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Nutrient distribution on soil and aboveground biomass of *Macaranga gigantea* five years after planting

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Abstract. Susanto D, Kusuma R, Amirta R. 2018. Nutrient distribution on soil and biomass of *Macaranga gigantea* five years after planting. *Asian J For* 2: 12-19. The aims of this study were to evaluate growth of *M. gigantea* and to calculate nutrient distribution in the soil and 5 year old *M. gigantea*. Soil sampling was conducted in all research plots with drill ground at a depth of 0-30 cm and 30-60 cm. The tree biomass were sampled within one stand to calculate the biomass of all the trees within a particular plot. The research findings revealed that plot 5 produces the best growth performance and the plant accumulates 2 times of N, P, K, Ca, Mg nutrients on wood, bark, branches and leaves, compared to the plants in plots 1. The most distributed nutrients in the soil were magnesium, nitrogen, calcium and phosphorus. Whereas the most accumulated nutrient in plant was potassium. The relative portion of K nutrients accumulates in the soil is quite small that is 44.18% but in stand was higher that is between 55.82%. It concluded that if the *M. gigantea* harvested at 5 years, it need to give attention to potassium nutrient for the next of planting cycles.

Keywords: Biomass, *Macaranga gigantea*, distribution nutrient, soil

INTRODUCTION

Macaranga gigantea is tree species that grows naturally in the lowland of tropical rainforest gaps after shifting cultivation (Susanto et al. 2016b), forest fires (Silk 2008) and timber harvestings (Susanto et al. 2017a). This species also potentially as a bioethanol feedstock (Amirta et al. 2016). The plant reproduces by forming flower buds initiated in the dry season and the fruits ripened in the rainy season. The seeds that fell under the tree germinated in approximately 24 days (Susanto et al. 2016a). Bentos et al. (2008) also reported that the flowering of pioneer trees happening at the end of the dry season and fruiting happening at the beginning of the wet season.

M. gigantea seeds have low water content, classified into orthodox seeds and produce low seed germination of 2-10% when using dry seed extraction treatment (Suita and Nurhasbiy 2009). Mindawati et al. (2010) also reported that soaking the seeds into 0.2% potassium nitrate solution for 20 minutes before germinate on sand medium able increasing seed germination rates up to 20%. On the other hand, Susanto et al. 2016a reported that wet extraction without fruit drying treatment, able increased seeds germination (65%), with germination time first seeds (GTFS) 7.67 ± 1.15 days, germination time last seeds (GTLS) 17.33 ± 4.04 , and mean germination times (MGT) 11.97 ± 1.93 days. In the germination process of *M. gigantea* seedlings showed that the highest relative growth rate obtained by seedlings planted on mushroom spawn waste media, followed by compost media, top soil media and sand media.

Lawrence 2001, reported that seedlings of *M. gigantea* grow rapidly over the first of 18 weeks when planted in polybags if enough supplied with a combination of nitrogen and phosphorus fertilizers. While, *M. gigantea* 6 months after planting in degraded land from unused log piles in Malaysia, indicates that nutrition deficiency is an important factor that inhibits early growth of this plant (Nussbaum in al. 1995).

Susanto et al. (2016b) reported that in secondary forests after shifting cultivation, *M. gigantea* plants accumulate phosphorus and potassium nutrient mostly in the leaves part. On the other hand, in secondary forest after selective logging, *M. gigantea* most accumulated nutrients potassium, calcium and magnesium. It suggested that bases nutrients, potassium, calcium, and magnesium large quantities absorbed by *M. gigantea* and extremely important to its growth (Susanto et al. 2017a). In monoculture system, *M. gigantea* was fertilized with NPK fertilizer treatment (age of 1 year), and the most nutrient element accumulated were potassium, followed by phosphorus and then nitrogen (Susanto et al. 2017b).

There is lack information about nutrients content distribution in the soil and aboveground biomass of *M. gigantea*. Therefore, our research focuses on the growth evaluation and soil nutrients and aboveground biomass distribution on 5 years *M. gigantea* planted using monoculture system. This information is very important in the sustainable of *M. gigantea* plantation.

