

## Acacia plantation in different quality sites and fertilization in Northeast Vietnam

Tran Van Do\*

Silviculture Research Institute, Vietnamese Academy of Forest Sciences, Hanoi, Vietnam

Received:

December 07, 2019

Accepted:

March 03, 2020

Published:

July 30, 2020

### Abstract

The impacts of site quality and fertilization on the growths of acacia plantation have become important in plantation management. It could provide information on which site and how much fertilizer should be applied, contributing to sustainable plantation management. In this study, two sites of different conditions of soil depths (30-40 cm/shallow soil site and 70-80 cm/deep soil site) and of rock contents (< 10% and > 45%); and fertilizing 200 g NPK (16:16:8)/tree/year and control (non-fertilization) were experimented in an *Acacia mangium* plantation in northeast Vietnam. The plantation was established in September 2017, fertilizer was applied in June 2018 and 2019. Site conditions and fertilization significantly affected the growths of 2-year-old plantation. In shallow soil site, the plantation in fertilization treatment achieved 498% basal area and 595% aboveground biomass of plantation in non-fertilization treatment. The difference among control and fertilizing 200 g NPK/tree in deep soil site, and fertilizing 200 g NPK/tree in shallow soil site was not significant. It is concluded that fertilizing NPK to acacia plantation in the present study site is necessary for shallow soil site even trees become older, while in deep soil site fertilization is required only in the first year to support initial growths.

**Keywords:** Fertilization, Plantation growth, Shallow soil, Site condition, Soil nutrient pool

### How to cite this:

Tran VD, 2020. Acacia plantation in different quality sites and fertilization in Northeast Vietnam. Asian J. Agric. Biol. 8(3): 240-246. DOI: <https://doi.org/10.35495/ajab.2019.12.554>

\*Corresponding author email:  
dotranvan@hotmail.com

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## Introduction

Fertilization has been widely applied in many species around the world to increase forest plantation productivity (Shi et al., 2019; Hung et al., 2009), and it is a viable silvicultural option for sustainable plantation management (Fox et al., 2007). Site quality has the greatest and often longest-lasting effect on the productivity of plantations. Fertilization on high fertile

sites often has little effect, while that on low fertile sites can have remarkably positive effects. The macronutrients (Sulaiman et al., 1990) including Nitrogen (N), Phosphorus (P), and Potassium (K) are the key limiting nutrients in many sites (Goncalves et al., 2007). Fertilizers could be applied at and/or after planting annually to support tree's growths (Vu et al., 2019; Tran et al., 2018; Tran et al., 2017; Guo et al., 2016; Lamani et al., 2004). The main purpose of



fertilization to any plantation is to supply nutrients to planted trees for better growths and higher survival rate (Earnshaw et al., 2016; Forrester et al., 2012). Therefore, growers expect that planted trees can absorb as much applied fertilizer as possible (Silva et al., 2013).

Fertilization at planting, which creates favorable soil chemical properties for root establishment, is considered to play an important role in the survival and early growth of the plantation. Plants with poorly developed root systems require high nutrients in the planting establishment stage. Therefore in low and medium natural fertility soil, forest productivity increases considerably by early fertilization (Goncalves and Barros, 1999). Maintenance fertilization is carried out after plantation establishment when soil nutrient does not meet plants' nutrient demand. Fertilizer is applied one a year, but usually only before canopy closure. This stage is characterized by a rapid increase of plantation biomass with the highest increment in leaf area index to promote photosynthesis (Viera et al., 2015; Goncalves et al., 2004). The main purpose of maintenance fertilization is to provide necessary amounts of fertilizers that can mismatch between plant's demand and edaphic supply.

Management of soil fertility and plant nutrition is important for increasing plantation productivity (Smethurst, 2000; 2010; Pinkard, 2003). In areas of low natural fertility, low production may be caused by inadequate plant nutrition, and therefore fertilization becomes necessary. The type and quantity of fertilizers to be applied depend on a number of factors such as nutritional demands of the species (Tran, 2019), the natural soil fertility, soil chemical, and physical characteristics, soil-fertilizer reaction, fertilization efficiency, and site hydric availability (Ryan et al., 2010; Smethurst, 2010). However, the plant nutrient demands should be balanced with the provision of nutrients in time and space. Soil nutrient balance and yield classes (Barros et al., 1992) and critical soil nutrient levels (Goncalves et al., 2008) are important tools for determining fertilizer needs.

