari segi geografi akan dipilih untuk program pembaikbiakan yang akan datang*

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LIST OF ABBREVIATIONS

KPD	Rural Development Corporation
ICSB	Innoprise Corporation Sdn. Bhd.
SAFODA	Sabah Forestry Development Authority
MT	Metric tonnes
RLI	Relative Light Intensity
^{o}C	Degree Celcius
>	More than
<	Less than
mm	millimeter
cm	centimeter
m	meter
ha	hectare
N	North
E	East
%	Percentage
σ	variance
h^2	heritability
pH	A measure of acidity
P	Significant value
r^2	Regression of coefficient
RCBD	Randomize Complete Block Design

CHAPTER 1

GENERAL INTRODUCTION

1.1 Rattan in General

The word rattan is derived from the Malay word "rotan", a local name for climbing palms (Sunderland & Dransfield, 2002). The rattan species use climbing organ called cirrus (a modified leaf rachis) or flagellum (a modified inflorescence) to hoist itself up to any trees in the vicinity. The large leaf provides mechanical support while the stem provides flexible structure with long internodes (Corner, 1966). The growth of rattan are usually indicated by the elongation of rattan stem. Generally, there are two distinct forms i.e. single-stemmed or clustered. In single stem rattan like *Calamus manan*, the stems attain considerable length as a matured rattan. In cluster form, the production of suckers either originated by axillary vegetative buds or stolons (Fisher & Dransfield, 1979). These suckers usually metamorphose into aerial stem. A typical rattan stem comprised well-defined and elongated internodes.

The internode is visible in mature cane without leaf sheath or concealed with leaf sheath armed with spines. Internode length varies along a stem; short at the base, very long at proximal region and slightly less long at the distal part of shoots. This variation was reported by a few studies (e.g Chia, 1995; Nur Supardi & Wan Razali, 1989). The internode length increase linearly from the first to the tenth internode in *Calamus manan* whilst in *Calamus subinermis*, the internode length increase linearly from the third to the tenth internode and fluctuate about a mean value thereafter.

The stem diameter of a rattan stem varies along the stem. Usually, stem diameter decreases where the stem elongates but more distally there is an increase in diameter from node to node until a more or less constant diameter is attained (Aminuddin, 1990). The stem diameter of *Calamus subinermis* increases rather constantly at the first 24 m and level off thereafter (Chia, 1995).

Generally, the life history of rattan is divided into three distinct stages i.e. seedling stage, establishment phase and aerial growth (Dransfield, 1979; Tomlinson, 1990; Dransfield, 1992a). Seedling stage refers to the stage where the appearance of first few leaves called ecophyl, which do not resemble the leaf of the mature plant (Dransfield, 1979). The establishment phase refers to a rattan which has develops into a stemless juvenile stage as defined by Tomlinson (1990). The aerial growth stage refers to a rattan that has develops a stem that climb rapidly up to the canopy (Dransfield, 1992a). The rattan stem continues to grow with the production of new leaves and each new leaf results in the production of a new internode at the apex of the stem (Dransfield, 1979).

The reproduction of rattan can be vegetative or sexual. The reproductive biology of rattan varies between genera; some genera are dioecious, with separate female and male plants whilst others are monoecious with either hermaphrodite flowers or separate male and female flowers borne on the same plant (Uhl & Dransfield, 1987). The pollinators of rattan are different between genera and species (Lee *et al.*, 1995; Bogh, 1996a). The main pollinators for *C. subinermis* were pyralid, noctuid and others moths besides wind which also play a role in short distance pollination in dense population (Lee *et al.*, 1995). Rattan species reproduce either hapaxanthically or pleonanthically. Hepaxanthy palm reproduce in a single massive effort that result in stem death whilst pleonanthy palm reproduce either in a regular seasonal pattern or aseasonal.

