THE POTENTIAL OF LOCAL TREE SPECIES TO ACCELERATE NATURAL FOREST SUCCESSION ON MARGINAL GRASSLANDS IN SOUTHERN VIETNAM

Nguyen Van So[1]

ABSTRACT

In Vietnam, to rehabilitate the marginal grasslands resulting from over-logging and shifting cultivation, reforestation has been applied as the most promising strategy to increase soil productivity and restore ecological balance. If protected from forest fire and over-grazing, such marginal, fallow lands will become colonised by fast growing, pioneer and later climax tree species. However, natural forest succession often takes a long time to accumulate enough nutrients, accelerate nutrient cycles and enhance the activity of soil micro-organisms and earth-worms. This can be solved by human intervention in selecting appropriate local fast growing pioneer species and planting them on marginal grassland to accelerate the natural pioneer-climax species succession.

This paper discusses the applicability of the Accelerated Pioneer-Climax Series (APCS) Method for restoring forests to degraded areas in Southern Vietnam, particularly for lowland and hilly Dipterocarp plantations, using many local species of both pioneer and climax trees. These include the pioneers *Indigofera teysmanii, Trema orientalis, Anthocephalus chinensis, Wrightia tomentosa* etc.; intermediate species e.g. *Dalbergia cochinchinesis, Xylia dolabriformis, Cassia siamea* and *Lagerstroemia angustifolia* and climax species e.g. *Dipterocarpus alatus, D. dyerii, Hopea odorata, Anisoptera cochinchinensis* etc.

Initial results from this method have shown that not only is the natural succession shortened and the biodiversity enhanced, but also local community and foresters can benefit from short and mid-term products such as fuel-wood, poles, small timber etc through thinning activities.

Key words: natural forest succession; natural pioneer-climax species succession; closed nutrient cycling process

INTRODUCTION

The forest area in Vietnam has been greatly decreased by the effects of war, heavy exploitation by logging, shifting cultivation and expansion of agricultural land. This decrease also adversely affects the upland environment, particularly the climatic and soil conditions of watershed catchment areas, causing several problems for agricultural production and directly to people's life in the uplands. More importantly, as a wave of colonisation and development

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clears new areas, it creates in its wake a land often thoroughly wasted for any meaningful human use: marginal grasslands. In some areas, forest clearing is followed by large tracts of monoculture for agricultural exports such as coffee, rubber, bananas etc, in a bleak agro-industrialised landscape.

Tropical forestland is difficult to exploit for several ecological reasons. One of the most important constraints is that tropical soils have low concentrations of nutrients, since high temperatures and rainfall throughout the year leach chemical nutrients from the soil. With few exceptions, the nutrients in a tropical forest ecosystem are mostly in the plants themselves. When plants die and are attacked by organisms, the nutrients that are slowly released are trapped by fungi, the main agents of decay, and delivered to the roots of the succeeding trees and shrubs through complex symbiotic interactions. If the forest is felled and burned for agriculture, nutrients are rapidly flushed into the soil, where they are only available for crops over a few rotations. Without the slow and complex mechanisms of nutrient recycling, these free ions are literally washed out of the soil. Vegetative cover is reduced and grasses and scrub invade the cleared areas. If the soil is compacted through mechanical clearing or subsequent grazing, the exposed soil will be eroded by large raindrops pounding its surface - a particularly acute problem on hillsides.

BARRIERS TO TROPICAL FOREST REGROWTH

Tropical forests seem distinctly unable to reclaim land once it has been cleared and used for agriculture. There are a number of reasons for this:

- Clearing and burning is likely to release most of the nutrients into poor tropical soils, which are then leached out by warm tropical rains.
- The process of forest regeneration is complex and the seedlings of hardwoods found in forest often tolerate only a narrow range of humidity and light conditions and cannot, therefore, grow in open areas. Under natural conditions a succession of different species, starting with pioneers, provides this environment.
- Tropical forest fruits and seeds are most often spread by animals, sometimes by relatively few species. That is why a seed source has to be near the clearing and disperser populations must be able to withstand drastic habitat changes.
- Forest species are often pollinated by means of animals through cross-pollination between individuals, so close proximity of individuals of the species and readily available suitable pollinators are essential.
- Both pollination and dispersal are made more difficult by the relative rarity of any tropical forest species. This rarity is a natural consequence of diversity since tropical forests are not usually dominated by a small number of species.
- Trees may require specific symbiotic relationships with fungi known as mycorrhizae.
- There is a collection of ungerminated seeds in the soil known as a seed bank, but it is unclear how long seeds remain viable under the of effects insect, fungal and human activities. This is part of the "gap ecology" in tropical forests.

