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Effect of Fertilization on Growth of *Eucalyptus urophylla* Plantation

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Authors' contributions

This work was carried out in collaboration between all authors. Authors TVD and DVT designed the study, wrote the protocol and interpreted the data. Authors DVT and NTT anchored the field study, gathered the data and performed preliminary data analysis. Author TVD managed the literature searches and produced the initial draft. All authors read and approved the final manuscript.

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ABSTRACT

Fertilization has been widely applied to increase and sustain productivity of plantations, especially in poor soils. N, P, K, and compost are usually used for forest plantation in Vietnam. The amount of fertilizer and rates of concerned nutrient are decided basing on species and edaphic condition. In this study, four fertilizer applications were used at planting; 100 g NPK+200 g compost, 150 g NPK+150 g compost, 200 g NPK+100 g compost, and control (no fertilization) for *Eucalyptus urophylla* plantation grown in North Central and Southern, Vietnam with planting density of 1,330 trees ha^{-1} (spacing 2.5 × 3 m). Growth data were collected after planting three years. Fertilizer applications had significant effects on diameter at breast height (DBH), crown diameter (D_c), and dry biomass of 3-year-old plantations in both sites. A 3-year-old. *E. urophylla* plantation had largest DBH (9.7 cm) and dry biomass (67.2 Mg ha^{-1}) in fertilizer application of 200 g NPK+100 g compost in Southern site, and smallest DBH (6.4 cm) and dry biomass (38.2 Mg ha^{-1}) in control also in Southern site. Comparing between two sites at three treatments with fertilizer indicated the significant higher dry biomass in Southern site than that in North Central site. While, it was

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converted in control, indicating higher dry biomass in North Central site. To grow *E. urophylla*, 200 g NPK+100 g compost should be applied at planting for Southern site. While, 100 g NPK+200 g compost is encouraged for North Central site.

Keywords: Edaphoclimatic condition; fertilizer requirement; soil nutrient; sustainable production.

1. INTRODUCTION

Plantations of exotic trees are assuming an increasingly significant role in landscape management and the rural economy in many tropical regions [1]. Of which, *Eucalyptus*, fast growing tree species, could meet the growing demands of pulp wood and timber.

The soils intended for forest plantations usually have low fertility, which require fertilization to maintain high yields. N, P, and K are major nutrients applied to plantation [2,3]. Fertilization in eucalypt plantations provides production gains, ranging from 5% to over 90% of wood production; depending on nutrient, stand age, and edaphoclimatic conditions of the site [4,5]. Stand growth may be greater in higher quality sites or may be accelerated by fertilizer application. Studies on eucalypt plantation have shown that absolute and relative responses of potential sawlog trees often increase with fertilizer application [6-8]. Similar to eucalyptus stands, fertilizer application has increased growths of other tree species such as *Pinus contorta* [9] and *Pinus sylvestris* stands [10].

The development of silvicultural practices and eucalypt breeding increased yields and reduced rotation time, which required high nutrient output to sites and raised the responses for N, P, and K fertilization [11]. To meet N, P, and K nutritional demands for different site conditions, different fertilizers and different amount are necessary to reach the maximum yield [12,13]. For optimum growth and development, planted trees requires large amount of nutrient [14]. N, P, and K play an important role for better growth and development in plants [15,16], especially when trees are planted in poor soil. Knowledge on nutrient relations in eucalypt plantations is therefore imperative for fertilizer application to maintain nutrient contents within limits that ensure the production sustainability.

In Vietnam, eucalypt plantation is becoming increasingly important in contributing to livelihood of million people in rural areas. It is imperative that fertilization is important to increase and sustain productivity for eucalypt plantations. The objective of this study was to examine the effects of fertilization on growth and dry biomass of eucalypt plantations in Vietnam.