Generally, rattan can be propagated either by seed or vegetative propagation (Aziah & Manokaran, 1985). Rattans can be propagated vegetatively by suckers, whole rhizomes and tissue culture (Dransfield & Manokaran, 1996).

1.2 Diversity of Rattan

Rattan is a general designation for climbing palms of the subfamily of *Calamoideae*. Two other palm genera with climbing members that are often mistaken as being closely related to true rattan are *Chamaedorea* (sub-family *Ceroxyloxidae*; tribe *Hyophorbeae*) and *Desmoncus* (sub-family *Arecoidea*; tribe *Cocoeae*; they climb through the means of reflexed terminal leaflets (Sunderland & Dransfield 2002).

Rattans are members of the *Palmae* family and of subfamily *Calamoideae.* There are about 600 species of 13 genera found in the world (Uhl & Dransfield, 1987). The fruits of all *Calamoideae* species are characterized by overlapping reflexed scales and required pre-adaptation to the climbing habit (Dransfield, 1992b). Some of the 13 genera are endemic to certain locality example genera Laccosperma (syn. *Ancistrophyllum*), *Eremospatha* and *Oncocalamus* are endemic to Africa (Dransfield, 1992); *Retispatha* is endemic to Borneo; *Pogonotium* is endemic to Peninsular Malaysia and Borneo (Dransfield, 2002). Some 10 percent of the world's approximately 600 species of rattans are commercial species. Many species, including some of commercial importance, have very restricted natural ranges. The majority of the world rattan resources (by volumes and by number of species) are in one country – Indonesia (Dransfield *et al.*, 2002). However, most of the rattan species are distributed in equatorial Africa, the Indian subcontinent, Sri Lanka, the foothills of the Himalayas, southern China through the Malay Archipelago to Australia and the western Pacific as far as Fiji with the greatest diversity of genera and species in the western part of Malesia (Dransfield and Manokaran, 1994). The largest genus is *Calamus* with 370 – 400 species, occurs throughout the geographical range of rattans (Dransfield and Manokaran, 1994). *Calamus* is predominantly an Asian genus and ranges from the Indian subcontinent and south China southwards and east through the Malaysian region to Fiji, Vanuatu and tropical and subtropical parts of eastern Australia (Sunderland & Dransfield, 2002). Rattan canes produced by some of the *Calamus* species occurring in the South-east Asian region are acknowledged to be of the highest quality in the world (Dransfield, 1992).

The greatest diversity of rattans occurs within South East Asia (Dransfield & Manokaran, 1994). South East Asia houses about 600 species of rattan and about 20 species (all from the genus of *Calamus*) are regarded as elite commercial species (Dransfield, 1981). There are 84 species of 7 genera found in Sabah (Dransfield, 1984). The rattan genera found in Sabah are *Calamus, Daemonorops, Korthalsia, Lectocomia, Plectocomiopsis, Retispatha, and Ceratobolus.* *Calamus* is the most diverse genera amongst the seven genera with 40 species found in Sabah (Dransfield, 1984). However, knowledge in the genetic diversity within and between species is still scarce for rattan (Hong *et al.*, 2002).

1.3 Rattan as an Important Non-Forest Product in Sabah

Rattan is an important non-timber product in the tropical rain forest. It is the raw material for the cane furniture industry, and is also used widely in matting, cordage, construction, basketry and thatching. In some parts of East and South-east Asia, several species are cultivated for their edible shoots. Rattan provides sustainable income to some of the most disadvantaged groups of people living in and on the fringes of forests. The global rattan industry is worth over US$7 billion per annum (Sastry, 2002). It has been estimated that 0.7 billion of the world's population use or are involved in the trade of rattan and rattan products (Sastry, 2002). Malaysia used to be one of the rattan cane exporter in 1980's and the export of raw rattan materials was banned by the Malaysian Government in 1989. Thus rattan cane exporters are encouraged to venture more into downstream industry (Nur Supardi and Aminuddin, 1991).

