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The Role of Biomulch *Arachis pintoi* In Increasing Soil Infiltration Rate on Sloping Land of Oil Palm Plantation

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Abstract

The slope of land in oil palm plantation areas is the one of the primary causes of low soil water content due to low rates of soil infiltration. Biomulch is one of the conservation methods that can be used to cover and shield the soil from weeds, prevent soil erosion, and increase the rate of soil infiltration. *Arachis pintoi* is a perennial, stoloniferous legume crop that has potentials to be used as biomulch. The objective of the research was to study the role of *Arachis pintoi* in increasing the rate of soil infiltration on a sloping land of oil palm plantation. The research was conducted on the slope land (22.8%) of the Bukit Kemuning Farmer Group, Mersam, Batanghari, Jambi, Indonesia (01⁰36'21", 102⁰57'11") from September 2017 to March 2018. The environmental design used in this study was a one-factor randomized block design (RBD) with five ground cover treatments, i.e. natural vegetation, *Arachis pintoi*, *Centrosema pubescens*, *Pueraria javanica* and *Calopogonium mucunoides.* The results showed that the average growth rate of *A. pintoi* was 2.47 cm per week, which was lower than the growth of other treatments. The root length of *A. pintoi* was 50.36 cm at 20 weeks after planting. *A. pintoi* can be used as biomulch; sloping land planted with *A. pintoi* had an infiltration rate of 49.30 cm per hour at 20 week after planting, i.e. an increase of 32.47% compared to the infiltration rate with the natural vegetation.

Keywords: cover crop, *Centrosema pubescens, Pueraria javanica, Calopogonium mucunoides*

Introduction

Oil palm (*Elaeis guineensis* Jacq) plantation continues to expand in Indonesia. The productive land area covered by oil palm plantations in Indonesia in 2015 was 11,300,370 ha (BPS, 2016). Oil palm in Indonesia is generally cultivated on marginal lands such as dry and hilly land (Farni et al., 2012), which may affect the availability of water in the soil caused by low infiltration and high erosion on the soil surface. Therefore, to prevent land degradation, conservation system such as the use of cover crops or biomulch should be implemented (Ministry of Agriculture, 2015). Biomulch includes living plants that are planted as ground cover (Silmi and Chozin, 2014). The use of biomulch has many advantages for marginal land, including improving soil fertility, inhibiting weed growth, reducing erosion rates and increasing soil infiltration (Reflianty et al., 2009; Kumar et al., 2010). In addition, the benefits of biomulch can increase soil porosity and soil absorption (Arsyad, 2006). Utaya and Sugeng (2008) stated that differences in infiltration rates in various land uses indicate that vegetation have a large role in determining soil infiltration. It is hypothesized that the infiltration capacity of soils under cover crop vegetation could be higher than that of bare soil.

Arachis pintoi is a herbaceous, perennial legume species that can be used as biomulch because it can cover the soil surface for erosion control (Silmi and Chozin, 2014; Carvalho et. al., 2009). *A. pintoi* growth does not interfere with the growth of the main crop and can potentially increase soil moisture content (Yuniarti, 2016; Yuniarti et al., 2018). A study by Mudarisna and Pujiono (2015) showed that the biomass of *A. pintoi* increased soil porosity and permeability, and improved soil aggregate. There has been limited information about the benefits of *A. pintoi* on soil physical improvement of the oil palm plantation.

C. pubescens, *P. javanica* and *C. mucunoides* are leguminous species that have been widely grown as cover crops. C. pubescens is resistant to drought and shade, so it is widely used to suppress the growth of weeds such *Imperata cylindrica* (Sutedi, 2015). *P. javanica* is a broadleaf leguminous creeper that has roots in each node and can cover the soil surface quickly; it is a very popular cover crop for plantations worldwide (Arsyad, 2012). *C. mucunoides* is a vigorous, annual trailing legume; it can reach several meters in length and form dense foliage with shallow root system. Leaf and stem of *C. mucunoides* have fine hairs. *C. mucunoides* is used as a pioneer in rehabilitating degraded land due to erosion but is not resistant to shade (Purwanto, 2007). The purpose of this study was to determine the potential uses of *A. pintoi* to increase soil infiltration on sloping oil palm lands, and to compare advantages of growing *A. pintoi* as biomulch on oil palm plantations was compared to those of the natural vegetation, conventional biomulch *Centrosema pubescens*, *Pueraria javanica* and *Calopogonium mucunoides*.