- Tough, browsing and fire-resistant grasses, such as *Imperata* and shrubs take hold after long periods of burning and grazing.

Given these constraints, it can be seen that belief in the ability of forests to regenerate quickly towards their original state is unfounded. Therefore, positive human interventions, enrichment planting and afforestation seem necessary to rehabilitate tropical forests from degraded secondary forests and marginal grasslands.

CONCEPT AND EVIDENCE FOR "ACCELERATED PIONEER-CLIMAX SERIES" (APCS) APPLICABILITY

APCS is based on the ecological principle of natural succession wherein pioneer species, which have the ability to adapt to adverse site conditions, improve the microclimate and soil conditions, rendering them favourable for the establishment of climax species. However, since natural succession is a slow process, this can be accelerated through the planting of pioneer species first and later inter-planting with climax species. To rehabilitate degraded upland soils, reforestation by APCS has been proposed as a promising strategy to improve the soil productivity and to restore ecological balance.

Advantages of APCS Strategy

APCS is an environmentally sound strategy, particularly in upland areas because of the following:

1. It follows the principle of natural succession.
2. It promotes biodiversity, since at least two types of species (pioneer and climax) are planted.
3. It can restore some grassland areas, which were formerly dipterocarp forests, into dipterocarp plantations,
4. It improves the microclimate and provides immediate cover, even if the inter-planted climax species fail.
5. It protects upland soils from erosion.

APCS is socio-economically sound because:

1. Thinnings from the pioneers and intermediates provide fuel-wood, pole-wood, fodder, mulch, organic fertiliser and small timber for local consumption.
2. Local people easily accept it, since the practice allows participating farmers to gain different products from the plantations shortly after establishment to the end of the climax species rotation.
3. It is cost-effective, especially on open grasslands, since the pioneers and intermediates quickly suppress light-demanding grasses. Their high survival guarantees suitable conditions for planting climax species in the long term.

Examples of Applying APCS to Rehabilitate Barren Land in Vietnam

Several versions of APCS have been applied in Vietnam using different tree species and various planting densities. Initially, the objectives were both to i) rapidly rehabilitate waste, marginal, hilly grassland; ii) produce fuel-wood and small timber to meet local demand and iii) improve and make site conditions favourable for the climax species development. These practices can be classified into 2 main ones as follows:

1. ***Plantations of fast-growing species*** to rehabilitate *Imperata* grassland to provide better cover for wildlife and later to provide fuel-wood and small wood for local requirements.

Plantation characteristics:

- high densities (2,000-3,300 trees/ha);
- trees quickly suppress light demanding grasses after 2 years;
- plantation design: trees are spaced 1.5-2.0 m apart within rows, with 2.0 m between rows;
- potential species: *Indigofera teysmanii, Gliricidia sepium, Sesbania grandiflora, Lagerstroemia angustifolia, L. calyculata, Trema orientalis, Anthocephalus chinensis, Acacia auriculiformis, A. mangium*;
- thinning: after 4 years of establishment, line-thinning operations are carried out to harvest one row in every three for fuel-wood and small pole production. This is flexible depending on the owner's objectives;
- agricultural crops and Dipterocarp species are then grown in the alleys between two bands of fast growing forest at its early stage and
- at years 8 and 12, pioneer species will be gradually cut and removed to provide more light and space for the climax species.

