PART A. INTRODUCTION ABOUT THESIS

1. BACKGROUND

Global climate change mitigation and adaptation is a very urgent matter in the world. Forest plays an important role in environment protection, improving the ecological environment. In which sustainable management and development of coastal forests and adapt to climate change are emergency issue in Vietnam.

Coastal sandy soil in the region including Quang Binh, Quang Tri and Thua Thien Hue have an area about 123,037 ha which shared to 7.23% of the total natural area of the three provinces. This land areas plays an important role in the economic development strategy of the region. Forestrt activities facing with many difficulties, in which the most important is the selection of species and appropriate techniques because the conditions of the site are very harsh, the soil is very poor, often affected by wind, strong storms causing moving sand, sand filled, some areas are partially flooded in the raining season.

"Research on the scientific background and technical measurement for planting of Acacia crassicarpa A. Cunn. Ex. Benth in coastal sandy soil for protection and economic purposes in Quang Binh, Quang Tri and Thua Thien Hue provinces" was conducted with the following objectives:

1) Research on propagation techniques of *Acacia crassicarpa* to ensure quality for afforestation on the sandy land of Binh-Tri-Thien provinces.

2) Research on planting techniques of *Acacia crassicarpa* to improve productivity and quality to provide protection and timber supply for socio-economic development of the region.

3) Evaluating the protection and economic efficiency of *Acacia crassicarpa* on coastal sandy land in Binh - Tri – Thien provinces.

2. THE NECESSARY AND APPLICABLE OF THE RESEARCH TOPIC

Acacia crassicarpa is able to grow well in slightly sour soil, poor sandy soil, can withstand flooding for a certain time. This tree has ability to improve the soil, withstand strong winds, which is in accordance with the sandy areas of Binh - Tri - Thien provinces. However, it has been studied in a fragmented and incomplete manner. It is necessary to make comprehensive researches on propagation, afforestation and tending techniques, evaluation the protection and

economic efficiency in order to develop this species aimed at protection and economic efficiency of the area.

Research results of the thesis are a scientific basis to develop technical guidelines for development of *Acacia crassicarpa* for coastal sandy areas of Binh - Tri - Thien provinces.

3. THE NEW CONTRIBUTION OF THE THESIS

The research conducted a systematic study of the scientific basis for the development of *Acacia crassicarpa* in coastal sandy soil in order to respond to climate change and socio-economic development in the Binh-Tri-Thien region. The new contributions of the thesis are:

i) Examine scientific bases for propagation and planting techniques of *Acacia crassicarpa* had been identified on the sandy land of Binh - Tri - Thien.

ii) Initial assessment of the protective and economic value of the *Acacia crassicarpa* on the coastal sandy land of Binh - Tri - Thien.

4. STRUCTURE OF THE THESIS

The thesis is 119 pages, consisting of: Introduction (4 pages)

Chapter 1. Overview of Research (27 pages)

Chapter 2. Natural - Socio-economic conditions of the research area (5 pages)

Chapter 3. Content, Materials and Research Methods (20 pages)

Chapter 4. Research results and Discussion (60 pages)

Conclusions and recommendations (3 pages)

The thesis consists of 35 tables, 28 images, charts and diagrams.

The thesis has 92 references (59 in Vietnamese and 33 in English).

PART B. THESIS CONTENT

Chapter 1: OVERVIEW OF RESEARCH

1.1. In the world

1.1.1. Research on coastal sandy soil and afforestation on coastal sandy land

- *Coastal sand movement:* Sand particles move when the wind is greater than its weight, according to Sokolow H.A. the small sand is, the lower the grain velocity by wind (<0.25 mm and 4.5-6.7 m/s) and vice versa > 1.0 mm and 11.4-13.0 m/s.

- Study on afforestation of coastal sandy areas

+ Forest belt structure: There are three types of forest belt structure: i) High density structure (multi-layer forest canopy, wind clearance coefficient <0.3), ii) Average densty structure (2-3 layer forest canopy, wind clearance coefficient 0.3-0.5) and iii) Low density structure (only one canopy layer, wind clearance coefficient 0.5 - 0.7).

+ Species and techniques for planting protection forest in coastal areas: In China and in the Middle East, East and West Africa, *Casuarinas* were planted on sandy areas to establish a forest belt systems of 100 - 200 m to 2 - 5 km wide, with a density of 5,000 to 10,000 trees per hectare. Behind this belt, other species such as *Eucalyptus, Acacia, Pine* and agricultural crop are planted (Zheng Haishui, 1996).

+ Effect of fertilizers on plantation productivity: Schonau (1985) studied fertilizer application for *Eucalyptus grandis* in South Africa. The author showed that the fertilizer treatment of 150 g NPK/tree with N: P: K = 3: 2: 1 could help to raise the average height of the plantations twice time after the first year.

+ Effect of density on plantation productivity: Evans, J. (1992) after 5 years, the average diameter of *Eucalyptus deglupta* in Papua New Guinea was increasely inversed with the density, but the total basal area increase was directly proportional to the density.

1.1.2. Study on the planting Acacia crassicarpa

Acacia crassicarpa is mainly propagated from seeds, treated by soaking seeds in boiling water (100^0C) 1-2 minutes), seedlings grow quickly, after 3 months for planting. Marcotting methods (mother trees < 3 years old) were successful in Indonesia at 85% (White et al, 2007). Numerous studies showed that the *Acacia crassicarpa* grew higher than *A. auriculiformis* and *A. mangium* (in Thailand, Myanmar, China, Laos, ...).

1.2. In Vietnam

1.2.1. Research on coastal sandy soil and afforestation

** Characteristics of coastal sandy land in Vietnam*

Classification of coastal sandy soil in Vietnam: Phan Lieu (1997) divided Vietnam's coastal sandy soil into six sub-types: coastal sand; sand

dunes; typical sandy soil; submerged sandy soil; alluvial sand and sandy soil with oysters, mussel, scallops.

Classification of coastal sand in the North Central Coast: Dang Van Thuyet (2004) divided the coastal sandy land of the North Central into 3 groups with 21 types. Group I (moving sand dunes, no trees) and group II (stable sand dunes with grasses and dry shrubs), Group III was stable sand banks.

** Research on afforestation on coastal sandy areas*

- *Species selection: Casuarina* grows rapidly in suitable conditions and is able to protect the field, *Acacia difficilis*, *Acacia auriculiformis*, *Neem* and *Eucalyptus camaldulensis* grew poorly and low survival rate. *Acacia crassicarpa* grew rapidly, adapted to semi-submerge sandy soil, was very promising for the central provinces (Le Dinh Kha, 1997).

