RESEARCH

Growth and nutrient balance of *Asystasia gangetica* (L.) T. Anderson as cover crop for mature oil palm (*Elaeis guineensis* Jacq.) plantations

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ABSTRACT

Nutrient recycling and mineral balance are important factors affecting nutrient budgets in oil palm (*Elaeis guineensis* Jacq.) plantations. The nutrient budget includes processes such as plant uptake, removal by harvesting, accumulation or storage in the standing plant, and recycling through decomposition of cover crop *Asystasia gangetica* (L.) T. Anderson can be utilized as cover crops in mature oil palm plantations with appropriate management. This study aimed to examine the growth of *A. gangetica* in 17 yr old oil palm plantations with different populations, understanding the contribution of *A. gangetica* to improve available nutrient in the plantation on the nutrient balance, and to study its role as cover crop in the mature oil palm plantation. The experiment was conducted in an experiment field of 17 yr old of mature oil palm at Bogor, Indonesia. Results showed that *A. gangetica* can be used as cover crops in mature oil palm plantations because it meets several conditions such as rapidly covering the land (11 wk after planting), and able to increase the available N, P, K as much as 18.49%, 9.20%, 38.36%, respectively, based on the nutrient balance with the optimum population is 1 000 000 plants ha^{-1}.

Key words: Cover crop, *Elaeis guineensis*, nutrient availability of N, P, K, nutrient balance.

INTRODUCTION

Asystasia gangetica (L.) T. Anderson is an annual weed that grows upright and creeps up to a very thick thicket (Priwiratama, 2011), has brush and nailed stem, each book easily forming roots the ground. The leaves are oval and dark green. The flowers are white with a purple mosaic on the petals (Elliot et al., 2004). The fruit is capsule-shaped with size 13 mm × 2 mm and contain 2-4 seeds (Globinmed, 2011). The crop is flowering and yielding seeds throughout the year (Sandoval and Rodriguez, 2016). In a shaded place, *A. gangetica* will show more vegetative organs; while in the open space will produce more flowers and seeds (Priwiratama, 2011).

Asystasia gangetica is an invasive weed in oil palm plantations due to its ability to produce large quantities of seeds, estimated produce around 27 million seeds per hectare (Priwiratama, 2011), thrown as far as 6 m (Adetula, 2004), and easily germinate so quickly dominate land. New plants can also grow from the stem when touching the ground (Priwiratama, 2011), and within 6 wk already flowering and producing seeds (Adetula, 2004).

Asystasia gangetica can be utilized as cover crops in mature oil palm (*Elaeis guineensis* Jacq.) plantations with proper management. The invasive nature can be utilized for rapid growth and rapid land cover. *Asystasia gangetica* is also able to grow well in low light conditions and low soil fertility (Samedani et al., 2013), even grow at a 90% shade level (Adetula, 2004). Type of *A. gangetica* which can be used as cover crop is *A. gangetica* (L.) T. Anderson subsp. *gangetica*, since such species do not have tendrils such as *A. gangetica* (L.) T. Anderson subsp. *micrantha* (Nees) Ensermu (Ismail and

Shukor, 1998), and lower plant height (0.3-0.5 m) (Cuo Shu et al., 2011) than *micrantha* subspecies (0.5-3.0 m) (CRC Weed Management, 2003).

Several researches indicate that *A. gangetica* subsp. *gangetica* can be used as cover crop (Adetula, 2004), rapidly decompose, i.e. within 30 d it has been decomposed by 90.0%-96.6% (Asbur et al., 2014), and contains some nutrients such as N, P, K, Ca, Mg, Fe, and Zn in the plant tissues (Odharva et al., 2007; Asbur et al., 2016), and able to increase groundwater availability in the dry season in mature oil palm plantation, South Lampung, Indonesia (Ariyanti et al., 2017).

Due to the function as cover crops, as well as biological agents to reduce pests and plant diseases, *A. gangetica* acts as biological agent controlling caterpillar pests in mature oil palm plantations because the flowers and trichoma of *A. gangetica* leaves can attract the parasitoid caterpillar bag (*Metisa plana*) to lay its eggs (Kusuma, 2010). *Asystasia gangetica* can also be used as a green manure for peanut (Junedi, 2014) and as a medicinal plant (Mugabo and Raji, 2013; Gopal et al., 2013).

