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EFFECT OF COASTAL SEDIMENT TO NUTRIENT AVAILABILITY AND MAIZE PRODUCTIVITY ON ENTISOLS

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ABSTRACT

Entisols had a great potential for maize planting area expansion in increasing its production. The low soil fertility could be improved by application of coastal sediment. This current research examined the effect of different amount of coastal sediment on nutrient availability and maize production on Entisols, West Kalimantan. The research was conducted from July to November, 2013 in green house, Faculty of Agriculture, Tanjungpura University, West Kalimantan. The treatment conducted was the application of coastal sediment at dosage of: 0 Mg ha^{-1} (L_0), 14 Mg ha^{-1} (L_1), 28 Mg ha^{-1} (L_2), 42 Mg ha^{-1} (L_3), 56 Mg ha^{-1} (L_4), 72 ton ha^{-1} (L_5), 86 Mg ha^{-1} (L_6) and 100 Mg ha^{-1} (L_7). The treatments were arranged by completely randomized design with 3 replications. Research results showed that 42 Mg ha^{-1} coastal sediment was the best treatment and able to increase soil nutrients availability and maize productivity. The provision of coastal sediment increased the availability of K, Ca, Mg and Na, also the availability of nutrients in accordance with the increase of the dosage of coastal sediment.

Keywords: coastal sediment; entisols; maize; nutrient availability; West Kalimantan

INTRODUCTION

Maize (*Zea mays* L.) was the third most important cereal crop in the world after rice and wheat (Kage *et al.,* 2013). It was one of the globe's most widely used cereal crops, which was not only as an important food crop for human, but also as a basic ingredient of feed and raw material for manufacturing of many industrial products (Orhun, 2013; Reddy *et al.,* 2013), and biofuel as well.(Koçar and Civaş, 2013).

According to Haryono (2012), In Indonesia, targeted maize production was 29,000,000 ton in 2014 and in order to achieve a sufficient amount of maize production, the area of production had to be expanded approximately to 4,999,000 ha and in line with that, the productivity had to be increased to 5.82 t ha^{-1}.

Maize production in Indonesia could be increased by both intensifying cultivation practices and expansion of cultivable area (Lalu *et al.,* 2012). One type of soil that could be used for the expansion of maize planting area in West Kalimantan province was alluvial soil which covered 2 million hectares or 10.29 percent (CBCI, 2011). In the Soil Taxonomy classification, alluvial soil groups were included in order of entisols (CRDALR, 2006).

Entisols were formed from various materials deposited at flat to nearly flat slope by fluvial and/or colluvial processes, through water flow and gravity force. The processes led to variation in physical, chemical, and mineralogical properties, as well as nutrient accumulation (Brubaker *et al.,* 1993). Entisols with the parent material of alluvial scattered at along the river side and sea-shores (Temenggung *et al.,* 2009). These soils had properties that were less conducive to growth and crop production because it had low nutrient availability, acidic and high Al solubility (Syamsuddin *et al.,* 2013). According to Hikmatullah and Jabri (2007), the soil CEC and exchangeable K were low.

One effort to improve fertility and productivity of Entisols was by adding ameliorants which was easily be obtained, and relatively available and relatively cheap in this area (Sulistyowati and Suswati, 2010). Application of coastal sediment could improve soil productivity and fertility because it could increase pH and added nutrients to the soil simultaneously (Suswati, 2012). The purpose of this study was to determine the effect

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of coastal sediment as ameliorant on nutrient availability and maize productivity in Entisols of West Kalimantan.

MATERIALS AND METHODS

The research was conducted at green house, Faculty of Agriculture, Tanjungpura University, West Kalimantan, from July to November 2013. Entisols surface soil samples (0 – 40 cm) were collected from Sungai Rengas Village in Sungai Kakap Subdistrict, Kubu Ray District; West Kalimantan Province. Coastal sediments were obtained from Kijing beach, West Kalimantan. Fertilizers required for maize were urea, SP-36, KCl, and applied based on calculation of soil analysis results and recommendations of N, P, and K to maize plants. The Pioner 21 hybrid variety of maize seed was used in this experiment.

