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The Roles of *Asystasia gangetica* (L.) T. Anderson and Ridge Terrace in Reducing Soil Erosion and Nutrient Losses in Oil Palm Plantation in South Lampung, Indonesia

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Abstract

Asystasia gangetica (L.) T. Anderson is a weed commonly found on oil palm plantations and can be used as cover crop for mature oil palm plantations due to its tolerance to shading. The use of cover crop is a soil conservation technique to support sustainable availability of soil nutrients by reducing erosion and nutrients loss, particularly during the rainy seasons. This research aims to determine the roles of *A. gangetica* as cover crop for measures against erosion and nutrients loss in mature oil palm plantation. This research was conducted in oil palm plantation, Unit Rejosari, PT Perkebunan Nusantara (PTPN) VII, District of Natar, South Lampung Regency from August 2014 to April 2015. The research used split block design in randomized complete block design with two factors and six replications. The main plots were ridge terrace, namely with and without ridge terrace. The sub plots were cover crops, namely with and without cover crops *A. gangetica*. The results show that using *A. gangetica* as cover crops in mature oil palm plantations effectively minimized erosion and loss of organic C, N, P, and K by 95.7%, 93.4%, 96.0%, and 90.0 %, respectively. The use of cover crop became more effective when combined with ridge terrace and reduced erosion by 94.1%, and loss of organic C, N, P and K by 99.1%, 99.2%, 90.0% and 98.5%, respectively.

Keywords: carbon-organic, cover crops, kalium, natrium, phosphat

Introduction

Soil erosion on agricultural land results in the loss of soil organic matter (Chen et al., 2011). Erosion caused reduction in fertile surface soil layer which are rich in organic matter and nutrients (Blanco and Lal, 2008), and reduce land and plant productivity. According to Abdurachman et al. (2003) loss of 10 cm top soil on oil palm plantation can decrease production by more than 50% despite complete fertilization was applied, because top soil as the source of nutrients will be eroded. Erosion does not only affect soil organic matter content but also the soil major nutrients N, P, and K. The amount of nutrients lost to erosion was usually greater than the predicted values, because fine and fertile soil particles will be leached, resulting in an accelerated decrease in soil fertility (Arsyad, 2010).

Oil palm plantations in PTPN VII Rejosari, Regency of Natar, South Lampung is generally dominated by S-2 (moderately suitable) and S-3 (marginally suitable) Ultisol, which indicates that the production potential of oil palm is relatively low. One of the constraining factors in oil palm production is the sloping contour of the land (3%-8%), shallow solum (± 1 m), and limited rainfall throughout the year in the area of oil palm production. Murtilaksono et al. (2009) reported pronounced dry seasons and excessive rainy season in South Lampung, which results in drought during the dry season and high rate of erosion during the rainy season.

Erosion in oil palm plantations can be reduced by creating ridge terraces and planting cover crops, a soil conservation technique to support a sustainable nutrient availability in agricultural land. Terracing is a combination of contouring and land shaping in which earth embankments, or ridges, are designed to intercept run off water and channel it to a specific outlet. Terraces reduce erosion by decreasing the steepness and length of the hillside slope and by preventing damage done by soil surface run off. Cover crops provide protective covering which is in direct contact with the ground provides more protection than canopy cover. By absorbing the destructive forces of raindrops and wind, cover crops reduce erosion, conserve water in the soil solum, and add organic matter and soil nutrients (Bunch, 2012).

Recently mature oil palm plantations no longer use legumes as cover crops due to their intolerance to shade, and because planted legumes were naturally overgrown by different types of shade-tolerant weeds, including *A. gangetica*.

A. gangetica is known as weeds to be controlled in oil palm plantations, because it produce seeds in large quantities (Adetula, 2004). However, *A. gangetica*, mainly subspecies *gangetica*, can be used as cover crop as it has no tendrils or spines (Ismail and Shukor, 1998), easy to grow and grow quickly (Yenni et al., 2015a), adaptable to different environmental conditions (Sandoval and Rodriguez, 2012), shade-tolerant (Yenni et al., 2015a), they can even grow well under 90% shaded (Adetula, 2004). *A. gangetica* was reported to increase water availability in ultisol (Junedi, 2014), and increase the availability of N, P, K through the creating nutrient balance (Yenni et al., 2015b).