- *Planting method of protection forest:* Vu Van Me (1990) planted protection forest on stable sandy land in Binh Thuan province cycled by the main belt which was 30-50m wide and planted 9-15 treelines, perpendicular to the harmful wind direction, sub-belt was 15m wide, 4 rows perpendicular to the main belt.

- *Soil preparation techniques:* In lowland areas, sometimes flooded with water for a few months, it was possible to grow *Casuarina* or *Acacia* by making bed so that the roots were above the highest water level in the raining season (Do Dinh Sam, Ngo Dinh Que, 1999).

- *Fertilizer application:* Currently mainly cattle manure, NPK fertilizer, microorganism organic fertilizer with NPK, ... but not yet fully evaluated.

- *Protection effectiveness of plantation belts:*

+ In terms of windbreak efficiency, improving sub-climate, Dang Van Thuyet (2005), the *Casuarina* plantation or 3-year-old *Acacia difficilis* in moving sand dunes with the density of 5,000 trees/ha, the width of 100m belt to reduce wind speed behind the forest belt 10m up to 0.7-0.8 times compared with the wind speed in front of the forest belt 10m, reducing the moving sand 2.4-4.2 times, increasing the air humidity 2.1-3.7%, reducing the air temperature from 0.9 to 2^0 C.

+ Carbon sequestration, research results of Vo Dai Hai, Vu Tan Phuong and Tran Duy Ruong for *Acacia hybrid, A. mangium* and *A. auriculiformis* from

6-8 years in different ecological zones in the hills, showing an accumulation of 30 - 70 tons C/ha, absorbing 110 - 257 tons CO_2/ha.

- *Economic efficiency:* plantation belt of 8 - 20 year-old *Casuarina* in coastal sandy area in North Central NPV = 9.76 million VND and BCR = 6.08 (Dang Van Thuyet, 2004), 6 - 34 year-old *Casuarina* belt, and 5 – 12-year-old Neem wind and sand defence in Ninh Thuan, Binh Thuan provinces' coast of which economic value from wood, firewood, leaves, seeds ... was 1.1 - 1.4 million VND/ha/year (Vu Tan Phuong, 2012).

1.2.2. Research on Acacia crassicarpa

Species and provenance trials: In several regions, *Acacia crassicarpa* grows faster than *A. auriculiformis* and *A. mangium*. The best are: *Manta prov*., *Gubam*, *Derideri* and *Pongaki* provenances. In stable sandy soil in TT Hue, the survival rate of *Acacia crassicarpa* was 100% and 6.0 m high, while survival rate of *A. mangium* was only 40% and 3.0 m high. Other species could not survive (Le Dinh Kha, 1997).

Genetic ability: the woody properties of *Acacia crassicarpa* in Cam Lo, cellulose content was 0.62 and density was 0.74, cumulative heritability was 29.1 and 10.0, at Phong Dien and Ham Thuan Nam, heritabilities of cellulose is range from 0.16-0.24 and density is from 0.16-0.17. (Pham Xuan Dinh, 2014).

Propagation techniques: cutting by using IAA 2,000 ppm and NAA 1000 ppm showed 60-80% of rooting rate (Nguyen Thi Lieu, 1998). Dang Thai Duong (2015), cuttings for some heat resistant clones of *Acacia crassicarpa*, the best result was bed component containing 100% of B layer soil, treatment with IBA 200ppm, no shading, watering for 0-60-day-old trees 4s every 3 minutes, 5 minutes/time, every 6s for 61-90-day-old trees.

Planting techniques: In stable sandy soil, the best result was completely plowing, making bed up to a height of 0.4 m, application of 200g/micro-organism/tree, density of 1,650 tree/ha (Nguyen Thi Lieu, 2006). In stable and moving sandy soil, the best result for some heat resistant clones of *Acacia crassicarpa* was plowing, making bed, digging, application of 2 kg cattle manure + 0.2 kg micro-organinsm, with a density of 2,200 tree/ha (Dang Thai Duong, 2015).

1.3. General discussion

Researches on propagation and planting techniques of *Acacia crassicarpa* were very sporadic and not systematically studied. They only partially researched the technique of afforestation for a few soil types and did not have any technical research on propagation from seed. The result of propagation cutting was not high and there was not any evaluation of the economic efficiency and protection effectiveness of this species. Based on that fact, the systematical research derives from propagation, afforestation techniques and assessment of protection and economic efficiency of *Acacia crassicarpa* on coastal sandy land in Binh - Tri - Thien provinces on typical soil types. This was the basis for the development of this species for the protection and socio-economic development of the area.

Chapter 2. NATURAL CHARACTERISTICS - SOCIO-ECONOMIC CONDITIONS OF RESEARCH AREA

This chapter presents the content of natural and socio-economic conditions in the research area of Quang Binh, Quang Tri and Thua Thien Hue provinces, total area of about 17,250 km2, length of about 350 km, width 50-80 km, geographic coordinates from $16^0$12' to $18^0$06' North latitude $105^0$37 'to $108^0$10' East latitude (details were presented in the thesis).

Chapter 3. CONTENT, MATERIALS AND RESEARCH METHODS

3.1. Research Materials

Seedlings and cuttings of *Acacia crassicarpa* Manta - PNG provenances.

3.2. Research content

3.2.1. Assessing the status of sandy soil and sandy land use in the Binh - Tri - Thien provinces

i) Assessment of the status and use of coastal sandy land;

ii) Evaluation of the current status of *Acacia crassicarpa* plantation on coastal sandy soil.

3.2.2. Acacia crassicarpam propagation techniques

a) Seed propagation technique:

i) Effect of water temperature on seed treatment result;

ii) Effect of potting component on the result of seedling propagation;

iii) Effect of shading on the result of seedling propagation;

b) Cutting propagation techniques:

i) Effect of IBA and IAA on rooting rate of cuttings;

ii) Effect of potting component on the result of cutting propagation

iii) Effect of irrigation regime on the result of cutting propagation;

iv) Effect of shading on the result of cutting propagation.

3.2.3. Techniques of planting Acacia crassicarpa on coastal sandy land

i) Effect of soil preparation measures; ii) Effect of planting density

iii) Effect of fertilizer application (basal fertilizing); iv) Effect of planting season v) Effect of seedling age; vi) Effects of tending techniques.

3.2.4. Protection and economic efficiency of Acacia crassicarpa in coastal sandy land

a) Protection effective:

i) Windbreaker effective; ii) Improving sub-climate;

iii) Land improvement effective; iv) Carbon absore.

b) Economic efficiency: i) Efficient from sale wood and firewood;

ii) Efficiency from carbon trading value

3.3. Research methods

- *Point of view:* With the view that the coastal sandy soils in Binh Tri Thien provinces were very harsh so first of all it should be successful in afforestation, then was the combination of protection and economic efficiency.