Materials and Methods

The study was conducted at the Bukit Kemuning Farmer Group's land, Mersam District, Batanghari Regency, in the Jambi Province (01°36'21", 102°57'11") with slope topography of 20.8%. This research was carried out from September 2017 to March 2018. The materials used were stem cuttings of *Arachis pintoi*, seeds of *Centrosema pubescens*, *Calopogonium mucunoides* and *Pueraria javanica*. Two-year-old oil palm "Sriwijaya" variety was planted with a spacing of 9 m x 9 m. The equipment used included analytic scales, ovens, double ring infiltrometer, clinometer and ombrometer. The environmental design used in this study was a one-factor randomized complete block design (RCBD) with five treatments. The treatments consisted of natural vegetation cover crops *C. pubescens*, *C. mucunoides* and *P. javanica*, and *A. pintoi* on 9m x 3m plots, and replicated four times. The total plots of 20 were made in the middle of oil palm plantation. Biomulch was planted one day after the rain; the biomulch seeds and cuttings of *A. pintoi* were planted at a depth of 5 cm. Cutting of *A. pintoi* consists of one internode with a pair of mature leaves; it was expected that these cuttings rooted at about the same time with germination of the other biomulches. Biomulch crops were planted with a spacing of 40 cm x 40 cm. The total number of seeds used in each biomulch treatment was 675 seeds.

Measurements were made on tendrils and root length, soil infiltration rate and soil infiltration capacity from 4 to 20 weeks after planting (WAP) of the four cover crops. Infiltration rate is calculated by the formula used by Budiarto et al. (2004):

$$f = \frac{\Delta H}{t}$$

where
F : infiltration rate (cm per hour)
ΔH: High decrease of water in a certain time interval (cm)
t : Time needed by water at ΔH to enter the ground (hour)

Infiltration capacity is calculated by the formula (Horton, 1939):
$f = fc + (f_0 - f_c)\ e^{-kt}$

where
F : infiltration capacity at time t (cm/hour)
f_c : rate of infiltration at a constant time (cm/hour)
f_0 : initial infiltration rate (cm/hour)
e : 2.718
t : Time needed by water at fc to enter the ground (hour)
K : constant for certain types of soil and soil cover

Horton infiltration parameters are used in the calculation of Horton's infiltration, to obtain the value of k, a decrease in Horton's infiltration formula (Beven, 2004; Dagadu, 2012):

f = fc + (fo - fc) e-kt
f - fc = (fo - fc) e -kt
the right and left sides are
logged in (f -fc) = log (fo-fc) - kt log e
log (f –Fc) - log (fo-fc) = - kt log e

$$t = \left(\frac{-1}{(k \log e)}\right) (\log\ (f\text{-}fc) - \log\ (fo\text{-}fc))$$

$$t = \left(\frac{-1}{(k \log e)}\right) \log\ (f\text{-}fc) + \left(\frac{-1}{(k \log e)}\right) \log\ (fo\text{-}fc)$$

it is changed in the linear regression equation
y = mx+c
y = t

$$m = \left(\frac{-1}{(k \log e)}\right)$$

x = log (fo-fc)

$$c = \left(\frac{-1}{(k \log e)}\right) \log\ (fo\text{-}fc)$$

k value can be obtained from the equation *m*

$$m = \left(\frac{-1}{(k \log e)}\right)$$

$$k = \frac{-1}{m\ \log e} = \frac{-1}{m\ \log 2.718} = \frac{-1}{m \times 0.4343}$$

Results and Discussion

Tendril Length of *A. pintoi*

Tendril is a stem that grows on the buds of plants and propagates on the soil surface. Based on our results, there was a significant difference in the effect of the biomulch on the tendril length starting 4 WAP. The data showed longer growth of tendrils in *C. pubescens* compared to *A. pintoi, P. javanica* and *C. mucunoides* at 8 to 20 WAP (Table 1).

Table 1 show that the average growth rate of tendrils of *C. pubescens* of 8.62 cm per week was higher than the average vine length of *A. pintoi, P. javanica* and *C. mucunoides* with a length of 2.47, 6.10 and 5.73 cm per week, respectively. The difference in the length of tendrils was possibly caused by the type of biomulch and the biomulch responses to the environment where they are grown. *C. pubescens* leaves and girth are relatively small, resulting in a dominant tendril growth while *P. javanica* and *C. mucunoidez* have large girth with broad leaf and long tendrils, resulting in slightly slower growth. In addition, the growing environment is also very influential on the growth of various types of biomulch. Indiana and Setiadi (2011) reported that the percentage of survival of *C. mucunoides* was 27.5% in straw husk media, which was higher than those of *C. pubescens* and *P. javanica*, i.e 20% and 14%, respectively. In other media such the leaf compost media, the percentage of *C. mucunoides* survival was 14% lower than *C. pubescens* and *P. javanica*, i.e. 18.33% and 20%, respectively.

