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SOIL LOSS AND CASSAVA YIELD UNDER RIDGE TILLAGE IN HUMID TROPICAL CLIMATE OF SUMATERA, INDONESIA

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ABSTRACT: Erosion is one of problem threatens the soil resource caused soil degradation. Applying the ridges system and organic fertilizer contributes to suppressing runoff and erosion. This study aims to determine the effect of applying different ridges system and the organic fertilizer on the runoff, soil erosion, nutrients loss of soil, nutrient enrichment ratio, starch content, growth, and yield of cassava on 12.5% slope land. The research was conducted at the field experiment, University of Lampung, under a humid tropical climate. This study used a Randomized Complete Block Design, which was arranged factorially with two factors, ridges system and organic fertilizer (organonitrofos) and four replications. Factor one is consists of G1 (ridges in the same direction with the slope) and G2 (ridges in the opposite direction with the slope), while factor two is consists of P0 (Organonitrofos 0 tons/ha) and P1 (Orgononitrofos 20 tons/ha). The results showed that the application of the ridges in the opposite direction with the slope significantly reduces the runoff 42.63%, soil erosion 61.68%, and suppress nutrient loss of N-total by 61.85%, P-available by 57.92%, K-total by 80.41% and C-organic by 61.22%, compared to ridges in the same direction with the slope. However, ridges systems do not give a significant difference to starch content, growth, and cassava yield. Physical obstacles formed by ridges in the opposite direction with the slope will force water to infiltrate into the soil so that the runoff rate, erosion, and nutrients loss can be reduced significantly. In reverse, the organic fertilizers do not affect all variables. The ridges system and the organic fertilizer did not significantly affect the starch content, growth, and yield of cassava. That caused by the application of synthetic fertilizers at the same dose (standard dose for planting cassava) in each experimental unit that fertilizer already enough to grow optimally.

Keywords: Cassava growth, Erosion, Organic fertilizer, Ridges System, Runoff, Soil nutrient loss.

1. INTRODUCTION

Indonesia is of the largest producer of cassava tuber in the world after Nigeria, and the highest production is in Lampung Province, with total production reached 7387084 tons in 2015 [1]. Cassava (*Manihot esculenta Crantz*) is one of the major crops in terms of staple food, raw starch production, and feed for animals in the tropics [2,3]. The advantage of planting cassava is they can produce high yield under low fertility and water stress conditions, however planting cassava in the hills/slope area, and dryland has high risk due to the erosion process [2,4]

Soil erosion is one of the main problems that threaten the soil resource on a global scale [5]. Moving or transporting soil or parts of land from one place to another place by natural media is call erosion [6]. The continuous use of soil in a tropical area without considering the conservation practice will reduce soil productivity and sustainability, also promote the occurrence of erosion [7]. In nature, there are two leading causes of erosion process; there are wind and water. In wet tropical climate regions such as Indonesia, water is a significant cause of erosion [6]. The erosion process was strongly influenced by the length of the slope and slope gradient. However, the slope gradient gives more impact compared with the length of the slope [6,7].

In the use of sloping lands, erosion is often a problem. The steeper the slope, the more erosion that occurs. Therefore, soil conservation is needed to overcome these problems by doing soil cultivation and planting over the ridges [7].

In the semi-arid regions, to control wind erosion, the ridge tillage was often used as an alternative practice [8]. Contour ridge tillage has been used worldwide because of its many advantages, such as improving soil physic conditions [9,10,11,12] protecting soil from erosion and nutrient loss [13,14,15,16]. Contour ridge systems were the most effective tillage systems are widely used on sloping land in northern China [17].

In the case of cassava, the cassava can produce high production under unfertile soil; however, soil conservation is still needed to support land sustainability. One conservation strategy is increasing the soil organic by adding the organic matter/ organic fertilizer [18].

The addition of organic fertilizer can improve soil structure so the soil is more resistant to damage due to blows of rain so it can reduce erosion. Besides, fertilization provides additional nutrients for plants, so those nutrient requirements during growth can be fulfilled [17]. One type of organic fertilizer that can provide sufficiently high N and P nutrients is organonitrofos fertilizer. Organonitrofos fertilizer is one form of organic fertilizer from 70-80 % cow dung and 20-30 % Rock phosphate, with the addition of N fixating microbes and solvent P [20].