- *Approach:* To be successful in afforestation in this particular land, this research used systematically approach *synthesized technical methods from* seedlings, planting and tending techniques which were very important factors affecting the plantation quality to be studied. In coastal sandy area, *soil* was considered as the main factor so that *the soil types* were chosen for research contents. In addition, the efficiency from the plantation helped to improve the environmental and economic conditions, which needed to be studied.

3.3.1. General research methods

- *Reference:* Reference the existing research results, published data, the works of the author myself and continuing to evaluate and study additionally.

- *Research layout:* using experimental ecology, arranging site layout to find out the best indicators for each factor.

3.3.2. Assessment of coastal sandy soil status in Binh - Tri - Thien provinces

+ General investigation: from current status maps and existing aggregate reports.

+ Field investigation: implementing on 3 investigation lines of 1 km wide from the highway 1A to the coast in 3 districts of 3 Binh - Tri - Thien provinces in which formed temporary sample plots of 500 m2 for evaluation. Investigation of *Acacia crassicarpa* at different ages 3,5,7,10 for > 40 models for 3 sites, investigation of other species> 40 models for 3 sites including *Acacia auriculiformis, A. mangium, Acacia deficilis, Acacia hybrid, Casuarina, Eucalyptus* at different age depending on reality.

3.3.3. Site layout and collecting data in researching seedling propagation

3.3.3.1. Seed propagation

a) Effect of soaking water temperature on seed germination rate

T1: Soak in water 100^0C; T2: Soak in water 75^0C

T3: Soak in water 50^0C; T4: Soak in nomal water 25-30^0C

b) Effects of potting mix on propagation results

*+ NPK fertilizer experiment (*16.16.8)

T1: 1% NPK + 10% cattle manure + 89% soil of B layer.

T2: 2% 1% NPK + 10% cattle manure + 88% soil of B layer.

T3: 3% NPK + 10% cattle manure + 87% soil of B layer.

T4: 4% NPK + 10% cattle manure + 86% soil of B layer.

T5: no NPK + 10% cattle manure + 86% soil of B layer.

+ Experiment: P_2O_5 *and* K_2O *in similar proportions*

c) Effect of light to propagation results

T1: shading 25%; T2: shading 50%; T3: shading 75%; T4: no shading.

3.3.3.2. Reproduction technique by cuttings

a) Effect of IBA and NAA on rooting rate of cuttings

T1:100ppm; T2: 200ppm; T3: 300ppm; T4: 400ppm;

T5: 500ppm; T6: 600ppm; T7: 700ppm; T8: 800ppm;

T9: 900 ppm; T10: 1.000 ppm, T11. Control: 0ppm.

b) Effect of potting component on the result of cutting propagation

T1: 100% B layer soil; T2: 50 % B layer soil + 50% husk charcoal

T3: 50 % B layer soil + 50% sand;

T4: 50 % husk charcoal + 50% sandy soil; T5: 100% sand.

c) Effect of irrigation regime on cutting results

T1: 1 minute/ 1 time; T2: 2 minutes /1 time; T3: 3 minutes /1 time;

T4: 4 minutes/1 time; T5: 5 minutes/1 time; T6: 6 minutes/1 time.

T7. no watering;

Spray time: < 60 days: 1 spray 4s, equivalent to 4.52 liters/50m^2.

From 60 -120 days: 1 spray 6s equivalent to 6.78 liters/ 50m^2.

d) The effect of light on the cutting results

T1: shading 25%; T2: shading 50%; T3: shading 75%; T4: shading 0%.

3.3.4. Experimental setup and data collection techniques for afforestation

a) Impact of soil preparation techniques on the quality of plantation

- In semi-submerged sandy soil uesed the old experimental model:

T1: No bed; T2: 4 rows bed 0,2 m high; T3: 2 rows bed 0,2 m high

T4: 1 row bed 0,2 m high; T5: 2 rows bed 0,4 m high;

T6: 1 row bed 0,4m high.

- In non-submerged and moving sandy soil, new models were arranged

T1: plough + made bed + digged hole; T2: plough+ digged hole;

T3: digged hole.

Ploughed all land; made bed 4m wide, distance 2m, 0,4m high; digged holes size 30 x 30 x 30cm.

b) Impact of planting density on the quality of plantation forests

- In semi-submerged sandy soil in Quang Tri province using the old experimental model:

T1: 1666 trees/ha; T2: 2200 trees/ha; T3: 2500 trees/ha; T4: 3300 trees/ha

- In non-submerged and moving sandy soil, new models were arranged

T1: 1666 trees/ha; T2: 2200 trees/ha; T3: 2500 trees/ha

c) Effect of fertilizer (basal fertilizering) on the quality of plantation

- In semi-submerged sandy soil in Quang Tri province using the old experimental model

T1: no fertilizer; T2: 100g P_2O_5/tree; T3: 150g P_2O_5/tree; T4: 100 g micro-organism/tree; T5: 150 g micro-organism /tree; T6: 200 g micro-organism /tree; T7: 50g NPK/tree; CT8: 75g NPK/tree; CT9: 100g NPK/tree.

- In non-submerged and moving sandy soil, new models were setup

T1: 1kg cattle manure + 0,2kg micro-organism;

T2: 2kg cattle manure + 0,2kg micro-organism

T3: 3kg cattle manure + 0,2kg micro-organism; T4: No fertilizer

d) Impact of technical tending on the quality of plantation forests.

T1: fertilizing 50g NPK + covering tree foot with soil;

T2: fertilizing 50g NPK + no covering tree foot;

T3: covering tree foot with soil without fertilizing;

T4: control (no fertilizing and no covering tree foot).

e) Impact of planting season on the quality of planted forests

T1: planting in November; T2: planting in February.

f) Effect of seedling age on plantation quality

T1: Four-month-old seedlings; T2: Six-month-old seedlings

3.3.5. Experimental setup and data collection techniques to evaluate protective effectiveness

Measuring time were at 10 am, 1 pm và 4 pm in hot days in July and August, 2016, at height of 1,5m from the ground (for soil measure at ground). Measuring inside the plantation and on the bare land in order to make comparision.

a) Windbreak effect

+ Wind deflector rate (wind speed decreased %): $E = \frac{V_0 - V}{V_0} x100$

+ Wind speed rate after the plantation belt: $F = \frac{V}{V_0} x100$

V_0: average wind speed at 120m before the platation belt;

V: average wind speed at different sites after the plantation belt.

b) Site layout for assessing the improving sub-climate conditions.

+ *Air temperature:* Using a thermometer to measure.

+ *Air Humidity:* using a moisture meter to measure.

+ *Radiation intensity:* using a radiation meter to measure.

c) Site layout for evaluating soil improvement effect

+ Soil humidity: $A\ (\%) = \frac{V_2 - V_3}{V_3 - V_1} \times 100$

V1: Aluminum box weight; V2: Aluminum box and soil weight before drying; V3: Aluminum box and soil weight after drying.

