



ROLE OF ALLEY CROPPING SYSTEM WITH CULTIVATED TITHONIA (TITHONIA DIVERSIFOLIA) ON SOIL EROSION AND SOYBEAN (GLYCINE MAX MERR L) PRODUCTION AT ULTISOL UNDER WET TROPICAL AREA

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ABSTRACT

Alley cropping is an alternative way to reduce erosion in cultivated sloping area. Tithonia, as a kind of green manure, can be used as alley fence due to its good growth and high nutrient content. The objective of this research was to study the role of cultivated tithonia as an alley fence in reducing erosion and providing nutrients especially N, P, K for soybean production at sloping area in poor Ultisol under wet tropical region. Tithonia used for this research was derived from cultivated tithonia which were introduced with some types of microorganisms. There were 6 treatments, those were: A= without alley fence, B= Tithonia without microbe reinoculation, C= Tithonia was reinoculated with Mycorrhizae + Azospirillum + Azotobacter, D=Tithonia was reinoculated with Mycorrhizae + phosphate dissolving fungi (PDF), E= Tithonia was reinoculated with micorhyza + phosphate dissolving bacteria (PDB), F=Tithonia was reinoculated with Mycorrhizae+PDF+PDB. Parameters analyzed were soil physical and chemical properties, soil runoff, erosion, as well as plant nutrients within eroded soil. And then, the dry matter and the nutrient (N, P, and K) content of the tithonia were also measured. The data resulted showed that soybean plots having tithonia as the alley fence could significantly reduce soil erosion by 46-

72% and runoff by 8-27% as found at treatment E (*tithonia reinoculate with mycorrhizae+PDF*) compared to that without alley fence. Reinoculated tithonia decreased runoff and soil erosion by 11-21% and 15-48%, respectively compared to tithonia without bioagents. The highest amount of nutrients (N, P, and K) contributed by tithonia were generally found under D (*Tithonia reinoculated with mycorrhizae and PDF*), which was 22,750; 993; 168; and 1,052 kg/ha for dry matter, total-N, -P, and -K, respectively. Soybean yields from the plots supplied with reinoculated tithonia tended to be higher than that without reinnoculation. However, production of soybean was still higher under control plot (100% synthetic fertilizer application) for the 1st planting time.

Keyword: Alley cropping, Erosion, Soybean, *Tithonia diversifolia*, Ultisol, Wet tropical area

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1. INTRODUCTION

Erosion is one of severe problem causing soil degradation, especially under wet tropical areas such as in West Sumatra. Soils in West Sumatra are dominated by problematic soils, one of which is potential for agricultural development is Ultisols. Yulnafatmawita *et al.*, (2013) [23] reported that Ultisol Limau Manis had very high (>65%) clay content, very low (<2%) soil organic matter (SOM) content, and unstable or low soil aggregate stability index (SAS index <50). This soil which is mostly found in sloping areas is very susceptible to degradation if it is opened and cultivated. Soil erosion cannot be avoided if cultivation is conducted for annual crop farming. Amount of soil eroded under corn cultivation in wet tropical area in Limau Manis, Padang Indonesia reached 2.9, 12.0, and 19.0 t/ha/3 months or equals to 5.3, 21.6, and 34.1 t/ha/y respectively for areas having slope 3%, 15%, and 25% [23].

Amount of soil loss from farming activities could be reduced by up to 99% by using conservation practices (Labriere *et al*, 2015) [13]. One effort which could control soil loss due to erosion is by using alley cropping method. Paningbatan *et al* (1995) [14] reported that soil erosion in Philippines markedly reduced from 100-200 t/ha/y into 5 t/ha/y by changing land cultivation from non to alley cropping system. Dixin *et al* (2002) [7] also found that soil erosion decreased from 43.2 t/hm² in traditional farming into 4 t/hm² by using alley cropping in sloping land in Guizhou Province, China. They also noted that alley cropping system could decrease slope gradient by 1.1° each year.

In alley cropping systems, cash crops are cultivated between the fences or hedgerows. There are many types of plants could be used as an alley fence or hedgerows, they are mostly from green manure types of plants such as *Gliricidia sepium* (Wilson, et al., 1986) [19], *Moringa* (Abdullahi et al, 2017) [1], *Leucaena glauca* (Akonde et al, 1996; Ehui et al, 1990) [2, 8], *Cajanus cajan L* (Akonde et al, 1996) [2], *Choerospondias axillaris* (Wei et al, 2007) [18] and even crop trees such as orange, cacao, and others. Hakim and Agustian, 2005 [11] reported that *Tithonia diversifolia* as a type of green manure could be used for alley fence since it could grow well and fast at any place and any circumstance. Furthermore, it can be also trimmed and added to soil either as source of SOM or as plant nutrients. Amelia (2010) [4] had done the same research for the first 2 trims applied for corn. She found that application of tithonia as an organic matter source could improve corn growth and production.