Cover crop is also able to withstand and reduce the destructiveness of rain and run off, as a source of organic matter, improve soil physical and chemical properties, and avoid intensive weeding (Dariah et al., 2005). Research of Asbur et al. (2016) in mature oil palm plantations, South Lampung, Indonesia, showed that *A. gangetica* effectively reduced erosion and N, P, K nutrient losses by 95.7%, 93.4%, 96.0%, and 90.0%, respectively.

The present study was therefore carried out to: (1) study the growth of *A. gangetica* in 17 yr old oil palm plantation with different population numbers, (2) understand its contribution in increasing soil nutrient available in the mature oil palm plantation on the nutrient balance, and (3) studying its role as a cover crop in the mature oil palm plantation.

MATERIALS AND METHODS

The experiment was conducted in an experiment field of 17 yr old of mature oil palm at Cikabayan University Farm (6º33'8.1" S, 106º42'56.4" E; 187 m a.s.l.), Institut Pertanian Bogor, Dramaga Bogor, Indonesia. The dry weight observation was conducted in Plant Laboratory, and the analysis of plants tissue and soil chemical properties was conducted in Soil Laboratory, Bogor Agricultural University.

The growth pattern of *A. gangetica* was studied using non factorial randomized design with three replicates. The treatments were population densities of *A. gangetica*, namely 1 000 000 (P1); 250 000 (P2) and 62 000 plant ha^{-1} (P3). Advanced test was conducted using LSD at 5% level. Planting of *A. gangetica* is using stem cuttings measuring 15 cm or two segments derived from Cikabayan Experiment field.

Soil chemical analysis was performed before and after the experiment. Soil samples were taken composite from five sampling site on topsoil as deep as 0-20 cm using a soil drill. The soil mixture was then taken as much as ± 1 kg soil, put into plastic bags and tied with rubber (Sutarta et al., 2013). Analysis of N-total was performed using Kjeldahl method while analysis of P-available and K-available was using Bray method 1.

The nutrients defined in plant tissues were N, P, and K, analyzed through wet destruction process (PPT, 2005). Prior to analysis, samples from the field were first washed with ion-free water to remove dust and other impurities that can give errors in the analysis. Plant samples were dried in an oven at 80 °C for 48 h, after reaching constant weight, milled and filtered using 0.5 mm sieves. Analysis of N-total was done by distillation (N-Kjeldahl), P and K by atomic absorption on a Techtron AA-3 atomic absorption spectrophotometer (Techtron 'Pty. Ltd., Melbourne, Australia).

The observed variables for growth were growth percentage, land coverage percentage using the square 0.5 m × 0.5 m in size and there were small holes measuring 5 cm × 5 cm to represent the amount covered by *A. gangetica*, plant height, number of branches per plant, number of nodes per plant, number of leaves per plant, total leaf area per plant using gravimetric method, leaf area index, and dry weight of seedlings. Measurement of dry weight of seedlings using sample plot 1 m × 1 m, then dry weight value per sample plot converted into experimental plot area.

Nutrient balance calculation was done with 1 000 000 plants ha^{-1}. The treatment was weed as cover crops, i.e. no cover crops (T_0), *Nephrolepis biserrata* (Sw.) Schott (as comparable because is maintained in mature oil palm plantations as cover crops) (T_1), and *A. gangetica* (T_2).

The calculation of nutrient balance was based on: (1) Nutrient sources, consisting of initial soil (initial soil nutrient content × initial soil weight) and fertilizer (fertilizer nutrient content × fertilizer weight); (2) recovery nutrients, consisting of final soil (nutrient content of final soil analysis × final soil weight) and nutrient uptake (plant nutrient content × dry weight); and (3) nutrient addition or subtraction (Recovery nutrient - Source).

