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Research Article

Effects of application of marine mud and manure on growth and yield of *Capsicum annum* L. on an Ultisol of Maluku

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Abstract: Marine mud and manure are potential for improving ultisol conditions, especially soil acidity, CEC, base saturation, organic acid, soil structure, soil nutrient retention, aeration, soil humidity, water holding capacity, infiltration, and supply of phosphorus for plant growth and development. Two treatments, namely planting media with 200 t marine mud /ha + 30 t manure / ha, and 400 t marine mud /ha + 30 t manure / ha were able to increase pH from 4.6 to 5.6. A significant decrease of exchangeable Al solubility of about 0.03 meq/100 g was found in M1O3; M2O1; M2O3 and M3O1 treatments. An increase of available phosphorus about 5.02 mg/kg was found at 200 t marine mud/ha + 30 t manure/ha treatment. There was a significant increase in plant height of about 62.42 cm in the media without marine mud and 30 t manure/ha. Application of 30 t manure/ ha yielded plant with leaf size of about 9552 cm^2 / plant and fresh fruit of about 9.81 t/ha.

Keywords: *acidity, available P, chilli, soil fertility*

Introduction

Ultisols are widely developed and found in rain forest zone having warm and moist climates (Kang and Tripathi 1992). Ultisols often have high acidity and low quantities of plant-available Ca, Mg, and K. These situations lead ultisols as soils with low fertility for agriculture. In such soils, the use of fertilizer and lime are desperately needed to improve soil fertility. There are five suborders of Ultisols, namely Aquults, Humults, Udults, Ustults, and Xerults. In Indonesia, there is abundance Ultisols which are potential to increase national agricultural productivity sectors. The management of ultisols to enhance agriculture productivity is therefore very important (Andrews et al., 2004).

The chemistry of soil is an important aspect in agricultural sectors, especially in order to increase commodity productivity. Naturally, soil is a mixture of abiotic and biotic components that are important to support plant life. Minerals, organic matter, and numerous microbes and soil fauna contribute to the soil ability to improve soil fertility. In the perspective of soil chemistry, soils with high acidity have high amount of aluminium.In soil with pH under 5.5 aluminum becomes more soluble and dominates adsorption complex and soil solution. Aluminum in ranges from 10 to 250 µM leads to the phosphorus and cation deficiencies in soil solution (Mokolobate and Haynes, 2002; Mora et al., 2006; Rout et al., 2001).Under pH 5.5., all plant species will face physiological stress and biochemical mechanism problems which lead to the vegetative and reproductive disturbance. The management and manipulation of soil pH are therefore important (Bronick and Lal, 2005).

Marine mud is rich mineral materials as a result of marine solid material sedimentation which is often found in coastal area. Marine mud is resulted from parent materials that are transferred by ocean water, and this sediment contains organic matter, illite and montmorillonite minerals. This sediment is also rich of NaCl, $CaCl_2$, Na_2CO_3, $CaCO_3$ and $MgCO_3$ (Foth, 1990). The addition of manure to soils provides numerous essential nutrients that are needed by plants. Application of manure is also important to improve soil physical characteristics, especially soil organic matter which is important for improving soil structure, nutrient retention, soil aeration, soil humidity, capacity and infiltration (Farhad et al., 2009; Iqua and Huasi, 2009).

Chili (*Capsicum annum* L.) is adaptive to wide range of environment. Chili is able to grow from lowland to highland and from dry season to rainy season. Chili, however, is very sensitive to salinity which can decrease seedling, plant high, root length, fresh weight, dry weight and production (Van Der Ploeg and Heuvelink, 2005). A research on tomatoes planted on an ultisol showed that application of 400 t marine mud/ ha as a single treatment yielded the best performance in plant high, number of flower, number of formed fruit and fresh fruit weight (Matulessy dan Hehanussa, 2006). This study was aimed to identify the effects of application of marine mud and manure on pH and phosphorus availability of an Ultisol and *Capsicum annum* L. growth and production.