Therefore, tithonia as an alley fence will have double profits, it could provide nutrients for plant growth (Hakim and Agustian, 2004; Yulnafatmawita *et al.*, 2010) [10, 20] and reduce erosion as well (Hakim and Agustian, 2005) [11].

As an alley fence in cultivated sloping areas, tithonia is able to retain or to slow down runoff, and therefore, it increases the chance of the water to infiltrate into soil. Then, suspended soil particles within runoff will be retained by the tithonia plants and then be deposited on the soil surface as well. It means that, the process will be able to reduce erosion risk on the soil. Additionally, organic matter (OM) contributed by tithonia is also able to create and stabilize soil aggregates and improved soil infiltration rate. Organic matter was considered as the best agent to bind soil aggregates (Albiah *et al.*, 2001) [3] as well as to stabilize them (Zhang *et al.*, 2012) [24].

Soils having high SOM content were reported to have higher index of aggregate stability [23]. It was also found that application of several types of green manure was able to improve aggregate stability (AS) of Ultisol. Among the green manure applied, *tithonia* showed the highest increase in aggregate stability (68%) of Ultisols Limau Manis compared to the initial soil sample after a three-month application. Barthes and Roose (2002) [6] confirmed that aggregate stability is a relevant indicator of soil susceptibility to runoff and erosion under intense rainfall area, especially in Mediterranean and tropical areas.

Soil aggregate which is considered as a key determinant for soil quality directly affects other soil properties, such as soil bulk density, total pore, water retention and transmission, as well as soil aeration. Furthermore, it also affects plant growth especially plant root development, water and nutrient uptake. In water transmission phenomenon, soil aggregate indirectly affects runoff and finally soil erosion. Since erosion is the main factor causing soil degradation in wet tropical area, improving soil aggregate stability by using tithonia as an OM source and alley fence means reducing soil degradation and erosion.

As an alley fence, tithonia must grow well and produce a large amount of biomass per unit land area in a short time and should be able to stand for a long time. Therefore, tithonia should be cultivated well in order to get maximum function as a fence for an alley cropping system and also as an organic matter as well as nutrient source for soils in a sloping area. As reported by Abdullahi *et al.* (2017) [1] alley cropping system with soybean as the main crop and moringa as the fence in Nigeria Guinea Savannah increased the soil fertility through organic biomass.

2. MATERIALS & EXPERIMENTAL PROCEDURES

This research was in form of field experiment. It was conducted in Experimental Station Andalas University, Limau Manis Padang, Indonesia. The geographical position of the site is 0°54'29.6"S and 100°27'44.4"E. The location was approximately 275 m above sea level. Mean annual rainfall received in the area was around 5,000 mm with mean annual temperature 26°C. Based on Schmidt and Fergusson (1951) [17], the area belonged to A_f class, very wet tropical area with > 9 months as wet month (rainfall > 100 mm/month). The soil order in the location was classified into Ultisols, advanced weathering soil. The research site had approximately 8% slope.

The experiment was about tithonia utilization and microorganism reinoculation to the tithonia growth for alley fence or hedgerow in an alley cropping system. This experiment consisted of 6 treatments and 3 blocks on which each treatment was randomly allocated within each block or using Randomized Block Design (RBD) from previous research by Amalia, 2010 [4]. The treatments were A= without alley fence, B= Tithonia without reinoculation, C=Tithonia was reinoculated with Mycorrhizae + Azospirillum + Azotobacter, D=Tithonia was reinoculated with Mycorrhizae + phosphate dissolving fungi (PDF), E=

Tithonia was reinoculated with micorrhyzae + phosphate dissolving bacteria (PDB), F=Tithonia was reinoculated with Mycorrhizae + PDB + PDF. Each treatment unit was allocated at a 7.2-m² plot. Tithonia was planted for an area of 20% of the total area in each plot. The tithonia was trimmed twice during the previous research, therefore in this research, two periods of trim conducted became trim III and IV.

Soil as the plant growth medium was tilled to meet favorable condition for plant growth. Plot was designed with 3.6 m x 2 m in size for 18 plots. Each plot was applied a barrier from metal with 30 cm height (15 cm above and 15 cm below the soil surface). At the lower part of the plot was designed a close box (11 cm x 12 cm x 200 cm) in which the one end was connected to a big container to catch runoff and soil eroded.

Tithonia as a kind of green manure was reinoculated and planted as the hedgerow or as a fence at lower end of each plot for the area 1 m x 2 m. Tithonia was trimmed twice (age 2 and 4 months) at previous research and then applied to the soil after being small cut into the alley. At the end of the first research, the biomass of the crop (corn) was also cut and applied to the soil in the alley for soybean cultivation.

