RESULTS OF AN UNDERPLANTING TRIAL WITH TWO NATIVE TREE SPECIES *T. javanica* AND *E. fordii* IN *Acacia* hybrid PROTECTION PLANTATIONS IN QUANG TRI PROVINCE

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ABSTRACT

This study was conducted to assess the growth of two native tree species planted under the canopy of *Acacia* hybrid plantations in Quang Tri province and Hue city. It provides the basic for selecting appropriate species to establish a model of converting monoculture *Acacia* hybrid plantation forest into mixed native forest in Quang Tri province. The ealier survey had identified eleven native tree species planted under the canopy of plantation forest within the study area. Among these, two species (*E. fordii* and *T. javanica* Blume) were selected for underplanting experiment in *Acacia* hybrid canopies at two different canopy closure levels (0.3 - 0.4 and 0.5 - 0.6, respectively). After 2 years of planting, *E. fordii* demonstrated a survival rate of 90.4 - 92.3%, while *T. javanica* showed a lower, rate of 88.0 - 91.3%. Both species showed greater diameter at ground level (D_{00}) and total height (Hvn) growth under the 0.3 - 0.4 canopy closure compared with the 0.5 - 0.6 canopy level. Within the 0.3 - 0.4 canopy condition, *E. fordii* achieved the average D_{00} of 1.55 cm and Hvn of 1.35 m, whereas *T. javanica* recorded as of 1.45 cm 1.25 m, respectively. The chlorophyll *a/b* ratio < 2.3 indicated that both species exhibit shade tolerance during the early growth stages, with *E. fordii* showing a higher degree of shade tolerance than that of *T. javanica*. The findings suggested that maintaining a closure level of 0.3 - 0.4 in the second year would be an appropriate silvicultural measure, facilitating optimal growth of underplanted native species in the process of converting *Acacia* hybrid plantations into mixed native forests.

Keywords: *Plantation forest, native trees, canopy closure, chlorophyll, Quang Tri province, underplanting.*

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1. INTRODUCTION

The North Central and South-Central Coastal regions of Vietnam together cover an area of 5,649,651 ha of forest, including 3,778,853 ha of natural forests and 1,870,798 ha of plantations, with forest cover reaching 54.23% [1]. Although forest areas and cover have increased markedly in recent years, the overall forest quality remains low: Much of the natural forest area is degraded, valuable timber species are scarce, natural regeneration is weak, and growth rate is slow.

Protection forests play a particularly important role in the North Central region by protecting watershed, reducing erosion, regulating water and conserving biodiversity. However, for many years, protection forests have been established predominantly as monoculture plantation forests - particularly *Acacia* hybrid and *Pinus massoniana* and *Pinus latteri*, which has revealed several limitations.

Monoculture Acacia plantations are easy to establish and fast - growing, but their single - layered canopies have low ecological resilience. Understory vegetation and biodiversity are poor, soil - erosion protection is suboptimal and the ecosystem is prone to degradation. Pest and

disease outbreaks are more likely, particularly under increasingly extreme weather. In some areas, serious diseases have been widespread, e.g., *Phanerochaete* sp. and heart rot in Acacia, reducing timber value and increasing fallen risk.

These issues degrade both productivity and protective function and lead to economic losses from premature stand failure. Sustainable forest development is therefore essential to conserve biodiversity, stabilize the environment, and enhance the protective functions of forests. Compared to monoculture forest, underplanting broadleaved native species under plantation forest canopy can reduce fire and pest outbreak risk, improve stand structural complexity and plant - community composition and enhance protective and carbon-sequestration functions. This approach can also mitigate erosion and landslides and increase resistance to windstorms and climate change, thereby pushing the forest ecosystem toward conditions approaching natural tropical forests and providing a foundation for sustainable forestry.

In recent years, some localities in the Central region have developed native tree planting under the canopy of monoculture Acacia and Pine plantations, with initial remarkable results. According to data from the Hue Forest Protection Department, the area of native tree planted under the Acacia and Pine forests was 586.22 ha; in which Quang Tri accounts for 3,082.04 ha, respectively with popular species including *E. fordii, Hopea odorata, Dipterocarpus alatus, Parashorea chinensis*, etc. Although underplanting under Acacia has been implemented, there has been little systematic research to identify which native species are suitable to local's specific site conditions, canopy - closure levels and planting methods. As a result, scaling up underplanting under monoculture Acacia forests remains challenging and lacks a firm scientific basis.

Moreover, native species differ in their adaptability and growth rate across sites, as well as in their tolerance capable of adverse environmental conditions and their growth dynamics change across space and time. Therefore, study on the growth of native tree species on different types of sites and specific planting techniques is necessary, providing a scientific basis for selecting appropriate tree species and planting techniques on each site condition, contributing to accelerating forest development towards sustainable development, meeting economic, environmental and social requirements in the North Central region.