Materials and Methods

This study was conducted from March to October 2013 at Soil Chemistry Laboratory of Brawijaya University, and at a screen house of Agriculture Office in Ambon. Materials used this study were marine mud, soil, manure, seed of *Capsicum annum* L, and fertilizer (NPK 15:15:15). Marine mud was collected from 10 m to 15 m from coastal lines of Hutumuri Village, Maluku Province. Soil used for this study was top soil (0-30 cm depth) of an Ultisol collected from Telaga Kodok Vilage, Maluku Province.

Experiment 1. Effects of marine mud and manure on soil chemical properties.

Treatments tested for this experiment 1 were combinations of four marine mud rates (0, 200, 400, and 600 t/ha) and four manure rates (0, 10, 20, and 30 t/ha). Sixteen treatments were arranged in a completely randomized design with three replications. Each treatment was placed in a 20 cm diameter plastic bag containing 1 kg of air-dried Ultisol. The water content of the mixture (marine mud, manure, and soil) in each bag was adjusted to approximate water holding capacity. After allowing 24 hours for the water to distribute in all parts of the mixed materials, the bag was incubated for 30 days in the laboratory room having average temperature of 25^{o}C. After 30 days of incubation, the material was air dried for three weeks. The air-dried material was then ground and sieved to pass through a 2 mm sieve for pH and P analyses. The collected soil debris was stored in a plastic bag and labeled for further analysis. Soil pH (H_2O and KCl) was measured using a pH meter. The contents of available P (Bray I) and exchangeable Al were determined using a Spectrophotometer. Data obtained were subjected to statistical analysis using SAS version 9.0. The different of treatment result was assessed using Duncan Multiple Range Test (DMRT) at 5% and 1%.

Experiment 2: Effects of marine mud and manure on growth and yield of Capsicum annum L.

This study was carried out in a screen house of Ambon. The treatments tested in this experiment 2 were similar to those of experiment 1, i.e. four marine mud rates (0, 200, 400, and 600 t/ha) and four manure rates (0, 10, 20, and 30 t/ha). Sixteen treatments were arranged in a completely randomized design with three replications. Each treatment was placed in a 32 cm diameter plastic bag containing 5 kg of air-dried Ultisol. Water content of the planting media in each pot was adjusted to approximate water holding capacity. After storing the planting media for one night, one seedling of *Capsicum annum* L. was then planted in each pot for 75 days. Before planting, each pot received 100 kg NPK/ha as basal fertilizers.

During experiment, water was regularly supply to ensure that water would not limit plant growth. Plant height and leaf area were measured every 14 days. Fresh fruit weight was measured at harvest (75 days). Data obtained were subjected to statistical analysis using SAS version 9.0. The different of treatment result was assessed using Duncan Multiple Range Test (DMRT) at 5%.

Results and Discussion

Soil characteristics after incubation

Application of marine mud and manure significantly in both single and interaction, contributed to changes of pH, exchangeable Al and available P of the soil studied (Table 1).

Soil pH

The treatment combination of marine mud and manure contributed to the significance changes of pH. It was observed that pH increased from 4.6 (control) to 5.6 at M1O3 and M2O2 treatments. Soil pH contributes to the solubility and availability of essential nutrient, and organic matter decomposition (McCauley et al., 2003). According to Mokolobate and Haynes (2002), treatment of 20 manure/ha will increase pH in range from 0.2 to 0.6. Treatment of 40 to 50 t manure/ha will increasepH in range from 0.8 to 1.5. In this experiment, the treatment of marine mud and manure contributed to the soil pH increase from 4.6 to 5.6. Aluminum in an acid soil (pH < 4.5) has been identified as a limiting factor to plant growth and inhibits roots to grows and therefore decrease ability of plant to absorb water and plant nutrients. In the highest level, the aluminum becomes toxic to soils and inhibits root function to absorb water and nutrients and therefore contributes to low plant productivity (Mokolobate and Haynes, 2002).