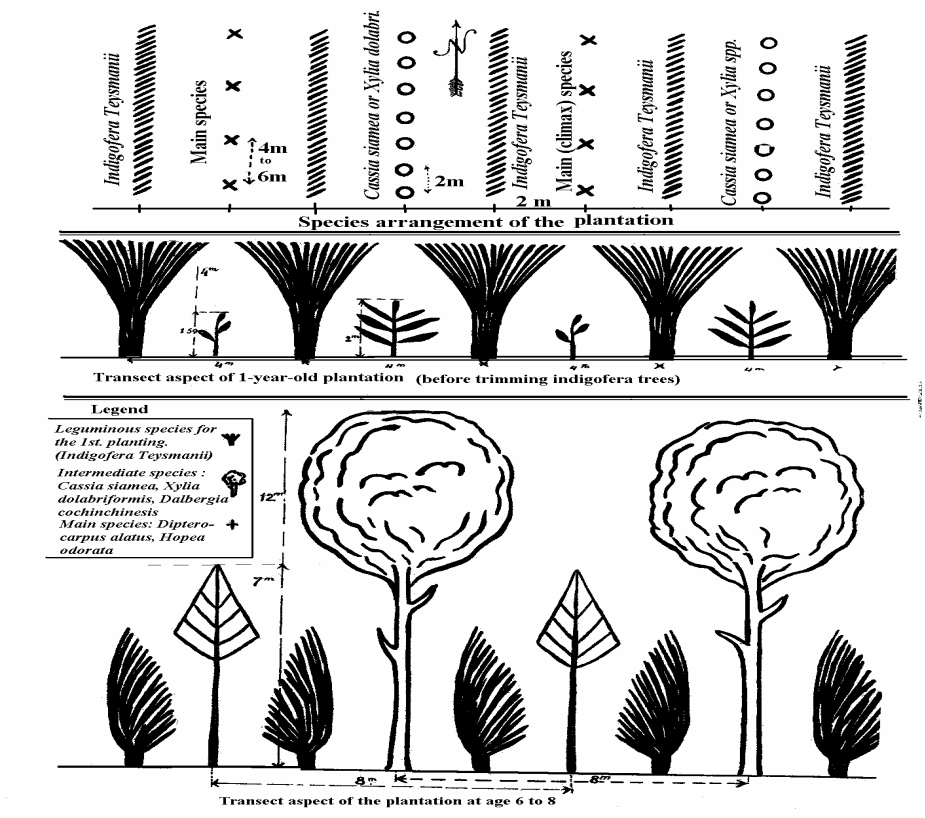
2. ***Mixed plantations*** with three pioneer, intermediate and climax tree species as illustrated in Fig. 1.

Plantation characteristics:

- species planted: *Indigofera teysmanii*, *Gliricidia sepium* (pioneer species), *Acacia auriculiformis*, or *Cassia siamea, Xylia dolabriformis, Dalbergia cochinchinensis* (intermediate species) and *Dipterocarp* species such as *Dipterocarpus alatus, D. dyerii, Anisoptera cochinchinensis, Shorea roxburgii* and *Hopea odorata*. Most of these species are chosen based on their establishment at several stages during natural forest succession, following forest clearance. Almost all selected species are indigenous species except for *Acacia auriculiformis*, a site-matching exotic species, which grows fast under all conditions.
- planting densities: 1666 trees/ha (4 m x 1.5 m) for pioneer species, 833 trees/ha (8 m x 1.5 m) for intermediate species and 278 trees/ha for climax species.
- cutting regime: the pioneer species *Indigofera teysmanii* is cut to ground level every two years for fuel-wood production, since this species grows fast and coppices well. Intermediate species (*Acacia auriculiformis, Xylia*

dolabriformis,etc.) are gradually thinned out over six years providing fuel-wood, poles, small timber and more light for the main species. Climax species (*Dipterocarpus alatus* or *Hopea odorata*) have a 60-year rotation producing timber for construction. (See Appendix A for species descriptions)

Fig.1. Model of Mixed Plantation by Mr. Paul Maurand



From some initial results in the southern part of Vietnam, this practice has proven to be technically sound because:

1. The pioneers have good potential to improve soil conditions particularly the soil biological and physical properties.
2. The growth performances of the intermediates and climax species are improved and much better than those in pure stands.
3. It enhances the nutrient cycling process. Therefore, it restores the productivity of the tropical forest ecosystem in uplands.
4. It provides short-term products such as firewood, fodder, poles and small timber from the cutting and thinning operations of the pioneers and intermediates.