Plantation has been contributing significantly to the rural economy in many tropical regions (FAO, 1981). Acacia plantations are becoming increasingly important to the national economy and contributing to livelihood of million people in rural areas, Vietnam (Kien et al., 2014). The objective of this study is to examine the effect of fertilization in different quality sites on *Acacia mangium* plantation in northeast Vietnam.

## Material and Methods

### Study site

The study was conducted in northeast Vietnam at 21°4'14.2"N and 107°2'52.6"E. The site belongs to the monsoon climate region with the average annual temperature of 22.2°C and air humidity of 81% (QCVN02, 2009). The area has an annual precipitation of 1600–2200 mm. The soil in the site is classified as Ferralic Acrisol. There are two microsites, which is 30 m far away from each other by a narrow canyon. The quality of microsites is indicated in Table 1.

**Table-1: Quality of two microsites for the experiment**

No	Characteristic	Site A	Site B
1	Initial vegetation	Some trees of <i>Acacia mangium</i> and <i>Eucalyptus urophylla</i> , and other shrubs (shorter than 3 m)	
2	Soil depth (cm)	70-80	30-40
3	Rock content (%)	< 10	> 45
4	Sand (0.02-2 mm) (%)	56.77	56.06
5	Loam (0.002-0.02 mm) (%)	23.53	25.93
6	Silt (<0.002 mm) (%)	19.70	18.01
7	pH	3.92	3.89
8	N (%)	0.07	0.07
9	P <sub>2</sub> O <sub>5</sub> (mg/100 g)	0.34	0.33
10	K <sub>2</sub> O (mg/100 g)	5.22	4.34

### Experimental design

The experiment included two sites (Table 1), including microsite A known as deep soil site and microsite B known as shallow soil site.

Fertilization experiment included two treatments, including (a) fertilizing 200 g NPK (16:18:8)/tree and control (non-fertilization). Fertilizer was applied at planting and in the first and the second year after planting with the same amount of 200 g NPK/tree/time.

Four-month-old *A. mangium* seedlings with a stump diameter (diameter measured at collar root) of 3.5–3.7 mm and a height of 0.55–0.57 m were used. Planting pit with sizes of 30 × 30 × 30 cm was prepared. Trees were planted in September 2017. Maintenance fertilization was conducted in June 2018 and 2019. A pit of 10 cm width × 10 cm length × 15 cm depth near a stump of *A. mangium* tree was made, and fertilizer was inserted and then covered with fine soil. Vegetation near the pit was cleared.



The experiments were conducted in two randomly completed blocks, one for microsite A and other for microsite B. Three replications were employed, leading to 6 subplots in each block. Each subplot contains 36 trees planted in 3 m × 3 m spacing. The distance between subplots is 6 m, which ensures no cross-interference among subplots.

### Data collection and aboveground biomass estimation

Stem diameter at breast height (DBH), stem height, and stem crown diameter ( $D_c$ ) were measured in September 2018 and October 2019. Then, aboveground biomass (AGB) of each stem was estimated based on DBH by applying allometry in Eq. 1 (Thanh and Thu, 2015). AGB of each replication was the total biomass of all stems in a subplot.

$$AGB = 0.223 * DBH^{2.251} \quad (1).$$

### Statistical analysis

Growth parameters are reported as mean and standard error (SE). AGB is reported as the mean of three replications (subplots) with SE. While a comparison of growth parameters and AGB between microsites and fertilizations is reported as percentage. Pair-comparison was employed to identify the effect of microsites and fertilization on growths and AGB of the plantation. All analyses were applied at  $p = 0.05$  using SAS 9.2 (SAS Institute Inc., Cary, NC, USA).