The experiment in greenhouse was conducted by using completely randomized design, with triplicates (Gomez and Gomez, 1984). The treatment consisted of 8 levels, namely L_0: Control (without coastal sediment), L_1: coastal sediment of 14 Mg ha^{-1} ≈ 70 g $polybag^{-1}$, L_2: coastal sediment of 28 Mg ha^{-1} ≈ 140 g $polybag^{-1}$, L_3: coastal sediment of 42 Mg ha^{-1} ≈ 210 g $polybag^{-1}$, L_4: coastal sediment of 56 Mg ha^{-1} ≈ 280 g $polybag^{-1}$, L_5: coastal sediment of 72 Mg ha^{-1} ≈ 350 g $polybag^{-1}$, L_6: coastal sediment of 86 Mg ha^{-1} ≈ 420 g $polybag^{-1}$ and L_7: coastal sediment of 100 Mg ha^{-1} ≈ 490 g $polybag^{-1}$.

Pots were filled as much as 10 kg of Entisol soil, which were firstly mixed with urea, SP-36, KCl as basal fertilizer and appropriate level of coastal sediment treatments. After one week, soil samples for selected soil chemical properties were taken at depths of 0-10 cm at every pot, prior to maize planting time. In each pot, 2 seeds were sown at a depth of 2 cm, followed by reduction to one plants after 10 days. Each pot was watered twice a day with 200 ml of water for a period of 60 days (harvest). Every 5 days, the weight of the pots was checked and adjusted with water in relation to the initiate of experiment. Maize grains were harvested at best physiological maturity from each pot and dry grains of maize in each plot that were extrapolated to a hectare basis using plant populations to determine maize productivity.

Selected physical and chemical properties of soil and ameliorant were determined using standard procedures. The coastal sediments texture was carried out using the International Pipette method (Sarkar and Haldar, 2005). The ameliorant pH determined in soil:water was (1:2.5). Distilled water suspension and KCl were used a glass of electrode. The content of organic carbon was determined using Walkley and Black method. Ameliorant cation exchange capacity (CEC) was determined by leaching 1 M ammonium acetate buffer adjusted to pH 7.0 followed by steam distillation (Pansu and Gautheyrou, 2006). Available phosphorus in ameliorant was extracted with $NaHCO_3$ (0.5 M) at pH 8.5 and colorimetrically determined after treated with ammonium molybdate and stannous chloride at a wavelength of 660 nm. The exchangeable base cations (K, Ca, Mg and Na) were extracted with 1.0 mol L^{-1} ammonium acetate (Pansu and Gautheyrou, 2006). After extraction, the cations were measured using atomic absorption spectrophotometry.

The data obtained were subjected to a two way analysis of variance (ANOVA) followed by a Duncan Multiple Range Test (DMRT) at 5% level and some data were correlated. The data were analyzed using the Statistical Analysis System package (SAS Institute, 2003).

RESULTS AND DISCUSSION

The Characteristic of Entisols and Coastal Sediment

Based on the standards of determining soil chemical properties (ISRI, 2005), the soil had acidic soil (pH 4.89). According to Tuyen *et al.* (2006), entisols soil had low pH value because entisols property was rich of SiO_2 and Al_2O_3. When silts deposited, the process of leaching of Ca, Mg and accumulating SiO_2, Al, Fe happened; therefore, soil pH was low. Organic-C (4.43%) was high, whereas total N content (0.39%) was medium (Table 1). Organic matter was an important source of nutrients for plants, strong activities of microorganism and soil absorption ability (Nath, 2014). The medium content of total nitrogen could be accounted by the high organic matter content of soil which supplied about 75-85% of soil organic nitrogen (Grubinger, 2007).