MATERIALS AND METHODS

Study area

This research was conducted in the plot of 5-year-old *M. gigantea*. Plot was 0.7 ha, at the research forest of Faculty of Forestry, Mulawarman University, Samarinda, East Kalimantan, Indonesia (000.44.71,11 "South and 117.0.21; 67,50" East). The trial was set up with five randomized treatments plots with 3 blocks (each containing 20 plants, making $20 \times 5 \times 3 = 300$ plants in the entire trial area). The initial treatment of *M. gigantea* with NPK fertilizer is P0: 0 g, P1: 40 g, P2: 80 g, P3: 120 g and P4: 160 g. Fertilization is conducted for two times, i.e after planting and 6 months after planting. Weed cleaning was done once for 4 months until the plant age was 2 years old (Susanto et al. 2017b).

Procedures

Plant measurement and soil analysis

The 5 years after planting of *M. gigantea* observed through direct measurement. The stem heights, diameter, height increment and diameter increment was parameter in this research. For soil analysis, soil samples were taken at a depth of 0-30 cm and 30-60 cm in each plot. The measurement were conducted after the samples were oven dried with the temperature of 150°C until the weight was

constant. Composite sample was wind-dried and its total Nitrogen (Kjendal), available phosphor (Bray), available potassium, calcium and magnesium were analyzed (Susanto et al. 2017b).

The sampling of *Macaranga gigantea* Biomass

Biomass measurements are limited only to above ground biomass with mean tree after stratification method. The Determination of the strata boundary for selection of sample trees representing the relevant strata in the plots is performed by the calculation of stratum boundaries by the cumulative method. The trees sampled from one plot were selected after all the available trees were grouped into three stages based on their estimated size according to the formula D^2H (diameter squared multiplied by height). The entire stand biomass was calculated by multiplying the dry weight of the components of the sampled tree by the number of trees in each stage, and then it was converted into a biomass per hectare. The wet weight of every component including wood, barks, branch and leaves was measured according to Ruhayat 1996 methods. Samples of the wood, barks, branch and leaves were weighing on wet and dry condition. The plant samples were taken to the laboratory and their nutrient contents (N, P, K, Ca, Mg) were analyzed.

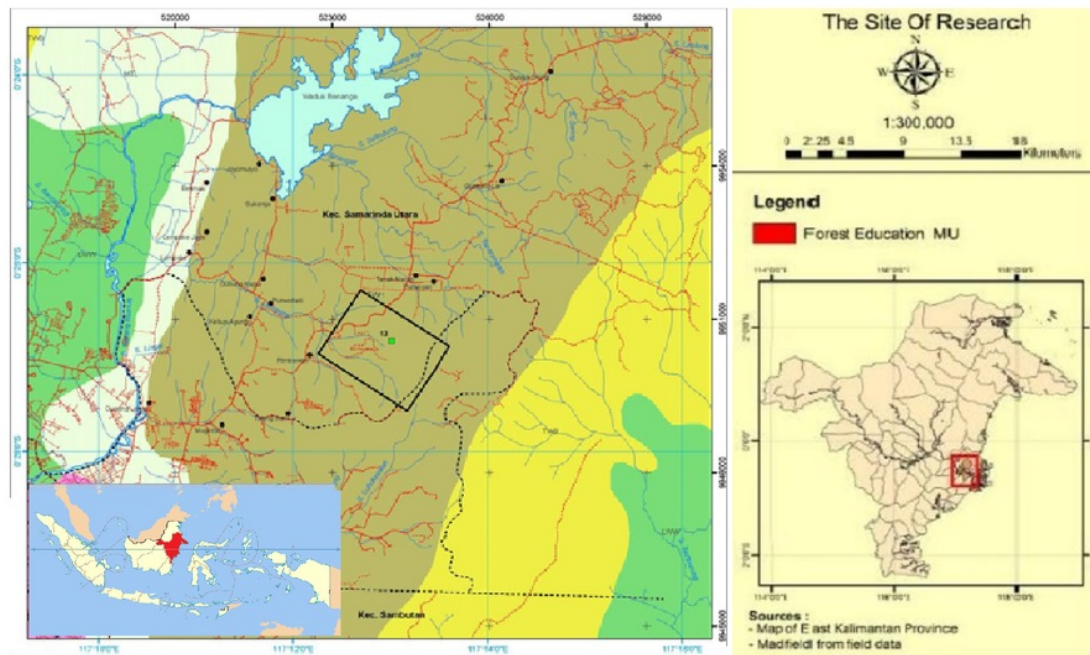


Figure 1. Map of research area in the research forest of Faculty of Forestry, Mulawarman University, Samarinda, East Kalimantan, Indonesia