2. STUDY MATERIAL AND METHODOLOGY

2.1. Study materials, timeframe and sites

2.1.1. Study materials

Native tree species underplanted in *Acacia* hybrid and *Pinus massoniana* plantations.

2.1.2. Study timeframe and sites

- Growth performance of native species underplanted in selected plantations has been monitored since 2023 in the North Central region, particularly in Trung Thuan commune and Dong Son ward, Quang Tri province; Chan May - Lang Co commune and Thuy Bang ward, Hue city.

- Research on the cultivation of two native tree species models, *E. fordii* and *T. javanica*, was conducted in Trung Thuan commune, Quang Tri province during the period of 2023 - 2025.

2.2. Study content and methodology

2.2.1. Study content

- Evaluation of growth of two selected native species underplanted in plantations some North Central provinces.

- Species selection and research on techniques for planting native tree species under the canopy of monoculture protection forests of *Acacia* hybrid in Quang Tri province.

2.2.2. Methodology

- Evaluate growth of selected native species underplanted in plantations:

+ Data collection: Data and information on site characteristics, afforestation and forest protection programs and projects in Quang Tri province and Hue city, forest status maps, forest planting design maps, etc, were collected from trustful sources.

+ Field survey: Sample plots were established to measure and monitor growth rates of native tree species planted in the study area.

Survey was conducted on native tree planted under pine and acacia forest canopy in Quang Tri province and Hue city to select points for establishing sample plots (OTC). The area of each OTC was from 500 - 1,000 m^2 (25 m x 20 m or 50 m x 20 m), ensuring that each OTC had a large sample capacity ($n \geq 30$ native trees/OTC). In total, 12 OTCs were surveyed in the 2 provinces. In each OTC, the following indicators were measured:

* Canopy closure, elevation, slope, species, year of planting, initial density (if known), current density, and survival rate.

* Diameter at breast height ($D_{1.3}$) or stump diameter (D_{00} - for small trees), Total height (H_{vn}) and height to crown base (H_{dc}), crown diameter (Dt).

+ Soil characteristics of the planting sites: On each OTC, one soil profile was excavated at the OTC center to describe soil depth, color, rock fragments, compaction and mechanical component.

- Species selection and research on techniques for planting native species under *Acacia* hybrid plantations in Quang Tri province:

Species selection: From the survey results, growth, survival rate and adaptability were assesed to select suitable native tree species for planting under plantation canopy in Quang Tri province and Hue city. From the list of selected tree species, 2 species with the best growth and adaptability, *T. javanica* Blume and *E. fordii* were chosen to develope a model of planting under the canopy of monoculture *Acacia* hybrid protection forests in Quang Tri province, with an experiment of 2 treatmentss on different canopy closure levels, including:

+ Treatment 1 (TN1): Canopy closure of 0.3 - 0.4.

+ Treatment 2 (TN2): Canopy closure of 0.5 - 0.6.

Each experimental area covered an area of 0.5 ha, with a density of 832 trees/ha, including 4 replications. *E. fordii* was planted alternately with *T. javanica* in each replication. To ensure that the canopy coverage was achieved according to the teatment and maintained throughout the monitoring period, Acacia trees were selectively thinned over the entire area before planting and after one year of planting. The canopy closure after thinning was checked through taking foliage photos.

Growth data (D_{00}, H_{vn}) were collected annually in the first 2 years. Shade tolerance was assessed in the second year through leaf chlorophyll content analysis according to the Grodzinxki method (1981), leaf samples were taken from the middle layer of the canopy in 4 directions East - West - South - North, 12 - 15 leaves/sample, 1 sample/tree x 3 trees/species x 2 species x 2 experiments = 12 samples.

2.2.3. Data analysis

Excel statistical processing software was used according to the instructions of Nguyen Hai Tuat *et al.* (2002) [2].

Student's t-test was used to compare D_{00} and Hvn of the two species across treatments on SPSS statistical software. Effect Size was calculated using Cohen's d coefficient to evaluate the level and practical significance of the observed difference between the two treatments.

3. RESULTS AND DISCUSSION

3.1. Evaluate growth of several native species planted under plantation forest canopies in some North Central provinces

3.1.1. Climatic characteristics of the study site

Table 1. Climatic characteristics of the area where native trees are grown under plantation forest canopy in the study area

No.	Indicator	Quang Tri province		Hue city	
		Trung Thuan	Dong Son	Thuy Bang	Chan May – Lang Co
1	Temperature (T)				
	Mean T (°C)	25	24.4	25.1	24.5
	Maximum T (°C)	40	40.6	41.3	41