In 1980's, rattan industry was a booming industry in Sabah due to the high demand of global market for rattan based furniture. During this time, rattan raw cane and furniture industry generated multi-million ringgit to the Sabah state revenue (Chia & Andurus, 2008). Semi government agencies like Sabah Forestry Development Authority (SAFODA) and Rural Development Corporation (KPD) are the main players in this industry. KPD established processing and manufacturing factories in various parts of Sabah. These factories solely dependent on the raw rattan cane collected from the jungle and 1,000 tons of raw cane per year is needed to support the mill (Shim & Tan, 1984). During this time, the KPD factories frequently faced shortage of cane supplies (Shim & Tan, 1984). Related to this, the commercial rattan plantation was established, mainly by SAFODA and Innoprise Corporation Sdn. Bhd. (ICSB) with the objective to supplement the shortage of supplies of raw cane in Sabah. At the same time, in view of the importance of protecting the industry and increasing the values of export, export of raw rattan materials was banned by the Malaysian Government in 1989. With the ban of rattan export by Peninsular Malaysia, the Sabah State Government followed suit by banning the export of raw rattan in 1990, followed by semi-finished rattan in 1993 and allowing only export of rattan in finished form such as *tatami* (a rattan mat)or/and furniture. Theoretically, this ban was imposed to stimulate the development of rattan-based industries and ensuring the value of the raw product to be increased by producing value added product. Ironically, the rattan industry in Sabah "collapsed" during this time. In the mid 1990's, there were two factories operating on a large-scale whilst more than 100 factories were operating on a small scale (Lee & Chia 1996). To date, only 11 factories are operating on a small scale in Sabah (Chia & Andurus, 2008).

The rattan industry has indicated the demand for rattan furniture in global market is high, however the raw materials available is not enough to meet the market. The main problem confronted by the rattan industry is the reduced supply of raw canes from natural forest. In 2006, rattan cane production from the natural forest was only about 110.56 metrics tonnes (MT) and 81.70 MT was used for furniture making (Sabah Forestry Department, 2006). The rattan factories find difficulties in securing raw cane for their industry. The extraction of rattan is difficult and gatherers are discouraged to gather rattan in view of supply getting deeper in the jungle. Rattan manufacturers normally procured raw material from middle men who secured the raw rattan materials from one district to another. Most of the rattan cane entering the market originates from wild populations and imported from neighboring countries like Indonesia and the Philippines.

In Sabah, for the furniture and matting industry, very few species are used and the majority of the commercial species are from the genus *Calamus*. The preferred indigenous species for furniture and matting industry are the large diameter *C. subinermis, C. manan, C. ornatus and C. scipionum*; and the small-diameter *C. caesius and C. trachycoleus* (Dransfield, 1977, 1984, 1992c). These mentioned commercial species are being heavily exploited to meet the market demand. The uncontrolled exploitation together with the destructive logging practices has resulted in the disappearance of many populations.

1.4 Conservation Status of Rattan Resources

The thriving international and domestic trade in rattan and rattan products has led to substantial over-exploitation of the wild rattan resources (Sunderland & Dransfield, 2002). The causes of depletion are well known and well documented (Salleh, 2002). These causes include;

i. Loss of habitat due the conversion of much of the tropical forest to other land uses, the habitat of rattan populations disappeared as well.
ii. Overexploitation of the wild resources. It was indicated that approximately 90% of rattan used commercially comes from the wild (Hunter & Lou, 2002)
iii. The rate of regeneration and replenishment by artificial means is inadequate.
iv. Poor management of the resources due to inadequate knowledge

The rapid resources depletion due the above causes is threatening the sustainability of rattan industry. The declining of wild rattan resources has led to the disappearing of genetic resources. It was indicated that approximately 600 species of rattan, 117 are recorded being threatened to some degree (Walter & Gillet, 1998). Based on the IUCN (International Union for Conservation of Nature and Natural Resources) Red List Categories, the 117 threaten rattan species was divided into different categories i.e. 21 species as endangered, 38 species regarded as vulnerable, 28 being rare and 30 as indeterminate (IUCN, 1998). Of the 194 indigenous palm species in Peninsular Malaysia, only 10 are not threathen, and 115 Calamoid species of 13 genera in this area are rare to endangered (Kiew, 1989b). The conservation of palms in Sabah also in the similar condition where only 10 out of 82 species are considered to be not threatened (Johnson *et al.*, 1996).

