I. Introduction

For 50 years the forests of Vietnam have been experiencing a severe spiraling down of both their resource and quality, leading to poor ecological conditions for forest tree growth and environmental disruption. Therefore, parallel with forest-restoration-orientated protection and enrichment planting, the establishment of new plantations has become a “must” in the forestry subsector, in which the choice of suitable forest tree species, especially those of prime and rare timber, has emerged as a vital task. For this, *Tarrietia javanica* Blume (vernacular Huynh) and *Michelia mediocris* Dandy (vernacular Gioi xanh), both well valued and productive indigenous timber species, these last 20 years have been tested in a number of provinces through enrichment planting trials. However, the extension of the technology used remained difficult, because of a lack of research and research findings on: site conditions, planting technics, seed supply and storage; in particular the lack of information on seed storage and seedling production seems to have tied up many enthusiastic extension workers.

To overcome the stumbling blocks, the Forest Ecology and Environment Research Centre (below referred to as the Centre) carried out a research project on “The Physiological and Ecological Characters of *Tarrietia javanica* Blume (Huynh) and *Michelia mediocris* Dandy (Gioi xanh) to Develop Forest Plantation technology”.

II. Research methodologies and materials

+ For site description and ecological studies: Field survey sampling plots of S=400 sq.m were established in the natural habitats of *Tarrietia javanica* (vernacular Huynh) and *Michelia mediocris* (vernacular Gioi xanh) to indentify and measure forest tree regeneration and growth and the natural factors governing these processes.

- The site requirements for tree growth were assessed based on site survey methods, with due attention being paid to the three main factors of climate, soil and vegetation.

+ For physiological studies:
  - Light requirements were assessed based upon the “shading cover” method as devised by Turskii, combined with improvements thereof related to degrees of shading (open area, shading over 20%, 40%, 60% and 80% of the area respectively and to the timing of shading during daytime with assessments of growth of the two species under study in different planting practices; with measurements of light intensity by “luxmeters” and with leaf anatomy and chloroplast analyses.

  - Nutrient requirements were measured based upon soil and foliar analyses carried out in the laboratories of the centre.

  - Water requirements were assessed through quick weighing of fresh leaves under field conditions in combination with leaf anatomical studies (counting of stomata and measuring of the cutin thickness).

III. Research findings on *Tarrietia javanica* (vernacular Huynh):

1. Ecological conditions suitable for tree growth

+ Climatic conditions: *Tarrietia javanica* (vernacular Huynh) naturally occurs from the pass of Deo Ngang southward to the province of Khanh Hoa, mainly along the western parts of the provinces of Quang Binh to Quang Nam (where it can account for 2.5-10% of total tree population in natural forests).

Its natural habitat is the moist tropical forests, in which annual rainfall of over 2,000 mm, and average air-temperature above 20°C (with a minima temperature rarely below 15°C) prevail.

+ Topographic and edaphic conditions
The species occurs in secondary growths at elevations of 200-400m above sea level, on “feralit” soils (in Bo Trach-Quang Binh, Tra My-Quang Nam), on soils developed from micaschists (at Truong Son Forest Enterprise-Quang Binh) and also on soils developed from argillaceous materials (in Ba Ren-Quang Binh, Phuoc Hiep-Quang Nam). The species grows well on slopes of hills or low mountains ranging from 15-20° and on sites with deep soils of over 50cm and of light texture.

+ Cover vegetation:

The species naturally occurs in forests of medium to poor standing volume, in mixture with a number of other hard-woods vernacular known as Tau, Vang, Lim xanh, Truong, Tram or Tau, Go, Uoi, Chua (as found at Tra My-Quang Nam). It always emerge as a dominant species in forests.

+ Regeneration habit /potential

The species regenerates very well among many other timber species such as Cho, Dau, Go (in Quang Nam) or Tau, Gie, Go, Lim xanh (in Quang Binh), sometimes reaching a very high density of 0.5-0.7 in terms of plant cover and it always tends to dominate other hardwoods, therefore a lot of Huynh plants used in plantations come from wildings harvested from natural forests.

2. Growth habits

In its natural habitats, Huynh grows quite fast in height from its 3rd to 9th years (with increments not below 0.9-1.5m a year). It also grows fast in diameter from its 3rd to 11 years (with annual increments ranging from 1.0 to 1.7 cm being usually noticed). In plantations, thing goes much better, with the highest increments in both diameter and height being observed from its 3rd to 10th years of age.

3. Physiological characteristics

+ Light requirement: Tarrietia javanica (vernacular Huynh) becomes a light demanding tree species when it is going to get mature and because of this it tends to reach the dominant layer of the stand with a number of other tree species. However, at its younger stage, Huynh as a hardwood, has to regenerate under forest canopy, and is shade loving, in particular at its first 2-3 years of age.