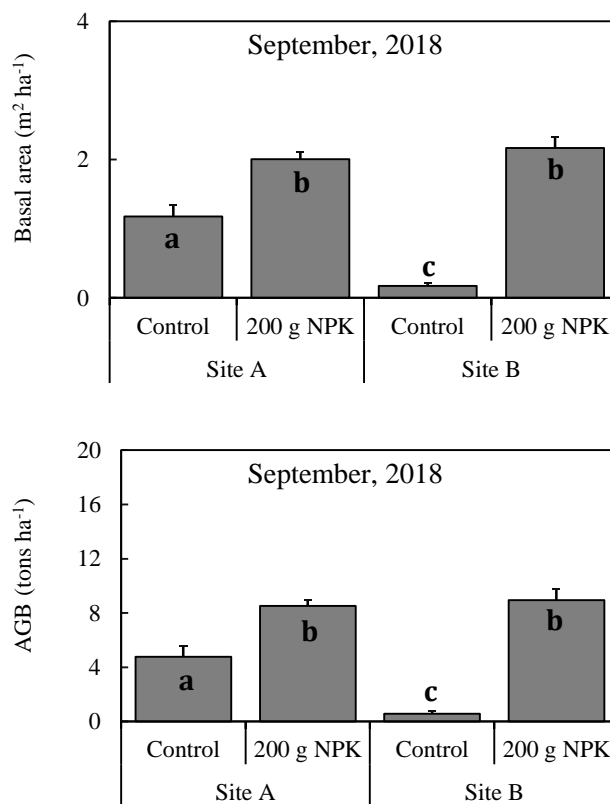
## Results

Site and fertilization significantly affected the growth of 1- and 2-year-old *A. mangium* plantations (Table 2). For 1-year-old plantation in each site, fertilization had higher growths than that in control. Comparing between two sites in control indicated significant better growths in site A than that in site B. However, the difference between two sites in fertilizing 200 g NPK was not significant for both DBH and stem height. Meanwhile, for 2-year-old plantation, the difference of DBH among control and 200 g NPK in site A and 200 g NPK at site B was not significant (Table 2), which was significantly higher than DBH in control at site B.

**Table-2: Growths (mean ±SE) of 1- and 2-year-old *Acacia mangium* plantations in different sites and fertilization**

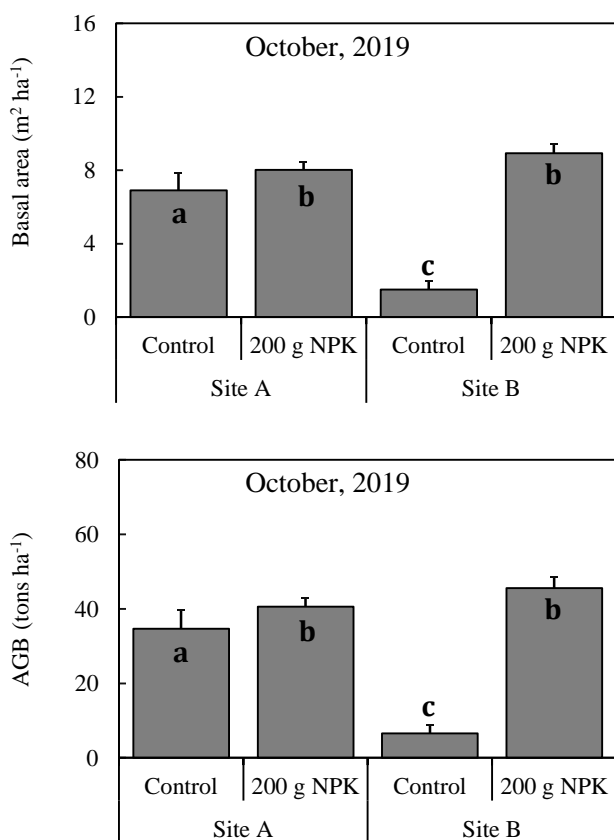
	Site A		Site B	
	Control	200 g NPK	Control	200 g NPK
<i>1-year-old plantation (data measured in September 2018)</i>				
DBH (cm)	3.54 ±0.26 <sup>a</sup>	4.75 ±0.13 <sup>b</sup>	1.24 ±0.17 <sup>c</sup>	4.94 ±0.17 <sup>b</sup>
Height (m)	2.92 ±0.10 <sup>a</sup>	3.77 ±0.07 <sup>b</sup>	2.05 ±0.11 <sup>c</sup>	3.98 ±0.10 <sup>b</sup>
<i>2-year-old plantation (data measured in October 2019)</i>				
DBH (cm)	8.68 ±0.59 <sup>a</sup>	9.46 ±0.29 <sup>a</sup>	3.52 ±0.57 <sup>b</sup>	10.09 ±0.29 <sup>a</sup>
Height (m)	6.87 ±0.17 <sup>a</sup>	6.97 ±0.14 <sup>a</sup>	3.76 ±0.34 <sup>b</sup>	7.83 ±0.14 <sup>c</sup>
$D_c$ (m)	3.70 ±0.21 <sup>a</sup>	4.19 ±0.11 <sup>a</sup>	1.48 ±0.31 <sup>b</sup>	4.77 ±0.10 <sup>c</sup>