Soybean seeds was planted in the plots with 40 x 10 cm row spacing. One seedling was selected 1 week after emergence and was kept until harvest time. Soybean was fertilized with 50% of synthetic fertilizer (N, K), the rest was expected from tithonia and corn biomass contribution, this was based on Hakim et al (2008) [9] founding. While for plots without alley fence, 100% of synthetic fertilizers was applied. Fertilizers applied to soybean were N (Urea), P (SP-36), K (KCl) and Kiserit. The dosage of the fertilizers was 100 kg Urea, 100 kg KCl, 100 kg SP-36, dan 100 kg Kiserit as recommended by Hakim et al (2008) [9]. For plots having alley fence, the N and K were only applied for 50%. All fertilizers were applied at planting time, except N which was applied twice (at planting time and the following 4 weeks). Soybean growth was sprayed by using Dithane M-45, Decis 2.5 EC, Curacron, dan Curater for the pest and disease control. Soybean was harvested at 90 days after planting. The seeds and biomass was dried in oven under 65°C temperature for 48 hours or until they had constant weight. Dry seed weight per plot was calculated for the 14% water content.

$$\text{Seed water content (\%)} = \frac{\text{wet wt} - \text{dry wt}}{\text{dry wt}} \times 100\%$$

$$\text{Seed dry wt at 14\% water content} = \text{Total seed dry wt} * 1.14$$

Parameter analysed at field were crops growth and rainfall during soybean cultivation. Erosion and runoff was measured every rainfall event. Runoff was measured by calculating the total amount of water collected (eg. x L). Erosion was measured from both suspended particles in runoff and sediment collected in the container. Runoff water was sampled for y L, and then analyzed for the suspended particles. Amount of suspended particles was oven-dried and weighed (eg. z g). Total amount of suspended particles (A) = $\frac{x}{y} * z$ (g). Amount of sediment in container was weighed for the total wet weight (a g), and then sampled (b g) to be oven-dried (c g). Total amount of sediment (B) = $\frac{a}{b} * c$(g). Total soil erosion in each plot = A + B g

At laboratory, disturbed soil samples from both experimental plots and eroded soil were air-dried, ground, and sieved using 0.5 mm sieve for analyzing soil chemical properties, especially organic-C (wet oxidation method), total N (digestion method), K-, Ca-, Mg-exchangeable (leaching method), and P-available (Bray II method). Undisturbed soil samples were used to measure soil BD (gravimetric method), void ratio, and total pore. The data collected were statistically analyzed for the variance using F test, and continued using HSD at 5% level of significance if the F-test > F-table.

3. RESULTS AND DISCUSSION

3.1 Rainfall, Runoff, and Erosion

Based on rainfall data collected (Tabel 1), the area of this research, Limau Manis, belongs to wet area since the rainfall >100 mm/month (Mohr classification). Rainfall received in the area during soybean cultivation for 4 months reached 1922 mm. The whole months had potency for runoff, because the amount of rainfall each month was > 200 mm.

Tabel 1 Amount of rainfall during soybean growth (Januari–April 2011) in Limau Manis

Month	Days of rainfall	Rainfall (mm)	Rainfall Intensity (mm/day)	Rainfall (L/plot)
January	11	363	33.00	2,613.6
February	7	292	41.71	2,102.4
March	12	621	51.75	4,471.2
April	21	646	30.76	4,651.2
Total	51	1922		13,838.4

Yulnafatmawita *et al* (2009) [22] reported that the research area received approximately 5000 mm rainfall per year with the wet season was in September until January. In northern part of the area, Bukit Pinang-Pinang received up to 6500 mm annual rainfall (Rasyidin, 1994) [16]. This area is considered as super wet tropical area.

Based on rainfall intensity presented in Table 1, the higher possibility of erosion happened during the 2nd and the 3rd months (February and March) of soybean growth, since the intensity of the rainfall in the months was >36 mm/day. As reported by Yulnafatmawita and Adrinal, 2014 [21] that amount of runoff and soil eroded in Ultisol Limau Manis could not be controlled under soybean growth as the rain intensity >36 mm/day.

Data in Table 2 showed that the highest amount of erosion was 1.40 t/ha or equals to 4.2 t/ha/y. This was approved by Yulnafatmawita and Adrinal (2014) [21] reported that total amount of soil erosion during soybean growth reached 8.25 kg/18 m² plot (=4.58 t/ha) under soybean cultivation at 25% slope in Ultisols Limau Manis. Increasing slope from 3 to 15 and to 25%, increased the amount of runoff by 1.19 and 1.34 times as well as the eroded soil by 2.88 and 4.0 times, respectively during corn growth for 3 months [23]. Therefore, they suggested not to open heavy clayey and low organic carbon (OC) Ultisols for seasonal crop farming during rainy season in wet tropical areas. This amount was quite low compared to predicted ones. As found by Aprisal (2011) [5] that amount of predicted erosion (using USLE method) under dryland farming reached 438 t/ha/y and under village reached 1098 t/ha/y after being conserved.