Nutrient concentrate of plant components analysis

The total N concentrate was measured using Kjeldahl method (extraction, distillation, titration). To measure element of P and K, the plant components were extracted using High Pressure Digestion method at the temperature of 180°C for 10 hours with HNO₃ as a reductant. Phosphorus was measured by using calorimetric technique and using nitrate-molybdate-vanadate acid as a coloring agent and was measured by using spectrophotometer at the wavelength of 470 nm. Potassium, calcium and magnesium were measured by using Atomic Absorption Spectrophotometer at the wavelength of 766 nm, 489.5 nm and 245.2 nm. To calculate macro nutrient elements (N, P, K, Ca, Mg) which were accumulated in the tree components in the stand, the dry weight of the tree component was multiplied by its nutrient concentrate (Susanto et al. 2017b).

Data analysis

Nutrient distribution in soil and 5 years old *M. gigantea* was observed. The macro nutrient content (N, P, K, Ca, Mg) in the tree component is calculated by multiplying the dry weight of tree component with nutrient concentration of the tree component. Based on nutrient content stored in the soil and which accumulates in the *M. gigantea* stands, it can be arranged information about the amount of nutrients stored in the soil system (kg.ha⁻¹) and its relative portion (%) for each plot research.

RESULTS AND DISCUSSION

Plant growth

At the age of 5 years, the best growth of *M. gigantea* on plot 5 with mean stem diameter of 12.88 ± 4.2 cm, stem height of 10.25 ± 2.9 m, increment diameter 2.58 cm.y⁻¹ and height increment 2.05 m.y⁻¹ (Figure 1).

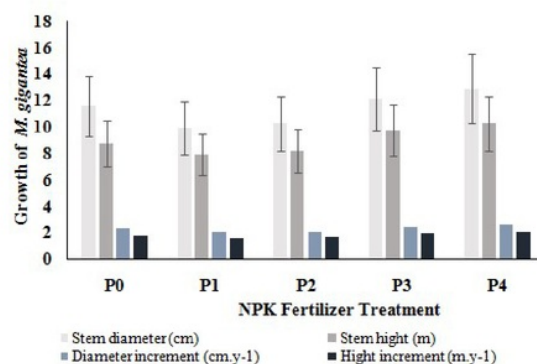


Figure 2. Growth of *Macaranga gigantea* 5 years after planting



Figure 3. *Macaranga gigantea* plants at planting plots (5 years)

Plant biomass

The result on aboveground biomass estimation of *M. gigantea*, showed that the highest biomass content produced on P4 plot those were 64.51 ton.ha⁻¹, consisting of 27.58 ton of wood, 5.078 ton bark, 22.938 ton of branch (wood and bark), and 8.914 tons of leaves. Wood is the largest component of 50.52 ton.ha⁻¹ and consisting of 27.58 tons of wood and 22.938 tons of branches. The lowest biomass showed on P0 plot those were 25.039 ton.ha⁻¹ and it can be concluded that fertilization of 160 g per plant (P4) increases the biomass production by 250 percent.

Nutrient content of plant components

Potassium is the most accumulated nutrient in five-year-old stands, followed by nitrogen, calcium, phosphorus and magnesium. The amount of nutrients consumed by *M. gigantea* stands are: potassium ranged from 239.88 - 676.20 kg.ha⁻¹ with an average of 413.50 kg.ha⁻¹; calcium ranged from 66.51-114.56 kg.ha⁻¹ with an average of 232.62 kg.ha⁻¹; nitrogen ranged from 155.91 - 344.00 kg.ha⁻¹ with an average of 232.62 kg.ha⁻¹; magnesium ranged from 36.09 to 77.64 kg.ha⁻¹ with an average of 51.93 kg.ha⁻¹. The highest concentration of nitrogen, phosphorus, potassium, calcium and magnesium stands of *M. gigantea* is at fertilization NPK 160 g per tree (Table.1).