FURTHER RESEARCH NEEDS

Although this afforestation scheme seems more complicated than pure plantations, it is consistent with natural ecological balance and supports wildlife development. Huge amounts of litterfall from the pioneers concentrated on the soil surface encourage micro-organisms and earth-worms. In addition, several tree species such as *Trema orientalis* and *Anthocephalus chinensis*, bear fruits which are particularly attractive to birds and bats.

However, in order to gain further knowledge more studies must be carried out to better understand the links between this scheme and wildlife conservation. On the other hand, the technology needs to be simplified and made economical, within the reach of rural poor farmers who are still working traditionally with slash and burn cultivation. One area, which deserves further attention, is the potential of using direct seeding to rehabilitate fallowed areas[2].

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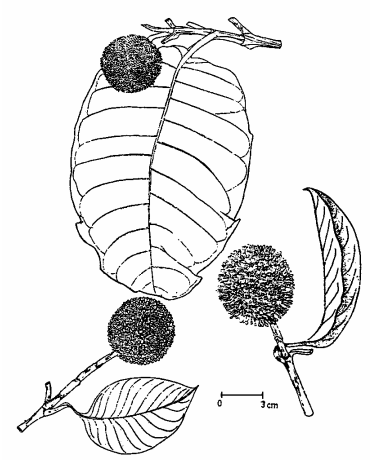
[2] Editor's note: this topic was subsequently taken up by discussion groups and a research proposal formulated. See Part 7, proposal 4.3).

Appendix A: Description of Local Species used in APCS

***Anthocephalus chinensis* (Lamk.) Rich. Ex Walp.**
Family: Rubiaceae



NAMES:

Synonyms: *A. cadamba* (Roxb.) Mig., *A. indicus* A. Rich., *Cephalanthus orientalis* Linn.

Vietnamese name: g*ao trang, gao nhot.*

DESCRIPTION: g*ao trang* reaches 25 to 38 metres in height and 60 cm in diameter, deciduous, open crowned; slightly buttressed trunk with good form. The leaves are simple, opposite, coriaceous, 20 to 25 cm long and 12 to 15 cm wide (see above Figure, source: HENSLEIGH & HOLAWAY, 1988). They are ovate to oblong, with an acute apex and an obtuse or rounded base, and overall are heart shaped. The margin is entire to slightly expand; the veins are distinct underneath. The leaves are dark green above and pale yellowish green underneath. The flowers are small, yellowish white, sessile, and set in stalked, round, burr like heads about 3 cm across. The corolla is a long, slender, narrowly lobed tube from which a style projects. The fruit is globose, 5 cm in diameter, orange mass of fleshy capsules each containing many minute seeds. The sapwood is white with a light yellow tinge and is not differentiated from the heartwood. The bark is slightly rough and grey or light brown.

DISTRIBUTION: The current range of this tree is in humid tropical areas from Nepal to New Guinea. In dry sites it is difficult to establish in a plantation, however it is more successful in hot and wet weather. *Gao trang* is very common in the midlands of the southern part of Vietnam.

ECOLOGY:

Soils: The species prefers deep, moist, well drained, alluvial soils, it grows poorly in heavy textured or very infertile soils.

Temperature: Mean annual temperature range in its native range is 20^{o} to 32^{o}C. It is frost sensitive.

Altitude: *gao trang* does best at altitudes below 1,000 meters.

Rainfall: It is found growing in areas with 1,500 to 5,000 mm of rain annually. It tolerates dry periods of less than 4 months in duration. Uniformly distributed rainfall is ideal.

Competitive ability: On good sites growth is vigorous and fast, it is a pioneer species common to old logging sites.

Limitations: *gao trang* needs full sunlight.

USES AND YIELDS: Under good conditions plantations can yield 50 m^3/ha/yr (MAI). Usual production is 10 to 40 m^3/ha/yr. The wood has a specific gravity of 0.35 to 0.40 and poor durability but is easy to work. Uses include light construction, short fibre pulp, veneer, plywood, carving, and wooden shoes.