Table 2. Amount of runoff and soil eroded during soybean growth (Januari–April 2011)

Treatment	Runoff (L/plot)	RO Coef.	Erosion (t/ha)
A =A = without tithonia as the hedgerows	173.55 a	0.13	1.40 a
B = titionia without inoculation	160.42 ab	0.12	0.75 b
C =C = Tithonia + Mycorrhizae + Azoto+ Azospirillum	143.07 ab	0.10	0.64 b
D = Tithonia + Mycorrhizae + PDF	133.50 ab	0.10	0.40 c
E = Tithonia + Mycorrhizae + PDB	126.33 b	0.10	0.39 c
F = Tithonia + Mycorrhizae + JPF + BPF	140.33 ab	0.10	0.57 bc

Note: Data followed by the same letter in a column was not significantly different based on HSD at 5% level of significance.

By using tithonia as the alley fence, the amount of runoff and soil eroded decreased by 8-27% and by 46-72%, respectively compared to without alley fence. It showed that tithonia as a kind of green manure was able to reduce runoff and soil erosion. Therefore, it could be used as a kind of the fence in an alley cropping system. Among the plots having alley fence, tithonia reinoculated with some microorganisms decreased runoff and soil erosion by 11-21% and by 15-48% respectively, compared to tithonia without microorganism reinoculation. It means that, tithonia reinoculated with some microorganisms could grow better and therefore, more roots helping rain water infiltrated into soil profile as well as more stems and leaves giving protection to soil against runoff and erosion.

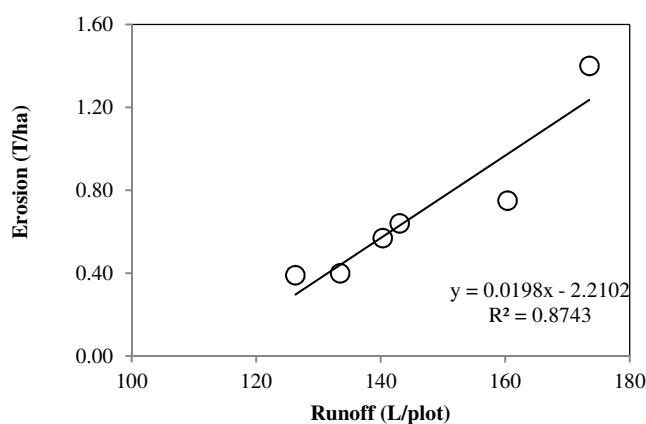


Figure 1 Relationship between runoff and soil erosion

Erosion happened in the research plot was converted into T/Ha. As shown in Figure 1, soil erosion was significantly affected by runoff ($R^2 = 0.8742$). Amount of runoff above 120 L/plot caused soil erosion in Ultisol sloping area under soybean cultivation. Runoff which was originally derived from rainfall has potential energy to erode soil. As reported by Yulnafatmawita *et al* (2013) [23] that amount of soil eroded in Ultisol Limau Manis under corn cultivation was mainly affected by the amount of runoff. It reported that about 83% of soil erosion was due to runoff.

3.2 Dry Matter and Nutrient Contribution of Tithonia

Dry matter (DM) production by tithonia during soybean cultivation as well as the nutrient (N, P, K) contribution was presented in Table 3. The dry matter of tithonia in Table 4 was derived from the 3rd and the 4th trimming time for 4 months. Generally, tithonia reinoculated with microorganisms had higher DM production than that of tithonia without microorganism reinoculation, except tithonia reinoculated with PDB. This was due to the function of the microorganisms in the root zone. The microorganisms help improving nutrients available for plant growth. Tithonia reinoculated with mycorrhizae and PDF (treatment D) showed the best DM production as well as the nutrient (N, P, K) contribution.

Table 3 Dry matter, total, N, P, and K production of tithonia from the 3rd and the 4th trimming time in Ultisols Limau Manis Padang

Treatment	Dry Matter III+IV	Total-N	Total-P	Total-K
	Kg/Ha			
B = Without bio-agent	18,563 b	798 b	146 b	844 b
C = Mycorrhizae + Azotobacter+ Azospirillum	18,938 b	942 a	147 b	851 b
D = Mycorrhizae + PDF	22,750 a	993 a	168 a	1,051 a
E = Mycorrhizae + PDB	23,375 a	778 b	120 c	948 ab
F = Mycorrhizae + PDF+PDB	20,688 b	925 a	115 c	793 b

Note: Data followed by the same letter in a column was not significantly different based on HSD at 5% level of significance.