Soil nutrient content

Soil nutrient concentration of each research plot varied in value. There is an increasing tendency of dosage of NPK fertilizer to decrease soil nutrient concentration in each plot. The mean concentration of nutrients N at the highest depth of 0-60 cm in the P2 plot is 13405.4 kg.ha⁻¹ followed by the P1 plot of 12744.5 kg.ha⁻¹, P3 plot 12210.7 kg.ha⁻¹, plot P0 12136.5 kg.ha⁻¹ and the lowest on plot P4 is 10888.7 kg.ha⁻¹. The mean concentration of nutrient P at the highest 0-60 cm of soil depth on plot P0 was 441.3 kg.ha⁻¹, followed by plot P1 435.4 kg.ha⁻¹, on plot P2 386.5 kg.ha⁻¹, plot P4 377.4 kg.ha⁻¹ and the lowest is on plot P3 that is 291.8 kg.ha⁻¹. The mean concentration of K nutrient at the highest depth of ground 0-60 cm in plot P0 is 1034.2 kg.ha⁻¹, followed by plot P2 603.7 kg.ha⁻¹, on plot P1 573.9 kg.ha⁻¹, plot P4 535.2 kg.ha⁻¹ and lowest is on plot P3 that is 448.8 kg.ha⁻¹. The average concentration of Ca nutrient at the highest 0-60 cm soil depth in P0 plot is 26953 kg.ha⁻¹, followed by plot P1 26232 kg.ha⁻¹, on plot P3 25085 kg.ha⁻¹, plot P2 23630 kg.ha⁻¹ and the lowest is on plot P4 that is 21963 kg.ha⁻¹. While the concentration of Mg nutrient at the depth of ground 0-60 cm highest in plot P0 is 51292 kg.ha⁻¹, followed by plot P1 that is 48111 kg.ha⁻¹, plot P2 45603 kg.ha⁻¹, plot P3 39800 kg.ha⁻¹ and the lowest plot of P4 is 38520 kg.ha⁻¹.

The nutrient content of *M. gigantea* biomass is positively correlated with biomass production at 5 years of age. The higher the nutrient content of biomass the higher the biomass production (Figure 5).

On the other hand, the relationship between soil nutrient content and biomass production shows negative correlation, ie the higher the biomass production, the lower nutrient content in the soil (Figure 6) The same is also

shown in the relationship between soil nutrient content and nutrient content plant biomass (Figure 7).

Distribution of soil nutrients and aboveground biomass *M. gigantea*

From the nutrient content accumulated in the soil and nutrients accumulated in the plant stand *M. gigantea* can be arranged graph of nutrient distribution in soil and plant *M. gigantea* (Figure 8).

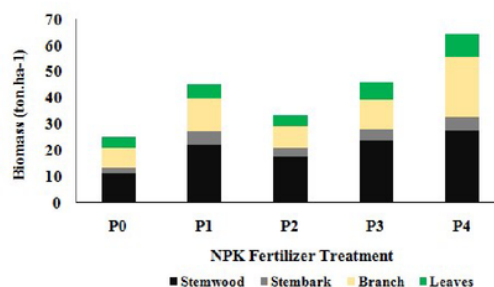


Figure 4. Biomass Production in *Macaranga gigantea* plantation (5 years)

Table 1. Nutrient component of *Macaranga gigantea* plant component in research plot age 5 years