Experiments made at Chem and Ba Ren for 15 months, during that growth stage, show that:

- Leaf colour and plant vigour vary from treatment 4 (with 60% shading) to treatment 1 (with no shading).

In fact, the leaf colour changes from: deep green to light green, yellowish green, then to greenish yellow (with decrease in shading);

- Growth response: as observed at Chem and Ba Ren under 60% shading reads as follows:

Better growth: twice higher than control (no shading) with mean height growth being increased to 107.5 and mean diameter growth being increased to 109.6% as compared to 57% and 70% respectively under no shading at Chem, and mean height growth being increased to 219.8% and mean diameter growth being increased to 203.6% as compared to 87% and 97.5% respectively at Ba Ren.

- Higher amount of chloroplasts a+b occurs under treatment 4 (amounting to 2.0mg/dm2) then the same under treatment 1 (with a lower amount of 1.04 mg/dm2 only), which is also confirmed by the colour of the leaves observed. The ratio of chloroplasts a/b under treatments 4 and 5 (85% shading) reaches the highest values of 2.6-2.8 and then decreases gradually under treatments 3 (40% shading), 2 (20% shading) and 1 (no shading).

- The thickness of the palissade tissue under 60% shading reacts accordingly to the impact of increasing sunlight, but the contrary occurs in lacunal (?) tissues.

+ Nutrient requirement: In its natural habitats at Bo Trach (Quang Binh) and Tra My (Quang
Nam), humic and total N contents of soil do not point to differences in tree performance. They usually come up to the following values (H=1.36-2.5% and total N =0.12-0.20%) as found elsewhere in this country. The same can be said of the readily assimilable amount of potassium (with K2O=10.4–46mg/100g of soil on the average). Results from foliar analyses tell us the same thing.

+ Water requirement: *Tarrietia javanica* naturally occurs in moist tropical forests from the pass of Deo Ngang southwards, in particular on the western parts of all provinces from Quang Binh to Quang Nam, where annual precipitation amounts to more then 2,000mm, but where the evapotranspiration process is quite intense due to the dry and strong westerly wind prevailing from June to August, which shows that in spite of being a hydrophilous tree species, *Tarrietia javanica* can stand well the dry and hot atmospheric conditions prevailing in parts of the year in its habitat. The evapotranspiration I varies from 0.30-0.60g/dm2/h in the experiments made. At the age of 12, the I value might go down 0.10-0.25g/dm2/h. The cutin layer thickness under shading is lowest under a cover of 60-80% (10.47... to 7.1..... respectively) while the same under a shading of 20% and no shading is of the order of 1.34.... and 14.23.... respectively.

4. Possible extension of *Tarrietia javanica* habitat

Based on the observations made, it is found possible to extend the habitats of *Tarrietia javanica* through plantation to the western low-mountain parts of Nghe An, further North of its natural habitat limits noticed at the pass of Deo Ngang, then from there southwards to similar sites of the provinces of Quang Ngai and Binh Dinh.

5. Research findings on seed production and supply

5.1. Phenological features:

*Tarrietia javanica* begins to flower profusely in April to May, but seed years only occur every four to five years. Its fruit matures in August and September and is dispersed by the wind around parent trees. Regeneration samplings made in Quang Binh and Quang Nam show that the species regenerates well in a circle radius of 40-60m around parent trees, thus showing the limits of its fruits and seeds dispersion.

5.2. Other research findings on seed storage and species propagation

+ *Tarrietia javanica* seed storage was tested following three treatments: dry storage, cold storage and seed stratification in sand. It is found that seed stratification with 20% moist sand brings in the best results (a germination rate of 65-70% can be expected after 3-5 months of seed storage under these conditions).

+ Vegetative propagation of the species can be carried out with success during early spring, using stem cuttings pretreated with AIB at a concentration of 200ppm for 2 hours (or at a concentrating of 1000ppm for 3 minutes). The use of stumps for plantation establishment yields very good results, and can produce quite high and homogenous plants.

6. Main conclusions

- Site selection for *Tarrietia javanica* plantation.

The habitat of the species can be extended with its upper limit removed northwards to appropriate sites found in Nghe An, to go from there along the central Vietnam coastal zone down to Quang Ngai and Binh Dinh.

- The species does not require high soil quality. It grows well in moist and well drained soils of degraded secondary regrowths or high shrubs. However it is not advisable to grow the species on strongly eroded sites of shallow and/or stony soils which are bare of vegetation or can support only drought-resistant shrubs and grasses.

- The species can be cultivated in mixture with other timber species or in pure strips of over 10m wide or in gaps in forests or on forest fallows following swiddening. It is not advisable to grow *Tarrietia javanica* in narrow belts of 2-3 metres, because of its development into light-demanding tree species at young age.