Soil erosion overcome using ridge tillage and crop production from the viewpoint of nutritional balance for sustainability in upland cropping systems are needed to be evaluated. Because still few a research about the ridge system under cassava cultivation to decrease the risk of soil erosion and soil nutrient loss.

2. MATERIALS AND METHODS

2.1 Study Area

The study site is Integrated Field Laboratory, and Soil Science Laboratory at the University of Lampung (105°14´E and 05°22´S), which is located in Bandar Lampung City, Lampung Province, Indonesia, with elevation 498 m.a.s.l. The research was conducted from December 2017 to May 2018.

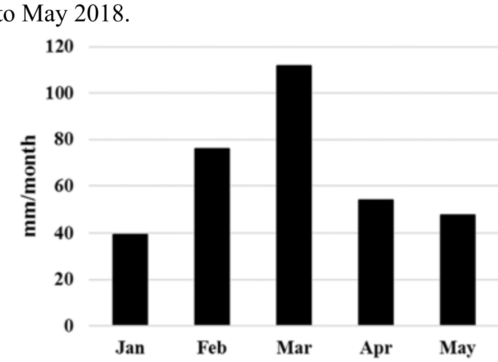

Fig 1. Rainfall during experiment in the site study

The climate type in Lampung Province is monsoonal type with high precipitation occur in November –March [21]

2.2 Nutrients, C-Organic, and Starch Content Analysis

N total analized by Kjehdahl distillation method, available P by Bray-1 method, exchange K (NH 4 OAc 1 N), c-organic (Walkey & Method Black), Fresh cassava starch content by the AOAC Method

2.3 Experimental Design and Data Analysis

This study used a Randomized Complete Block Design (RCBD) which was arranged factorials with two factors, ridges and organic fertilizer (organonitrofos) applied to 4 groups. The ridges factor consists of G1 (ridges in the same direction with the slope) and G2 (ridges in the opposite direction with the slope), while the organic fertilizer factor consists of P0 (Organonitrofos 0 tons/ha) and P1 (Orgononitrofos 20 t/ha). There are 4 combinations are obtained treatment, i.e. as the following:

1. Ridges in the same direction with the slope + Organonitrofos fertilizer 0 ton/ha (G1P0)
2. Ridges in the same direction with the slope + Organonitrofos fertilizer 20 ton/ha (G1P1)
3. Ridges in the opposite direction with the slope + Organonitrofos fertilizer 0 ton/ha (G2P0)
4. Ridges in the opposite direction with the slope + Organonitrofos fertilizer 20 ton/ha (G2P1)

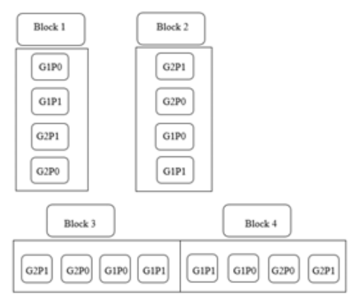

Fig 2. Erosion layout and treatment in the field

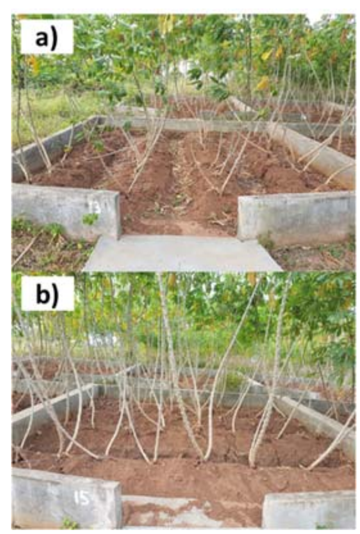

Fig 3. The ridges system with(a) and without (b) following direction with the slope

In this study four repetitions were performed for each treatment so that 16 experimental units were obtained, where each experimental unit was placed on 12.5 % slope erosion plot with 4 m x 4 m wide. All the data collected from the four replications were subjected to an analysis of variance (ANOVA, Mean comparison by LSD test on 5% alpha. The layout of erosion plots in the field can be seen in Figure 2.