2. MATERIALS AND METHODS

2.1 Study Site

This study was conducted in North Central and Southern, Vietnam. The Southern site has mean annual temperature of 25–27℃, annual precipitation of 1,400–2,500 mm, and annual humidity of 84%. Soil has average pH of 4.0–4.5, high organic matter, and nutrient content. The North Central site has mean annual temperature of 22–23℃, annual precipitation of 2,300–2,400 mm, and annual humidity of 85–90%. Soil has average pH of 4.1–4.3, high organic matter, and nutrient content [17].

2.2 Plantation Establishment

This study was conducted for *E. urophylla*, grown in North Central and Southern, Vietnam.

The experiment included four treatments; (a) 100 g NPK+200 g compost/tree, (b) 150 g NPK+150 g compost/tree, (c) 200 g NPK+100 g compost/tree, and (d) control (no fertilization application). In all fertilization treatments, planting density of 1,330 trees ha-1 (spacing 2.5 × 3 m) was used. Fertilization was applied at planting manually. Planting holes were prepared manually with the size of 30 × 30 × 30 cm. Fertilization was put in the hole, then well mixed with fine soil before growing seedlings of 30–35 cm tall. Seedlings were planted during rainy season. After planting, no further silvicultural techniques were applied.

Experiment was conducted in a randomized complete block with three replicates. Each replicate was conducted in a plot of 20 × 20 m, which included 36 trees. Totally, there were two blocks for two sites. Each block contained 12 plots (4 treatments × 3 replicates).

2.3 Data Collection and Analysis

Data included diameter at breast height (DBH in cm), stem height (H in m), and crown diameter (Dc in m) were measured after planting three years. All surviving stems in plots were measured.

Dry biomass of each stem (B in kg; including leaves, branches, stems, roots) was estimated following Eq. 1 [18]:

$$B = 2.7262 * DBH^{1.3016} \quad (1)$$

Survival rate, mean DBH, mean H, and mean Dc were calculated for each treatment in each site separately. Dry biomass was estimated for plot mean then transferred to unit of Mg ha^{-1}.

Comparison among treatments in each site was conducted with ANOVA one-factor and post-hoc test. While, comparing between two sites for each fertilization treatment separately was conducted by pair-comparison. Statistical analysis was conducted using SAS 9.2.

3. RESULTS

There was no significant difference of survival rate of a 3-year-old *E. urophylla* plantation in North Central among four fertilizer treatments (Table 1). The survival rates was ranging from 94.7% to 96%.

The deference of means of DBH, stem height, and Dc was statistically significant. The tallest mean stem height (8.9 m) was found in fertilizer application of 150 g NPK+150 g compost, and the shortest mean stem height (7.4 m) belonged to control. Meanwhile, the largest mean DBH (7.9 cm) and Dc (2.3 m) were found in fertilizer application of 100 g NPK+200 g compost, and the smallest mean DBH (7.4 cm) and Dc (1.7 m) were found in control (Table 1).

The significant difference of DBH led to significant difference of dry biomass of a3-year-old *E. urophylla* plantation in North Central among fertilizer applications (Table 1). The highest dry biomass of 50.7 Mg ha^{-1} belonged to fertilizer application of 100 g NPK+200 g compost, reducing to 48.8 Mg ha^{-1} in fertilizer application of 200 g NPK+100 g compost, to 47.3 Mg ha^{-1} in fertilizer application of 150 g NPK+150 g compost, and to 46.6 Mg ha^{-1} in control (Table 2).

There was no significant difference of survival rate of a 3-year-old *E. urophylla* plantation in Southern among four fertilizer applications (Table 2). The survival rates was ranging from lowest 94% in control to highest 96.3% in fertilizer application of 200 g NPK+100 g compost.

The deference of mean Dc was not significant, ranging from 1.1 m in control to 1.3 m in both fertilizer applications of 100 g NPK+200 g compost and 150 g NPK+150 g compost. Meanwhile, the deference of means of DBH and stem height was statistically significant. The tallest mean stem height (8.2 m) was found in fertilizer application of 100 g NPK+200 g compost, and the shortest mean stem height (6.4 m) belonged to control. The largest mean DBH (9.7 cm) and Dc (2.3 m) were found in fertilizer application of 200 g NPK+100 g compost, and the smallest mean DBH (6.4 cm) was found in control (Table 2).