	Minimum T (°C)	10	7.8	7.7	9
2	Rainfall (P)				
	Mean annual rainfall (mm/year)	2,100 - 2,500	2,100 - 2,600	2,500 - 2,800	2,400 - 2,900
	Months with rainfall ≥ 100 mm	3 - 6	3 - 6	4 - 6	4 - 7
3	Mean annual relative humidity (W; %)	80 - 84	83 - 86	82 - 85	80 - 90

Source: Data reported by local Protection Forest Management Boards

Table 1 showed that: In Trung Thuan commune Dong Son ward, the average annual temperature (T) was from 24.4 - 25^{0}C, the average annual humidity (W) was from 80 - 86%, the average annual rainfall (P) was from 2,100 - 2,600 mm/year, the number of months with rainfall ≥ 100 mm was from 3 - 6 months/year. Meanwhile, in Chan May - Lang Co commune, Thuy Bang ward, Hue city, T from 24.5 - 25.1^{0}C, W from 80 - 90%, P from 2,400 - 2,900 mm/year, the number of months with rainfall ≥ 100 mm was from 4 - 7 months/year. Thus, in all areas, the average T was from 24.4 - 25.1^{0}C, W was from 80 - 90% and rainfall was 2,100 - 2,900 mm/year, the number of months with rainfall ≥ 100 mm was from 3 to 7 months in a year.

Thus, at 4 survey positions, the climatic conditions were quite similar, with average temperature, rainfall and high annual air humidity suitable for the biological characteristics of many native tropical plants.

3.1.2. Terrain and soil characteristics

Table 2. Terrain and soil characteristics of the area where native trees are grown under plantation forest canopy in the study area

Forest type	Sample	Absolute height (m)	Soil profile thickness (cm)	Mixed rock ratio (%)	Compactness	Mechanical composition	Color by depth layer (cm)		
							0 - 20	21 - 40	41 - 70
Acacia hybrid	QT-1	102	68	31	Tight	Loam	Yellowish brown	Yellow	Yellow
	QT-2	110	72	35	Tight	Loam	Light brown	Yellow	Yellow
	QT-3	115	65	37	Tight	Loam	Yellowish brown	Yellow	Yellow
Pinus masso-niana	QT-4	131	56	38	Tight	Silt loam	Brown	Brown	Yellow
	QT-5	135	62	43	Tight	Silt loam	Yellowish brown	Yellow	Yellow
	QT-6	125	65	38	Tight	Silt loam	Yellow	Yellow	Yellow
Pinus latteri	H-1	75	55	46	Tight	Loam	Yellowish red	Yellow	Yellow
	H-2	60	60	50	Tight	Loam	Yellowish red	Yellow	Yellow
	H-3	58	58	43	Tight	Loam	Yellowish red	Light yellow	Yellow
Acacia hybrid	H-4	145	63	40	Tight	Loam	Yellowish brown	Gray	Yellow
	H-5	155	70	32	Tight	Loam	Yellowish brown	Yellow	Yellow
	H-6	150	73	30	Tight	Loam	Brown	Yellowish brown	Light yellow

Note: QT - Quang Tri; H - Hue.

Table 2 reflected the clear differences in site quality among the plantation models. In general, soil under Acacia canopy had more favorable conditions for the development of native trees thanks to its relatively thick profile, low rock content and suitable mechanical composition,

which helps retain moisture and create better root development space. In contrast, soil under Pine canopy showed typical limitations of feralit soil group on acid rocks: thinner soil profile, high rock content and low moisture and nutrient retention capacity, reducing the suitability for growing native trees.

The characteristic of soil color gradually changing from yellowish-brown to yellow in deep layers showed the strong weathering and leaching of materials common in humid tropical climates, contributing to the reduction of natural soil fertility.

Compared with the site suitability classification of Ngo Dinh Que (2015) [3], the models under the canopy of Acacia generally belong to the very suitable group (S1) thanks to favorable site conditions. On the contrary, the models under the canopy of *Pinus massoniana* were at less favorable level due to thin soil profile and high rock content, while the models under the canopy of *Pinus latteri* were mostly unfavorable because of dry soil, limited soil profile and high rock content.

3.1.3. Growth characteristics of the upper tree layer

Table 3. Growth characteristics of upper tree layer where native trees are grown under the plantation forest canopy in the study area

Loca-tion	Forest type	OTC	Current density (trees /ha)	Age	$D_{1.3}$ (cm)		Hvn (m)		Canopy closure
					Xtb	S%	Xtb	S%	
Quang Tri province	*Acacia* hybrid	QT-1	820	6	17.6	16.0	14	8.4	0.65
		QT-2	825	8	18.0	14.3	13.9	8.1	0.72
		QT-3	815	8	18.2	14.9	13.9	8.3	0.60
	Pinus masso-niana	QT-4	515	26	36.0	5.3	18.2	3.4	0.58
		QT-5	525	26	36.6	5.0	18.3	3.8	0.62
		QT-6	521	26	36.5	5.1	18.3	3.8	0.60
Hue city	*Pinus latteri*	H-1	750	39	30.8	7.8	19.8	4.0	0.50
		H-2	748	39	30.8	7.1	19.9	3.7	0.56
		H-3	760	39	31.3	7.4	19.6	3.5	0.48
	Acacia hybrid	H-4	1890	12	24.8	16.6	16.4	4.7	0.65
		H-5	475	19	25.3	4.1	18.1	5.9	0.60
		H-6	460	19	25.5	4.1	18.2	6.0	0.58