Nutrients	Fertilizer application	Nutrient content of plant components (kg.ha ⁻¹)				
		Stem wood	Stem bark	Branch	Leaf	Total
N	T0	39.48	13.16	33.81	69.48	155.92
	T1	63.59	24.18	44.05	91.74	223.56
	T2	48.75	21.40	35.50	70.69	176.34
	T3	65.28	23.92	53.96	120.13	263.29
	T4	79.16	24.74	89.54	150.57	344.01
Mean		59.25	21.48	51.37	100.52	232.63
P	T0	6.08	1.30	7.07	6.46	20.91
	T1	4.94	1.34	3.35	8.17	17.79
	T2	2.16	1.35	5.79	6.95	16.23
	T3	3.47	1.99	8.52	8.53	22.52
	T4	11.72	3.14	14.79	13.39	43.04
Mean		5.67	1.82	7.90	8.70	24.10
K	T0	69.86	28.80	66.17	75.06	239.89
	T1	165.96	32.47	104.23	97.07	399.72
	T2	57.04	40.48	104.65	86.63	288.79
	T3	144.57	49.58	145.97	122.81	462.93
	T4	198.95	66.95	240.08	170.23	676.20
Mean		127.28	43.66	132.22	110.36	413.51
Ca	T0	27.08	13.12	14.20	12.11	66.51
	T1	11.78	28.02	20.97	15.06	75.83
	T2	22.36	16.85	11.27	13.07	63.55
	T3	14.91	24.21	20.94	16.59	76.65
	T4	30.47	17.87	40.16	26.07	114.57
Mean		21.32	20.01	21.51	16.58	79.42
Mg	T0	14.46	4.50	8.318	8.82	36.10
	T1	18.99	11.47	12.66	12.57	55.69
	T2	16.44	6.81	10.79	10.52	44.55
	T3	13.97	6.82	11.18	13.72	45.69
	T4	25.17	8.49	25.80	18.19	77.64
Mean		17.81	7.62	13.75	12.76	51.93

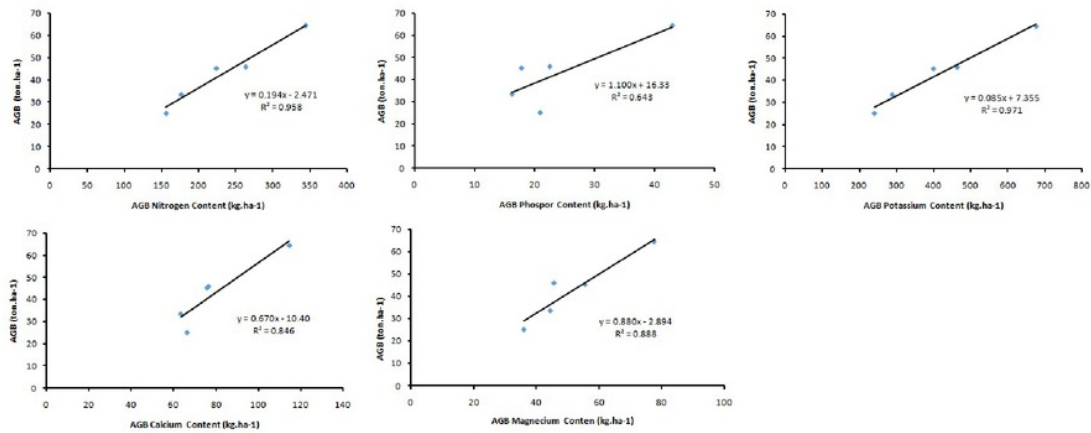


Figure 5. Correlation between aboveground biomass nutrient content with aboveground biomass of *Macaranga gigantea* 5 years old