+ Soil analysis: At the Laboratory of Hue University of Agriculture and Forestry.

+ Measuring soil temperature: using a regular thermometer.

+ Root sampling: Digging of trees with average diameter and height of the model plots, weighing and calculating the number of nodules of each tree, calculated on average of the trees.

d) Site layout for assessing the possibility of Carbon sequestration

Used IPCC method (2002)

Carbon sequestration: Mc = Mk * k; (Mk: dry weight; k= 0,47).

Absorbing CO_2: $M_{CO_2} = \frac{M_C * 44}{12} tấn/ha$

3.3.6. Site layout for assessing the economic velue

Measuring $D_{1,3}$, H, V, M to evaluate wood, firewood, NPV, BCR & IRR and CO_2 trading.

3.3.7. Methods of Data analysis

Data were collected, analyzed by SPSS 16.0. If $\chi^2_{counted} > \chi^2_{0,05}$ or $F_{counted} > F_{0,05}$, the treatments significantly influence the evaluation factors. $\chi 2$ was used to compare rating fators and Duncan group was used to compare valuable fators. The same group is homogeneous, the other group is completely different. The group symbols are a, b (in χ^2) and A, B, C ... (in Duncan group) in the exponent.

Chapter 4: RESEARCH RESULTS AND DISCUSSION

4.1. The status and the land use of coastal sandy land in Binh - Tri - Thien

4.1.1. Land use status of coastal sandy areas

Total area of natural coastal sandy land in Binh - Tri - Thien is 123,037 ha, forestry land is 40,953.7 ha, accounting for 33.29%, forest area is 35,765.5 ha (accounting for 87.33%), mainly plantation forest: 32,950.5 ha, natural forest: 2,815.0 ha. The area of bare land is 5,188.2 ha (accounting for 12.67%), protection forest is 20,153.3 ha and production forest is 20,800.3 ha.

** Assessment of forest status on coastal sandy land in Binh - Tri - Thien provinces*

Natural forests: Most of them are rehabilitation forests in sand dunes, which are narrowly distributed. There are few species, mainly as *Syzygium corticosum, Lithocarpus sabulicolus*, *Litsea glutinosa*. Group distribution of trees can prevent sand moving.

Plantation forests: mostly *Casuarina, Acacia auriculiformis, Acacia mangium, Acacia difficilis, Eucalyptus camaldulensis... Casuarina* is an important species in critical defense in coastal sandbanks and high sand dunes. *A. auriculiformis* grows slowly but good protection efficiency for nearly 20 years. *Acacia hybrid and A. mangium* grow relatively well on suitable sites, required relatively high nutrient content and are made high bed. Other species grow slowly, low canopy cover rate, low efficiency, scattered distribution. Some plantations only form low shrubs, sand spreading, poor protection efficiency. In the poor sand dunes, strongly moving sand cause the phenomenon of sand fly or sand filling field, residential.... Land is also abandoned much, which is the great potential development of protective and economic species.

4.1.2. Status of planting Acacia crassicarpa on coastal sandy land

No	Province	Planting year			Total
		2000 – 2004	2005 – 2009	2010 – 2014	
1	TT Hue	3149.1	1811.4	208.9	5169.4
2	Quang Tri	11	0	103.5	114.5
3	Quang Binh	0	8	3	11
Total		**3,160.1**	**1,819.4**	**315.4**	**5,294.9**

Plantation area of *Acacia crassicarpa* reached 5,294.9 ha, mainly in Thua Thien Hue (5,169.4 ha), Quang Tri and Quang Binh provinces were very few. The plantations had high survival rate, good growth rate in plowed soils, made high bed and fertilized, unless the plantations were in bad quality. In the same soil condition, compared to other species, *Acacia crassicarpa* had higher survival rates, superior growth, broader and thicker. *Acacia crassicarpa* increased the coverage of sandy areas, decreased the intensity of winds, storms, decreased moving sand, and protected agro-forestry production in the area. The species was mainly planted for protection purpose, the technical methods were not appropriate, therefore the economic efficiency was not high.

4.2. *Acacia crassicarpa* propagation techniques

4.2.1. Seedling propagation technique

- Influence of soaking water temperature on seed germination rate

The soaking water temperature affects the seed germination rate. Although the shell thickness is very high, when impacted with 100^0C water, it is stimulated good germination, reached 84.78%, surpassed the rest of the treatment from 13.6 % - 68.33%.

- Effect of potting components on seedling performance

All potting components with small chemical fertilization (NPK, P_2O_5 and K_2O) gave higher survival than control (except treatment of 4%, all seedlings dead). Treatment with 1% NPK fertilizer (or 1% of P_2O_5 or 1% of K_20) showed growth exceeded the other treatments (devided in group A), the average root diameter from 3.38 to 3.64 mm, the height from 29.96 to 31.52 cm exceeded the rest treatments (D_0 exceeds 11,67% – 20,0% and H exceeded = 7,01% – 14,92%). The coefficient of variation from 11 to 18% between the treatments which showed that the seedlings were relatively equal.

- Effects of shading regime on seedling propagation results

After 120 days, the decreasing survival rate was inversely proportional to the shading ratio, the best was 90.83% for not shading treatment, the worst was shading 75% light treatment with survival rate of 80%.

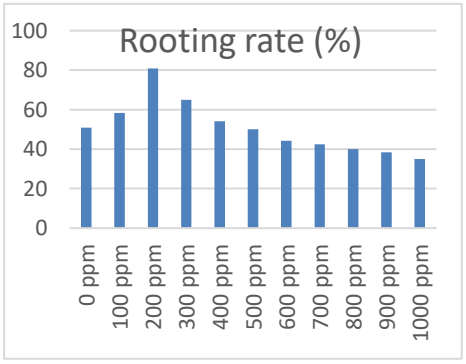
Growth height, root diameter in the no shading treatment was better than the rest (devided in group A), D_0 = 3.47 mm and H = 30.87 cm, exceeded the rest treatments (D_0 exceeds 9,46% - 23,93%, Hvn exceeds 6,19 – 27,88%).

Thus, the *Acacia crassicarpa* seedlings prefered to light completely. Seedling propagation without shading had the best survival rate and growth.

4.2.2. Cutting propagation technique

a) Effect of IBA and NAA on rooting rate

- Effect of IBA on rooting rate



The best result was 200ppm IBA treatments with rooting rate of 80.83% and different from the other treatments (devided in group A). With an IBA < 200 ppm or > 200 ppm, the rooting rate was much lower than the

200 ppm dosage, when increasing the IBA dosage, the rooting rate decreased, when increasing > 500 ppm, the rooting rate was lower than the control (without chemicals), the lowest rooting rate was 33.61% at 1,000 ppm.