Table 1 showed that the content of available P was high (28.11 ppm), while the potential K was low (0.19 cmol(+)kg^{-1}). CEC value was medium (17.21 cmol(+)kg^{-1}) but bases saturation (BS) was very low (6.68%). The very low BS showed low basic cation availability, i.e. K, Ca, Mg and Na, this could be as a result of high average rainfall ranges from 2,500 to 4,500 mm per year which leaching those nutrients (Lusiana *et al*., 2008; Laird *et al*., 2010). It might inhibit equilibrium of nutrients, especially K, Ca and Mg in soil.

Table 1. The properties of the initial Entisols and coastal sediment

Soil properties	Entisols	Coastal sediment
Texture		
Sand (%)	2.40	10.20
Silt (%)	52.04	51.85
Clay (%)	45.56	37.95
pH	4.89	8.13
C-organik (%)	4.43	1.96
N-total (%)	0.39	7.26
Available P (ppm)	28.11	3.45
Cations		
Exch. K (cmol(+)kg^{-1})	0.19	1.71
Exch. Ca (cmol(+)kg^{-1})	0.52	14.62
Exch. Mg (cmol(+)kg^{-1})	0.16	1.73
Exch. Na (cmol(+)kg^{-1})	0.28	2.65
CEC (cmol(+)kg^{-1})	17.21	15.33
Base Saturated (%)	6.68	>100
Exch. Al (cmol(+)kg^{-1})	0.36	-

Coastal sediment samples were analyzed for chemical properties. Coastal sediment had very high base saturation (>100%) and consisted of 10.20% sand, 51.85% silt and 37.95% clay (silty clay loam texture). It had very low available P and potential K with 3.45 mg P_2O_5 kg^{-1} and 1.71 mg K_2O kg^{-1}, respectively. The addition of coastal sediment on entisols might raise soil pH due to neutralization reaction of H^+ ions from Entisols by OH^- ions from coastal sediment. Coastal sediment also contained high alkaline cations, which decreased CEC, increased BS and availability of cations Ca^{2+}, Mg^{2+}, Na^+ and K^+ (Suswati, 2009).

The Effect of Coastal Sediment to the Availability of Nutrients in Entisols

The availability of base cations in the entisols due to the provision of coastal sediment was measured using indicators of soil pH, K, Ca, Mg and Na available (Table 2). The results of variance analysis showed that after incubation coastal sediment treatments significantly affected soil pH after incubation. Table 2 showed that addition of coastal sediment 14 Mg ha^{-1} in the Entisols had been able to increase the pH of the soil after incubation compared to control. Soil reaction (pH) increased significantly with the addition of coastal sediment 14 Mg ha^{-1} - 100 Mg ha^{-1}. This was due to the coastal sediment containing alkaline cations, so the higher the addition of coastal sediment the soil pH would increase. This was due to the added ameliorant containing alkaline cations that could increase soil pH. Sabiham (1993) explained that the addition of coastal sediment to peat soil can raise the pH, due to neutralized reaction of ion H^+ from peat by ions OH^- of base cations contained on the coastal sediments.

Tabel 2. The effect of application coastal sediment to available nutrients after incubation

Coastal sediment (Mg ha^{-1})	Soil pH	Available K	Available Ca	Available Mg	Available Na
		cmol(+)kg^{-1}			
L_0 (control)	4.54 f	0.77 d	4.22 g	1.14 h	0.39 g
L_1 14	4.70 e	0.85 c	5.34 f	1.39 g	0.81 f
L_2 28	4.70 e	0.87 bc	6.46 e	1.61 f	1.07 e
L_3 42	4.82 d	0.89 ab	7.50 d	1.76 e	1.35 d
L_4 56	4.83 d	0.90 a	9.36 c	2.07 d	1.63 c
L_5 72	4.88 c	0.90 a	10.52 b	2.21 c	1.79 b
L_6 86	4.96 b	0.90 a	12.32 a	2.60 b	2.03 a
L_7 100	5.06 a	0.91 a	12.26 a	2.49 a	2.05 a

Remarks: Values followed by the same letter in the column and the same treatment groups did not differ by Duncan's test 5%.

