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Application of Organonitrofos and Inorganic Fertilizer on Cassava (*Manihot Esculenta* Crantz) in Ultisol Soil

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ABSTRACT

A field experiment was conducted to find out a combination dose of a novel organic fertilizer (Organonitrophos, OP) and inorganic fertilizers (N, P, and K) for the growth and yield of cassava (*Manihot esculenta* Crantz) during two planting periods of 2012-2013 and 2013- 2014 in ultisol soil (low in nutrients and organic matter) of Bandarlampung. The treatments were a six combination of organic and inorganic fertilizer. The experiments were laid out in a randomized block design with three replications. The difference combination of Organonitrophos and NPK fertilizers showed significantly effects on the plant height, the NPK sorption of total plant and total root, and the yields of cassava. The highest NPK sorption of total plants and total yields and the highest yields of cassava were found in $N_{45}P_{36}K_{120}OP_{1,000}$ kg ha^{-1} combination for the two planting periods. Based on *Relative Agronomic Effectiveness* (*RAE*) of cassava root yield, it can be concluded that 45-36-120-1,000 N-P-K-Organonitrophos kg ha^{-1} was the best combination dose of inorganic and organic fertilizers for the production of cassava in ultisol soil of Bandarlampung.

Keywords: Cassava, combination dose, fertilizer, *Manihot esculenta*, yield

INTRODUCTION

In Indonesia cassava (*Manihot esculenta* Crantz.) is a very popular food source after paddy and corn that is consumed directly by people and as a raw material for various industries. Increased public interest in utilizing cassava as food is one of the positive indications for the achievement of food diversification efforts in support of food security in Indonesia. Cassava plants with several advantages agronomic characters such as tolerance to drought, soil pH, low nutrient levels, as well as pests and diseases have a huge potential to be developed into one of the alternative food commodities. Cassava is also a nutritious food. A 100 g of fresh cassava tubers contains 157 cal, 0.70 protein, 0.20 g fat, 38.10 g carbohydrate, 50 mg calcium, 40 mg phosphorus, 0.60 mg fiber, 25.20 mg vitamine C, and 59.4 g water (FAO 1997). Even cassava leaves contain up to 25 percent protein, on a dry weight basis (Chavez *et al*. 2000).

However, total production of cassava in Indonesia is still low. In 2012, it reached 24,177,372 ton with land area of 1,129,688 ha equal to 21 Mg ha^{-1} yr^{-1}; while in Lampung Province, it reached 8,387,351 ton with land area of 324,749 ha equal to 26 Mg ha^{-1} yr^{-1} (Indonesian Statistical Centre Bureau 2013). One of the constraints to improve the productivity of cassava in Indonesia is low fertility of ultisol soils that have a high of soil acidity and aluminum saturation, a low of macro nutrients (especially P, K, Ca and Mg) and organic matters content (Prasetyo and Suriadikarta 2006). To improve the fertility of ultisol soil and to increase the yields of cassava, the application of fertilizers are necessary. Especially cassava as a crop that transports nutrients from the soil in large quantities. When cassava produces 37 Mg ha^{-1} of root fresh weight, it will transporting nutrients as much as 198 kg N, 70 kg P_2O_5, 220 kg K_2O, 47 kg MgO, 143 kg CaO, and 19 kg S ha^{-1} (Roy *et al*. 2006). Therefore, additional nutrients with a rate at least equal to that transported are neded at each growing season.

Beside inorganic fertilizers (N, P and K), organic fertilizers are important to be considered as a part of nutrient management. Since an organic matter is important to support plant productivity as well as to maintain soil condition to achieve a sustainable agriculture. Organonitrophos is a novel organic fertilizer made from fresh cow manures and rock phosphates as raw materials which is enriched by nitrogen fixer and phosphorus solubilizer microbes. Hopefully the application of

Organonitophos as organic fertilizer combined to inorganic fertilizer could reduce the dose of inorganic fertilizer. Therefore, the research to find the best combination dose of inorganic and organic fertilizers to get the optimal growth and yield of cassava in ultisol soil was important to do.

MATERIALS AND METHODS

Experimental Site and Soil Characteristics

The experiment was conducted at Integrated Field Laboratory of University of Lampung, Bandarlampung, Indonesia during the seasons of May 2012 to February 2013 and March 2013 to January 2014. The experimental site was located at Gedungmeneng at about 5°21'10" south latitude and 105°14'38" east longitude. The experimental plot was having silty clay soil. The soil was slightly acidic (pH of 6.4) and low in organic carbon (2.25%) and in available-P (7.2 ppm) (Table 1).

Treatment Details, Inorganic and Organic Fertilizer Application

The treatment combinations of an inorganic (NPK) and organic (Organonitrophos, OP) fertilizer were: T1=native nutrient (control), T2= $N_{90}P_{108}K_{240}OP_0$ kg ha^{-1}, T3= $N_{67.5}P_{36}K_{180}OP_{500}$ kg ha^{-1}, T4=$N_{45}P_{36}K_{120}OP_{1,000}$ kg ha^{-1}, T5=$N_{22.5}P_{18}K_{120}P_{1,500}$ kg ha^{-1}, and T6=$N_0P_0K_0OP_{5,000}$ kg ha^{-1}.