- *Effect of NAA on rooting rate:*

The highest rooting rate in NAA untreatment was 50.83%, which indicated that NAA did not have a good effect on the rooting rate of the cuttings.

b) Effect of potting components on cutting propagation results

Potting components affected rooting rate, survival rate and growth of *Acacia crassicarpa* cuttings. The best potting component was 100% layer B soil which had 79,14% of rooting rate, 74,17% of sevival rate, 3,18 g in root weight; D_0 = 4,5 mm; H = 33,21 cm, higer then other treatments (Survival rate and rooting rate were 14% - 35% higher; root weight was 13,57% - 43,24% higher; D_0 was 26,76 – 48,51% higher and H was 14,05% - 31,21% higher).

During first stage, cutting did not supply any nutrient so the potting components with B layer soil met the nutritional needs for growing stems, while maintaining good moisture in hot weather and strong winds and good drainage, good ventilation for plants to grow well.

c) Effect of irrigation regime on cutting results

The results of the study determined the appropriate irrigation regime for *Acacia crassicarpa* cuttings from 1 to 60 days stage to be sprayed 3 minutes once, each spraying 4 seconds for the highest rooting rate of 76.67%. From 60 to 120 days stage, they were sprayed 5 minutes once, each spraying 6 seconds for best growth, root weight = 3,51 g, D_0 = 4,50 mm; H = 34,7 cm, higher than other treatments (Root and survival rates exceeded 10-15%, root weight exceeded 20,80% - 62,26% and D_0 exceeded 14,21 – 42,28%, H exceeded 6% - 29,9%).

In the first stage, when the stems were not rooted, it was necessary to keep the stem and leaves moist, to help the cuttings photosynthesize and stimulate roots, so the frequent and short irrigation was reasonable. After 2 months of rooting, stems can absorb water in the soil and it was necessary to reduce the humidity in the stems and leaves to reduce the fungal diseases. Therefore, the frequency of irrigation was reduced but the amount of irrigation water increased.

d) Effect of shading regime on cutting results

The results showed that the *Acacia crassicarpa* in the nursery did not need to shade the stems. Plants grew best with 100% direct light (without shading), rooting rate = 79,17%; survival rate = 74,72%; D_0 = 4,51 mm; H = 34,40 cm. Compared with other treatments, the rooting rate and survival rate exceeded 12-18%, D_0 exceeded from 21.89 to 24.24%, root weight and height were not completely different. In propagation by cutting, no shading was best.

4.3. Planting technique of *Acacia crassicarpa* on coastal sandy soil

4.3.1. Impact of soil preparation techniques on plantaion quality

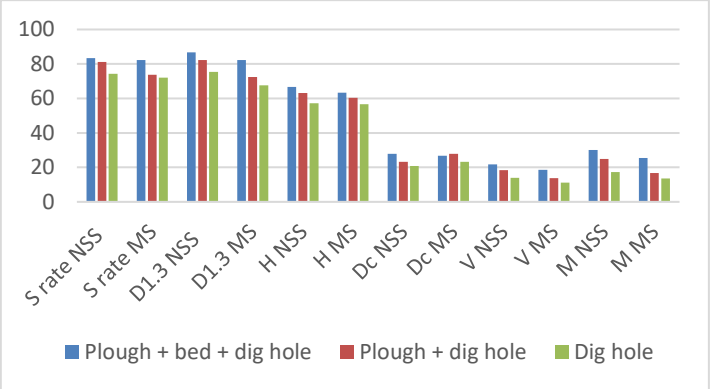
4.3.1.1. Impact of soil preparation techniques on semi-submerged sandy soil

Soil preparation by making bed is significantly influence on the growth of *Acacia crassicarpa* on semi-submerged stable sandy soil. When making bed reached a height of about 0.4 m, it would decrease waterlogging to create favorable conditions for plants to grow well. The treatment of single and double bed at the height of 0.4 m gave the best result: survival rate = 80,23% and 79,12%; $D_{1,3}$ = 17,25 cm and 16,89 cm; H = 14,77 m and 14,12m; V = 0,1833 m^3 and 0,1800; M = 238,47 m^3/ha and 243,39 m^3/ha, totally different from other treatments. Average annual growth rate ΔM = 23,90 m3/ha/year and 24,23 m3/ha/year, in excess of other treatments from 15.65% to 76.63% and exceeded the control 158.94 - 163.71%.

The coefficient of variation of the making bed at the height of 0.4 m treatment (12.21% - 21.14%) was lower than that of 0.2 m treatment (14.34% - 27.15%) and lower than the control (22.15% 76%). It meant the making bed at the height of 0.4m got the highest equal growth rate, followed by 0.2 m high and the control.

4.3.1.2. Impact of soil preparation on non-submerged soils and mowing sandy soils

With non-submerged and moving sandy soil, the treatment of plowing + making bed + digging hole to make soil porous, increased the survival rate and growth of the plants, increased plantation productivity, indicators were superior. Average annual growth ΔM = 10,02 m^3/ha/year and 8,47 m^3/ha/year, exceeded 20,68% and 51,69% of the treatment of making bed + digging hole and exceeded 73,20% and 87,87% of the digging hole treatment.



Regarding the coefficient of variation, the treatment of plowing + making bed + digging hole got the lowest point (11,12% - 17,42%) the highest was in the digging hole treatment (14.21% - 21.34%) which meant that plowing + making bed + digging hole to grow more equally.

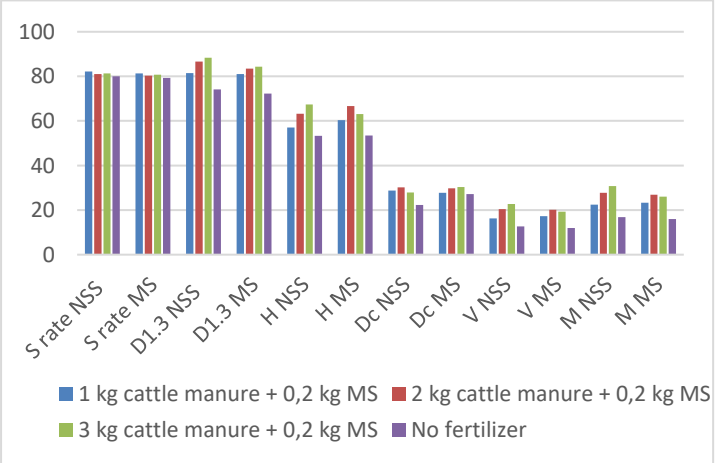
Comparing the results between non-submerged stable sandy soil and moving sandy soil, non-submerged stable sandy soil got higher results than most of the relevant indicators corresponding to each soil preparation technique treatment. However, the difference was not large.