RESULTS AND DISCUSSION

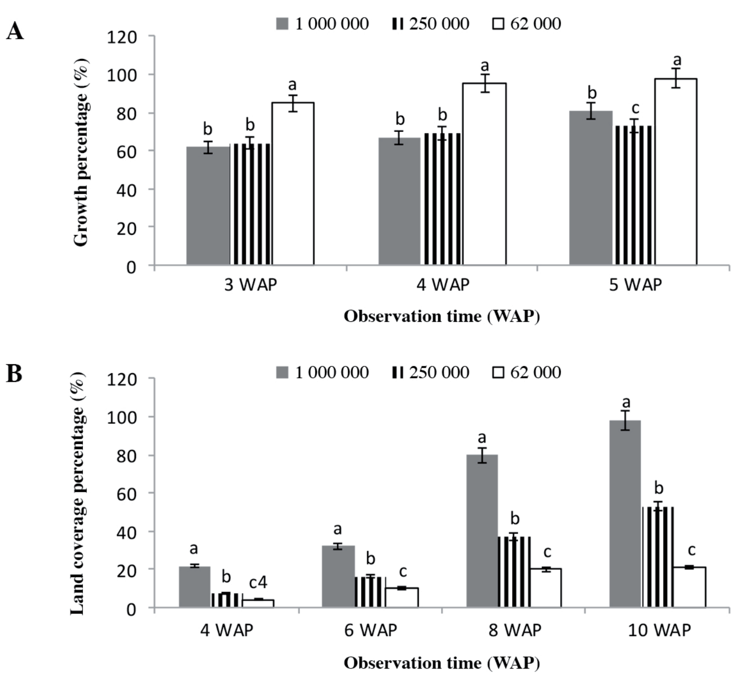
Growth of *Asystasia gangetica*

The growth percentage of *A. gangetica* was calculated according to the live percentage of plant divided by the number of population per area. Statistical analysis indicated that plant population had significant effect on growth percentage of *A. gangetica* at 3-5 wk after planting (WAP) (Figure 1A). The growth percentage of *A. gangetica* was higher in 62 000 plants ha^{-1} caused by growing percentage of *A. gangetica* is the ratio of living population number with population of *A. gangetica* per planting area. This indicates that in the more populous population, there has been sunlight competition from the beginning of cuttings planting because the leaves have shaded each other, thus affecting the results of photosynthesis for root growth. As the roots grow, there will be more competition in water taking. Competition for sun and water will affect the growth of shoots.

The percentage of land coverage is percentage of *A. gangetica* that cover the soil surface at each squared meter. Statistical analysis showed that plant population had significant effect on the percentage of land coverage (Figure 1B). The percentage of land coverage was higher in plots with 1 000 000 plants ha^{-1} than plots with 250 000 and 62 000 plants ha^{-1}. This is due to the large number of population per unit area, so that the land coverage by *A. gangetica* becomes faster. The requirement of a plant can be used as cover crop is rapidly covering the entire surface of the land, so the number of *A. gangetica* as a cover crop in the mature oil palm plantation was 1 000 000 plants ha^{-1}.

Plant height is one of the most frequently observed measure as growth indicator as well as an indicator to measure of environmental impact or given treatment as it is easiest to observe (Sitompul and Guritno, 1995). Statistical analysis showed that population has a significant effect on plant height of *A. gangetica* at age 11-25 WAP (Figure 2A). The highest plant height is found at treatment of 62 000 plants ha^{-1}. This indicates that in a lesser number of populations, the competition for light and water decreases, so the plant can grow and develop well. Growing space management is one for

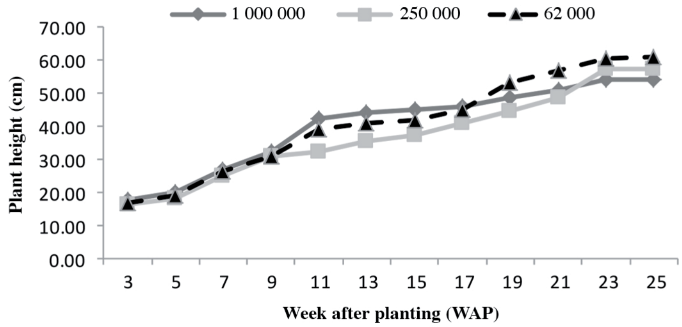
Figure 1. Growth percentage (A) and land coverage percentage of *Asystasia gangetica* (B) by different population density.