The results showed that the growth rate of tendrils *A. pintoi* was lower than other biomulch species (Table 1). The slow growth of tendrils in *A. pintoi* was possibly caused by the excessive number of branches and the number of leaves which tend to reduce the growth of the tendrils. The average vine length of *A. pintoi* in this study was similar to the results of Dianita and Abdulah (2011) where the average growth rate of tendrils in *A. pintoi* was 1.60 cm per week. Yuniarti (2016) demonstrated that the average number of tendrils and branch numbers of *A. pintoi* was more than *C. pubescens, P. javanica* and *C. mucunoides*.

Root Length

Roots of biomulch have important roles in the conservation of plantation land; they improve soil structure and increase soil pores through root penetration to the soil. In addition roots hold the soil in position and prevent it from being washed away. In our study the growth of *P. javanica* roots significantly faster (4.52 cm per week) compared to those of the other biomulches from 4 to 20 WAP (< 3 cm per week; Table 2).

The longest root of *P. javanica* was 15.90 cm at 20 week, which was longer than the root length of *A. pintoi*, *C. pubescens* and *C. mucunoides*, i.e. 50.36, 59.93 and 60.06 cm at 20 week, respectively. (Table 2). This rapid root growth in *P. javanica* was possibly related to the ability of *P. javanica* to absorb nitrogen better than other biomulches. As shown by Darmawati et al. (2015) that *P. javanica* biomulch is very responsive to nitrogen applications, and the nitrogen content in the tissues of *P. javanica* was higher than *C. pubescens* and *C. mucunoides.*

Table 1. Tendril growth of different biomulch in oil palm plantation

Treatment	Tendril length (cm)					Average growth per week (cm)
	Week after planting					
	4	8	12	16	20	
A. pintoi	11.12a*	25.11a	34.02a	43.32a	49.57a	2.47 a
C. pubescens	15.82b	62.07c	104.67c	125.92c	172.55c	8.62c
P. javanica	11.62a	39.52b	66.1b	81.37b	122.05b	6.10b
C. mucunoides	10.75a	39.05b	63.07b	79.15b	114.75b	5.73b

Note: *Values followed by the same letters within the same column show no significant differences according to the Duncan multiple range tests (DMRT) at α = 5%.

Table 2. Root length of different biomulch in the oil palm plantation

Treatment	Root length (cm)					Average growth per week (cm)
	Week after planting					
	4	8	12	16	20	
A. pintoi	12.83a*	24.63 a	31.21a	39.61 a	50.36a	2.81a
C. pubescens	18.93b	25.96ab	39.92c	47.92a	59.93a	2.99a
P. javanica	20.71b	28.86 b	40.53c	68.86b	90.46b	4.52b
C. mucunoides	20.06b	26.63ab	34.13b	45.36a	60.06b	3.01a

*Values followed by the same letters in the same column show no significant differences according to the Duncan multiple range tests (DMRT) at α = 5%.

The results also showed that the root growth of *A. pintoi* was slower relative to other biomulch at 20 WAP. This may be due to in the differences in the planting materials used in the study. The *A. pintoi* were grown from stem cuttings and had fibrous roots, so that the number of roots is more dominant than the root length growth. The use of stem cuttings as planting material in *A. pintoi* is due to the fact it produces very few seeds, even though it produces abundant blooms; only 4 to 8% flowers developed seeds (Adjolohoun et al., 2013). Planting material from stem cuttings will predominantly produce numerous shorter roots rather than long roots. A study by Sumiahadi et al. (2016) showed that the average number and length of roots in *A. pintoi* were 42.4 and 17.1 cm at 12 WAP.

Soil Infiltration

The results showed that the biomulch treatments affected the actual infiltration rate at 20 WAP (Figure 1). Infiltration is the process of absorbing water into the soil vertically through the soil surface and thoroughly passing through the soil pores. Infiltration rate is the speed of water entering the soil for a certain time, while infiltration capacity is the minimum rate of movement of water into the soil in saturated conditions (Hanks and Ashcroft, 1986).