3. RESULTS AND DISCUSSIONS

3.1 Runoff and Erosion

The results of statistical tests showed that the treatment of ridges affected surface flow and erosion. The mean comparison of treatments is presented in Table 1

Table 1 Mean comparison between ridges and organic fertilizer treatments on runoff (mm) and erosion (t/ha).

Treatment	Runoff (mm)	Erosion (t / ha)
G1	258.40 a	55.96 a
G2	148.23 b	21.44 b
P0	208.03 a	40.90 a
P1	198.60 a	36.50 a
LSD 5%	73.57	33.17

Note: The numbers followed by the same letters are not different at the 5% level according to the LSD Test, G1: Ridges in the same direction with the slope, G2: Ridges in the opposite direction with the slope, P0: Organonitrofos fertilizer 0 tons/ha, P1: Organonitrofos fertilizer 20 tons/ha

Table 1 shows that the ridges in the same direction with the slope treatment have higher runoff and erosion rates compared to the ridges in the opposite direction with the slope. Lands with a ridges opposite direction with the slope can reduce surface runoff as much as 110.17 mm (42.63%) when compared to ridges in the same direction with the slope. The ridges in the opposite direction with the slope treatment also decrease erosion significantly 34.52 t / ha (61.68%) compared to ridges in the same direction with the slope. Adding the Organonitrofos can decrease the surface runoff and erosion rate in lands with a ridges opposite direction with the slope, however, based on statistical analysis not significantly different.

3.2 Nutrient and C-organic Loss

Nutrients and C-organic loss from the surface of the soil is one of the main consequences of erosion. By erosion, the topsoil, which contains a lot of nutrients and organic material, will be transported, so that some nutrients are also transported to another place. The mean comparison of treatments is presented in table 2.

Table 2 shows that the ridges treatment influences the loss of N, P, K, and C-organic elements from the soil. The use of ridges in the opposite direction with the slope can reduce the loss of N elements around 33.28 kg/ha (61.85%), P elements 0.95 kg/ha (57.92%), K elements 5.5 kg/ha (80.41%) and C- Organic 363.34 kg/ha (61.22%).

Table 2. Mean comparison between treatments on nutrient and c- organic loss

Treatment	Nutrient			C-org (kg/ha)
	N-total (kg / ha)	P Avail (kg / ha)	K (kg / ha)	
G1	55.43 a	1.64 a	6.84 a	593.53 a
G2	22.15 b	0.69 b	1.34 b	230.19 b
P0	39.99 a	1.26 a	5.32 a	419.21 a
P1	37.59 a	1.07 a	4.66 a	404.51 a
LSD 5%	32.82	0.88	4.04	363.3

The loss of N, P, K, and C-organic elements from the ridges in the same direction with the slope was significantly different from ridges in the opposite direction with the slope. The use of organonitrofos fertilizers has a small impact on decreasing nutrient loss and not significantly different.

Nutrient enrichment ratio is the ratio between nutrient on eroded soil (Table 3) and uneroded (Table 4) soil. All treatments did not affect all nutrient enrichment ratio lost through erosion of the soil, except for ridges treatment that gives a difference in the available P ratio, the mean comparison of treatments is presented in Table 5.

Table 3. Nutrient composition of eroded soil

Treat ment	N-Total (%)	P-avail (ppm)	Ex-K (me/100g)	C-Org (%)
G1P0	0.175 (±0.04)	47.09 (±16.14)	0.545 (±0.05)	1.705 (±0.21)
G1P1	0.1775 (±0.02)	52.48 (±6.20)	0.55 (±0.03)	1.89 (±0.27)
G2P0	0.1925 (±0.018)	62.44 (±19.26)	0.6575 (±0.04)	1.9575 (±0.18)
G2P1	0.1775 (±0.02)	47.55 (±1.85)	0.675 (±0.08)	1.76 (±0.27)

Note: G1: Ridges in the same direction with the slope, G2: Ridges in the opposite direction with the slope, P0: Organonitrofos fertilizer 0 tons/ha, P1: Organonitrofos fertilizer 20 tons/ha

Table 4. Nutrient composition of uneroded soil

Treatment	N-Tot (%)	P-Avail (ppm)	Ex-K (me/100g)	C-Orgc (%)