Application of coastal sediment significantly affected K soil availability after incubation. The provisions of coastal sediment of 14 Mg ha^{-1} in the Entisols soil could increase K soil availability compared to control (Table 2). Provision of coastal sediment of 42 Mg ha^{-1} could still increase K soil availability significantly, but there was no difference than provision of coastal sediment at a higher dosage of up to a dosage of 100 Mg ha^{-1}. This was due to coastal sediment containing K, so that when it was added to the soil it could increase K soil availability. Besides of the coastal sediment as a K source nutrients, a high proportion of clay mineral at coastal sediment gave a great potential to soil K availability. Soil containing montmorillonite or mica had greater K availability than kaolinite (Havlin *et al.,* 2005).

The results of variance analysis of Ca soil availability after incubation showed that coastal sediment treatments significantly affected Ca soil availability. Table 2 showed that the application of coastal sediment of 14 Mg ha^{-1} could increase Ca availability compared to control and there was a difference with the addition of coastal sediment until the dosage of 86 Mg ha^{-1}. This was due to the coastal sediment containing high Ca, higher than the content of other base cations (K, Mg and Na), so it could act as a source of Ca. In addition, the coastal sediment was very important factor in determining the Ca availability including soil pH and CEC (Havlin *et al.,* 2005).

Table 2 showed that the addition of coastal sediment of 14 Mg ha-1 significantly increased the availability of Mg. Provision of coastal sediment until the dosage of 100 Mg ha-1 could increase the availability of Mg soil after incubation and it was significantly different from control. Mg availability increased by the addition of coastal sediment up to 100 Mg ha-1. This was due to the coastal sediment containing Mg so it could serve as a source of soil Mg. Provision of coastal sediment would reduce the availability of soil Mg, because Mg tend to accumulate in rich clay soil (Bohn *et al.,* 2001).

The results of variance analysis of the Na availability in soil after incubation showed that the coastal sediment treatments significantly affected Na availability. Table 2 showed that the addition of coastal sediment 14 Mg ha-1 increased Na availability. Provision of coastal sediment until the dosage of 86 Mg ha-1 could increase the availability of Na after incubation and it was significantly different from control. This was due to the coastal sediment containing high Na (Table 1) so it could serve as a source of Na.

The Effect of Coastal Sediment to Maize Productivity

Table 3 showed that treatment of coastal sediment of 28 Mg ha^{-1} could increase the weight of dry grain per plant and dry grain per hectare when compared control and dosage of 14 Mg ha^{-1}. The addition of coastal sediment of 28 Mg ha^{-1} produced 106.88 g of dry grain per plant, whereas dosage of 14 Mg ha^{-1} and control only 90.88 and 81.53 g respectively. Treatment of coastal sediment of 42 Mg ha^{-1} could still increase the weight of dry grain per plant significantly compared to control, dosage of 42 Mg ha^{-1} of coastal sediment could increase maize productivity as 84.7%. Furthermore, treatment of 56 and 72 Mg ha^{-1} of coastal sediment significantly decreased weight of dry grain per plant and did not differ by treatment of coastal sediment of 86 Mg ha^{-1}.

The effect of coastal sediment on productivity of maize in hectare showed that dosage of 42 Mg ha^{-1} as optimal dosage to increase maize productivity in Entisol in West Kalimantan. It produced the highest dry grain per hectare than other treatment. Application of coastal sediment at 42 Mg ha^{-1} could produce dry grain 9.23 Mg ha^{-1}, whereas the other dosage ofs of coastal sediment (L_0, L_1, L_2, L_4, L_5, L_6 and L_7) only generated 7.59 – 5.00 dry grain Mg ha^{-1}.