Table 1. The interaction effect of marine mud and manure on pH, exchangeable Al, and available P of an Ultisol of Maluku.

Observed variables	Manure treatment (O)	Marine mud treatment (M)							
		M0 (0 t/ha)		M1 (200 t/ha)		M2 (400 t/ha)		M3 (600 t/ha)	
pH	O0 (0 t/ha)	4.60	f	5.00	e	5.07	de	5.20	cd
	O1 (10 t/ha)	5.20	cd	5.00	e	5.20	cd	5.20	cd
	O2 (20 t/ha)	5.40	b	5.20	cd	5.30	bc	5.30	bc
	O3 (30 t/ha)	5.40	b	5.60	a	5.60	a	5.30	bc
Exch Al	P0 (0 t/ha)	2.17	a	0.64	c	0.16	g	0.09	i
	P1 (10 t/ha)	1.09	b	0.29	e	0.03	j	0.03	j
	P2 (20 t/ha)	0.26	f	0.25	f	0.05	j	0.13	h
	P3 (30 t/ha)	0.57	d	0.03	j	0.03	j	0.15	gh
P	P0 (0 t/ha)	0.00	i	0.00	i	4.41	b	0.00	i
	P1 (10 t/ha)	0.00	i	3.55	c	2.96	e	2.68	g
	P2 (20 t/ha)	1.91	h	3.48	d	2.70	g	2.69	g
	P3 (30 t/ha)	1.91	h	5.02	a	2.75	f	3.54	c

Note. Variables followed by similar letters in the same column indicate not significant in DMRT 5 % test.

Soil exchangeable Al

The highest content of exchangeable Al (Al_{exc}) was found in control (M0O0 = 2.17meq/00 g). The significant decrease of exchangeable Al of about 0.03 meq/100 g occured after marine mud and manure in M1O3; M2O1; M2O3 and M3O1 treatments. Decrease of aluminum significantly occurred in control or ultisol without marine sludge and manure. In such a case, the decrease was calculated about 2.17 meq/100 g. Decrease of aluminum occurred after marine sludge and manure treatments in different concentration. DMRT test 5% (Table 1) shows the analysis result of Al_{exc} where the lowest aluminum (0.03 meq/100 g) occurred in M1O3, M2O1, M2O3 and M3O1 treatments.

Soil available P

In ultisols, the initial phosphorus content could not be measured. However, there was available P increase significantly after marine mud and manure treatment to 5.02 mg/kg in M1O3 treatment. The interaction of marine mud and manure treatment to the value of pH, Al_{exc} and phosphorus of an Ultisol of Maluku is presented in Table 1.

There were positive correlations between marine mud, manure and soil pH increase. It was observed in M1O2 with pH of 5.20 and M2O2 with pH of 5.30. These values were under regression line. There were negative correlations in terms of Al_{exc}, and all combinations of marine mud and manure that were in regression lines. The positive increase of available P was found in M0O3 (1.91); M2O2 (2.70); M2O3 (2.75) and M3O3 (3.54).

Phosphorus is an important macro nutrient needed by plants for numerous metabolism reactions, especially for growth and development. Phosphorus is also important in seedling, photosynthesis, energy transfer and protein synthesis (Hopkins and Huner, 2009). Naturally, the availability and concentration of phosphorus in soil is low, about 0.3-3 mg/kg. Physiologically, plant needs about 0.0001 to 0.0002 mg P/kg to meets its basic needs for growing (Mengel et al., 2001).

Phosphorus in soil is a immobile element, which is able to bind with loam in acid soil, and therefore it becomes unavailable for plant to support its growth. The existence of phosphorus has relationship with aluminum element in soil. In this study, it is clear that the tested treatments contributed to the aluminum and phosphate contents in the soil. Figure 1 shows the decrease of aluminum concentration from initial concentration of about 2.17 meq/100 g to 0.03 meq/100 g.

Growth and yield of Capsicum annum L.