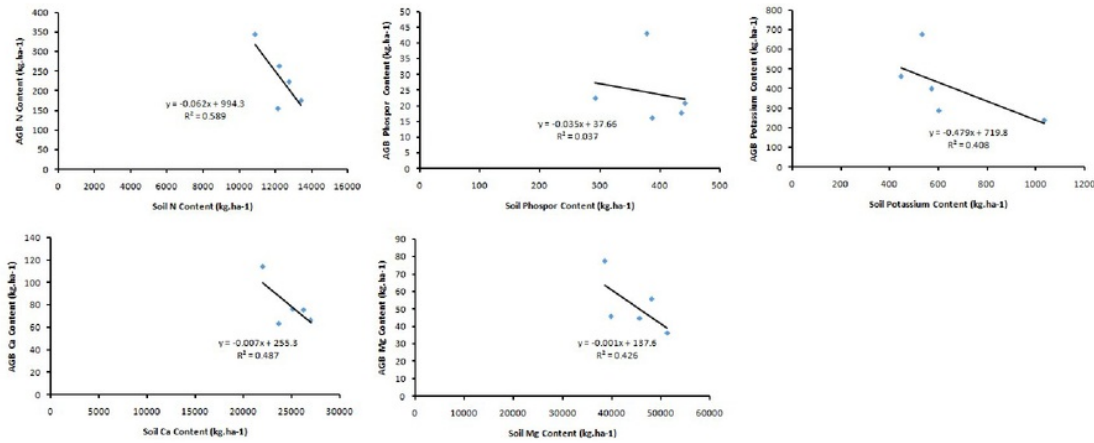


Figure 6. Correlation between soil nutrient content with aboveground biomass nutrient content of *Macaranga gigantea* 5 years old

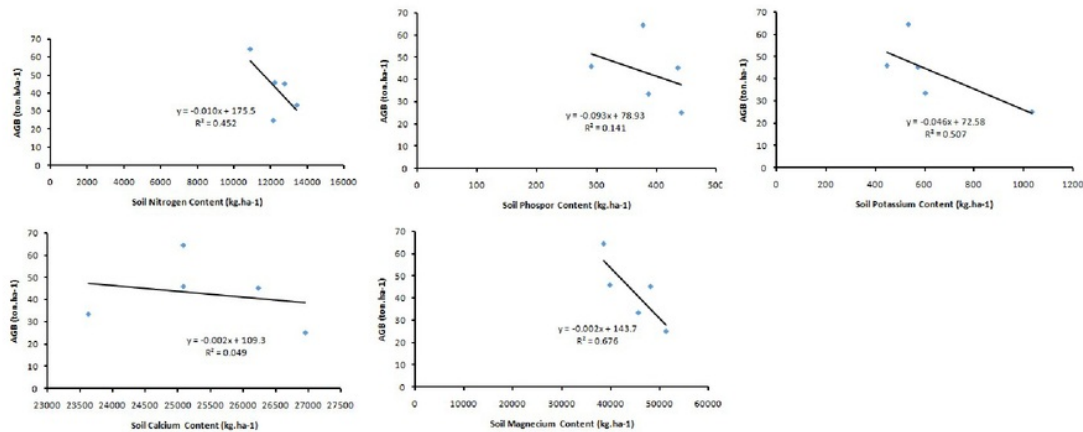


Figure 7. Correlation between soil nutrient content with aboveground biomass of *Macaranga gigantea* 5 years old