The study was conducted in a randomized block design with three replications. Organic fertilizer (Organonitrophos) and Urea, Superphosphate 36% (SP-36), KCl were used as the sources of N, P, and K, respectively. Organonitrophos was applied one week before planting. The entire quantities of P and K were applied at 2 weeks after planting (WAP) and mixing into the soil. Nitrogen was dressed at 2 and 16 WAP.

Planting and Harvesting

Cassava (*Manihot esculenta* Crantz.) variety of UJ-5 (*Cassesart*) was used as a test crop. The unit plot size was 3 m x 3 m. Cassava plants were planted with a spacing of 1 m x 0.5 m on 2nd May and 5th March of 2012 and 2013, respectively and they were harvested on 10th February and 12th January of 2013 and 2014, respectively.

Intercultural Operation

The field was intensively kept free from weeds for the first three months. Thereafter, weeding was done mechanically if the weed reached crop damage threshold. Plants were watered rutinously if no rainfall. If there was rainfall, subsequently watering was done after the soil dried. Dead leaves were removed regularly from the field. Pests and diseases were controlled mechanically. Controlling of plant bedbugs was done by spraying with water so that their population would be reduced.

Soil Sampling and Chemical Analysis

Soil samples were collected, dried and ground for chemical analysis. Soil pH was determined by glass electrode pH meter (1:2.5) and organic carbon by wet oxidation method (Walkey and Black 1935). Total N content of soil was determined by using the the Kjeldahl method (Jackson 1973), whereas available-P, exchangeable K by using 0.5M $NaHCO_3$ (pH 8.5) and NH_4OAc extraction method, respectively, as outline by Page *et al*. (1982).

Data Collection

Yield attributes (plant height, total plant fresh weight, total plant dry weight, total root fresh weight and total root dry weight) and NPK sorption of total plant and total root of cassava were recorded from 10 randomly selected plants. Cassava yield per plot was recorded and based on that, per hectare yield was calculated.

Statistical Analysis

The analysis of variance for yield attributes and NPK sorption was done follow the ANOVA (Analysis of Variance) test and the mean values were compared by Duncan Multiple Range Test (DMRT) at 5% level (Steel and Torrie 1960). One-way ANOVA table was used to perform this analysis. A correlation test was done to perform correlation between NPK sorption and a total plant and total root dry weight.

RESULTS AND DISCUSSION

Effect of Fertilizers on the Fertility Status of the Soil

Soil fertility status of of the experimental field was only slightly affected by the application of fertilizer (Table 1). Soil organic-C and soil total-N was not affected by all fertilizer treatments at 2012-13 and 2013-14 growing season, respectively. However, there was decreasing soil total-N at 2013-14 compared to 2012-13 growing season. This was likely due to lost of nitrogen uptaking by cassava plant during the two growing season. While, soil pH, soil exchangeable-K, and soil available-P increased

Table 1. Fertility status of soils of the experimental field

Soil property	Planting time	Value	Treatment					
			T1	T2	T3	T4	T5	T6
Total-N	Initial	0.21						
(%)	2012-2013		0.20	0.25	0.31	0.42	0.66	0.39
			(M)	(M)	(M)	(M)	(H)	(M)
	2013-2014		0.09	0.15	0.15	0.15	0.17	0.15
			(L)	(L)	(L)	(L)	(L)	(L)
Available-P	Initial	7.2						
(ppm)	2012-2013		6.31	23.69	16.05	8.08	19.26	16.47
			(L)	(VH)	(VH)	(M)	(VH)	(VH)
	2013-2014		9.80	35.92	24.28	14.75	11.05	26.95
			(M)	(VH)	(VH)	(H)	(H)	(VH)
Exchangeable	Initial	0.61						
K (cmol kg^{-1})	2012-2013		0.45	0.88	0.78	0.63	0.65	0.73
			(M)	(H)	(H)	(H)	(H)	(H)
	2013-2014		0.66	1.03	1.04	0.90	0.94	1.05
			(H)	(VH)	(VH)	(H)	(H)	(VH)
Organic-C	Initial	2.25						
(%)	2012-2013		1.82	1.74	2.09	1.82	1.98	2.49
			(L)	(L)	(M)	(L)	(L)	(M)
	2013-2014		1.42	1.49	1.44	1.52	1.52	1.44
			(L)	(L)	(L)	(L)	(L)	(L)
pH (H_2O)	Initial	6.4						
	2012-2013		6.50	7.30	7.10	6.90	7.10	7.10
			(SA)	(N)	(N)	(N)	(N)	(N)
	2013-2014		6.40	6.71	6.63	6.65	6.4	6.91
			(SA)	(N)	(N)	(N)	(SA)	(N)