Different letters <sup>a, b, c</sup> in a line indicate significant difference of means at  $p = 0.05$



**Fig-1: Basal area and aboveground biomass (AGB) of 1-year-old *Acacia mangium* plantation in different sites and fertilization. Different letters <sup>a, b, c</sup> indicate significant difference of means at  $p = 0.05$ . Bars indicate +SE**

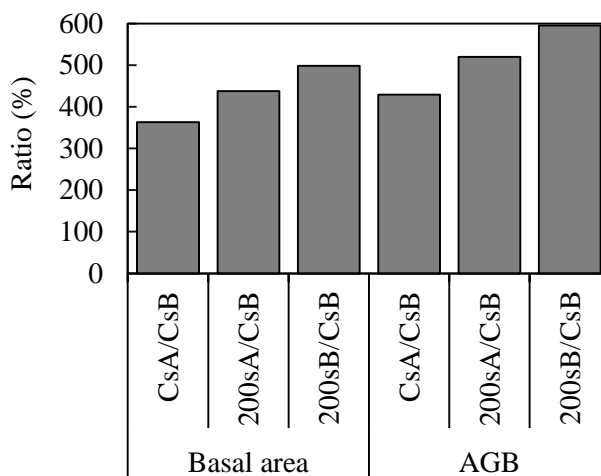
The pattern of difference of height and crown diameter between sites and fertilization was similar. The best belonged to 200 g NPK at site B, reduced to control and 200 g NPK at site A, and the lowest belonged to control at site B. The difference of height and crown diameter between control and 200 g NPK at site A was not significant (Table 2). Basal area and AGB were significantly different between sites and fertilization in 1-year-old plantation (Fig. 1). The highest belonged to 200 g NPK at both sites, reduced to control at site A, and the lowest belonged to control at site B. A 1-year-old plantation achieved basal area of 2.17 m<sup>2</sup> ha<sup>-1</sup> at site B and 2.01 m<sup>2</sup> ha<sup>-1</sup> at site A in fertilizing 200 g NPK, 1.18 m<sup>2</sup> ha<sup>-1</sup> in control at site A, and 0.17 m<sup>2</sup> ha<sup>-1</sup> in control at site B. It achieved AGB of 8.96 tons ha<sup>-1</sup> at site B and 8.53 tons ha<sup>-1</sup> at site A in fertilizing 200 g NPK, 4.76 tons ha<sup>-1</sup> in control at site A, and 0.57 tons ha<sup>-1</sup> in control at site B (Fig. 1).



**Fig-2: Basal area and aboveground biomass (AGB) of 2-year-old *Acacia mangium* plantation in different sites and fertilization. Different letters a, b, c indicate significant difference of means at  $p = 0.05$ . Bars indicate +SE**

Basal area and AGB were significantly different between sites and fertilization in 2-year-old plantation (Fig. 2). The highest belonged to 200 g NPK at both sites, reduced to control at site A, and the lowest belonged to control at site B. A 2-year-old plantation achieved basal area of 8.92 m<sup>2</sup> ha<sup>-1</sup> at site B and 8.02 m<sup>2</sup> ha<sup>-1</sup> at site A in fertilizing 200 g NPK, 6.91 m<sup>2</sup> ha<sup>-1</sup> in control at site A, and 1.49 m<sup>2</sup> ha<sup>-1</sup> in control at site B. It achieved AGB of 45.55 tons ha<sup>-1</sup> at site B and 40.60 tons ha<sup>-1</sup> at site A in fertilizing 200 g NPK, 34.68 tons ha<sup>-1</sup> in control at site A, and 6.55 tons ha<sup>-1</sup> in control at site B.

Comparing to control at site B (Fig. 3), plantations in 200 g NPK at site B, and control and 200 g NPK at site A had much higher ratios of basal area and AGB. Basal area increased 360-500%, while AGB increased 430-600%.