Table 1. Effects of fertilizer application on survival rate, growth, and dry biomass of a 3-year-old *Eucalyptus urophylla* plantation in North Central, Vietnam (means ±SD)

Fertilizer application	Survival rate (%)	DBH (cm)	H (m)	D_c (m)	Dry biomass (Mg ha^{-1})
100 g NPK+200 g compost	95.0 ±1.57	7.9 ±0.75^{a}	8.4 ±1.12^{a}	2.3 ±0.21^{a}	50.7 ±2.8^{a}
150 g NPK+150 g compost	94.7 ±2.15	7.5 ±0.68^{b}	8.9 ±0.91^{a}	1.7 ±0.19^{b}	47.3 ±2.8^{b}
200 g NPK+100 g compost	96.0 ±1.32	7.6 ±0.67^{b}	7.9 ±1.01^{b}	1.8 ±0.19^{b}	48.8 ±2.4^{b}
Control	95.0 ±2.23	7.4 ±0.65^{b}	7.4 ±0.89^{b}	1.7 ±0.15^{b}	46.6 ±2.1^{b}

In a column, the different letters $^{a,\,b}$ indicated the significant difference of mean at p = 0.05

Table 2. Effects of fertilizer application on survival rate, growth, and dry biomass of a 3-year-old *Eucalyptus urophylla* plantation in Southern, Vietnam (means ±SD)

Fertilizer application	Survival rate (%)	DBH (cm)	H (m)	D_c (m)	Dry biomass (Mg ha^{-1})
100 g NPK+200 g compost	95.3 ±2.15	8.6 ±0.81^{a}	8.2 ±1.11^{a}	1.3 ±0.19	56.9 ±3.4^{a}
150 g NPK+150 g compost	95.0 ±2.21	8.3 ±0.79^{a}	7.2 ±1.02^{b}	1.3 ±0.18	54.1 ±2.7^{a}
200 g NPK+100 g compost	96.3 ±1.95	9.7 ±0.89^{b}	8.1 ±1.09^{a}	1.4 ±0.17	67.2 ±3.7^{b}
Control	94.0 ±2.35	6.4 ±0.65^{c}	6.4 ±0.89^{c}	1.1 ±0.19	38.2 ±1.7^{c}

In a column, the different letters $^{a,\,b,\,c}$ indicated the significant difference of mean at p = 0.05

Dry biomass was significant different among four fertilizer applications, as a result of significant difference of mean DBH (Table 2). The highest dry biomass of 67.2 Mg ha^{-1} belonged to fertilizer application of 200 g NPK+100 g compost, reducing to 56.9 Mg ha^{-1} in fertilizer application of 100 g NPK+200 g compost, to 54.1 Mg ha^{-1} in fertilizer application of 150 g NPK+150 g compost, and to 38.2 Mg ha^{-1} in control (Table 2).

Comparing dry biomass of a 3-year-old *E. urophyll*a plantation between North Central and Southern indicated that at all fertilizer applications the dry biomass was statistically significant different (Fig. 1). Of which, in fertilizer applications of 100 g NPK+200 g compost, 150 g NPK+150 g compost, and 200 g NPK+100 g compost dry biomass in Southern was significant higher than that in North Central. While, in control it was converted; dry biomass in North Central was significant higher than that in Southern. The comparison was 138% in fertilizer application of 200 g NPK+100 g compost, 122% in control,112% in fertilizer application of 100 g NPK+200 g compost, and 109% in fertilizer application of 150 g NPK+150 g compost.

4. DISCUSSION

The response of fertilizer applications to plantation depends on degree of mismatch between nutrient supply and nutrient demand [2,19]. Nutrient did not affect on survival rate at both sites, as bagged-seedlings were used and planted in rainy season with enough water supply for initial growth which promotes enlargement of root system both vertically and horizontally before dry season coming [17]. In both sites, control treatment (no fertilizer application) had lowest growth of DBH and H, resulting in lowest dry biomass (Tables 1 and 2). This indicated the significant importance of fertilizer applications in forest plantation, which were mentioned in other researches [7,8,12,13].