4.3.2. Effect of first fertilizing applied for planting on sandy soil

4.3.2.1. Effect of first fertilizing applied for planting on semi-submerged sandy soil

Fertilizer supplied the nutrients needed for plant growth, increased the productivity of *Acacia crassicarpa* plantations on semi-submerged sandy soil, where 200 g of microorganism/tree or 100g of NPK/tree applied were the best results ($D_{1,3}$ = 17,33 cm and 17,14 cm; Hvn = 14,68 m and 15,02 m; V = 0,1904 m^3 and 0,1902 m^3; M = 254,45 m^3/ha and 260,24 m^3/ha). Similarly, the annual average growth rate was 25.45 m^3/ha/year and 26.02 m^3/ha/year, exceeded other treatments by 9.23% - 67.27% and exceeded the control by 129.28% - 134.41%.

4.3.2.2. Effect of first fertilizing on non-submerged moving sand



Non-submerged moving coastal sandy land in Phong Dien district, Thua Thien Hue province, both cattle manure and micro-organism application provided nutrients for plants and increased organic content in the soil, limited sand moving, increased plant growth and

resistance and increased productivity and quality of plantations. In which 3 kg of cattle manure + 0.2 kg of micro-organism or 2 kg of cattle manure + 0.2 kg micro-organism gave the best results, completely superior to other treatments. The average annual growth was 10.26 m^3/ha/year and 8.66 m^3/ha/year; 9,24 m3/ha/year and 8.95 m^3/ha/year, which exceeded other fertilizer treatments from 11.65% to 37.59% and exceeded the control from 63.29% - 82.35%.

On comparing the results between non-submerged stable and non-submerged moving sandy soil, there was a slight difference in growth, in which non-submerged stable sandy soil got higher results, but with very little difference.

4.3.3. Effect of density on forest quality

4.3.3.1. Effect of density on forest quality on semi-submerged soil

Density (tree/ha)	1666	2200	2500	3300	$F_{counted}/\chi^2_{counted}$	$F_{0,05}/\chi^2_{0,05}$
TLS (%)	$81,32^{a}$	$80,05^{a}$	$79,67^{a}$	$73,71^{b}$	10,56	7,81
$D_{1.3}$ (cm)	$17,44^{A}$	$15,61^{B}$	$14,11^{C}$	$12,42^{D}$	38,35	4,07
Hvn (m)	13,33	13,73	13,68	14,04	0,44	
D_t (m)	4,73	4,17	4,33	4,54	0,55	
V (m^3)	$0,1750^{A}$	$0,1445^{B}$	$0,1176^{C}$	$0,0935^{D}$	20,28	
M (m^3/ha)	$237,12^{AB}$	$254,37^{A}$	$234,18^{B}$	$227,65^{B}$	4,21	
ΔM (m3/ha/year)	23,71	25,44	23,42	22,77		

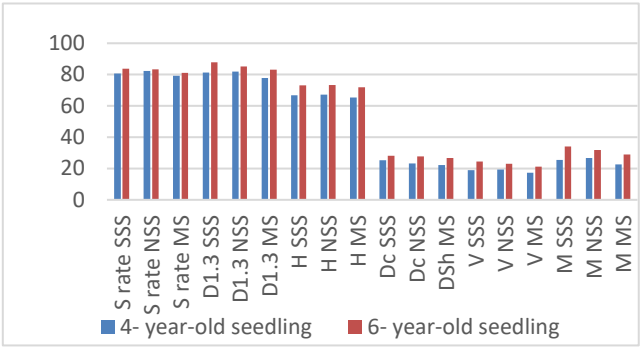
Low density (1666 trees/ha) showed larger individual tree growth ($D_{1,3}$ and V) than the others, but high density (2200 trees/ha, 2500 trees/ha and 3300 trees/ha) showed the same productivity. The average annual growth of 2200 trees/ha with the highest results was ΔM = 25.44 m^3/ha/year, exceeded other densities from 7.30% to 11.73%. However, regarding economic efficiency, it was clear that high density plantations would cost more in materials and labor, whereas low density forests' yields would be achieved equally and higher quality. Overall, the density of 1666 trees/ha and density of 2200 trees/ha were superior to 2,500 trees/ha. The density of 3,300 trees/ha showed the lowest result, not being set up in new sites.

4.3.3.2. Effect of density on forest quality on non-submerged moving sandy soil

The results of density experiments on moving sandy soils and non-submerged sandy soils were similar, the effect of density on growth of 3-year-old trees was unclealy, requiring longer evaluation time, about 5-7 years old.

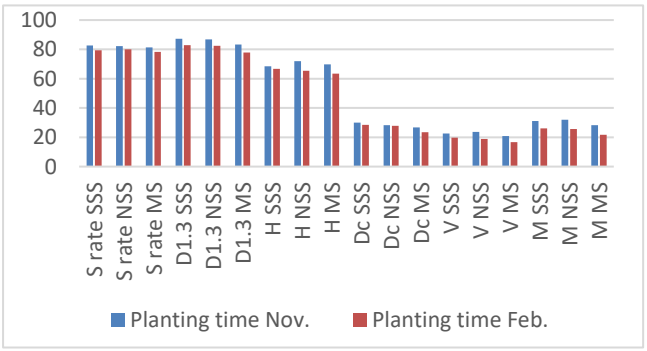
4.3.4. Effect of seedling age on the quality of the forest

Due to the specific conditions of coastal sandy soils in Binh - Tri - Thien provinces, the percentage of sand is high, easily moving and filling so the seedlings must be planted to ensure large size, deep planting and strong root growth. Therefore, the 6-month-old seedlings were better than 4-month-olds. The growth indicators showed that the 6-month-old seedlings exceeded 4 months of age, the average growth rate was the highest in the semi-submerged land of 32.83%, followed by the sandy soil 28.23% and the lowest in the non-submerged stable sandy soil of 19.57%.