- Its seed can be stored using the method of seed stratification with 20% moist sand for 3-4
months, after which the seeds lose their viability very quickly.

- The production of *Tarrietia javanica* stumps can help produce high-yielding and homogenous plantations of that species. In short, the main points for site selection for the cultivation of *Tarrietia javanica* are:

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Site factors</th>
<th>Requirements for productive plantation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Climate</td>
<td><em>Annual precipitation</em> 2,000-3,000mm&lt;br&gt;23-25°C&lt;br&gt;16-18°C&lt;br&gt;over 100 days&lt;br&gt;</td>
</tr>
<tr>
<td></td>
<td><strong>Mean annual temperature</strong></td>
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<td></td>
<td><strong>Mean minimum temperature</strong></td>
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<tr>
<td></td>
<td><strong>Number of rainy days per year</strong></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Topography</td>
<td><em>Elevation above sea level</em> 200-500m&lt;br&gt;Below 25°&lt;br&gt;Slopes, tops, foot of hills&lt;br&gt;</td>
</tr>
<tr>
<td>3</td>
<td>Soils</td>
<td><em>Parent materials</em> Acid magma, argillaceous schists, micaschists&lt;br&gt; <em>Soil depth</em> Over 50cm&lt;br&gt; <em>Soil texture</em> Sandy loam to loam&lt;br&gt; <em>Ph KCl</em> 4.5-5.0&lt;br&gt; <em>Humus in A horizon</em> &gt; 20%&lt;br&gt;</td>
</tr>
<tr>
<td>4</td>
<td>Vegetation type</td>
<td><em>Forest vegetation type</em> Degraded forest of III A1 type, shrubs of over 3-4m high&lt;br&gt;0.5-0.6&lt;br&gt;</td>
</tr>
<tr>
<td></td>
<td><strong>Vegetation cover</strong></td>
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</tbody>
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IV. Research findings on *Michelia mediocris* (vernacular Gioi xanh)

1. Ecological conditions

1.1. Climatic conditions and natural habitats

*Michelia mediocris* (vernacular Gioi xanh) is regarded as an endemic timber species in Vietnam, because its habitat is extending over large areas from the North West, the Central North, to the provinces of Thanh Hoa and Nghe An, then along the Coastal Central Vietnam, to finally reach the Western Highland and the South of Vietnam. However the species seems to prosper in Kon Ha Nung in the province of Gia Lai. It grows on low mountains of less than 1,000m above sea level, mainly in areas with an annual rainfall of 1,000-2,000 mm and an average annual temperature of 20-25°C.

1.2. Topographic and edaphic conditions:

Because of its wide habitat, it can be found on soils developed on acid magma as in Central Vietnam and on the Western Highland, on grey soils developed from old alluvia as in the South of Vietnam, and on many others soils developed from argillaceous schists or micaschists as observed in the northern provinces of Central Vietnam, or on soils on metamorphic rocks as in the mountains of North Vietnam. It thrives well only in moist evergreen tropical forests, and is known as a hydrophilious timber species growing well on moist, well–drained and deep soils with high humus content (4-10%) and appreciable amount of readily assimilable K₂O (above 10mg per 100g of soil).

1.3. Main features of its forest vegetation associations

*Michelia mediocris* occurs naturally in evergreen moist tropical forests, in mixture with other hardwoods so to create temporary or established "ecological patches" in which of the species is growing together with *Machilus* spp. (Khao), *Lithocarpus* spp. (Soi), and *Engelhardtia chrysoplepis*...
(Cheo) (as at Bac Ha, Lao Cai); with Cinamomum spp. (Re) and Canarium album (Tram trang) (as at Chiem Hoa-Tuyen Quang); with Amesiodendron chinensis (Sang), Symplocos cochinchinensis (Dung), (as at Ba Vi-Ha Tay); with Aglaia giganta (Goi), Madhuca pasquieri (Sen) (as at Song Hieu-Nghe An); or with Vatica tonkinensis (Tau mat), Schima wallichii (Vo thuoc) (as at Huong Son-Ha Tinh); or also with Dialium cochinchinensis (Xoay) (as at Kon Ha Nung-Gia Lai).

1.4. Regeneration habits/potential

Michelia mediocris flowers and sets fruit every year, with seed years being noticed only in years of favourable weather conditions. When mature, its fruits fall down to the forest floor, thus providing a high amount of viable seeds, which because of its aroma are very often eaten by birds and wild animals. The amount of Michelia mediocris advance growth, however, goes decreasing with their density and growth, resulting in a poor regeneration under natural conditions, in particular in degraded forests where the species can be seen.