Plant height and leaf size

Marine mud and manure contributed significantly to plant height variable. The highest plant height of about 62.42 cm/individual was found in the M0O3 treatment (Table 2). There were no significant interactions between marine mud and manure in leaf size (Table 3). However, the single factor of such aspect seemed to influence leaf size significantly. Manure was found to contribute significantly in leaf size. It was found in O treatment (95.52 cm^2/individual) and O2 (93.20 cm^2/individual).

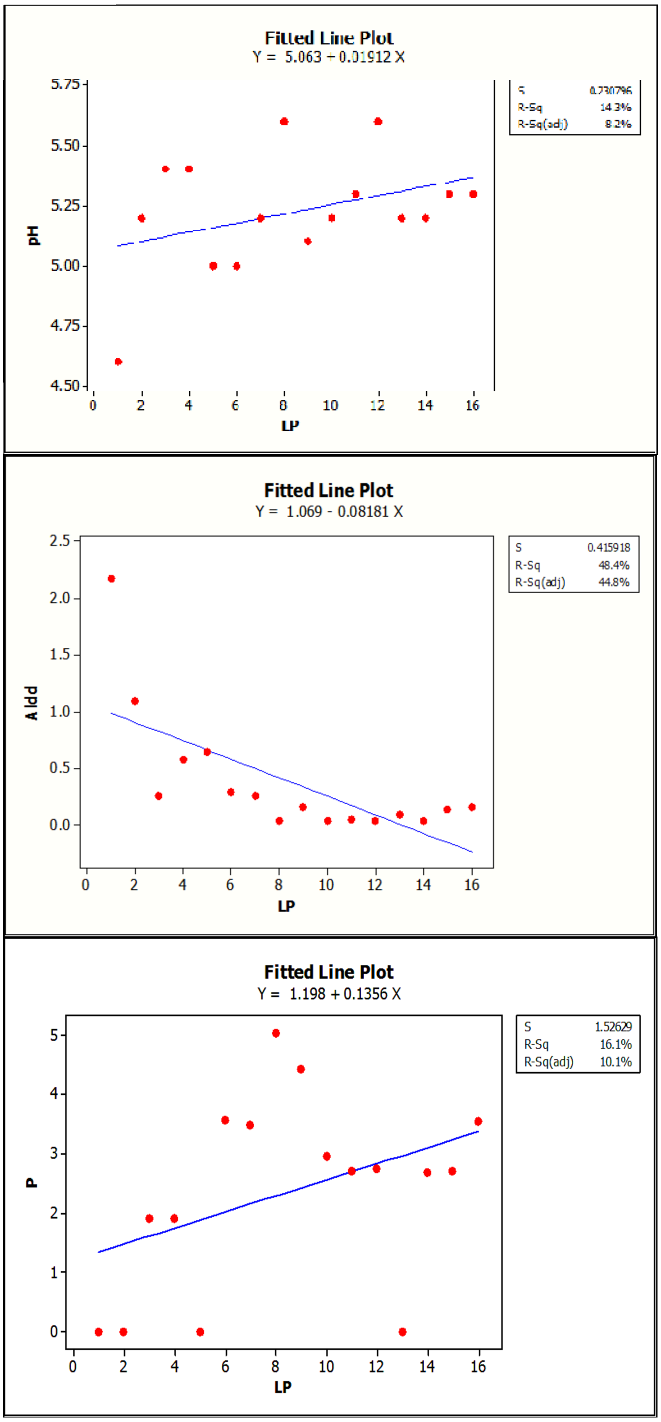

Figure 1. The relationship between marine mud and manure treatment, and changing of pH, available phosphorus and exchangeable Al in an ultisol of Maluku