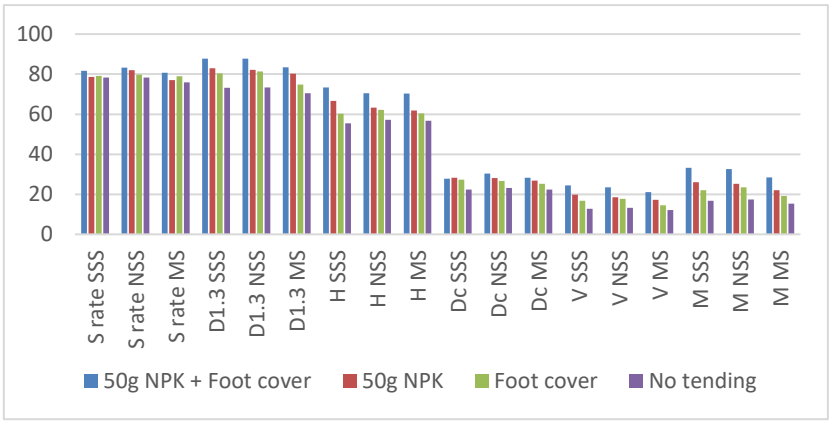


4.3.5. Effect of planting season on forest quality

The best planting season was in November, the growth rate was higher than that in February, the average annual growth rate in the November treatment was always higher than the other, the highest exceeding rate in the moving sites was 30.62%, followed by non-submerged stable sand 25.14%; the lowest was in semi-submerged stable sand 18.65%. The reason of this result was that November was the end of the big storm season, the average rainfall was favorable for the plant, so the survival rate was high, long time for stable growth before the hot dry season. In February, there was a slight spring rain, but soon after planting, the hot and longlasting southwest wind season started at the end of March, the temperature on the sand sometimes reached 60^0C, which can cause the plant die or grow poorly.



4.3.6. Effect of tending techniques on plantations



Fertilizing and foot-covering were always effective techniques in planting, especially in coastal sandy soils in Binh Tri Thien provinces where the nutrient was low, the rate of sand was high. Tending did not only provide nutrient for trees but also clear grass, covering foot with soil which helped to moisturize the trees, limited sand moving to increase the growth of trees and increase the productivity and quality of the plantations. Specifically, application of 50 g NPK + foot-covering would help the plants grow best, the growth rate exceeded the other treatments, the average growth rate exceeded the other treatments from 27.92% to 50.25% and exceeded the control from 84.35% - 98.80%.

4.4. The protective effect of *Acacia crassicarpa*:

4.4.1. Windbreak effect of Acacia crassicarpa

The wind speed behind the belt at distances of 5H, 10H and 15H (equivalent to 40m, 80m and 120m) reached 62.03 - 90.94% of the initial wind speed before the 15H (120m) belt. Plantation belts with different densities differed in windbreaker, with a density of 1,666 trees/ha the wind speed behind the belt reached 62.03% -89.56%, the figure was higher when the density increased to 2,200 trees/ha and 2,500 trees/ha (65.28% - 90.94%). The best protective effect was at the density of 1,666 trees/ha (23.89%), decreasing as the density increased, lowest at 2,500 plants/ha (21.71%).

4.4.2. Improvement of the sub-climate of Acacia crassicarpa forests

The 7-year-old *Acacia crassicarpa* plantations were potential to improve the sub-climate very well. In the hot and dry summer, inside plantation the average temperature was always 3.1 ^{0}C - 3.3^{0}C lower and average humidity was always 7.83% - 8.33% higher than the bare land. The radiation intensity in the forest was lower than the bare land from 92.36 lux - 94.83 lux, decreasing 7 - 8 times. Reducing the radiation intensity in the forest while reducing the temperature and increasing humidity, thereby improving the sub-climate in the forest.

4.4.3. Efficiency of soil improvement of the Acacia crassicarpa

a) Effectively improve soil temperature and soil moisture

The average soil temperature in the bare land in stable sandy soil was 38.1^0C and in moving sandy soil was 38.4^0C, which was very detrimental to the growth of most plant species. The soil temperature in the *Acacia crassicarpa* plantation in stable sandy soil was 31.5^0C and in the moving sandy soil was 31.7^0C, lower than the bare land of 6.6 and 6.7^0C respectively. With this temperature and humidity conditions there were many species could grow well.

Relative humidity at the surface layer of 0 cm - 30 cm and 30 cm - 60 cm in the bare land was very low at only 4.0% - 4.2% and 5.5% - 6.9% respectively, which illustrated the harsh conditions of coastal sandy areas in Binh - Tri – Thien provinces. Since there were *Acacia crassicarpa* plantations, the soil moisture has improved significantly, reaching 13.4% - 17.5%, increasing from 9.2% to 11.6%.

b) The Acacia crassicarpa root improved resistance and self-fixed natural nitrogen: Acacia crassicarpa has great root system, reaching a weight of 13.8 - 50.6 kg/tree root, contained a very large number of nodules from 13.494 - 81.389 nodules/tree root. Besides absorbing water and nutrients from the soil, the root also naturally fixed natural nitrogen, contributed to sand fixation and increased the ability to resist sand fly and sand fill.

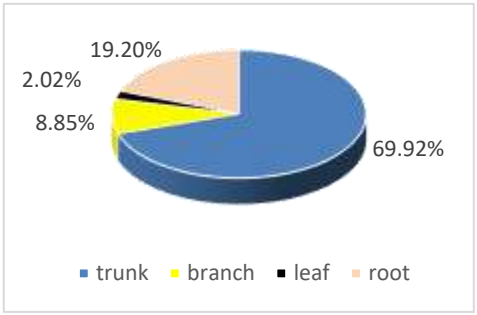


Root systems of 12-year-old Acacia crassicarpa in Trieu Phong, Quang Tri

c) Effect of chemical soil improvement: Compared to bare land, the *Acacia crassicarpa* plantation has a higher pH from 0.6 to 0.66 (an increase of 12.44% - 13.84%), the humidity increased from 67.39% to 73.53%, the humus ratio in the soil was higher by 75% - 80%, Ca^{++} and Mg^{++} increased by 265.39% - 437.66% and 160.61% - 193.02%, respectively; the content of easily digestible phosphorus was higher than 1.66 - 1.77 mg / 100g (increased by 50% - 74.68%) and easily absorbed Kali was higher than 1.21 - 1.55 mg/100g (43.68% 93.37%).

4.4.4. Carbon sequestration and CO_2 absorption

The amount of carbon was mainly concentrated in the trunks, accounting for 69.92%; followed by tree roots accounting for 19.20%; branches accounted for 8.85%; and lowest leaves 2.02%.



The average amount of carbon in the total biomass of the 10-year-old plantation was 36,44 t/ha, the 12-year-old plantation was 39.69 t/ha, the amount of CO_2 absorption was 33,62 t/ha and 145,51 t/ha in those mentioned plantations.

The average amount of carbon in the plant litters was 6.4 t/ha, the amount of CO_2 absorption was 21.94 t/ha. Besides, thick plant litters could prevent sand moving and keep soil moisture and gradually improve ecological environment.