Survey results showed that in Quang Tri province, Pine and Acacia species grew at an medium rate. Acacia density ranged from 815 to 825 trees/ha while Pine from 515 - 521 trees/ha. After 6 - 8 years, Acacia reached the following growth indicators: average $D_{1.3}$ 36.0 - 36.6 cm, Hvn 18.2 - 18.3 m. After 26 years of growth, *Pine* reached: average $D_{1.3}$ from 17.6 - 18.2 cm, Hvn 13.9 - 14 m. The fluctuations in diameter, height and canopy diameter of both Acacia and Pine were low to medium.

In Hue, the density of Pine was 748 - 760 trees/ha, after 39 years the growth indicators were as follows: $D_{1.3}$ ranged from 30.8 - 31.3 cm, Hvn from 19.6 - 19.9 m. As for Acacia, the density had a clear difference between the two age groups: Age

12 had a density of 1,890 trees/ha while at age 19 the remaining density reached 460 - 475 trees/ha. However, the growth of 12 and 19-years old Acacia trees in Hue city showed no difference: Average diameter 24.8 - 25.5 cm, Hvn 16.4 - 18.2 m.

In general, the tree species were growing and developing as normal, the coefficients of variation of diameter, height and canopy diameter remained relatively stable, in addition to the site factor in the growing areas of Acacia and Pine, it depended heavily on the application planting and tending techniques, particularly Acacia trees in these two areas.

The canopy closure of Acacia in the two provinces reached from 0.58 - 0.72, remaining at a higher level compared to that of Pine which ranged 0.48 - 0.62.

The remaining tree density and canopy closure of plantation forests posed a great impact on the growth and development of native tree species planted under the canopy.

3.1.4. Growth characteristics of the native tree species

The results of growth assessment of native tree species under plantations in the study sites were summarized in table 4.

Table 4. Growth characteristics of native tree species planted under forest canopy in the study area

Loca-tion	Forest type	OTC	Spe-cies	Age	Planting density (trees /ha)	Current density (trees /ha)	Sur-vival rate	$D_{1.3}$ (cm)			Hvn (m)			Dt (m)	
								Xtb	$\Delta D_{1.3}$ (cm/ year)	S%	Xtb	ΔHvn (m/ year)	S%	Xtb	S%
Quang Tri province	*Acacia* hybrid	QT-1	Ef	6	500	460	92.0	6.5	1.1	16.8	7.4	1.2	24.7	3.1	24.4
		QT-2	Ef	8	550	515	93.6	6.2	0.8	23.5	7.5	0.9	23.8	3.0	28.5
		QT-3	Tj	6	550	472	85.8	9.6	1.6	16.7	5.6	0.9	17.9	3.2	15.5
	Pinus masso-niana	QT-4	Ef	6	500	442	88.4	8.5	1.4	12.9	3.9	0.7	3.5	2.8	6.5
		QT-5	Ef	6	500	460	92.0	8.2	1.4	12.8	3.8	0.6	3.5	2.7	7.0
		QT-6	Ef	6	500	455	91.0	8.0	1.3	13.2	3.6	0.6	3.6	2.7	7.8
Hue city	*Pinus latteri*	H-1	Lf	7	100	85	84.0	9.4	1.4	7.8	8.4	1.2	2.5	3.6	2.0
			Tj	7	100	80	80.0	6.8	1.0	3.8	5.9	0.8	3.3	2.9	2.6
			Pp	7	100	78	78.0	5.6	0.8	15.4	4.8	0.7	12.9	1.9	10.2
		H-2	Mm	7	100	76	76.0	7.4	1.1	5.6	6.5	0.9	7.2	2.2	3.0
			Sz	7	100	86	86.0	10.5	1.5	3.7	11.3	1.6	1.6	3.3	3.8
			Ef	7	100	82	82.0	5.9	0.8	8.1	5.1	0.7	4.9	2.1	12.2
		H-3	Cb	7	100	84	84.0	10.7	1.5	2.8	8.4	1.2	2.1	3.8	5.1
			Vk	7	100	70	70.0	4.6	0.7	4.1	6.3	0.9	11.6	1.8	9.3
			Pa	7	100	86	86.0	6.3	0.9	4.3	3.8	0.5	10.9	3.5	5.5
	Acacia hybrid	H-4	Ef	8	700	620	88.5	9.3	1.2	30.9	6.8	0.9	7.8	2.8	18.7
			Ho	8	700	612	87.4	6.2	0.8	14.3	5.6	0.7	5.0	2.4	8.8
		H-5	Ef	8	266	242	93.0	6.9	0.9	30.4	5.5	0.7	13.6	2.0	31.6
			Ct	8	266	236	90.0	6.2	0.8	8.4	5.3	0.7	2.6	1.8	5.5
			Tj	8	266	238	91.5	17.4	2.2	8.8	11.6	1.5	5.3	5.1	9.9
		H-6	Ef	8	266	235	90.4	6.8	0.8	29.2	5.5	0.7	13.9	2	29.7
			Ct	8	266	218	83.8	6.5	0.8	8.3	5.3	0.7	2.4	1.7	7.2
			Tj	8	266	220	84.6	17.0	2.1	9.4	11.4	1.4	6.7	5	10.6