3.3 Soil Physical Properties

Physical properties of the Ultisol especially bulk density, total pore, and void ratio (Table 4) were not significantly different among the treatments. This could be due to the effect of soil tillage before planting besides the clay dominated soil texture. Compared to sandy soils, clayey textured soils have usually lower soil bulk density, since clayey soils have more total pores dominated by micropores. Then, cultivation

Table 4 Some soil physical properties of Ultisol Limau Manis applied with tithonia

Treatment	BD (Mg/m ³)	Total Pore (%)	Void Ratio (e)
A = Without alley fence	1.07 a	58.02 a	1.49 a
B = Without bio-agent	0.99 a	60.53 a	1.66 a
C = Mycorrhizae + Azotobacter+ Azospirillum	1.05 a	57.95 a	1.52 a
D = Mycorrhizae + PDF	1.03 a	59.26 a	1.57 a
E = Mycorrhizae + PDB	1.05 a	58.81 a	1.54 a
F = Mycorrhizae + PDF+PDB	1.03 a	59.07 a	1.57 a

Note: Data followed by the same letter in a column was not significantly different based on HSD at 5% level of significance.

Also affects soil bulk density. Cultivation improves soil volume under the same mass of soil, therefore, weight of dry soil per unit volume or the bulk density decreases.

On the other hand, decreasing bulk density causes increasing total soil pore, since BD and total pores are inversely related. Yulnafatmawita *et al.* [21, 23] reported that cultivation improves soil macropores filled by air at each unit volume of Ultisol Limau Manis, therefore, the bulk density decreased.

Low bulk density and high total pores due to cultivation and also OM application caused the ability of the soil to infiltrate water better. Compared to OM application, effect of cultivation was more dominant. This was found to be true since the treatment A, without alley fence meaning without OM application, showed that the BD was not significantly different from other treatments applied with OM.

It can be concluded that soil physical properties, especially BD, total pore, and ratio ruang, did not significantly change for a period of soybean-growth. This could be very much due to the effect of tillage at the beginning, while the effect of OM addition did not yet give impact to the soil physical properties which might be caused by a short period of crop growth.

3.4 Soil Chemical Properties

Soil total nitrogen and organic matter content as well as C/N ratio of the soil were presented on Table 5. Among the parameters, OM content of soil under plot without alley fence or hedgerows showed the lowest (107.86 T/ha/20 cm soil depth) and under plot having tithonia reinoculated with mycorrhizae + PDB showed the highest (155.40 T/ha). This was due to the fact that there was no OM addition coming from the tithonia as the hedgerows in treatment A (without alley fence). Tithonia as a green manure contributed to SOM content after being trimmed.

Table 5 Some soil chemical properties of Ultisol Limau Manis applied with tithonia

TREAT	N	OM	C/N	P-avail.	K-exch.	Ca-exch.	Mg-exch.
MENT	T/Ha		Ratio	Kg/Ha			
A	7.70 a	107.86 c	8.14 c	85.90 ab	37.56 c	17.55 b	30.05 a
B	7.33 a	130.09 b	10.32 b	44.33 c	41.70 c	17.42 b	19.96 c
C	8.40 a	152.67 a	10.58 b	68.40 b	54.05 b	23.52 a	24.70 ab
D	5.36 b	146.67 ab	15.92 a	89.98 ab	52.22 b	19.36 b	26.70 ab
E	7.35 a	155.40 a	12.29 ab	76.38 b	60.61 a	20.16 ab	19.15 c
F	5.97 b	146.26 ab	14.24 a	104.15 a	63.47 a	22.25 a	26.94 a

Note: Data followed by the same letter in a column was not significantly different based on HSD at 5% level of significance.

Soil N content before planting time (after incubation) was found significantly lower under treatment Mycorrhizae + PDF (treatment D) and *Mycorrhizae* + PDF + PDB (treatment F) than the other treatments. The N values at both treatments decreased by 36% and 29% compared to treatment B (*Mycorrhizae* + *Azotobacter*+*Azospirillum*) respectively. Low N content at both treatments correlated to the higher C/N ratios. It means that the percentage of soil N content correlated to the quality of the OM in the soil. The soil in the plot contained OM having low N.

The N content under plot without hedgerow as well as with hedgerow without microorganism reinoculation was not significantly different with treatment C. This might be caused by the mineralization of OM residue from the original soil, and since there was no microorganism reinoculation, the N was not immobilized by the added microorganisms.