A. gangetica is able to grow well in full of light and low soil fertility (Samedani et al., 2013; Kiew and Vollesen, 1997), to restrain or reduce erosion due to raindrops and surface run off (Adetula, 2004), has high nutritional value (antioxidants) for animal feed and drugs (Adetula, 2004; Gopal et al., 2013; Mugabo and Raji, 2013), and can serve as bio-monitor for the presence of heavy metals such as mercury (Hg) (Chew et al., 2012). In addition *A. gangetica* contributed N, P, and K to the soil (Yenni et al., 2015b), rapidly decomposed (Yenni et al., 2014), and can serve as soil carbon stock (Yenni et al., 2015b).

Results of Fuady and Satriawan (2011) showed that planting cover crops such as corn and peanuts as well as ridge terracing was able to control run off and erosion to 63.5% and 90.3%, respectively, compared to the absence of cover crops and ridge terrace. Planting cover crops on palm oil plantations were effectively reduced run off and soil erosion, and prevent loss of nutrients (Fuady et al., 2014; Satriawan et al., 2011; Satriawan et al., 2012).

This study aims at examining the roles of *A. gangetica* as cover crop to minimize soil erosion and loss of nutrients in mature oil palm plantation in South Lampung, Indonesia.

Materials and Methods

This research was conducted in the field using split block design in a randomized block design with two factors and six replications. The main plots were: ridge terrace consists of with and without ridge terrace. The subplots were cover crop, consists of with and without cover crops *A. gangetica*.

Before the erosion plots were constructed ridge terraces were arranged in the same directions to contour on each vertical interval 80 cm. Height, width and depth of mounds channel was 30 cm (Figure 1). Erosion plots were made on each block experiment with an area ± 300 m^2 using ebonite tarpaulin material. Erosion materials from the erosion plots were collected using Tub A measuring 5 m x 1 m x 1 m, and on outwards facing side created 7 sinkholes, 6 cm in diameter. The center hole was connected by pipes Ø 6 cm into Tub B (Figure 1). Gauze was placed above the Tub A which serves to accumulate soil erosion by run off. *A. gangetica* for cover crop was planted after erosion plot has been constructed, with a spacing of 10 cm x 10 cm.

Erosion measurements were performed following every rainfall event during the study. The erosion measurement includes soil filtered on gauze and sediments that were dissolved in the tub A and B. Soil particles that were collected in gauze was weighed by draining in oven at 105 ºC until reaching a constant weight. The weight of soil sediment samples were weighed by filtering the water using filter paper. Sediments that were left on the filter paper were dried in the oven at 105ºC until reaching a constant weight. The amount of soil and sediment (E) was calculated using the following equation :

$$E = \frac{(S + (C_{apA}\ x\ V_A) + (C_{apB}\ x\ V_B\ x\ 7))\ x\ 10^{-3}}{A}$$

Where

E	: soil erosion ($t.ha^{-1}$)
C_{apA} and C_{apB}	: concentration of sediment load in Tub A and B ($kg.m^{-3}$)
V_A and V_B	: run off volume (m^3)
A	: area (ha)
10^{-3}	: conversion unit from kg to ton.

Soils and sediments analysis were performed to measure the concentration of organic C using Walkley & Black Method, Total N using Kjeldhal Method, P_2O_5 available using Bray Method with spectro-photometer, and K_2O available using Bray Method with flame photometer. The analysis results of organic C, Total N, P_2O_5 and available K_2O through erosion (soil and sediment) were calculated by the following equation:

$$X = Y \times E$$

Where:

X = Amount of organic C, N, P and K lost through erosion ($kg.ha^{-1}$)
Y = Concentration of Organic C, total N, P and K available in sediment
E = Amount of total soil erosion ($t.ha^{-1}$).

Data obtained from the amount of erosion and nutrients loss through erosion were analyzed using ANOVA; further testing used Least Significant Difference (LSD) at 5% significant level. Data were analysed using the Statistical Analysis System (SAS) Software 9.1. (SAS, 2004).