1.5. Growth characteristics

In natural forests, the species grows quite slowly; at Nghia Dan, the highest increment in terms of Dbh is about 1cm per year at its age of 19 and after that its diameter growth goes decreasing gradually (Nguyen Ba Chat). Its increment in terms of height at its 12-30 years of age is about 0.6m per year. The same result has been recorded in surveys made at Kon Ha Nung, where the species reaches an annual increment of its Dbh of about 0.6cm/annum, i.e. the same as with other species such as Parashorea stellata (Cho chi), Erythroploem fordii (Lim xanh), Vatica tonkinensis (Tau mat), Lagerstroemia tomentosa (Sang le) (Bui Doan). However in plantations of different cultivation patterns, there are considerable variations. Michelia mediocris planted in large strips performs better than the same grown in narrow belts in both diameter and height growth; for instance in strips it can reach an Dbh increment of 1.9-2.1 cm/annum and an annual height growth of 1.5-1.7m, while in belts, the increments in terms of Dbh and height are 1.4-1.6 cm/a and 1.2-1.3m/a respectively.

2. Physiological characteristics

Chloroplast (a,b and a/b) analyses show that young saplings of the species at its age of 2-3 years (or 29 months) are going to be light-demanding and require full sunlight to grow in height.

2.1. Nutrient requirements

Michelia mediocris is said to grow well on soils of different parent materials; most of them are moist and deep ones, quite rich in nutrients (with a humus content of 3-5%, a total N content of more than 0.3% at their surface layers, where silt particles prevail). There are no regrowths of Michelia mediocris on loamy sand.

2.2. Water requirements

Michelia mediocris is a hydrophilous timber species thriving well in moist tropical forests, and much more rarely in degraded secondary regrowths. Its requirements in water is higher than the same by Tarrietia javanica as shown in some studies of its evapotranspiration, using the rapid weighing method of Ivanop, which shows that its I value amounts to 0.48=0.92 g/dm2/h, as compared to I=0.30-0.60 g/dm2/h for Tarrietia javanica. The counting of stomata and the measurements of cutin layers on the two species point to the same conclusion, with 56 stomata/mm2 and a cutin layer of 1.7... thick for Michelia mediocris and over 80 stomata/mm2 and a cutin layer of 13-14... thick for Tarrietia javanica.

3. Research findings on seed production and supply

3.1. Phenological features

Michelia mediocris is a timber species evergreen round the year, it flowers and sets fruit quite regularly, with its fruit matures somewhat later in the Central Vietnam, especially in the former 4th zone. Its germination rate and its growth into plantable seedings vary, depending on a lot of factors, of which the seed collection season and the seed source play a very important role. Experiments made to choose the right season for seed collection show that it is best to collect its seeds from 30 September to 15 October every year, which can secure a higher germination percentage of 78-79% and also a higher rate of plantable seedlings of nearly 54-65%.
3.2. Seed storage

The seeds of *Michelia mediocris* do not yield easy storage. It is best to sow seeds as soon as possible after their harvesting. Storage in 20% moist sand with a percentage of four parts of sand to one part of seeds can be used for storage for three months, which enables plantors for reach a germination rate of about 60%.

4. Main conclusions

- *Michelia mediocris* is found adaptable to a wide range of ecological conditions, so it can be cultivated from North to South at the sites most suitable to its requirements.

- It grows well on fertile moist deep forest soils rich in nutrients under degraded secondary regrowths or newly regenerated forests having a vegetation cover of about 0.4-0.6. It is not advisable to plant the species on degraded shrubly and /or denuded hillsides.

- It is a shade-tolerant species (with a shading of 40-60% being the best) until its 1-3 years of age. It is right to grow *Michelia mediocris* in strips of more than 10m wide. If it is planted in narrower belts of 5m wide, then vegetation clearing in the third year after plantation is necessary.

- Mixture with other timber species can be carried out using such hardwoods as *Machilus* spp. (Khao), *Canarium* spp. (Tram), *Cinamomum* spp. (Re)... as mentioned earlier.

- The best seed sources to be used are the local ones, in particular the sources readily available in each province so to avoid long distance transportation of seeds, which can have a negative impact on its germination rate.

- The seeds of the species can be best harvested from mid-September to mid-October every year, and then sown as soon as possible after collection. When storage is necessary seed stratification with 20% moist sand (one part of seed to four parts of moist sand) can be used for three months, after that the seeds loose their viability.

The main points for site selection for *Michelia mediocris* cultivation are:

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<td>Forest vegetation type, Vegetation cover</td>
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8. Liên hợp Lớp nghiên cứu Long 84-1987: Bền hình ổn thiết kế Erick establishment of Trarrietia javanica plantations