Note: Ef: E. fordii; Tj: T. javanica Blume; Mm; Michelia mediocris Dandy; Vk: Vatica tonkinensis A. Chev.; Ho: Hopea odorata; Cb: Cinnamomum bejolghota; Lf: Lithocarpus fissus Champ ex Benth; Pp: Peltophorum pterocarpum; Sz: Syzygium zeylanicum (L.) DC.; Pa: Prunus arborea; Ct: Chukrasia tabularis A. Juss.

** In Quang Tri province*

The survival rate of the species was fairly high, ranging from 85.8 - 93.6%. Of which, 6-year-old *E. fordii* planted under Acacia forest canopy achieved the highest rate of 93.6%

The growth of *E. fordii* under Acacia forest canopy was surveyed at QT-1, QT-2 at age 6: $D_{1.3}$ from 6.2 - 6.5 cm, Hvn from 7.4 - 7.5 m, Dt from 3.0 - 3.1 m. The growth of 6-year-old *T. javanica* under Acacia forest canopy was evaluated at QT-3: $D_{1.3}$ reached 5.6 cm, Hvn 7.9 m, Dt 3.2 m. It can be seen that the growth of these two species was relatively good, the fluctuations of the indicators were at medium level.

The growth of *E. fordii* under pine forest canopy was observed at QT-4, QT-5 and QT-6 at the age 6. The growth indicators were specifically evaluated as follows: $D_{1.3}$ from 8.0 - 8.5 cm, Hvn from 3.6 - 3.9 m, Dt reached 2.7 - 2.8 m. The growth of the species under pine forest canopy

was quite good, but the height was lower than that of planted trees at the same age under the Acacia forest canopy.

** In Hue city*

Native trees planted under the canopy of monoculture pine and Acacia protection forests were diverse and showed positive results. Popular planted native trees under the canopy included: *Lithocarpus fissus*, *Peltophorum pterocarpum*, *Tarrietia javanica*, *E. fordii*, *Michelia mediocris*, *Vatica tonkinensis*, *Hopea odorata, Cinnamomum bejolghota*, *Syzygium zeylanicum*, *Prunus arborea*, *Chukrasia tabularis*.

The survival rate of native tree species ranged from 70.0 - 93.0%. In which, the highest survival rate belonged to 8-year-old *E. fordii* planted under Acacia forest canopy and the lowest was 7-year-old *Vatica tonkinensis* planted under pine forest canopy.

The growth of some species planted under the canopy of Acacia forest was surveyed at H-4, H-5 and H-6 at age 8 as follows:

- *E. fordii*: $D_{1.3}$ from 6.8 - 9.3 cm, Hvn 5.5 - 6.8 m, Dt 2.0 - 2.8 m. The growth of the species after 8 years of planting was quite good. The fluctuation of the indexes was at average level.

- *Chukrasia tabularis*: $D_{1.3}$ at 6.2 - 6.5 cm, Hvn at 5.1 - 5.3 m, Dt 1.7 - 1.8 m. The growth of the species after 8 years of planting was quite good. The fluctuation of the growth indexes was at a low level, showing high growth uniformity.

- *Hopea odorata*: $D_{1.3}$ at 6.2 cm, Hvn 5.6 m, Dt 2.4 m. The growth of this species after 8 years of planting was quite good. The fluctuation index of the indexes is at an average level.

- *Tarrietia javanica*: $D_{1.3}$ at 17.0 - 17.4 cm, Hvn 11.4 -11.6 m, Dt 5.0 - 5.1 m. After 8 years of planting the species grew very well. Some indicators such as diameter and height were almost double that of the two species *Chukrasia tabularis* and *E. fordii*. Showing the suitability and development of *T. javanica* here, it was tending to rise to the upper layer to replace a part of the Acacia trees that had past maturity and were drying out or dying.