G1P0	0.15 (±0.02)	60.52 (±10.69)	0.39 (±0.08)	1.285 (±0.13)
G1P1	0.15 (±0)	64.72 (±12.29)	0.375 (±0.05)	1.31 (0.08)
G2P0	0.14 (±0.01)	46.28 (±6.45)	0.425 (±0.12)	1.32 (0.10)
G2P1	0.15 (±0.01)	49.33 (±3.87)	0.415 (±0.07)	1.3825 (0.29)

Note: G1: Ridges in the same direction with the slope, G2: Ridges in the opposite direction with the slope, P0: Organonitrofos fertilizer 0 tons/ha, P1: Organonitrofos fertilizer 20 tons/ha

Table 5. Mean comparison between ridges and organic fertilizer treatments on enrichment ratio

Treatment	N-Total (%)	available P (ppm)	Ex-K (me/100g)	C-Organic (%)
G1	1.15 a	0.8 b	1.47 a	1.39 a
G2	1.28 a	1.19 a	1.64 a	1.40 a
LSD 5%	0.27	0.43	0.43	0.3
P0	1.25 a	1.09 a	1.55 a	1.41 a
P1	1.18 a	0.90 a	1.56 a	1.37 a
LSD 5%	0.27	0.43	0.43	0.3

Note: The numbers followed by the same letters are not different at the 5% level according to the LSD Test, G1: Ridges in the same direction with the slope, G2: Ridges in the opposite direction with the slope, P0: Organonitrofos fertilizer 0 tons/ha, P1: Organonitrofos fertilizer 20 tons/ha

The nutrient composition in eroded soil and uneroded soil quite similar for all variable except available of P (Table 3,4). And same pattern on enrichment ratio (Table 5).

3.3 Growth and Yield

The growth and yield variables of cassava plants that were measured and analyzed included variable plant height (m), stem diameter (cm), plant weight (ton/ha), and yield (ton/ha). Based on the results of statistical analysis, all growth parameters and yield were not affected by treatments, the mean comparison of treatments is presented in Table 6.

Table 6. Mean comparison between ridges and organic fertilizer treatments on plant height, stem diameter, plant weight, and yield.

Treatment	Plant Height (m)	Stem Diameter (cm)	Plant Weight (t / ha)	yield (t/ ha)
G1	2.16 a	1.97 a	20.79 a	23.87 a
G2	2.30 a	2.09 a	22.54 a	24.32 a
LSD 5%	0.18	0.24	4.12	4.88
P0	2,18 a	1.98 a	20.52 a	22.83 a
P1	2.29 a	2.08 a	22.80 a	25.36 a
LSD 5%	0.18	0.24	4.12	4.88

Note: The numbers followed by the same letters are not different at the 5% level according to the LSD Test, G1: Ridges in the same direction with the slope, G2: Ridges in the opposite direction with the slope, P0: Organonitrofos fertilizer 0 tons/ha, P1: Organonitrofos fertilizer 20 tons/ha

Based on Table 6. The yield produced ranged from 22.36 t/ha to 25.32 t/ha.

3.1.4 Carbon Stock and Starch Content

Carbon stock is one indicator of plant growth that is measured to determine the metabolic results of plants to the treatment that has been given. The starch content was also measured to see if the treatment of organic fertilizer can provide more cassava starch produced. Statistical analysis shows that carbon stock and cassava starch content did not differ between treatments; the mean comparison of treatments is presented in Table 7.

Table 7. Mean comparison between ridges and organic fertilizer treatments on carbon stock and starch content

Treatment	Carbon stock (%)	Starch content (%)
G1	48.77 a	35.20 a
G2	48.71 a	37.02 a
LSD 5%	1.63	6.32
P0	48.68 a	36.18 a
P1	48.81 a	36.05 a
LSD 5%	1.63	6.32

The runoff and erosion in opposite ridges of slope significantly lower compared to ridges in the same direction with the slope. Those are because the opposite ridges to slope will hold the surface flowing when there is rain in each ridge. Moreover, then the water will infiltrate to the soil. Compared to ridges in the following direction with the slope, the surface flow will smooth flow in the soil surface because of no holding agent due to the direction of the ridges following the slope. Sutrisno and Haryono [22] Reported, that planting peanut crop on ridges in the opposite direction of the slope in Suka Resmi Village, Cianjur, significantly reduce runoff.