CULTURE:

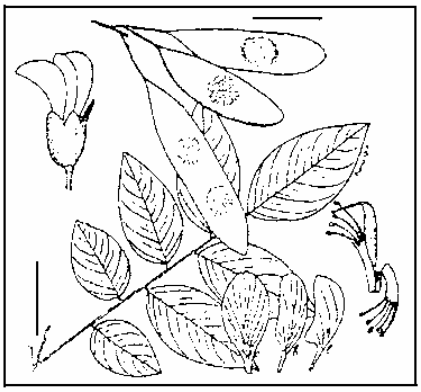
Seed collection and storage: ants readily eat fruits, so collect immediately after fruit fall. Seed maintains its viability for 2 years under refrigeration or for 3 to 6 months if stored in dry, airtight containers in a shaded area. There are approximately 2,600,000 to 6,000,000 seeds/kg or 150,000 seeds/litres. Extract seeds from the fleshy fruit and dry. No germination treatment is needed.

Sowing and producing seedlings: broadcast the seeds in a seedbed or box composed of 50% sand. Provide heavy shade. Germination is in 7 to 14 days. Potted seedlings 3 to 4 months of age are recommended for out-planting.

Care and harvest: after germination, water regularly (in the morning only to avoid problems with damping off) for 3 to 4 months or until seedlings are 30 to 45 cm tall. Outplant with 3 x 3 or 4 x 4-metre spacings.

Pests and diseases: seedlings are susceptible to damping off. The trees may be attacked by root knot nematodes (Meloidogyne) resulting in root knots and galls, *Arthoeshista hilarallis* may defoliate it.

***Dalbergia cochinchinensis* Pierre**
Family: Leguminosae; Sub family: Papilinoideae



Vietnamese name: *Trac*

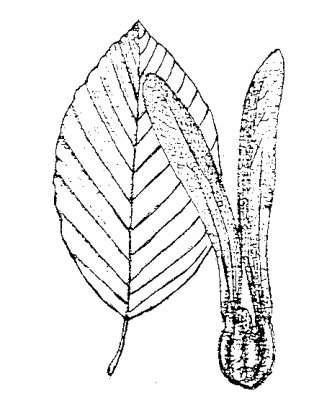
DESCRIPTION: A large evergreen tree, 25-30 m tall, diameter 60-120 cm. Bark brownish-yellow, longitudinally fissured, sometimes peeling. Profusely branched. Crown spherical. Leaves pinately compound, alternate or subopposite, apex obtuse, or shortly acuminate, base cuneate, 3-5 cm long and 1.8 - 2.5 cm wide, leathery (see above Figure, source: HO, 1990). Veins slightly prominent. Inflorescence paniculate, axillary, bracteate and braeteolate. Flowers white. Sepals connate, glabrous. Petals with straight claws, standard rectangular. Stamens 9. Pod flat, narrow, 5-6 cm by 1cm. Seeds 1-2, brown.

DISTRIBUTION AND ECOLOGY: Distributed in Vietnam, Laos and Cambodia. In Vietnam found from Quang Nam - Da Nang southwards, in Gia Lai and Kom Tum (Dacto, An Khe, Sa Thay). Scarce in other provinces. Llight-demanding and drought-tolerant but not demanding with regard to soil conditions. Shade-tolerant when young, growing in open and semi-deciduous forests, occasionally in pure stands, mostly at altitudes of 400-500 m above sea level. Prefers deep sandy clay soil and calcareous soil. Growth rate is rather slow, but it coppices strongly. Flowering in May to July, seed matures in September-November.

CULTURE: Pods are collected in September-November and sun dried to extract seeds manually. Approximately 30,000-40,000 seeds/ kg. Store seeds ventilated containers until sowing. Seeds are sown in nursery beds immediately after extraction. Seedlings are transferred into plastic bags. To hasten germination, seeds are dipped in hot and then cold water to 24 hours. Seedlings are raised in the nursery for 6-7 months before planting in the field when the rains are due. Young seedlings need shade, which is gradually reduced when older. *Trac* can be planted bare-rooted or as a potted seedlings as well as by stumps.

USES: Timber large-sized, sapwood and heartwood distinctive: sapwood greyish, heartwood brown-red or black, texture fine, very hard and heavy with a density of 1.09, easy to work and resistant to insects and termites, durable, and not splitting when dry. This wood has beautiful patterns when sawn, being classified as a first class prime timber, and is used for furniture, wood turnery, fine-art articles, musical instruments and sewing machines. Vulnerable species.