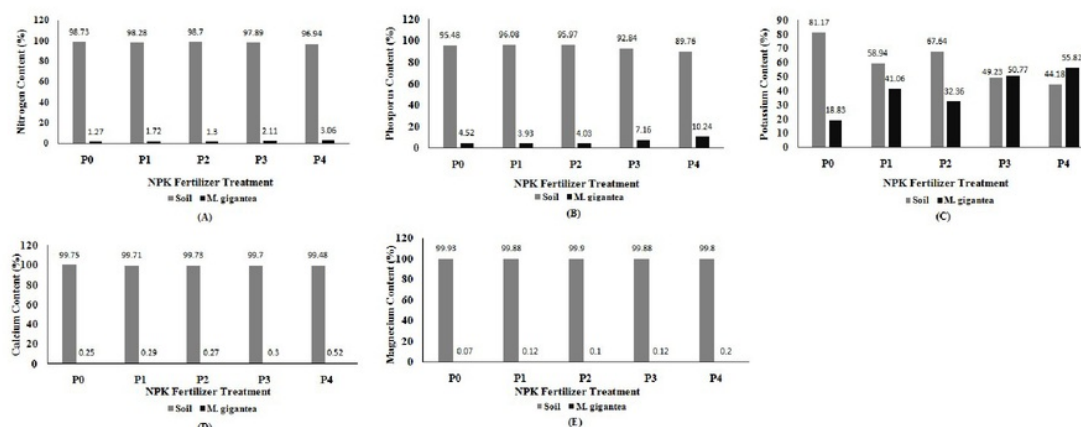


Figure 8. Nutrient distribution in soil and *Macaranga gigantea* plants

Table 2. Soil nutrient contents in *Macaranga gigantea* plant age 5 years

Fertilizer application	Soil depth	Soil nutrient content (kg.ha ⁻¹)				
		N	P	K	Ca	Mg
P1	30-60	5385.7	290.7	705.9	10159	24100
	0-60	12136.5	441.3	1034.2	26953	51292
	0-30	6561.9	191.8	280.8	8710	24068
	30-60	6182.6	243.7	293.1	17522	24043
P2	0-60	12744.5	435.4	573.9	26232	48111
	0-30	7667.8	140.9	373.1	15770	22234
	30-60	5737.6	245.6	230.6	7860	23369
	0-60	13405.4	386.5	603.7	23630	45603
P3	0-30	6867.9	96.9	239.4	11872	18774
	30-60	5342.8	195.0	209.5	13213	21026
	0-60	12210.7	291.8	448.8	25085	39800
	0-30	6045.9	153.8	281.5	12169	21444
P4	30-60	4842.8	223.6	253.7	9794	17076
	0-60	10888.7	377.4	535.2	21963	38520

Note: P0 = control without fertilizer, P1 = NPK fertilizer 40 g, P2 = NPK 80 g fertilizer, P3 = NPK fertilizer 120 g and P4 = NPK 160 g fertilizer.

The relative portion of N, P, Ca and Mg nutrients accumulated in the soil is still very large at 89.76-99.93%, whereas those accumulating in *M. gigantea* stands are very small at 0.20% - 10.24%. It means that absorbed nutrients N, P, Ca and Mg by *M. gigantea* are relatively small. On the other hand the relative portion of accumulated K nutrients in the soil is quite small that is 44.18-81.17% and in *M. gigantea* stands large enough that is between 18.83-55.82%. It means that nutrients K is highly absorbed from soil and accumulates in *M. gigantea* plant tissue, followed by phosphorus, nitrogen, calcium and magnesium (Figure 8).

Discussion

At the age of 5 years, the best growth of *M. gigantea* found in P4 plot. The plant in P4 plot fertilized by NPK 160 g fertilizer (Figure 1). The same result also found in biomass estimation (Figure 3). In contrast to Susanto et al. (2017b), which states that at the age of 1 year the best growth and production of above-ground biomass were found in the application of NPK fertilizer with the dosage of 120 g. In other hand, Nusbaum et al. (2005) reported that application of soil fertilizer in degraded soil are able to increase dry weight, basal diameter, and height for all plant species at the age of 6 months. The relative height and basal diameter increasing in of fertilized *M. gigantea* seedlings is four times higher than unfertilized plants which have the same treatment.

The result on accumulated nutrient content analysis of N, P, K, Ca and Mg in *M. gigantea* plant compartment showed that the highest nutrient content found in P4 plot, which is treated using NPK 160 g fertilizer. The most N nutrient accumulation was found in the leaves, followed by branches of wood and bark. The most P nutrient element accumulates on the branch followed by leaves, wood and bark. In other hand, K, Ca and Mg nutrients was more accumulate in branches, wood, leaves and bark. The absorbed nutrient of *M. gigantea* from the soil were K reaches 676.20 kg.ha⁻¹, followed by N: 344.01 kg.ha⁻¹, Ca: 114.57, Mg: 77.64 kg.ha⁻¹ and P: 43.04 kg.ha⁻¹.

The nutrient N, P, K, Ca and Mg content in soil (0-60 cm) showed that plot P4 had the lowest nutrient content compared to Plots P0, P1, P2 and P3. Elements of K and P have a lower content than N, Ca and Mg nutrients. It means that *M. gigantea* plant will easily absorb nutrients in the soil for its growth. This plant is a pioneer fast growing species which requires high levels of light in the extensive forest gaps and secondary forest habitats (Davies et al. 1998; Romell et al. 2008). Fast-growing tree species are generally considered to accumulate soil nutrients faster than slow-

growing ones when multiple rotations are implemented (Cossalter and Pye-Smith 2003). Inagi and Tange (2014) also reported that fast growing *Eucalyptus* trees can accumulate more aboveground biomass than N_2 -fixing and other non- N_2 -fixing broadleaved trees while incorporating less aboveground N. Furthermore, some *Acacia* and *Eucalyptus* trees can produce more aboveground biomass than other non- N_2 -fixing broadleaved trees while using less P. Montagnini (1998) reported that four years after planting, decrease in soil nutrients were apparent in pure plots of some of the fastest growing species. On the other hand, some fast-growing tree species have strategies that allow them to grow on degraded soils. Montagnini (2000) reported that decreases in soil P, K and Ca were apparent in pure plots of the fastest growing species with the largest accumulation of nutrients in above-ground biomass, such as *J. copaia* and *V. guatemalensis*, five years after planting.