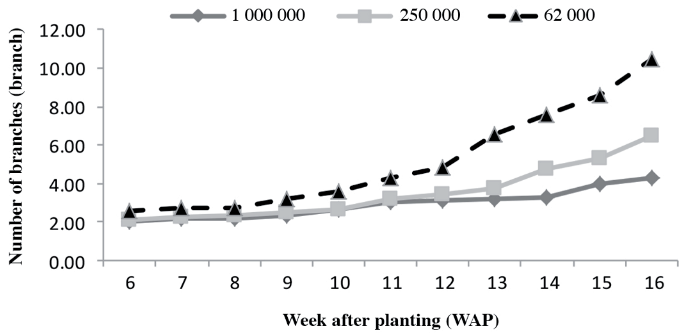
Different letters on bars in the same figure, indicate significant differences between population densities of *A. gangetica* according to LSD test ($P < 0.05$). Vertical bars correspond to standard error. Population densities of *A. gangetica*: 1 000 000; 250 000; and 62 000 plants ha^{-1}.
WAP: Weeks after planting.

Figure 2. Increasing plant height (A) and number of branches per plant (B) of *Asystasia gangetica* by different population density.

A



B



competition of sunlight, nutrients and water. Growing space management is intended for the canopy to develop optimally and reduce the competition of sunlight (Rusdiana et al., 2000). The results of this study indicate that *A. gangetica* is shade tolerant crop, since there is no etiolation although it is planted with a more dense population.

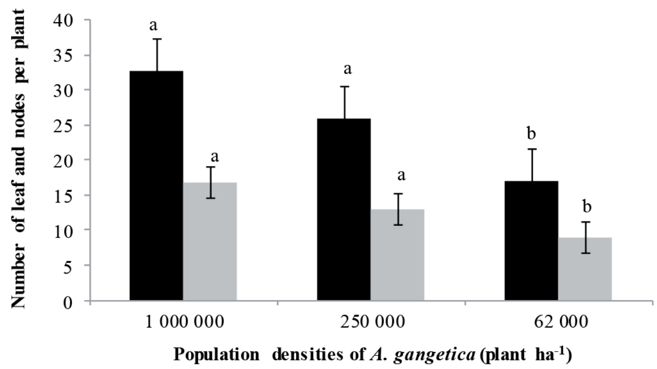
The effect of the population on the number of *A. gangetica* branches has the same pattern with its effect on plant height (Figure 2B). The number of population had significant effect on the number of branches per plant aged 13-25 WAP. Population of 1 000 000 plants ha^{-1} produces the least number of branches per plant and population of 62000 plants ha^{-1} produces the largest number of branches per plant. This is in line with the results of Souza et al. (2016); Cox and Cherney (2011), which indicates that the fewer number of plant populations, the greater the number of branches of soybean. Procópio et al. (2013) and Balbinot Junior et al. (2015) suggest that higher plant populations will increase competition among plants against natural resources that are essential for growth.

Leaves are very important variables associated with overall plant growth, because leaves are the main organ for photosynthesis which produces photosynthate needed by other plant organs (Gardner et al., 1991). Statistical analysis showed that population number had significant effect on the number of leaf and number of nodes of *A. gangetica* (Figure 3), where the population of 1 000 000 plants ha^{-1} produce the number of leaves and nodes per plant higher than the population of 250 000 and 62 000 plants ha^{-1}. This is due to the leaves of *A. gangetica* out of the nodes, so with the increasing number of nodes per plant indicates higher leaves. Correlation analysis showed that the number of nodes correlated very significantly with the number of leaves per plant of *A. gangetica* (r = 0.9**).

The total population of *A. gangetica* also had significant effect on total leaf area per plant and leaf area index (LAI) per plant (Figure 4A and 4B). Figures 4A and 4B showed that leaf area and LAI are highest in the population of 1000000 plants ha^{-1}. Contrary to the results of Souza et al. (2016) in soybean, indicating that the more densely populated, the fewer the leaves of soybean.