***Dipterocarpus alatus* Roxb.**
Family: Dipterocarpaceae
Vietnamese names: *Dau rai, dau con rai, dau nuoc.*



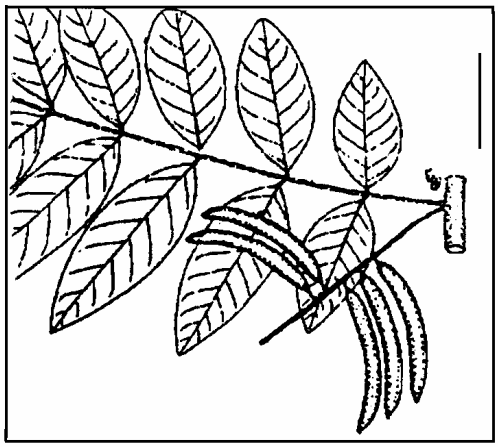
DESCRIPTION: A big tree, 35-45m tall, diameter 60-100cm. Trunk cylindrical, straight. Crown umbellate, late branched. Branches big. Twigs coarse. Bark white-grey. Inner bark yellowish-brown, resinous. Leaves simple, alternate, ovate or oblong-ovate, elliptic, 20-25cm long, 10-15cm wide, slightly acute, dark green above, pale green beneath, tomentose (see above Fig., source: HO, 1990). Lateral veins 15-20 pairs, parallel, evident beneath. Bud-stipule large, red, covered with tomentum. Inflorescence, a white-pink raceme. Flowers pentamerous (sepals 5, petals 5). Stamens about 30, arranged in two rings. Fruit, 1.5-2cm in diameter with 2 big wings, developed from sepals, 11-14cm long and 1.5-2cm wide, red when young and yellowish-brown when mature. One seed.

DISTRIBUTION AND ECOLOGY: Common in India, Myanmar, Thailand, Laos, Cambodia, Vietnam, Indonesia and the Philippines. In Vietnam, found from Quang Nam Da Nang province and southwards, in Dong Nai, Binhduong, Binhphuoc and Ba Ria Vung Tau provinces, growing gregariously in small pure stands along streams and river banks. The species always occurs at the highest storey of tropical evergreen forests, below 800m asl. (mainly from 200-500m asl.), usually mixed with *Dipterocarpus turbinatus, Sindora siamensis, Dalbergia cochinchinensis and Pterocarpus macrocarpus*. A light-demanding tree, but shade-tolerant when young, after 4-5 years, it demands full light for development. Natural regeneration is good, especially along rivers or on moist, flat lands. Flowering in November-December, fruiting in April- May.

CULTURE: Fruits are collected from the ground in May after the rains. Fruits have a reduced germination capacity after 1 month of storage, therefore they need to be sown as soon as possible after collecting. Fruits are sown directly in pots or in nursery beds and then transplanted to pots later. Shading and watering are needed to raise the seedlings for at least 1 year in the nursery. Dau rai can be established as seedlings in enrichment planting or by planting on barren land with pioneer species.

LIMITATION: It can not tolerate after being burnt and coppices poorly.

***Indigofera teysmanii* Miq (*I. Zollingerana* Miq)**
Family: Leguminosae; Subfamily:*Papilionoideae*



NAMES: Vietnamese: Dau cham, cham canh ranh.