The actual infiltration rate curve in Figure 1 describes the rate of infiltration of each biomulch species. Infiltration rate is calculated by the formula used by Budiarto et al. (2004). The infiltration rate of soil covered with *P. javanica* was 58.75 cm per hour, which is faster than the infiltration rate in the treatment of natural vegetation, *A. pintoi*, *C. pubescens* and *C. mucunoides* of 33.29, 49.30, 51.52 and 44.87 cm per hour, respectively. The high rate of soil infiltration in *P. javanica* may be related to the faster growth of root *P. javanica* as compared with other biomulch, thus may increase the number of soil pores (Table 2). Soils covered with *P. javanica* could increase ultisol pores by 27.47% compared to the natural vegetation treatment, and the number of soil pores in *P. javanica roots* was higher than *C. pubescens* which was 15.39% and *C. mucunoides* by 17.81% (Refliaty et al, 2009). Figure 1 also shows soil infiltration rate of *A. pintoi* which is higher than natural vegetation treatment. The ability of *A. pintoi* to increase soil infiltration rate may be caused by the long roots of A. pintoi. Sumiahadi et al. (2016) reported that *A. pintoi* has an average number of roots of 42.4 with an average root length of 17.10 cm at 12 WAP; it also formed numerous roots in each node on each of the tendrils. The high infiltration rates of the different biomulch are evidence that biomulch can increase the rate of soil infiltration compared to the natural vegetation. Gao-Lin et al. (2016) investigated the effects of different artificial grasslands on soil physical properties and soil infiltration capacity, and reported that mixtures of Legume (*Astragalus adsurgens* and *Artemisia desertorum*) and Poaceae (*Bromus inermis*) to create grasslands provided an effective ecological restoration approach to increase soil infiltration properties by 72.38% due to their greater root biomasses. In addition to soil infiltration rate, the soil infiltration capacity needs to be determined. Soil infiltration capacity is a soil hydrological parameter that can be used as an indicator of soil degradation and the drought potential of the soil (David et al., 2015).

Table 3 shows that the soil infiltration capacity of each biomulch treatment consistently increased from 4 to 20 WAP. *P. javanica* had a significantly higher soil infiltration capacity compared to other biomulch at 20 WAP. The increase in soil infiltration capacity by *P. javanica* may be caused by a faster root length in this crop compared to the other biomulch (Table 2). Roots can improve soil structure and increase soil pores which in turn increased the soil field capacity. In Refliaty et al. (2009) study *P. javanica* increased the field capacity of ultisol by 48.26% compared to that of the natural vegetation treatment, and that the field capacity of *P. javanica* was higher than *C. pubescens* (28.68%) and *C. mucunoides* (30.73%).

Table 3. Soil infiltration capacity as affected by biomulch treatment in oil palm plantation

Treatment	Infiltration capacity (cm per hour)				
	Weeks after planting				
	4	8	12	16	20
Natural vegetation	12.34	13.10	13.51ab*	13.89a	14.66a
A. pintoi	12.68	13.51	14.09b	14.31ab	14.95a
C. pubescens	12.80	13.69	13.82ab	13.89a	14.45a
P. javanica	12.88	13.52	14.11ab	14.73b	16.56b
C. mucunoides	12.44	12.62	13.27a	14.04ab	14.87a

*Values followed by the same letters within the same column show no significant differences according to the Duncan multiple range tests (DMRT) at α = 5%.