Growth of some 7-year-old native tree species planted under the canopy of pine forest: *Michelia mediocris*, *Syzygium zeylanicum*, *E. fordii*, *Cinnamomum bejolghota*, *Vatica tonkinensis*, *Prunus arborea, Tarrietia javanica, Lithocarpus fissus* were as follows: $D_{1.3}$ of the species was from 4.6 - 10.7 cm in which *Cinnamomum bejolghota* had the largest figure while *Vatica tonkinensis* had the lowest one; Hvn was from 3.8 - 11.3 m in which the highest was found in *Syzygium zeylanicum*, the lowest was in *Prunus arborea*; Dt was from 1.8 - 3.8 m in which the largest was *Cinnamomum bejolghota*, the smallest was *Vatica tonkinensis*.

In 11 native tree species investigated and evaluated. Native trees planted under the canopy of Acacia forest: 8-year-old *E. fordii* in Quang Tri province and 8-year-old *T. javanica* in Hue city had the highest survival rate of 91.5 - 93.6%, besides, the growth of the latter in Hue was also superior compared to other tree species in the same conditions (1.5 - 2 times higher). For native tree species planted under the canopy of Pine forest: *E. fordii* in Quang Tri province; *Prunus arborea*, *Cinnamomum bejolghota* and *Syzygium zeylanicum* in Hue city were the 3 species with the highest survival rate of 85 - 86%. According to the general assessment of growth indicators of diameter and height, the 2 species with the ability to develop outstandingly were *Cinnamomum bejolghota* and *Syzygium zeylanicum*.

3.2. Species selection and research results on techniques for planting native tree species under the canopy of monoculture protection forests of *Acacia* hybrid in Quang Tri province

3.2.1. Species selection for developing forest conversion model

Through the results of growth assessment and site conditions in content 3.1, it could be seen that:

Among the 11 species of trees surveyed, 5 tree species with the best survival and growth rates, adapting to different canopy levels are: *E. fordii*, *Tarrietia javanica*, *Prunus arborea*, *Cinnamomum bejolghota*, *Syzygium zeylanicum*

Among the 5 identified tree species, 2 with the widest adaptability to site conditions in the 2 provinces, *E. fordii* and *Tarrietia javanica*, were selected to establish a model of planting under the canopy of Acacia forest in Quang Tri province for futher asessement.

3.2.2. Results of establishing a model to convert monoculture plantation forests to mixed forests of native trees after 2 years in Quang Tri province

Table 5. Growth of *E. fordii* and *T. javanica* planted under Acacia forest canopy in Quang Tri province

Species	Canopy closure	1 year after planting					2 years after planting				
		Survival rate (%)	D_{00} (cm)		Hvn (m)		Survival rate (%)	D_{00} (cm)		Hvn (m)	
			Xtb	ΔD_{00} (cm/year)	Xtb	ΔHvn (m/year)		Xtb	ΔD_{00} (cm/year)	Xtb	ΔHvn (m/year)
E. fordii	0.3 - 0.4	93.3	0.99	0.28	0.76	0.31	92.3	1.65	0.67	1.36	0.59
	0.5 - 0.6	92.8	0.97	0.24	0.73	0.27	90.4	1.51	0.55	1.25	0.52
P-value			0.36		0.007			0.007		<0.001	
Effect size			0.09		0.27			0.56		0.48	
Tarrietia javanica	0.3 - 0.4	92.3	0.88	0.22	0.65	0.24	91.3	1.50	0.62	1.20	0.55
	0.5 - 0.6	90.4	0.86	0.23	0.62	0.21	88.0	1.40	0.54	1.06	0.45
P-value			0.20		0.03			<0.001		<0.001	
Effect size			0.13		0.22			0.63		0.98	

The results of the growth measurement of 2-year-old *E. fordii* and *T. javanica* planted under the canopy of Acacia protection forests at different canopy levels of 0.3 - 0.4 and 0.5 - 0.6 in Quang Tri province were summarized in table 5.

After 2 years, the two species planted under monoculture Acacia protection forest canopy with 2 canopy levels of 0.3 - 0.4 and 0.5 - 0.6 showed differences in some growth indicators and characteristics, as follows:

3.2.2.1. E. fordii

Under canopy closure of 0.3 - 0.4: After 1 year of planting, the survival rate was 93.3%, slightly decreased in the second year but maintained a very high level of 92.3%.

After 1st year, D_{00} reached 0.98 cm corresponding to a diameter growth of 0.28 cm/year, the average Hvn reached 0.76 m corresponding to a height growth of 0.31 m/year

After 2nd year, the average D_{00} reached 1.65 cm corresponding to a diameter growth of 0.67 cm/year, the average Hvn reached 1.35 m or a growth rate of 0.59 m/year.

Under canopy closure of 0.5 - 0.6: After year 1st, the survival rate was 92.8%, slightly decreased in the second year but still at a very high level of 90.4%.