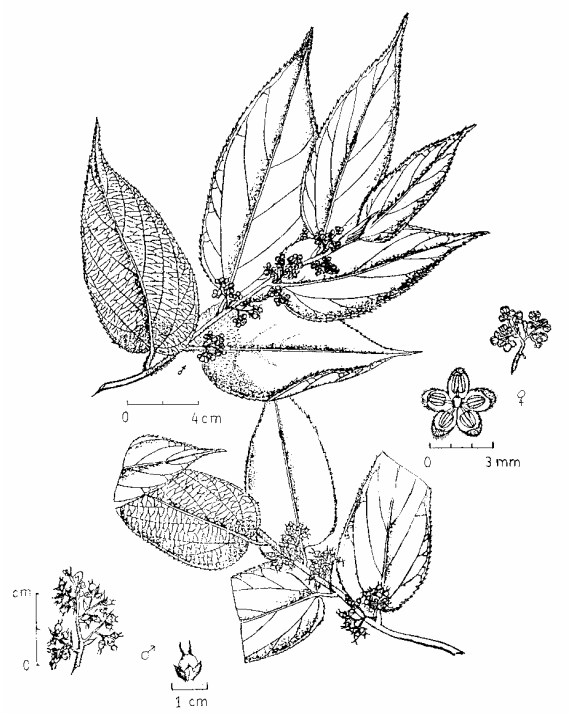
DESCRIPTION: Small to medium tree up to 12 m in height; branches and leaves have white hairs. Leaf is 20 cm long and composed of 11-17 leaflets, sized 4-7 x 2-3 cm (see above Fig., source: HO, 1990). Flower is a corolla, 10-20 cm long, brownish hairs, pink flowers, 2 mm high. Fruit is a legume, pods 35-45 mm long, indehiscent, each contains 10 round seeds.

DISTRIBUTION: Naturally grown along fences, savannah, open forest, on abandoned slash and burn fields. It can be found throughout Vietnam from Hoang Lien Son mountain in northern to the southern parts. This is a pioneer species, which often invades open areas or degraded land after burning. *Indigofera* can tolerate living on poor soils and enriches them due to nitrogen fixation and high litterfall that reverts organic matter back to soil.

CULTURE: Dau cham bears flowers in October-November and fruits in January-March. Seed is harvested in February by collecting the pods and drying them in open areas to gather seeds. Dried seeds can be well stored in normal conditions for 2 years. To hasten seed germination, dip seeds into hot and cold water successively. Planting can be done by direct seeding or by seedlings. Seedlings develop quickly and can reach 2 m high after 1 year old, this species coppices very well and is vigorous. It is a full light-demanding species and can suppress *Imperata* grass easily after 1-year of establishment. 1 kg of seeds consists of more than 100,000 seeds.

USES: Dau cham is a pioneer species for degraded and *Imperata* grass lands, it provides a good firewood source since it coppices easily, and can also be used as a shade tree for tea and coffee plantations, or a hedgerow species to control soil and water erosion. The leaf provides good folder for livestock and poultry and can be fed to some grass fish. This is a good species to rehabilitate barren lands before planting climax species.

***Trema orientalis* (Linn.) Blume**
Family: Ulmaceae



NAMES: Synonyms:
Vietnamese local name: Trung ca rung
Other common names: Charcoal tree, gunpowder tree

DESCRIPTION: Trung ca rung is a small tree with a spreading crown reaching heights of 18 m and diameters of 60 cm. Branches have a monopodial growth habit. Leaves are alternate in 2 ranks, ovate to lanceolate, 6 to 15 cm long, 2 to 7 cm wide, acuminate, usually pubescent and rough, and finely toothed (see above Fig., source: HENSLEIGH & HOLAWAY, 1988). The leaves are unequal sided, have 3 main veins extending from a slightly notched base, and are thin. The upper surface is dull, rough, and light green with sunken veins; the lower surface is pale, slightly hairy, with prominent light yellow veins. The petiole is grooved above and 6 to 10 cm long. Flower clusters are shot cymes in leaf axils, 1 to 2 cm long and 1 to 2 cm broad. The many flowers are nearly stalkless, 3mm wide, and light green. The purple or black fruits are round, 3 to 5 mm in diameter, and juicy with a stone 1.5 mm long inside.

The bark is light gray brown, smooth, finely fissured, and thin. The inner bark is pink, soft, fibrous, and bitter tasting.

DISTRIBUTION: Trung ca rung is native species in Vietnam and other South East Asian, South Asian countries, and China where it is widespread and abundant.

ECOLOGY: Trung ca rung is a pioneer species of newly cleared lands, eroded soils, and volcanic ash, it is common in secondary forests.

Soil: The tree grows in poor soils and barren environments.

Altitude: It is found growing to 2000m in the Himalayas. However, it is rare above 1000m in Vietnam.