In North Central site, compost fertilizer had better effects on growth and dry biomass of a 3-year-old *E. urophylla* plantation than NPK as highest mean DBH and dry biomass were found in fertilizer application of 100 g NPK+200 g compost, highest amount of compost fertilizer (Table 1). While, it was converted in Southern site as largest mean DBH and dry biomass were found in fertilizer application of 200 g NPK+100 g compost, highest amount of NPK. This may be explained by the difference of annual precipitation, which was higher in North Central site, leading to higher NPK loss by leaching and soil erosion [17].

The loss or infectiveness of fertilizer application, and other unknown reasons led to difference of dry biomass between two sites.

Crown diameter represents Leaf Area Index (LAI) of plantations. At the same planting density of 1,330 trees ha^{-1}, Dc of a 3-year-old *E. urophylla* plantation in North Central site was larger than

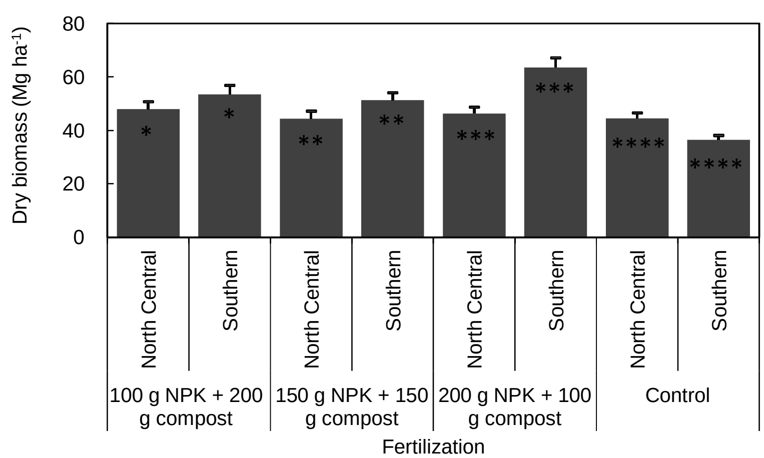

Fig. 1. Comparison of dry biomass of a 3-year-old plantation of *Eucalyptus urophylla* between North Central and Southern, Vietnam with different fertilizer applications

Vertical bars indicated ±SD. Asterisks indicated the significant difference of dry biomass in corresponding fertilizer application at p = 0.05 that in Southern site (Tables 1, 2), leading to higher LAI in North Central site. Higher LAI plantation has higher photosynthesis, which may lead to higher primary production [2,20,21]. However, dry biomass in Southern site, which had lower mean Dc, was higher than that in North Central site at all fertilizer applications. This may be explained by higher autotrophic respiration at higher mean Dc/LAI of plantation in North Central site, leading to lower dry biomass.

The difference of growth and dry biomass between two sites may also result from difference of climate regime [4,5]. There are two distinct seasons in North Central site as summer/rainy season and winter/dry season (November–March), when planted trees may grow slower, leading to lower total production. While, in Southern site there is no winter season and rainfall distributes through the year, therefore planted trees grow equally whole year.

5. CONCLUSIONS

Fertilizer application had significant effects on growth and dry biomass of *Eucalyptus urophylla* plantation in both Southern and North Central, Vietnam. In both sites, control treatment (no fertilizer application) had lowest dry biomass as 46.6 Mg ha^{-1} in North Central site and 38.2 Mg ha^{-1} in Southern site. While, the highest dry biomass in Southern site was 67.2 Mg ha^{-1} in fertilizer application of 200 g NPK+100 g compost and it was 50.7 Mg ha^{-1} in North Central site in fertilizer application of 100 g NPK+200 g compost. Compost fertilizer is better to apply for North Central site. While, NPK is better for Southern site.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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