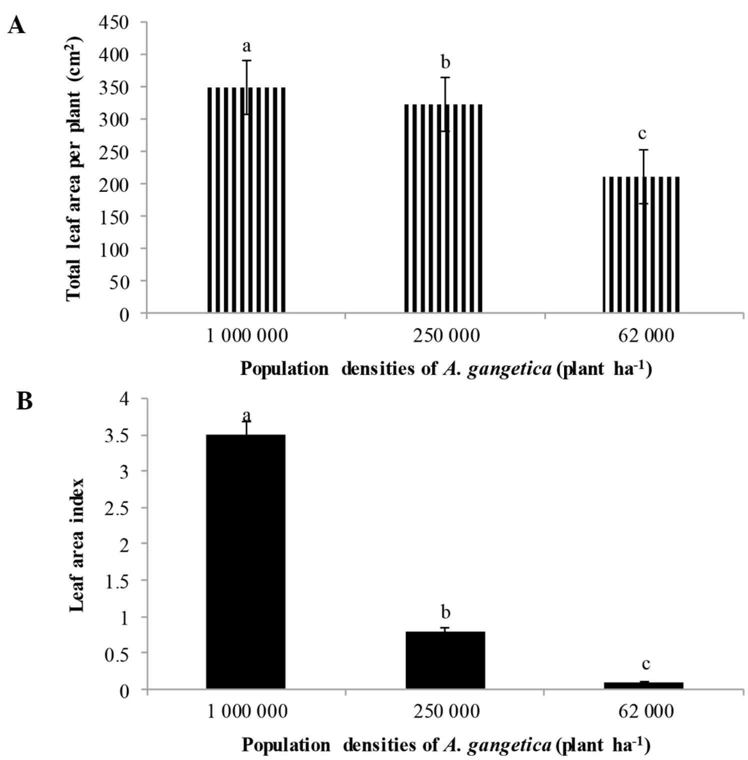
Leaf area index showed the ratio of upper leaf surface to the area occupied by the plant (Gardner et al., 1991). The largest LAI was found at the total population of 1000000 plants ha^{-1}, which was 3.5 (Figure 4B). This shows that, in a population of 1000000 plants ha^{-1}, there is occurred shade and land coverage. Sitompul and Guritno (1995) stated that LAI > 1 describes the existence of mutual shading among the leaves. Gardner et al. (1991) suggest that high LAI scores (LAI ranges from 3 to 5) are required for crops purposed for total biomass, not economic yield.

Figure 3. Number of leaf and nodes per plant *Asystasia gangetica* by different population density.



Different letters on bars corresponding to the same response variable, number of leaf per plant (black) or number of nodes per plant (grey), indicate significant differences between population densities of *A. gangetica* according to LSD test ($P < 0.05$). Vertical bars correspond to standard error.

Figure 4. Total leaf area per plant (A) and leaf area index per plant (B) of *Asystasia gangetica* by different population density.



Different letters on bars in the same figure, total of leaf area per plant (A) and LAI (B) indicate significant differences between population densities of *A. gangetica* according to LSD test ($P < 0.05$). Vertical bars correspond to standard error.

Table 1. Dry weight of *Asystasia gangetica* for different population densities on 4 and 16 WAP.

	Dry weight	
Population densities	4 WAP	16 WAP
plant ha^{-1}	kg ha^{-1}	
1 000 000	482.1a	1420.0a
250 000	160.0b	444.2b
62 000	46.0c	152.6c

Distinct letters in the column indicate significant differences according to LSD test ($P \leq 0.05$).
WAP: Weeks after planting.

Plant dry weight is a combination of root and canopy dry. Dry weight is an indicator of plant growth. The greater dry weight of plants can be interpreted as normal growth. Analysis on dry weight of *A. gangetica* per plot is presented in Table 1; the number of population had significant effect on dry weight of *A. gangetica* per experimental plot aged 4 and 16 WAP. The population of 1 000 000 plants ha^{-1} produced dry weight of *A. gangetica* higher than 250 000 and 62 000 plants ha^{-1}. The high dry weight of *A. gangetica* per plot of the population of 1 000 000 plants ha^{-1} was caused by the high number of leaves and leaf area (Figure 3A and 3B). Correlation analysis between dry weight of *A. gangetica* and the number of leaves and leaf area showed very significant correlation ($r = 0.9^{**}$ and 0.8^{**}, respectively). Haryantini and Santoso (2001) stated that plants with higher leaf area will increase plants ability to photosynthesis more optimally due to wider surface of plant leaves receive sunlight as the main energy source in photosynthesis process, thus dry weight is also greater.