At the same time, the average D_{00} reached 0.96 cm (diameter growth of 0.24 cm/year), the average Hvn reached 0.73 m, corresponding to a height growth of 0.27 m/year.

After 2 years, the average D_{00} reached 1.51 cm, corresponding to a diameter growth of 0.55 cm/year; the average Hvn reached 1.25 m (growth rate of 0.52 m/year). The t-test results (Student) showed that after one year of planting, the D_{00} growth of *E. fordii* was not statistically difference ($p > 0.05$); while Hvn, on the contrary, had a difference ($p < 0.05$). However, the average difference between the two treatments was only 0.03 m (0.73 m and 0.76 m), a small value with no biological meaning. This difference was within the range of natural fluctuations, reflected in a small statistical effect (Cohen's d = 0.27). However, after two years, the difference in D_{00} and Hvn between the two treatments was significant ($p < 0.05$), the

effect size was high (Cohen's d = 0.48 - 0.56) showing a difference with biological and practical significance, in which the growth of trees at a canopy closure of 0.3 - 0.4 was higher than at a canopy closure of 0.5 - 0.6. It can be seen that *E. fordii* planted in Quang Tri showed great potential with stable growth and development indexes. This indicated the suitability of this species to the site conditions. According to initial assessment, after 2 years of planting, the species had better growth and development under canopy closure of 0.3 - 0.4 than 0.5 - 0.6.

3.2.2.2. Tarrietia javanica

Under canopy closure of 0.3 - 0.4: After 1 year of planting, the survival rate of the species was 92.3%. In the second year, it decreased slightly to 91.3%.

At 1st year, the average D_{00} reached 0.88 cm (diameter growth of 0.22 cm/year), the average Hvn reached 0.65 m, corresponding to a height growth of 0.24 m/year.

After 2nd year, D_{00} reached 1.50 cm, corresponding to a diameter growth of 0.62 cm/year, Hvn reached 1.20 m, or a growth rate of 0.55 m/year.

Under canopy closure of 0.5 - 0.6: After 1st year, the survival rate of the species was 90.4% then decreased slightly to 88.0% after the 2nd year.

At year 1, D_{00} reached 0.86 cm, corresponding to a diameter growth of 0.23 cm/year, the average Hvn reached 0.61 m (height growth of 0.21 m/year).

After 2 years, the average D_{00} reached 1.40 cm, corresponding to a diameter growth of 0.54 cm/year, Hvn reached 1.06 m (growth rate of 0.45 m/year). This result was in-line with the the result published by Pham Xuan Dinh (2022) [4], *T. javanica* was the native tree species that had been planted widely in the Central Central region, especially in Quang Tri province, with Hvn growth from 0.6 - 0.9 m/year, $D_{1.3}$ from 0.7 - 1.0 cm/year, in which planting on bare land had the lowest growth rate, mixed planting and under poor forest canopy had better growth.

Figure 1. 2-year-old green *E. fordii* under canopy closure of 0.3 - 0.4

Figure 2. 2-year-old green *T. javanica* under canopy closure of 0.3 - 0.4

The t-test (Student) result showed that after one year, there was no statistically significant difference in D_{00} growth ($p > 0.05$). For Hvn, the difference was significant ($p < 0.05$); however, the average difference was only 0.03 m (0.65 m and 0.62 m), this small value has no biological significance, as shown by the low effect size (Cohen's d = 0.22). After two years, the difference in D_{00} and Hvn between the two treatments was clearly evident and had both statistical and biological significance ($p < 0.05$). Notably, the level of growth difference was large, as shown by the

high effect size (Cohen's d = 0.63 - 0.98). Tree growth at canopy closure 0.3 - 0.4 was superior to that at of 0.5 - 0.6.

General assessment of *E. fordii* and *T. javanica* showed that in the first year of planting, there was no difference or the difference was relatively small and had little biological significance in D_{00} and Hvn growth at 2 different canopy closure levels. However, in the second year, the effect of canopy closure became more evident when both species grew better at canopy level 0.3 - 0.4 compared to 0.5 - 0.6. This showed that in the second year, reasonable thinning techniques should be applied to the upper tree layer to adjust the canopy closure appropriately to ensure favorable light conditions for better tree growth.

3.2.3. Results of determining chlorophyll content of E. fordii and T. javanica

Leaves were very important part of plants where photosynthesis, water and gas exchange took place. In addition, leaves were also an indicator to determine the nutritional status as well as the suitability of plants to the external environment.

Chlorophyll a and b were pigments that play an important role in the photosynthesis process of vascular plants. However, chlorophyll content was an easily fluctuating index, depending on internal and external conditions, especially lighting regime. Chlorophyll content and chlorophyll a/b ratio indicated whether the plant was light-tolerant or shade-tolerant. The chlorophyll a/b ratio most clearly reflects the light-tolerant or shade-tolerant nature of the plant. According to the color comparison method of Lichtenthaler and Wellburn. (1983) [5], it was believed that light - tolerant plants had a chlorophyll a/b ratio greater than 3; neutral plants had a chlorophyll a/b ratio of about 2.3 - 3 and shade - tolerant plants had a chlorophyll a/b ratio less than 2.3.