Results and Discussion

Soil Erosion

Effect of ridge terrace and cover crops *A. gangetica* on erosion in oil palm plantation PTPN VII Rejosari, South Lampung is presented in Figure 2. Erosion is the loss of soil surface top layer along with run off caused by rain (Arsyad, 2010). Run off as the cause of soil erosion occurred due to heavy rainfalls, demonstrated in Figure 2. Erosion did not occur in August and September 2014 where there was no rain whereas erosion occurred in October 2014 when rainfall was 21.8-251.3 mm. In December 2014 with rainfall of around 220.9 mm, erosion in plots with ridge terrace with *A. gangetica* as cover crop (G_1T_1) was smaller than without ridge terrace and cover crop (G_0T_0), i.e. 0.03 $t.ha^{-1}$ and 3.3 $t.ha^{-1}$, respectively. This is because in the G_0T_0 treatment rain droplets directly falling onto the unprotected soil surface, accelerating run off and caused soil erosion. Sinukaban (1989) stated that erosion will increase drastically with increased rainfall when the soil surface is not covered by vegetation, or contoured with ridge terrace due to limited opportunity for water infiltration.

Treatment with ridge terrace and planting cover crop *A. gangetica* was able to reduce soil erosion despite the high rainfall; the plant canopy of the cover crops protected the soil surface from the kinetic energy of rain droplets. In addition, more rain water was intercepted by plants, and the ridge terrace improved water infiltration to the soil through trenches and holes in the ridge terrace. Other studies show that oil palm planting + upland rice followed with soybean + *Mucuna bracteata* strips were able to minimize erosion in the five to seven-year-old oil palm plantation (Fuady et al., 2014). Similarly, ridge terrace and cover crops significantly supress erosion in coffee plantation compared to coffee without cover crops (Dariah et al, 2004).

Table 1 shows that interaction between ridge terrace and cover crops had significant effects on erosion. Ridge terrace with cover crop *A. gangetica* (G_1T_1) had the lowest soil erosion of 3.3 $t.ha^{-1}$ per year, whereas those without ridge terrace and cover crops (G_0T_0) had the highest soil erosion of 56.4 $t.ha^{-1}$ per year.

Growing *A. gangetica* in the oil palm plantation improved the effectiveness of ridge terrace on reducing erosion from 47.1 % (G_1T_0) to 94.1 % (G_1T_1) (Table 1). Idjudin (2011) reported that the effectiveness of ridge terrace in reducing erosion will increase if this practice is combined with planting cover crops. Satriawan et al. (2015) also showed that combination of ridge terrace and cover crop reduced erosion 1.8 times more effective than without ridge terrace and cover crops, whereas Nursa'ban (2009) reported 100% soil protection from erosion by ridge terrace and cover crop.

Loss of Organic C, N, P, and K

Table 2 shows that soil erosion caused the loss of organic C, N, P and K in the soil, and that ridge terrace and cover crops has significantly reduced the losses of organic C and total N, P_2O_5 and K_2O. Loss of organic C, total-N, P_2O_5 and K_2O by erosion were lower on ridge terrace (G_1) treatment compared to without ridge terrace (G_0). This is because ridge terrace will delay run off and provide channels for the run off, thereby increasing the rate of water infiltration into the soil, reduce loss of organic C and soil nutrients through erosion.

Loss of organic C, total-N, P_2O_5 and K_2O through erosion in the plots with cover crops *A. gangetica* (T_1) were also less than without the cover crop (T_0), likely because the presence of canopy and root system from the cover crop were able to improve soil carrying capacity and facilitated water infiltration into soil, in turn reduce loss of organic C and soil nutrients.

Combination of ridge terraces and cover crops also significantly reduced the loss of organic C, total-N, P_2O_5 and K_2O through erosion. Cultivation of *A.*