However, the lowest OM content was found under plot without hedgerow and the highest under Mycorrhizha + PDB. Application of tithonia after trimming the hedgerows increased soil organic matter content by 21%-44% compared to that under plot without hedgerows. Reinoculation of microorganisms to tithonia as the hedgerows improved SOM content by 12-19% compared to plot having tithonia without microorganism reinoculation. It means that, microorganisms reinoculation was able to improve tithonia growth in producing more biomass which finally contributed to higher SOM content.

Furthermore, other nutrients such as P-avalabile, K-, Ca-, and Mg-exchangeable containing in the soil were significantly different among the treatments. Treatment F (Tithonia reinoculated with Mycorrhizae and PDF and PDB) showed the highest nutrient (P, K, Ca, Mg) content among the treatments. Mycorrhizae, association between fungi and plant roots, functions to extend the root surface in absorbing nutrients from soil (Peterson *et al*, 1984) [15]. Phosphate dissolving fungi as well as phosphate dissolving bacteria can improve P-available, therefore it can be uptake by plants (Khan *et al.*, 2009) [12] for their better growth.

3.5 Nutrient Loss through Soil Erosion

Besides crop uptake, nutrients released from soil was also due to erosion. Water erosion commonly happens in West Sumatra as a super wet tropical combined with hilly and mountainous area. As presented in Table 6 that total-N, K-, and Mg-exchangeable loss varied between medium to low. While Ca-exch loss, on the other hand, was very low, and it did not change among the treatments. Among the treatments, application of Mycorrhizae + Azotobacter + Azospirillum showed the least nutrient loss except K-exchangeable loss.

Tabel 6 Amount of nutrients in eroded soil during soybean cultivation

Treatment	Total-N	K-exch	Ca-exch.	Mg-exch
	Kg/Ha			
A = Without alley fence	0.39 a	0.51 b	0.75 b	1.10 b
B = Without bio-agent	0.36 a	0.60 a	0.88 a	1.56 a
C = Mycorrhizae + Azotob.+ Azospir.	0.17 d	0.64 a	0.60 c	0.83 c
D = Mycorrhizae + PDF	0.32 b	0.68 a	0.75 b	0.75 c
E = Mycorrhizae + PDB	0.24 c	0.54 b	0.71 b	1.32 ab
F = Mycorrhizae + PDF+PDB	0.29 b	0.42 b	0.75 b	1.61 a

Note: Data followed by the same letter in a column was not significantly different based on HSD at 5% level of significance.

There was no special trend of nutrient loss from soybean plots in this study. However, plots without alley fence and with alley fence tithonia without microorganism reinoculation tended to loss more nutrients, especially total-N and Ca-exchangeable than the other plots. This was due to more soil eroded (Table 2) containing nutrients from the both plots.

3.6 Soybean Production

Statistically, soybean production as presented in Table 7, either dry biomass or dry seed yield, was significantly different among the treatments. It was showed that the highest soybean biomass and dry seed yield was found under the plot without alley fence. This might be due to the effect of synthetic fertilizer on which the treatment A (without alley fence) got 100% fertilizer from synthetic one which is fast and easily available. Since the soil of the experiment had been used for corn growth and previously applied with tithonia compost, the physical properties of the soil was still good for soybean cultivation. Therefore, soybean growth without OM addition still gave the highest dry seed yield and dry biomass.

Tabel 7 Soybean production as affected by application of cultivated tithonia as an alley fence in Ultisol

Treatment	Dry Seed	Dry Biomass
	(T/Ha)	
A = Without alley fence	0.71 a	1.15 a
B = Without bio-agent	0.15 c	0.72 b
C = Mycorrhizae + Azotobacter+ Azospirillum	0.21 c	0.82 b
D = PDF	0.51 b	0.79 b
E = PDB	0.23 c	0.65 b
F = Mycorrhizae + PDF+PDB	0.30 c	0.82 b

Note: Data followed by the same letter in a column was not significantly different based on HSD at 5% level of significance.

Compared to the description, the soybean yield resulted from this research was still low. This was mainly due to the area of planting was only 80%, the rest was for tithonia cultivation. Furthermore, lower yield could also be affected by the high rainfall during the last two months of the cropping season. The condition of heavy rainfall had caused lower photosynthesis activity besides loss of nutrients for the growth, meaning reducing yield.

4. CONCLUSION

Based on data collected from the field (8% slope) and soil analyses from laboratory, it can be concluded that reinoculation of bacteria and fungi into soil for tithonia growth did significantly increase the amount of soil N, P, K, Ca, and OM contributed to the soil for soybean cultivation, as well as significantly decreased some nutrient (total-N, exchangeable-K and -Mg) lost through soil erosion during soybean cultivation. However, the dry seeds of the soybean were not significantly different each other. Amount of runoff and soil eroded reduced from plots getting OM application derived from alley fences (tithonia) compared to the plot without alley fence. Alley fence from tithonia without microorganism reinoculation could reduce runoff by 13.13 L/plot and eroded soil by 0.47 kg/plot, while from tithonia with reinoculation reduced runoff by 30.48-47.22 L/plot and eroded soil by 0.55-0.73kg/plot compared to RO and eroded soil from the plot without alley fence.