Rattan areas are being seriously affected by habitat loss and fragmentation. The conservation status of rattans is unknown and it is difficult to assess and monitor. In addition, rattan species were assumed not to be "safe" in protected areas or in national parks, as harvesting in such areas was usually permitted or tolerated. It was also assumed that the genetic basis of rattan species is narrowing. Some species are likely to be at risk of extinction (Dransfield *et al.*, 2002). The *ex-situ* and *in situ* conservation effort needs to be intensified to ensure the survival of rattan industry. In view on the value of rattan conservation, rattan plantation is suggested as an option for rehabilitation of degraded forest in Sabah (Tan, 1992a).

1.4.1 Conservation Status of the Major Commercial Species in Sabah

Table 1.1 shows the conservation status of the major commercial rattan species used Sabah. This table indicates that the conservation status of most commercial rattan species is unknown. *Ex situ* conservation efforts had been carried out back in early 1990's in Sabah for some of these species. This effort includes the establishment of provenance *cum* progeny trial of *C. subinermis* by Sabah Forestry Department and the *C. manan* seeds stand in Luasong Forestry Centre by Rakyat Berjaya Sdn. Bhd.

Table 1.1: Conservation status of the major commercial rattan species in Sabah

Species	Conservation status
Calamus caesius Bl.	Unknown
Calamus manan Miq.	Threatened
Calamus merrilli Becc.	Threatened
Calamus ornatus Bl.	Unknown
Calamus scipionum	Unknown
Calamus subinermis (eddl. ex Becc.)	Unknown
Calamus trachycoleus Becc.	Not threatened

Source: Sunderland & Dransfield (2002)

1.5 Rattan Plantation Development in Sabah

In Sabah, rattans in the natural forest have not been inventoried. Therefore there has not been adequate management of these natural resources for sustainable production. This was indicated by the drastic drop in rattan production from the natural forest. The rising demand together with high market price in the 1980's resulted in an increased in harvesting rate and diminished supplies of raw rattan materials from natural forest (Shim & Tan, 1984). In this regard, planting will be the only viable alternative for the sustainable supply of raw materials.

The commercial rattan plantation in Sabah started since 1980's. The Sabah Forestry Department initiated rattan silviculture research in 1979 following the high demand for rattans. Similar step was taken by the semi government agencies and private sector to establish big scale rattan plantations. Table 1.2 shows the rattan plantations for the past 10 years in Sabah. In 1996, the total area of rattan plantations in Sabah was 23,157 ha and in 2005, only 53% or 12,380.88 ha of rattan plantation was available in Sabah. This figure indicates that the rattan raw materials in Sabah are depleting and new planting area should be initiated to ensure the sustainable supply of raw canes. As indicated earlier, the global demand for rattan products is increasing but the supply of rattan raw materials is decreasing. This scenario created difficulties for rattan manufacturer to sustain their enterprises. The high demand of raw rattan canes is indicated by the promising current commercial price for large diameter cane of RM3,000/ton while for small diameter cane is RM2,500/ton. However, neither government nor private agencies have taken any notable steps forward to plant rattan on a larger scale. The major constraint faced by rattan planter is the land-use competitions with specific reference to oil palm plantation development, with no expansion in rattan plantation by the private sector. Rattan has a long gestation period before it matures and the return is not as attractive as oil palm (Chia & Andurus, 2008).