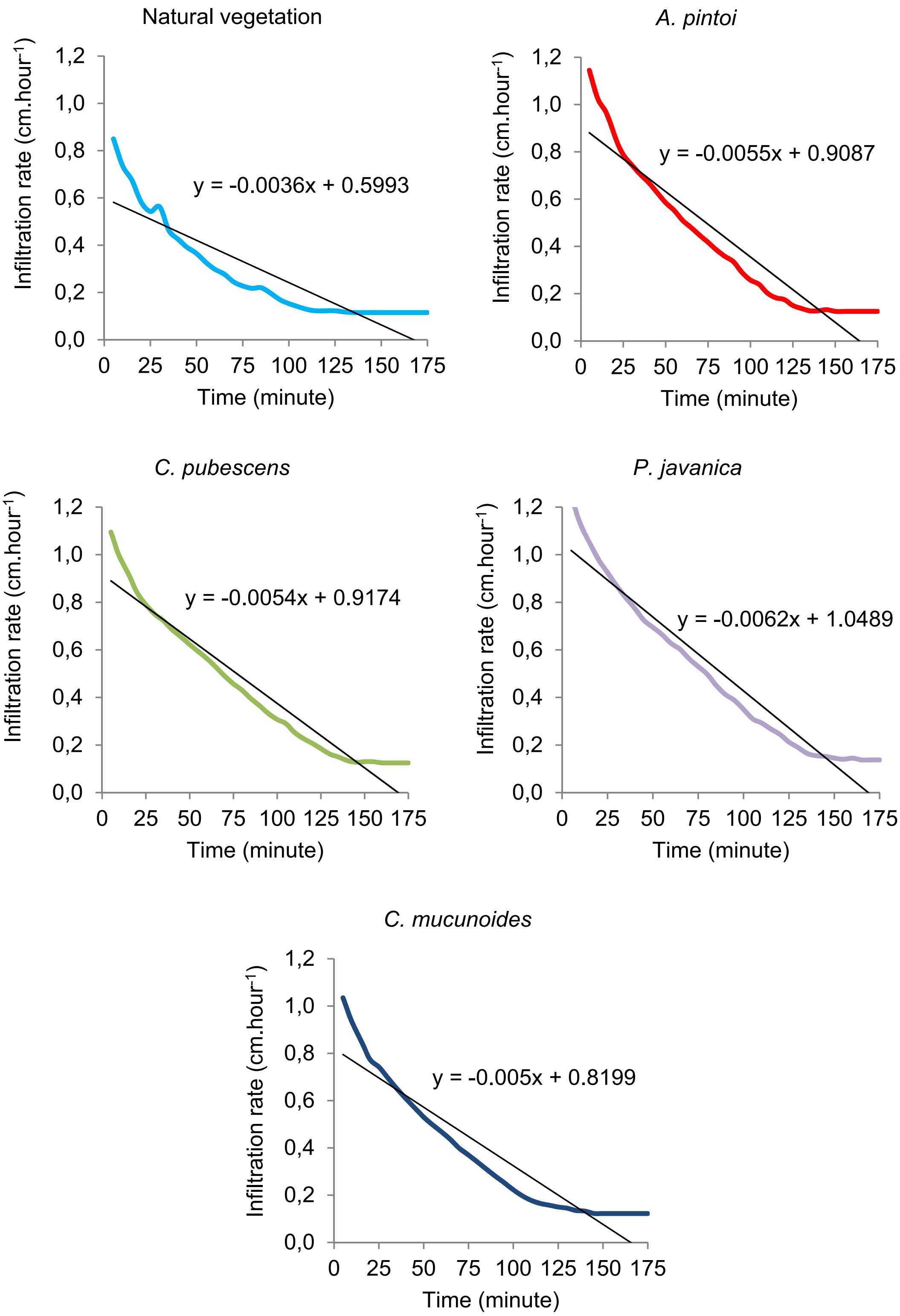

Figure 1. Soil infiltration rate as affected by bio mulch treatment at 20 week after planting

The results of this study showed that the soil infiltration capacity of soil with *A. pintoi, C. pubescens* and *C. mucunoides* were not significantly different from that of the natural vegetation treatment (Table 3). Although it was not significantly different, biomulch treatment significantly increased soil infiltration capacity from 4 to 20 WAP. The role of biomass is very important to protect the soil surface from direct collision with raindrops and to improve soil structure. Infiltration capacity can be maintained if soil porosity is not disturbed during rain (Arsyad, 2012). Closed soil pores reduce soil infiltration capacity, whereas soil with stable aggregates will maintain high infiltration capacity. The value of infiltration capacity of 12.5 to

25 cm per hour is considered rapid according to Lee (1980).

The results of this study demonstrated that *A. pintoi* can potentially be used as biomulch in oil palm plantations. *A. pintoi* can increase the rate of soil infiltration so it can reduce the run off and soil erosion rates, as demonstrated in Table 3. Erosion is the main cause of land degradation which can reduce soil fertility, especially on sloping land. The ability of *A. pintoi* in suppressing the rate of erosion and increasing the rate of soil infiltration will optimize nutrient absorption in sloping lands, hence preventing land degradation and creating a more eco-friendly oil palm plantation system.

Conclusion

The growth rate of tendrils of *A. pintoi* (2.47 cm per week) was slower than the growth of other biomulch treatments. The root length of *A. pintoi* (50.36 cm at 20 weeks after planting) was shorter than *P. javanica* but it was not significantly different from *C. pubescens* and *C. mucunoides*. Soil infiltration rate with *A. pintoi* as biomulch was 49.30 cm per hour at 20 weeks after planting, or an increase in soil infiltration rate of by 32.47% compared to that of the natural vegetation. The soil infiltration capacity with *A. pintoi* (14.95 cm per hour at 20 WAP) was lower than *P. javanica*, but it was not significantly different from *C. pubescens* and *C. mucunoides*. The result of this study demonstrated that *A. pintoi* can increase the rate of soil infiltration in sloping land so it can be used as an bio mulch for oil palm plantation.

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