Rainfall: It prefers a humid, moist climate with high rainfall but it is also found in areas which have a 6 month dry season.

Competitive ability: This is a fast growing, pioneer species which can outgrow other species in recently cleared areas, it dominates abandoned, fallowed land in some parts of Vietnam.

Limitations: This trees serve as a reservoir for populations of defoliating insect pests and thus may put at risk nearby plants of economic value. The tree grows rapidly but is short lived .

CULTURE:

Seed collection and storage: Trung ca rung is reported to flower from January to April. Lopez , in the Philippines, reports flowering from June through July with fruit maturing in September.

Establishment: *Trema orientalis* regenerates easily from seed if kept moist or stump cuttings may be used. Heating the seeds in water at 38^{o} C to 58^{o} C for 5 to 10 minutes encourages even germination and improves germination percentage (LOPEZ, 1953). Maceration and washing the fruits to remove the seeds may improve germination also.

Pests and diseases: This tree coppices vigorously but mortality of new shoots may be high. Causes of sprout mortality are not well understood. Trung ca rung harbors defoliating insects (of the *Lepidoptera* genus) but these seem to serve as natural pruning agents since they generally do not kill the tree.

USES AND YIELDS: Suitable for afforestation programmes in denuded and disturbed areas, it is also planted for shade in coffee, cacao, and other plantation crops.

Mainstem and branches: Due to its fast, growth, coppicing ability, and availability, it is widely used as a fuelwood although light. Specific gravity is 0.28 to 0.40 and the calorific value is 4500 kcal/kg. On good sites in Vietnam this has yielded from 28 to 40 m3/ha/yr with a 6 year rotation. In a study of this species growing in abandoned fallowed land in the midlands of the southern part of Vietnam (100-200m) 2-year-old trees were 10 to 13 cm in diameter, from 2 to 3-year-old trees were 14 to 20 cm in diameter and 3-4 year old were 20 to 40 cm. The wood is used to make gunpowder charcoal and is comparable to that of *Anthocephalus chinensis*. In the past it has been mixed with bamboo pulp to make paper. In some areas of Vietnam the tree is used for construction poles and in the manufacture of wall board, it rots easily and is destroyed by termites.

Leaves: The leaves may serve as a substitute source of folder, forage or browse. The leaf analysis reports 18% crude protein in dried leaf meal of trung ca rung.

Fruits: The small sweet fruits are edible.

Others: The bark is a source of tannin. Rope made from the bark is weak but when wet its resistance is doubled. Tensile strength of dry rope is 134 kilos/cm2.

QUESTIONS AND COMMENTS

Kate Hardwick

Where *Imperata* is dominant, you said that the grass is shaded out after 2 years. How did you control it at the beginning when the trees were too small to shade it out?

Nguyen Van So

We use fast-growing species such as *Indigofera*. We have to use easily grown species. If they need lots of nursery care, farmers won't grow them, so we are trying direct seeding. We weed twice: 1 month after planting and at the end of the rainy season.

Salamat Ali

Do you use line sowing or broadcasting?

Nguyen Van So

We sow the seeds in lines. We prepare a line and use as many seeds as possible, but the distance between the lines stays the same.

Nigel Tucker

How do you treat the seed? What was the *Imperata* grassland structure when you sowed the seeds?

Nguyen Van So

We treat the seeds with hot water, using a formula to determine the amount of hot water for the weight of seeds. *Indigofera* seeds are very small. Along the planting lines, we put in sticks and weed. We maintain the line for at least 6 months, checking germination and weeding. Especially in harsh conditions, you should not suppress *Imperata* by burning in the dry season. We suppress the grass by cutting in the rainy season and the rhizome decays. We don't dig out the rhizomes. If you cut during the dry season it will come again.

Laura Johnson

What is the effect of fire on your plantations? Does the plantation act as a barrier?

Nguyen Van So

After 6 months as the canopy has already closes there is no risk of fired. *Indigofera* suppresses fire in the plantation.

Yadi Setiadi

I'm very surprised that direct-seeding works in the grassland, this is very hard in Indonesia because of competition. Do you put on any fertiliser?

Nguyen Van So

On acidic soils we use lime to enhance the performance of legumes.