The effect of coastal sediment to weight of dry grain per plant was quadratic with the regression equation $Y =- 0.0181x^2 +1.7633x + 79.186$, as shown in Figure 1. Ameliorant treatment could improve dry grain weight per plant at a certain dosage; at dosage of 14, 28 and 42 Mg ha^{-1} of coastal sediment (L_1, L_2 and L_3) and it had generated dry grain 90.88, 106.88 and 150.54 g, respectively. Applying coastal sediment at dosage of more than 42 Mg ha^{-1} caused reduction of dry grain weight per plant, though it was still higher than control (L_0). Dry grain weight per plant at dosage of 56, 72, 86 and 100 Mg ha^{-1} of coastal sediment (L_4, L_5, L_5 and L_7) was 123.76, 92.41, 88.86 and 86.35 g, whereas controlled produce 81.53 g of dry grain. There was a declining trend of dry grain weight per plant with addition of increasing coastal sediment due to the availability of nutrient conditions that role in increasing the weight of dry grain per plant.

Table 3. The effect of application coastal sediment to maize productivity

Coastal sediment (Mg ha^{-1})	Maize productivity		Increasing in maize productivity as compared to L_0 (%)
	Dry grain per plant (g)	Dry grain per hectare (Mg)	
L_0 (control)	81.53 f	5.00 f	
L_1 14	90.88 de	5.57 de	11.5
L_2 28	106.88 c	6.55 c	31.1
L_3 42	150.54 a	9.23 a	84.7
L_4 56	123.76 b	7.59 b	51.8
L_5 72	92.41 d	5.67 d	13.4
L_6 86	88.86 de	5.45 de	9.0
L_7 100	86.35 e	5.30 e	5.9

Remarks: Values followed by the same letter in the column and the same treatment groups did not differ by Duncan's test 5 %.

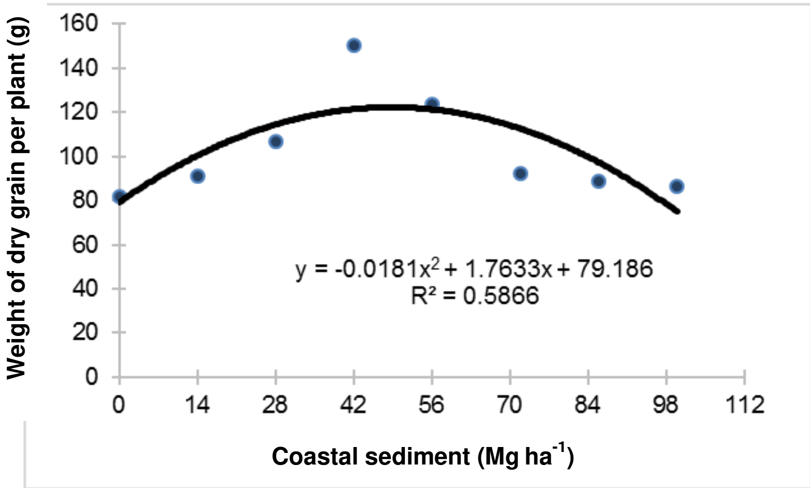

Figure 1. The weight of dry grain per plant with coastal sediment treatment

CONCLUSION AND SUGGESTION

CONCLUSION

Application of coastal sediment on Entisols had a positive effect on all parameters analyzed, such as: pH, availability of K, Ca, Mg and Na in soil. Dosage of coastal sediment of 42 Mg ha^{-1} was the best treatment than other treatments. This treatment could increase the availability of base cations (K, Ca, Mg and Na) and maize productivity compared to control (without coastal sediment) and when converted per hectare then the result to 9.23 Mg ha^{-1} was higher than mean.

SUGGESTION

The results of this study showed that the increasing nutrient availability and maize productivity was caused by the addition of coastal sediment. It is necessary for the further researcher to do research in the field on the same soil type. This is to determine the effect of environmental factors influencing coastal sediment in increasing nutrient availability and productivity of maize.

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