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REFERENCES

- [1] Abdullahi, Ndaginna, I., Anyaegbu, and Ozobia, P. The performance of Soybean using Moringa as alley to improve soil productivity in North-Central Nigeria. *African J. Agric. Res.* 12 (14), 2017, pp. 1182-1189. Doi:10.5897/AJAR2017.12128
- [2] Akonde, T.P., Leihner, D.E., and Steinmuller, N. Alley cropping on an Ultisol in subhumid Benin. Part 1: Long-term effect on maize, cassava and tree productivity. *Agrofor. Systems*, 34 (1), 1996, pp. 1-12. <https://link.springer.com/article/10.1007/BF00129628>
- [3] Albiach, R., Canet R., Pomares, F., and Ingelmo, F. Organic matter component and aggregate stability after the application of different amendments to a horticultural soil. *Bioresource Technol.* 76, 2001, pp. 125-129
- [4] Amelia, K. Utilization of fungi and bacteria on tithonia (*Tithonia diversifolia*) as an alley fence to control erosion at Ultisol under corn cultivation. (In Indonesian *Pemanfaatan Jamur dan Bakteri pada Budidaya Tithonia (Tithonia diversifolia) sebagai pagar lorong untuk mencegah erosi pada Ultisol yang ditanami jagung*). Master Thesis, Graduate Program, Universitas Andalas Padang, 2010, pp. 120
- [5] Aprisal. Erosion and sedimentation prediction on several types of land use in upper sub watershed Masang, Agam Regency. (In Indonesian *Prediksi Erosi Dan Sedimentasi Pada Berbagai Penggunaan Lahan Di Sub Das Masang Bagian Hulu Di Kabupaten Agam*). *J. Solum*, 8 (1), 2011, pp.11-18.
- [6] Barthes, B. and Roose, E. Aggregate stability as an indicator of soil susceptibility to runoff and erosion; validation at several levels. *CATENA*, 47 (2), 2002, pp.133-149.
- [7] M Boughlala, A Laamari, A Abdouni and M Belmekki. Can Payments For Ecosystem Services Reduce Soil Erosion? The Case of Eastern Region of Morocco. *International Journal of Advanced Research in Engineering and Technology*, 6(11), 2015, pp. 18-36.
- [8]