Nutrient balance of N, P, K

Nutrient balance is the balance of nutrient quantities that are fed into the production system (source) with the amount of nutrients returned into the system (recovery nutrient). Calculation of nutrient balance will show unmeasured nutrients due to leaching, evaporation, mobilization, immobilization (inorganic to organic), nutrient fixation and mineralization (organic to inorganic). Nutrient fixation means a nutrient absorbed by soil colloids so that it cannot be utilized by plants. The calculation of nutrient balance on the treatment of cover crops is presented in Table 2.

Availability of N, P, and K after treatment (recovery nutrient) was higher in soils with *N. biserrata* and *A. gangetica* than without cover crops (Table 2). Dube and Stolpe (2016) and Alfaro et al. (2018) reported that soil nutrient availability was higher in soil covered by cover crops than without cover crops. According to Alfaro et al. (2018), availability of soil nutrients is related to cover crops. Soils without cover crops can cause soil erosion and soil loss, thus reducing the availability of nutrients and C stocks in the soil. In addition, Asbur et al. (2015) reported that C stocks in mature oil palm plantations in South Lampung, Indonesia, are lower with no cover crops than cover crops. Asbur et al. (2016) also showed that erosion and nutrient loss of N, P, K, is higher in mature oil palm plantations with no cover crops. This is due to the interaction between the quantity and quality of organic residues that enter the soil and the subsequent use of soil macro and microorganisms will affect the accumulation rate of organic and soil nutrients (Dube and Stolpe, 2016; Wang et al., 2017). Litter accumulation is higher in the soil with cover crop than without cover crops (Alfaro et al., 2018).

Soils with *A. gangetica* and *N. biserrata* will increase the availability of N-total, P, and K based on the nutrient balance due to the role of cover crops in producing litter and root exudates that can increase nutrients and soil moisture content, increasing infiltration water along the roots, thereby increasing soil fertility and biomass of soil microorganisms within the root zone that contribute in the nutrient balance (Schade and Hobbie, 2005; Housman et al., 2007). Hu et al. (2018) states that cover crops will increase crop residues that are closely related to increased organic C content and high soil nutrients as well.

Table 2. Nutrient balance of N, P, K with cover crops treatment.

Description	No cover crops	*Nephrolepis biserrata*	*Asystasia gangetica*
N-total, kg ha^{-1}			
Source			
Nutrient availability before treatment	1966.67	2166.67	2033.33
Fertilizer	100.00	100.00	100.00
Total source	2066.67	2266.67	2133.33
Recovery nutrient			
Nutrient availability after treatment	1900.00	2333.33	2500.00
Uptake	0.00	80.79	27.82
Total recovery nutrient	1900.00	2414.12	2527.82
Nutrient increase/loss	166.67 (-)	147.45 (+)	394.49 (+)
P, kg ha^{-1}			
Source			
Nutrient availability before treatment	8.29	8.27	8.31
Fertilizer	3.75	3.75	3.75
Total source	12.04	12.02	12.06
Recovery nutrient			
Nutrient availability after treatment	6.30	11.90	8.90
Uptake	0.00	9.88	4.27
Total recovery nutrient	6.30	21.78	13.17
Nutrient increase/loss	5.74 (-)	9.76 (+)	1.11 (+)
K, kg ha^{-1}			
Source			
Nutrient availability before treatment	74.13	74.13	74.01
Fertilizer	37.50	37.50	37.50
Total source	111.63	111.63	111.51
Recovery nutrient			
Nutrient availability after treatment	48.92	57.11	77.31
Uptake	0.00	75.75	76.97
Total recovery nutrient	48.92	132.86	154.28
Nutrient increase/loss	62.71 (-)	21.23 (+)	42.77 (+)

(+): Source < Recovery nutrient = enhancement nutrient done; (-): Source > Recovery nutrient = reduction nutrient done.

CONCLUSIONS

Asystasia gangetica can be used as cover crop in mature oil palm plantation because it fulfills several conditions such as quickly covering the land (11 wk after planting), and ability to increase available N, P, K in the soil as much as 18.49%, 9.20%, and 38.36%, respectively, based on the nutrient balance with the optimum population of 1000000 plants ha^{-1}.

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