**Fig-3: Comparisons of basal area and aboveground biomass (AGB) of 2-year-old *Acacia mangium* plantation between treatments. CsA/CsB is between control at site A and control at site B; 200sA/CsB is between 200 g NPK at site A and control at site B; 200sB/CsB is between 200 g NPK at site B and control at site B**

### Discussion

N and P contents in soil are not different between two sites (Table 1), while K content in site A is higher than that in site B. Other soil characteristics are also not different, accept soil depth and rock content; soil is shallower and rock is more numerous in site B. Such characteristics indicated that total nutrient pool in site A is much higher than that in site B. It is indicated that

legumes require higher P and lower N than non-legumes, as they can fix nitrogen themselves (Inagaki et al., 2009). Meanwhile, there has not recorded the importance of K in the growths of acacia trees. Therefore, P could be limited nutrient in the present study site and P application becomes important for acacia plantation (Vu et al., 2019).

Control in site B with a low total nutrient pool had the lowest growths, basal area, and AGB (Table 2, Fig. 1 and 2). The gaps of difference in the 2-year-old plantation were even much higher than that in the 1-year-old plantation. This again indicated the importance of total nutrient pool in the soil for tree growths when they are getting older (Chi et al., 2015; Mohren and De Veen, 1995). Meanwhile, in the 2-year-old plantation, the difference of growths between control and 200 g NPK at site A (Table 1) was not significant, indicating the unnecessary of fertilization in the deep soil site with a high total nutrient pool. In older plantation, trees develop a good root system that is deeper and larger to acquire naturally available nutrients (Nicoll and Ray, 1996) in high total nutrient pool soil of site A meeting their nutrient demands. Conversely, in site B with shallow soil and high rock content, trees could not develop their root systems and there is low nutrient availability in nature. Therefore, they cannot grow well and fertilization becomes necessary.

The present study sites seem K rich but P poor. Therefore K fertilization is not necessary, while P fertilization becomes important (Vu et al., 2019). Applying NPK in the present study may lead to a high loss rate of K. Therefore, applying sole P fertilizer may bring more benefit to forest growers as it is cheaper than NPK fertilizer and can reduce the loss rate of applied fertilizer.

Fine roots (diameter  $\leq 2$  mm) absorb water and nutrients for a tree's life (Nguyen et al., 2019). Fine roots usually distribute in the top and fertile soil layer, however, it can also be found deeper than 70 cm (Lai and Tran, 2019; Nguyen et al., 2019). Meanwhile, in site B there is a shallow soil layer of  $< 40$  cm and a deeper layer is parent rock, which is hard and fine roots could not grow in. Therefore, nutrient deficiency becomes more serious in the site with a shallow soil layer (Nicoll and Ray, 1996). Leaching will bring nutrients to deeper soil layer and it could be taken up by fine roots in deeper soil, but it may not be a case in shallow soil as site B. Therefore, fertilizing more amount of fertilizer in a time in shallow soil will lead to high loss rate by erosion, which washes away

nutrients from the site and planted trees cannot absorb anymore compared to leaching. In shallow soil, fertilization should be conducted more times with a less amount in each time to ensure as much fertilizer uptake by planted trees as possible.

## Conclusion

This study examined the effects of fertilization and site quality on the growths of *Acacia mangium* plantation in northeast Vietnam. The results indicated that fertilization is necessary for shallow and high rock content soil even when trees become older. While in deep and less rock soil, fertilization is required only in the first year to support initial growth. A 2-year-old plantation in deep (70-80 cm) and less rock content ( $< 10\%$ ) soil without fertilization can achieve 363% basal area and 429% AGB of plantation in shallow (30-40 cm) and high rock content ( $> 40\%$ ) soil. While in shallow and high rock content soil with fertilizing 200 g NPK/tree could achieve 498% basal area and 595% AGB of plantation in the same site without fertilization.

*Acacia mangium* plantation in the present study may require only P other than N and K. Therefore, a study on using sole P should be conducted to reduce the loss rate of N and K fertilizer and increase benefit for forest growers.

## Acknowledgment

I would like to thank all colleagues for constructive comments on the manuscript.

**Disclaimer:** None.

**Conflict of Interest:** None.

**Source of Funding:** This research was funded by Vietnam National Foundation for Science and Technology Development (NAFOSTED) under grant No. 106-NN.06-2016.10.

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