4.4.2. Economic efficiency of the Acacia crassicarpa forest

a) Economic efficiency from wood, firewood

Planted *Acacia crassicarpa* in Binh Tri Thien coastal areas reached 22.73m^3/ha/year, reached 159.17 m^3/ha/7years, earning 77.583.000 VND/ha. Net profit (NPV) = 15.2 million VND/ha, BCR = 1.56, IRR = 18.09%. It was shown that *Acacia crassicarpa* could be a key species for coastal sandy areas, contributing to poverty alleviation and environmental improvement.

b) Carbon trading value of Acacia crassicarpa plantations

10-year-old forests brought economic benefits from trading Carbon from VND 12.12 - 22.87 million/ha and 12-year-old forests brought VND 13.52 - 33.92 million/ha, the average was VND 18,1 million/ha.

Thus, in terms of economic efficiency*, given the poor sandy soils in coastal sandy areas, the disadvantaged sites, the Acacia crassicarpa plantations provided relatively high economic value with impressive figures such as average income of 77 million VND/ha, net profit of 15.2 million VND/ha and Carbon trading value of 17.1 million VND/ha. It was clear that the Acacia crassicarpa plantation was the best solution for the development of coastal sandy areas in Binh Tri Thien provinces.*

CONCLUSIONS

1. Status of coastal sandy land use in Binh - Tri - Thien provinces

- The area of forest land in the sandy areas of Binh - Tri - Thien is 40,394 ha, accounting for 33.29% of the total natural area, 35,766 ha of forest land, but poor forest quality, low coverage and low protection and economic effeciency. The bare land is 5,188.3 ha, which is sandy and sand filled, badly affects the production of agroforestry and life. Major plantation species are *Casuarina, A. auriculiformis, A. crassicarpa, A. mangium, Acacia defficilis* and *Eucalyptus*.

- *Acacia crassicarpa* is superior to sandy coastal areas, which is planted in 5,295 ha, mainly in Thua Thien Hue. The survival and growth are superior to other species on the same site, which has done a good job in protectionism. However, the planting techniques are not appropriate so economic efficiency of plantations is low.

- The current status and use of sandy soils in Binh - Tri - Thien is potential for the development of *Acacia crassicarpa* with appropriate planting techniques that will increase productivity and quality to meet the protection and effectiveness of economy.

2. *Acacia crassicarpa* propagation techniques

- *Techniques for seedling propagation by seeds: Seed treatment:* to soak seeds in boiled water and keep natural cooler in 8-10 hours then soak in clean water and keep warm in cloth bag in 3 days and daily washing up seeds, rate of germination reaching 84,78%, exceeded other treatments from 13,6% - 68,33%. *Potting components*: 89% of the first layer of plantation soil + 10% cattle manure + 1% P_2O_5 and without shading. After 4 months, seedlings alive rate was about 88% – 91%; root diameters were 3,3 - 3,5 mm and height were about 31,2 – 31,5 cm and higher 9,5 – 23,9% in root diameter and 7,5 – 27,9% in height in comparison with normal methods of seedling propagation.

- *Techniques for seedling propagation by cutting: treating stems* with IBA 200ppm and rooting rate was 80,83%, exceeded other concentrations from 17,14% - 47,22%; *Potting components* 100% B layer soil, no shading; *watering* from first to 60 days: showering 4 seconds every 3

minutes, from 61 days to 120 days showering 6 seconds every 5 minutes and without shading. After 4 months, seedlings alive rate was about 59% - 75%; root diameters were 3,4 mm – 4,5mm and heights were about 33,2 cm – 34,7 cm and higher 14,5 – 42,2% in root diameter and 12,3 – 31,21% in height in comparison with normal methods of cutting propagation.

3. Technique of planting Acacia crassicarpa on coastal sandy soil

Soil preparing techniques: Complete plowing, making single bed with 1.5m wide, trench width 1.5m, 0.4m height, on each bed growing 1 line; or double bed 4m wide, trench width 2m, 0.4m height, growing 2 lines. *Planting time* was in November; *density* was 1.666 trees per ha in stable sandy soil and 2.200 trees per ha in moving sandy soils; *first fertilizering* 200g micro organism per tree in semi-submerged stable sandy soil, in non-submerged stable and moving sandy soil 2 kg cattle manure + 200g micro organism per tree; *seedlings to be planted*: 6-month-old seedlings reached about 4.0 - 5.0 mm in root diameters and about 40 to 55 cm in height; *tending:* once a year, implementing 50 g NPK application and covering tree foot with soil in each tree in width 50 - 60 cm, height 30 cm. The results showed that the annual average growth of the best treatments exceeded the rest treatments from 20% -> 50%, even to 98.80%.

4. Protection effectiveness of *Acacia crassicarpa* plantation

Good windbreak effect: In the distance from 40 m to 120 m after the plantation belt, the remaining wind decreased from 62.03% to 90.94% in comparison with front of the belt and wind deflector rate was from 21.23 % - 23.89%. *Improving sub-climate effect:* In the Summer, inside the plantation the air temperature decreased from 3.1 - 3.3^0C; air humidity increased 7.83 - 8.33%; radiation intensity decreased from 92.36 to 94.83 lux. *Land improvement effect*: in summer, soil temperature decreased 6.6 - 6.7^0C; Soil moisture increased by 9.4 - 10.6%. pH_{KCl} in the forest was higher than in bare land by 0.6. All the nutrients in the soil under plantation were higher than the bare land's, in which humus ratio increased 62.39 - 73.53%, Nitrogen increased by 75-80%, ion Ca^{2+} increased by 265,39% - 437,66%, ion Mg^{2+} increased by 160,61% – 193,02%, the content of easily digestible phosphorus increased 1,66 – 1,77 mg/100g (increased by 50% - 74,68%) and easily absorbed Kali increased 1,21 – 1,55 mg/100g (increased by 43,68% - 93,37%).

5. Economic efficiency of *Acacia crassicarpa* platations

The economic efficiency of the *Acacia crassicarpa* plantation on coastal sandy soils in Binh-Tri-Thien is relatively high, after 7 years, the yield was 22.7 tons / ha / year, earning VND 77.58 million / ha, earning a net profit of 15.3 million VND / ha. Carbon trading value was 18.1 million VND / ha, much higher than other forest belts planted on sandy soil. Acacia crassicarpa can become a staple species for coastal sandy areas, both protection and economic efficiency, contributing to poverty reduction and ecological environment.

RECOMMENDATIONS

- Additional research is needed in the form of strong moving sand dunes and experimental design in Quang Binh province for more complete results.

- It is necessary to multiply the area of *Acacia crassicarpa* plantation on coastal sandy soils in Binh-Tri-Thien and other localities with similar soil conditions, to apply the best techniques from research results of the thesis. At the same time, it is necessary to select recognized breeds to improve the environment while improving economic efficiency.

- Today, most of the *Acacia crassicarpa* plantations on the coastal sandy area are protection forests, it is necessary to develop the production forests on the bare land or replace the poor quality and low effective forests with the extracting plan and reforestation to meet the protection and economic objectives.