The retention of surface runoff by a ridge causes many opportunities to seep into the soil so that the surface flow decreases so that the speed will be significantly reduced. Experiments conducted on 5% slope in Lampung, Indonesia, indicate that erosion losses measured under cassava depended greatly on its spacing. When planted in a 1-meter square arrangement, erosion losses of cassava were similar to those of peanut and slightly higher than those measured under upland rice or maize. However, when grown in widely-spaced or double rows, erosion losses in cassava were significantly higher than those of other crops tested [23]. Planting potatoes on the ridge in the opposite direction with the slope can reduce erosion to 81, 21%, ridge in the opposite direction with the slope can also significantly inhibit the loss of N, P and C-Organic nutrients compared to the slope in the direction of the slope [24]. That is because the loss of nutrients and organic matter is directly related to the amount of erosion and the concentration of nutrients and organic matter in the sediment.

While the planting of cassava has risk in more erosion than of other crops. Howeler [23], explains that erosion can be significantly reduced by minimum tillage, contour ridging, closer plant spacing, adequate fertilization, mulching, intercropping, and the planting of contour barriers like vetiver grass Vetiveria zizanioides. The cultivation of cassava on ridging across the slope was found to be the most effective in reducing soil loss.

Organic fertilizers (organonitrofos) do not affect the rate of runoff and erosion, nutrient loss, and the growth of cassava. Organonitrofos organic fertilizer mainly consists of 70-80% of cow dung and 20-30% rock phosphate[20]. Indonesia is one of the countries included in a tropical monsoon climate with average annual rainfall ranging between 2,500 and 3,000 mm. The mean day time and night time air temperatures are 32ºC and 22ºC, respectively, with mean annual relative humidity between 80% and 90%. High air temperature and high solar radiation intensity in tropical countries cause high evaporation as they strongly correlate with each other such as a rapid decomposition process [25]. In the term of organic matter cow dung is one of easy to decomposition [26]. The reason organonitrofos not influence soil erosion, runoff, or nutrition loss is because organonitrofos already finish (disappear) in the soil due to the high decomposition rate in Indonesia.

The addition of organonitrofos organic fertilizer also cannot significantly increase plant growth and yield. Those are because of nutrients before adding organonitrofos is enough to growth optimally because cassava can produce high yield under low fertility and water stress conditions. Moreover, organonitrofos may already disappear in the soil after decomposition and only influence on the initial stage of the plant. The yield reaches around 20-25 tons/ha.The other research in India from 1983-1986 cassava yield were 25.07 t/ha [27], while some genotypes tested by Noerwijati [28], in Indonesia produced cassava yield are UJ5 (25.22 t/ha), Malang 6 (32.58 t/ha), Malang 4 (37.79 t/ha), CMM 03025-43 (26.91 t/ha), CMM 03036-7 (31.52 t/ha), CMM 03036-5 (29.93 t/ha), CMM 03038-7 (37.52 t/ha), CMM 03094-12 (24.40 t/ha), CMM 03094-4 (34.55 t/ha), CMM 03095-5 (23.95 t/ha), CMM 02040-1 (28.13 t/ha), CMM 02033-1 (29.49 t/ha), CMM 02035-3 (24.16 t/ha), and CMM 02048-6 (26.69 t/ha). That means the production of cassava in this research is in the range of the optimum production and reveals with adding the organonitrofos not give impact plant growth and production.

5 CONCLUSIONS

The application of the ridges in the opposite direction with the slope significantly reduces the amount of runoff 42.63%, soil erosion 61.68%, and suppress nutrient loss of N-total by 61.85%, P-available by 57.92%, K-total by 80.41% and C-organic by 61.22%, compared to ridges in the same direction with the slope. However, the ridges system does not give a significant difference to starch content, growth, and cassava yield. In reverse, the organic fertilizers do not affect all variables. The ridges system and the organic fertilizer did not significantly affect the starch content, growth, and yield of cassava. That caused by applying synthetic fertilizers at the same dose (standard dose for planting cassava) in each experimental unit that fertilizer already enough to grow optimally. Organic fertilizers (organonitrofos) do not affect the rate of runoff and erosion, nutrient loss, and the growth of cassava due to the material of organonitrofos is labile organic matter fraction and rapidly to decompose because of climatic condition in Indonesia.

6 ACKNOWLEDGMENTS

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