The single treatment of manure contributed to the height of *capsicum annum* L. The manure treatment of 30 t/ha (M0O3) contributed to the plant height of about 62.42 cm/individual and the manure treatment of 20 t/ha contributed to the 58.38 cm/individual. In manure, there are numerous nutrients which area important and needed by plants, especially to support plant vegetative growth. Similarly, the application of 12 t manure/ ha in corn contributed to the plant height about 230 cm (Farhad et al., 2009). There were no interactions between marine mud and manure in leaf area size, but the single factor of such treatment seemed to contribute significantly in leaf size area. Manure treatment of 30 t/ha contributed the leaf size of 95.52 cm^2/individual and manure treatment of 20 t/ha contributed to the leaf size of 93.20 cm^2/individual. Single treatment of media without marine mud contributed to the largest area of leaf compared to the media with marine mud. It was found that the use of manure contributed significantly to provide nutrient for plant to support its vegetative growth, especially in vegetables such as amaranth. Manure increases amaranth leaf area and quality (Mufwanzala and Dikinya, 2010).

Table. 2. The interaction between marine mud and manure in plant height variable

Observed variable	Manure Treatment (O)	Marine mud treatment (M)							
		M0 (0 t/ha)		M1 (200 t/ha)		M2 (400 t/ha)		M3 (600 t/ha)	
Plant height	O0 (0 t/ha)	45.92	ef	47.13	ef	45.00	f	47.21	ef
	O1 (10 t/ha)	52.17	bcde	55.38	bcd	52.08	bcdef	52.58	bcde
	O2 (20 t/ha)	58.38	ab	57.50	ab	51.75	bcdef	49.00	cdef
	O3 (30 t/ha)	62.42	a	54.58	bcd	56.33	abc	48.75	def

Note. Variables followed by similar letters in the same column indicate not significant in DMRT 5 % test.

Table 3.Impact of single factor of marine mud and manure in leaf size variable

Treatments	Mean (cm^2 /individual)		Treatments	Mean (cm^2 individual)	
M0	82.09	a	O0	79.35	c
M1	78.50	ab	O1	86.94	b
M2	74.08	b	O2	93.20	a
M3	77.90	ab	O3	95.52	a

Note. Variables followed by similar letters in the same column indicate not significant in DMRT 5 % test.

Fruit weight of Capsicum annum L.

Fresh fruit weight of harvested *Capsicum annum* L. is presented in Table 4. There was no interaction between two tested treatments. The significant factor was caused by manure as important single factor. The highest production was about 9.81 t/ha produced from manure treatment about 30 t/ha (O3).

Table 4. Impact of single factor of marine mud and manure in fresh fruit weight variable

Treatments	Mean (t/ha)		Treatments	Mean (t/ha)	
M0	7.64	a	O0	2.88	d
M1	6.52	a	O1	6.61	c
M2	6.74	a	O2	8.16	b
M3	6.55	a	O3	9.81	a

Note. Variables followed by similar letters in the same column indicate not significant in DMRT 5 % test.

The treatment of 30 t manure/ha (O3) produced fresh fruit about 245.13 g/plant. Treatment without manure produced the lowest fresh fruit about 72.08 g/plant. Magagula et al. (2010) found that application of 20 t manure/ha contributed to the highest potatoes tuber compared to the application of 40 t manure/ha and 60 t manure/ha. In the treatment of 60 t manure/ha produced 20.6 t tuber/ha (Magagula et al., 2010). The application of 20 t manure/ha in tomatoes contributed to the tomato production of 31.6 t/ha (Ewulo et al., 2008).

Conclusion

The treatment of M1O3 (200 t marine mud/ha + 30 t manure/ha) and M2O3 (400 t marine mud/ha + 30 t manure/ha) increased pH from 4.6 to 5.6. The significant decrease of Al_{exc} of 0.03 meq 100/ g was found in M1O3; M2O1; M2O3 and M3O1 treatments. Increase of available phosphorus of about 5.02 mg/kg in the soil was found in M1O3 treatment (200 t marine mud/ha + 30 t manure/ha). There were significant interactions on plant high of 62.42 cm at the M0O3 treatment (without marine mud and 30 t manure/ha). The single factor of 30 t manure/ha contributed to the leaf area and fresh fruit of the harvested chili.

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