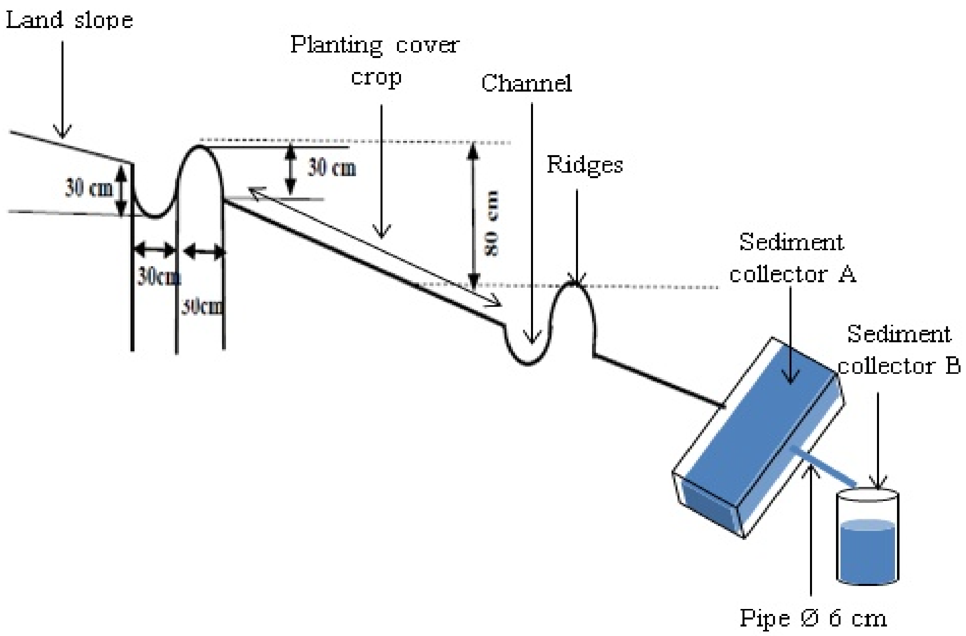
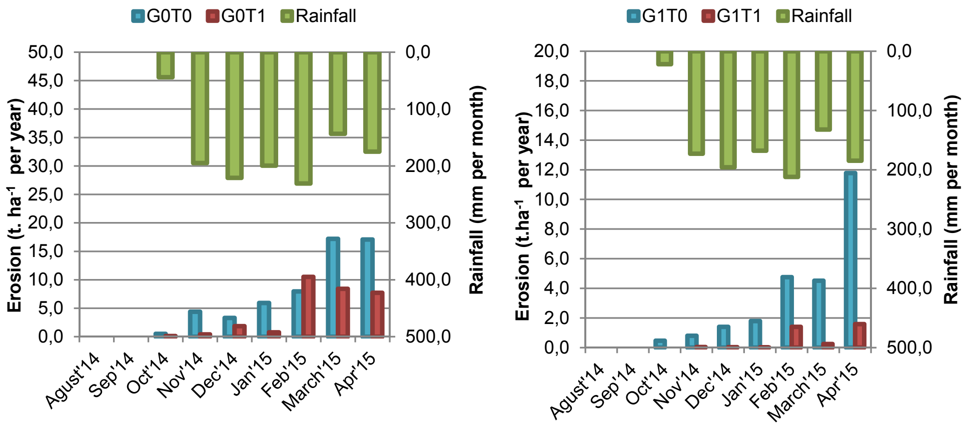


Figure 1. The ridge terrace and sediment collector system at the experimental plots.

Table 1. Effectiveness of ridge terrace and cover crop *A. gangetica* in reducing erosion in palm oil plantation PTPN VII Rejosari, South Lampung, from August 2014 to April 2015

Treatments	Erosion (t.ha^{-1} per year)	Effectiveness to minimize erosion (%)	Total rainfall (mm per year)	Rainfall day (day)
G_0T_0	56.4a	-	1208.1	44
G_0T_1	25.5b	54.7	1208.1	44
G_1T_0	29.8b	47.1	1120.0	43
G_1T_1	3.3c	94.1	1120.0	43

Note : Different letters in the same column show significant differences at 5% LSD. G_0 = without ridge terrace, G_1 = ridge terrace, T_0 = without cover crop; T_1 = with cover crop *A. gangetica*. The effectiveness to minimize erosion is calculated by comparing the erosion of G_0T_0 treatment (control) with other treatment.



A B

Figure 2. Average erosion and monthly rainfall during the period of August 2014 to April 2015. A: without ridge terrace + without cover crop A. gangetica (G0T0), and without ridge terrace + cover crop *A. gangetica* (G0T1); B: with ridge terrace and without cover crops (G1T0) and with ridge terrace and cover crop A. *gangetica* (G1T1).

Table 2. Effect of cover crops and ridge terraces to the loss of total organic C, total-N, P_2O_5 and K_2O *throug erosion* in oil palm plantation PTPN VII Rejosari, South Lampung from August 2014 to April 2015.