- [9] Dixin, Y., Huabing, T., Qing, Z., Yurong, L., Dengmei, L., and Dachao, L. Research on alley cropping technology on sloping land of Guizhou Province. Proceeding 12th ISCO Conference, Beijing, 2002, pp. 13-18
- [10] Ehui, S.K., Kang, B.T., and Spence, D.S.C. Economic analyses of soil erosion effects in alley cropping, no-till, and bush fallow systems in Southwestern Nigeria. *J. Agric. Systems* 34 (4) 1990 pp. 349-368. [https://doi.org/10.1016/0308-521x\(90\)90013-g](https://doi.org/10.1016/0308-521x(90)90013-g)
- [11] Hakim, N. Utilization of bioagent in cultivating and composting tithonia as an alternative fertilizer and erosion control in Ultisols. (In Indonesian Pemanfaatan Agen Hayati dalam Budidaya dan Pengomposan Tithonia sebagai Pupuk Alternatif dan Pengendali Erosi pada Ultisol). Research Report (Hibah Pasca) Year II. Program Pascasarjana Universitas Andalas. Padang. 2008. 61 p.
- [12] Hakim, N. and Agustian. Tithonia cultivation for horticulture crops at field. (In Indonesian Budidaya tithonia untuk Tanaman Hortikultura di Lapangan). Competitive Research Report (Hibah Bersaing) XI/I Perguruan Tinggi Fakultas Pertanian Universitas Andalas, Padang, 2004, pp 65.
- [13] Hakim, N. and Agustian. Tithonia cultivation and utilization at sustainable horticulture and food crop farming in Ultisols. (In Indonesian Budidaya Tithonia dan Pemanfaatannya dalam Usaha Tani Tanaman Hortikultura dan Tanaman Pangan Secara Berkelanjutan pada Ultisol). Competitive Research Report (Hibah Bersaing) XI/III Perguruan Tinggi, Unand, Padang, 2005, pp.61
- [14] Khan, M.S., Zaidi, A. , Ahemad, M. , Oves, M and Wani, P.A. Plant growth promotion by phosphate solubilizing fungi – current perspective. *J. Archives of Agron. and Soil Sci.* 56 (1), 2010 . <http://dx.doi.org/10.1080/03650340902806469>
- [15] Labrière, N., Locatelli, B., Laumonier, Y., Freycon, V., and Bernoux, M. Soil erosion in the humid tropics: A systematic quantitative review. *Agric. Ecosys. & Environ.* 203, 2015. 127-139. <https://doi.org/10.1016/j.agee.2015.01.027>
- [16] Paningbatan, E.P., Ciesiolka, C.A., Coughlan, K.J. and Rose, C.W. Alley cropping for managing soil erosion of hilly lands in the Philippines. *Soil Tech.* 8 (3), 1995, pp. 193-204. [https://doi.org/10.1016/0933-3630\(95\)00019-4](https://doi.org/10.1016/0933-3630(95)00019-4)
- [17] Peterson RL, Piché Y, Plenchette C. Mycorrhizae and their potential use in the agricultural and forestry industries. *Biotechnol Adv.* 2(1) 1984 pp. 101-20. <https://www.ncbi.nlm.nih.gov/pubmed/14543722>
- [18] Rasyidin, A. The method for measuring rates of weathering and rates of soil formation in watershed. Disertase. Tottory Univ. Japan, 1994, pp. 110
- [19] Ravi Kumar, Akhil Nandu, Dr. S.K. Kumaraswamy, Dr. Uday Krishna Ravella and Dr. Anil Midathda Erosion Wear of Solid Particles in 317 Stainless Steel, *International Journal of Mechanical Engineering and Technology*, 8(7), 2017, pp. 1748–1754.
- [20] Schmidt, F.H. and Fergusson. Rainfall Type based on wet and dry period ratios for Indonesia with western New Guinee. Kementrian Perhubungan Jawatan Metereologi dan Geofisika, Djakarta, Venhandle. No.24. 1951
- [21] B.Somasundaram, N. Jegadeeswaran, Madhu.G and M.R.Ramesh, Erosion Behaviour Of Hvoc Sprayed (Cr3c2-35%Nicer) +5%Si Coatings, *International Journal of Mechanical Engineering and Technology* 8(8), 2017, pp. 1124–1134.
- [22] Wei, L., Zhang, B., and Wang, M. Effects of antecedent soil moisture on runoff and soil erosion in alley cropping systems. *Agric. Water Manag.* 94 (1-3), 2007, pp. 54-62 <https://doi.org/10.1016/j.agwat.2007.08.007>
- [23] Wilson, G.F., Kang, B.T., and Mulongoy, K. Alley copping: Trees as sources of green-manure and mulch in the tropics. *Biol. Agric. Horticulture* 3, 1986, pp. 251-267. <http://www.tandfonline.com/doi/abs/10.1080/01448765.1986.9754474>

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- [24] Yulnafatmawita, Gusnidar, A. Saidi, Adrinal, and Suyoko. 2010. Role of plant green materials in improving soil organic matter and aggregate stability of Ultisol Limau Manis under corn (*Zea mays L*) cultivation. (In Indonesian "Peranan Bahan Hijauan Tanaman dalam Peningkatan Bahan Organik dan Stabilitas Agregat Tanah Ultisol Limau Manis yang Ditanami Jagung (*Zea mays*). *Solum J.* 7 (1), 2010, pp.37-48
- [25] Yulnafatmawita and Adrinal. Physical characteristics of Ultisols and the impact on soil loss during soybean (*Glycine max merr*) cultivation in a wet tropical area. *Agrivita J.A.S.* 36 (1), 2014, pp. 57-64. DOI: <http://doi.org/10.17503/agrivita.v36i1.350>
- [26] Yulnafatmawita, Asmar, dan R. Enrella. Laboratory measurement of soil infiltration in Bukit Pinang-Pinang, area of tropical rainforest Gadut mount Padang. (In Indonesia Pengukuran Infiltrasi Tanah Bukit Pinang-Pinang Kawasan Hutan Hujan Tropik Gunung Gadut Padang Di Laboratorium). *J. Solum* 6 (2), 2009, pp.78-86
- [27] Yulnafatmawita, S. F. Nasution and Adrinal. Dynamics of soil physical properties, erosion, and nutrient loss during corn growth under wet tropical area. *Proceeding ESAFS 11th BOGOR.* 2013.
- [28] Zhang S., QLi, X Zhang, K Wei, L Chen, and W Liang. Effects of conservation tillage on soil aggregation and aggregate binding agents in Black soil of Northeast China. *Soil Till. Res.* 124, 2012, pp. 196-202. <https://doi.org/10.1016/j.still.2012.06.007>