The highest is also found in P4 plot. Nitrogen accumulates 344.01 kg.ha⁻¹, 121% higher than non-fertilized control plants accumulating only 155.9 kg.ha⁻¹. The accumulation of phosphorus biomass of *M. gigantea* on P4 plot is 43.04 kg.ha⁻¹, twice higher than the phosphorus content in control plot is 20.9 kg.ha⁻¹. Potassium accumulates was 676.20 kg.ha⁻¹, three times higher than control plot (239.89 kg.ha⁻¹). While, for the calcium and magnesium nutrients, each accumulates 114.57 kg.ha⁻¹ and 77.64 kg.ha⁻¹ in biomass in plot 4, twice higher compared to the biomass of the P0 control plot those were 66.51 kg.ha⁻¹ and 36.1 kg.ha⁻¹. NPK fertilizer addition higher than 160 g significantly increased N, P, K, Ca and Mg content of *M. gigantea* plant biomass. This nutrient have important role in photosynthesis because used for the synthesis of organic biomass plant material. This is in accordance with Cossalter and Pye-Smith (2003), which states that fast-growing tree species are generally considered to accumulate soil nutrients faster than slow-growing.

Potassium is the most accumulates nutrient in *M. gigantea* biomass of 676.20 kg.ha⁻¹ consists of 64% in stem and branch, and 36% in leaf and bark. On the other hand, the relative portion of K nutrients that accumulates in *M. gigantea* stands is quite large, ranging between 18.83-55.82% (Figure 7) compared to other nutrients. This result shows that nutrient K is the most absorbed nutrient by *M. gigantea*. Hertemink (2001) reported that fast growing species *Piper aduncum* also accumulated large amounts of biomass and nutrients, particular K.

When *M. gigantea* plant is harvested at 5 years old with stems and branches taken out of the system, the greatest nutrient that will be reduced from the soil is potassium, followed by phosphorus, nitrogen, calcium and magnesium. In the first cycle of harvesting *M. gigantea*, the soil will lose nutrients by 438 kg.ha⁻¹ (64%), with leaf and bark notes left on the land system. Meckensen, (1999) and Meckensen et al. (2001) reported that nutrient content of fast growing *Eucalyptus deglupta* in industrial plant forests in East Kalimantan (100 m³ log and barks) was N: 44. 4 kg.ha⁻¹, P: 2.3 kg.ha⁻¹ and K: 125 kg.ha⁻¹. Uri et al. (2003) found that the amount of nutrients accumulated by 1 year old grey alder in producing one tonne of biomass at an

N:P:K ratio of 100:9:43. The uptake of nutrients K by *M. gigantea* is more abundant than *Eucalyptus deglupta*. Montagnini (2000) reported that in monoculture plantation, *Vochysia guatemalensis* had the greatest accumulation of K and Ca. *V. guatemalensis*, stem harvest would remove less than 30% of N for 50% of total above-ground tree Ca, K, Mg and P. Branches and foliage summed together were 25 to 35% of total above-ground tree biomass, but they generally represent about 50% of above-ground tree nutrients. Mackensen and Foster (2000) reported that calculated major differences in the fertilizer expenses between species. Fertilization costs for *Eucalyptus deglupta* are generally higher than *Acacia mangium*. Alriksson and Eriksson (1998) suggested that the choice of tree species harvest and stem-wood harvest, also at similar rates of stem-wood biomass production. On the other hand, Montagnini (2000) reported that continued sampling will be needed to assess the long term effects of plantation treatments on soil chemistry, especially near the end of the rotation

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