Treatments	Cover crop		Mean
	T_0	T_1	
Ridge Terraces	Organic C ($kg.ha^{-1}$)		
G_0	97.4a	5.1c	34.4a
G_1	40.8b	0.9c	13.9b
Mean cover crop [1)]	69.1a	3.0b	
	Total N ($kg.ha^{-1}$)		
G_0	8.70a	0.80c	3.2a
G_1	3.50b	0.07c	1.2b
Mean cover crop [1)]	6.10a	0.44b	
	P_2O_5 ($kg.ha^{-1}$)		
G_0	0.020a	0.002c	0.009a
G_1	0.007b	0.002c	0.003b
Mean cover crop [1)]	0.050a	0.002b	
	K_2O ($kg.ha^{-1}$)		
G_0	1.4a	0.20c	0.5a
G_1	0.5b	0.02c	0.2b
Mean cover crop [1)]	1.0a	0.11b	

Note : G0 = without ridge terrace, G1 = ridge terrace, T0 = without cover crop A. gangetica; T1 = with cover crop *A. gangetica*
Values in the column and row followed by the same letter are not significantly different at 5% LSD
1) The mean values in the same column and row followed by different letters show significant differences at 5% LSD.

gangetica improved the effectiveness of ridge terrace in reducing the loss of organic C, total-N, P_2O_5 and K_2O from 58.1% (G_1T_0) to 99.1% (G_1T_1), 59.8% (G_1T_0) to 99.2% (G_1T_1), 65.0% (G_1T_0) to 98.9% (G_1T_1) and 64.3% (G_1T_0) to 98.5% (G_1T_1), respectively.

Loss of soil organic C also means losing of soil organic matter, because Organic C is the main constituent of soil organic matter. The loss of Organic C by erosion is a serious problem as it will accelerate soil degradation and declining soil fertility. Content of soil organic matter is one indicator of land resources sustainability (Wolf and Snyder, 2003). Organic materials serve to recycle nutrients back into the soil, and improve water holding capacity. The organic matter content of agricultural top soil is usually in the range of 1 to 6%. A study at Michigan demonstrated potential crop yield increases of about 12% for every 1% organic matter. In a Maryland experiment, researchers saw an increase of approximately 2 tons of maize per acre when organic matter increased from 0.8% to 2% (Magdoff, 2012). Soil organic matter affects soil biological, chemical and physical properties, and makes it of critical importance to healthy soils (Magdoff, 2012; Bunch 2012).

The loss of total N through erosion was higher than the loss of P and K. This might be because one of N sources is soil organic matter (Hardjowigeno, 2010), so the increased loss of organic C through erosion resulted in the higher leach of N. Loss of K by erosion is usually higher than P because by K is more susceptible to leaching compared to P (Havlin et al., 2005).

Information from this study shows that oil palm plantations may have experienced accelerated land degradation due to erosion, which resulted in decreased soil organic matter content and soil nutrients (Arsyad, 2010). However, with ridge terrace and cover crops *A. gangetica* erosion and loss of organic matter and nutrients can be controlled, as the loss of nutrients was directly related to the amount of erosion, and it is a function of organic C and nutrients concentration in the sediment (Sinukaban, 2007; Arsyad, 2010).

Similar results were reported in teak (Didjajani, 2012) and coffee plantation (Dariah et al., 2004) that higher soil erosion resulted in a higher loss of organic C, N, P, and K. Similarly, Henny et al. (2011) show that planting potato on ridges across the slope land decreased loss of organic C, N, P, and K due to reduced erosion. Other studies show that ridge terrace and intercropped areca nut with maize, and ridge terrace and intercropped cocoa with peanut reduced the loss of organic C, N, P, and K due to lower incidence of erosion (Satriawan, 2015).

Conclusion

A. gangetica as cover crops in mature oil palm plantations can effectively minimize erosion and reduce the loss of organic C, N, P, and K by 95.7%, 93.4%, 96.0% and 90.0%, respectively. Combination of ridge terrace with cover crop *A. gangetica* in mature oil palm plantations was more effective to reduce erosion and loss of organic C, N, P, and K, i.e. by 94.1%, 99.1%, 99.2%, 90.0% and 98.5%, respectively.

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