The results of the analysis of chlorophyll a and b content in the leaves of *E. fordii* and *T. javanica* after two years of planting under the canopy of *Acacia* hybrid forest showed that the content of Chlorophyll a in the former ranged from 2.520 - 2.565 mg/g, Chlorophyll b from 4.212 - 4.591 mg/g, while in the latter it was 1.460 - 1.525 mg/g and 0.890 - 1.102 mg/g, respectively. Thus, the total chlorophyll content (TChl) of *E. fordii* (6.732 - 7.156 mg/g) was significantly higher than that of *T. javanica* (2.350 - 2.627 mg/g).

Table 6. Results of analysis of chlorophyll a, b content in *E. fordii* and *T. javanica* leaves in Quang Tri province after 2 years of planting

Species	Canopy closure	Chlorophyll content (mg/g)			a/b ratio
		Chl.a (mg/g)	Chl.b (mg/g)	Total a+b	
E. fordii	0.3 - 0.4	2.520	4.212	6.732	0.598
	0.5 - 0.6	2.565	4.591	7.156	0.559
T. javanica	0.3 - 0.4	1.460	0.890	2.350	1.640
	0.5 - 0.6	1.525	1.102	2.627	1.383

The a/b ratio of both species was < 2.3 (*E. fordii* 0.559 - 0.598; *T. javanica* 1.383 - 1.640), showing that both species belong to the group of shade-tolerant trees in the early stages, suitable for planting under the forest canopy at a certain shade level. The total chlorophyll content of *E. fordii* increased slightly when the shade level increased from 0.3 - 0.4 to 0.5 - 0.6, demonstrating the ability to adapt to low light conditions. This was also a physiological characteristic of shade -

tolerant species when increasing the total chlorophyll content to increase the ability to absorb low light. However, the growth results (Table 5) show that D_{00} and Hvn of this species at canopy closure of 0.3 - 0.4 were higher than at 0.5 - 0.6, demonstrating that although high canopy closure stimulated chlorophyll synthesis, it still limits actual photosynthesis due to reduced light intensity, reducing growth rate.

For *T. javanica*, the total chlorophyll content was lower but the a/b ratio was still < 2.3, showing that this species had a certain shade tolerance level but lower than *E. fordii*. The slight increase in Total a+b content when the canopy closure increased reflected an adaptive physiological response, but the amplitude of change was small, showing that the light demand of this species was higher.

The results showed that *E. fordii* was a shade-tolerant species at early stage, after 2 years there was no need to adjust the canopy closure in case the upper layer cannot be thinned. However, if conditions permit, adjusting the canopy closure to 0.3 - 0.4 would be optimal. *T. javanica* was moderately shade - tolerant, after 2 years it was recommended to reduce the canopy closure from 0.5 - 0.6 to about 0.3 - 0.4 to ensure the best growth of the tree. In the mixed planting model with both species, maintaining a uniform canopy closure at 0.3 - 0.4 after two years would be appropriate, meeting the ecological requirements of both species and improving the efficiency of converting *Acacia* hybrid forests into mixed forests of native trees.

4. CONCLUSION

Initial research results show that planting native trees *E. fordii* and *T. javanica* under *Acacia* hybrid forest canopy in Quang Tri province was feasible and had high prospects. These two tree species had a high survival rate (over 85%), grew stably in the site conditions in Quang Tri province, especially at a canopy of 0.3 - 0.4.

Both species showed shade-tolerant ability in the early stages, adapt well under the canopy of *Acacia* hybrid forest, with a fairly high growth rate. After two years, *E. fordii* reached an average diameter at ground level of 1.65 cm, height of 1.35 m; while these figures for *T. javanica* was 1.55 cm and 1.20 m, respectively. High total chlorophyll content, a/b ratio < 2.3 proved their shade-tolerant characteristics, suitable for intercropping or converting monoculture plantation forest to mixed forests.

The combined planting of *E. fordii* and *T. javanica* under Acacia forest canopy helped increase biodiversity, improved the structure and protection capacity of the forestand at the same time contributed to the restoration of the natural forest ecosystem. In particular, *T. javanica* was a fast - growing species with good coverage ability, while *E. fordii* developed stably and sustainably, creating a long-term foundation for mixed forests.

The research results were important scientific basis for selecting suitable native tree species and building mixed-species models, converting monoculture Acacia plantation forest in Quang Tri province in particular and the North Central region in general, towards the goal of sustainable forest development, enhancing ecological and economic values.

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