Notes: T1=$N_0P_0K_0OP_0$ kg ha^{-1} (native nutrient, control), T2=$N_{90}P_{108}K_{240}OP_0$ kg ha^{-1}, T3=$N_{67.5}P_{36}K_{180}OP_{500}$ kg ha^{-1}, T4=$N_{45}P_{36}K_{120}OP_{1,000}$ kg ha^{-1}, T5=$N_{22.5}P_{18}K_{120}OP_{2,000}$ kg ha^{-1}, and T6=$N_0P_0K_0OP_{5,000}$ kg ha^{-1}. SA (Slightly acid), N (Neutral), L (Low), M (Medium), H (High), VH (Very high).

by the application of fertilizer treatments compared to control (T1) both for 2012-13 and 2013-14. Increasing soil available-P was likely due to the application of inorganic fertilizer (Superphosphate 36%, SP-36) as well as organic fertilizer (Organonitrophos, OP) which contained 20 percent of rock phosphate in its composition that gave slow release during the growing periode of cassava. Gomez *et al.* (1980) reported that good soil fertility and adequate fertilizer increased the yield potential of cassava.

Effect of Fertilizers on the Growth Parameter of Cassava

Plant height of cassava was significantly influenced by the application of fertilizers (Table 2). The highest plant height was found in T4 ($N_{45}P_{36}K_{120}OP_{1,000}$) for 2012-13 and in T2 ($N_{90}P_{108}K_{240}OP_0$ kg ha^{-1}) for 2013-14. The addition of fertilizer did not significantly increase plant height of cassava of 2012-13 but T2 treatment significantly increased the plant height of cassava of 2013-14 compared to control (T1: native nutrient) and other combination dose treatments (T5: $N_{22.5}P_{18}K_{120}P_{2,000}$ kg ha^{-1} and T6: $N_0P_0K_0OP_{5,000}$ kg ha^{-1}). It means that at the first growing season (2012-13) all fertilizer treatments did not have significantly effect to the plant height of cassava yet, while at the second growing season (2013-14) increasing dose of chemical fertilizer increased the plant height of cassava. These results were in agreement with Streck (2014) who stated that the growth of cassava was affected by the application of fertilizer. Also, residual effects of fertilizer application would affect the following growing season.

Total plant fresh weight (green matter of leaves, stems and branches) was also significantly influenced by the application of fertilizers (Table 2). The highest total plant fresh weight for 2012-13 and 2013-14 were found in T4 ($N_{45}P_{36}K_{120}OP_{1,000}$) and significantly different with other treatments, and the lowest was in T1 (control). These results were in

Table 2. Plant height, total plant fresh weight, total root fresh weight and *Relative Agronomic Effectiviness* (RAE) of cassava (*Manihot esculenta* Crantz.) root yield as influenced by different fertilizer combination.

Treatment	Plant height (cm)		Total plant fresh weight (t ha^{-1})		Total root fresh weight (t ha^{-1})		RAE (%)	
	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014
T1	80.11 a	187.93 a	19.73 a	48.17 a	32.57 a	35.00 a	-	-
T2	93.70 a	257.10 c	45.33 e	64.22 bc	40.51 a	52.78 ab	100	100
T3	100.20 a	235.23 bc	35.64 c	54.89 ab	35.88 a	48.44 ab	37.91	75.63
T4	111.75 a	229.01 bc	46.31 e	70.94 c	56.47 b	59.83 b	301	139.69
T5	105.19 a	221.35 b	23.20 b	53.05 ab	35.00 a	43.62 ab	30.60	48.50
T6	95.80 a	217.98 ab	41.42 d	51.89 ab	33.02 a	41.33 ab	5.67	35.63
CV (%)	3.98	1.31	0.74	2.26	2.40	3.62		

Figures in a column having common letters do not differ significantly at 5% level of DNMRT. Notes: T1=$N_0P_0K_0OP_0$ kg ha^{-1} (native nutrient, control), T2=$N_{90}P_{108}K_{240}OP_0$ kg ha^{-1}, T3=$N_{67.5}P_{36}K_{180}OP_{500}$ kg ha^{-1}, T4=$N_{45}P_{36}K_{120}OP_{1,000}$ kg ha^{-1}, T5=$N_{22.5}P_{18}K_{120}OP_{2,000}$ kg ha^{-1}, and T6=$N_0P_0K_0OP_{5,000}$ kg ha^{-1}.

Table 3. NPK Sorption of root and total plant of cassava (*Manihot esculenta* Crantz.) as influenced by different fertilizer combination.

Treatment	N sorptio						(kg ha^{-1})		K sorption of cassava (kg ha^{-1})			
	Total root		Total plant		Total root		Total plant		Total root		Total plant	
	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013					2012-2013	2013-2014
T1	74.51 a	73.56 a	175.25 a	554.35 a	7.45 a	29.43 a	13.03 a	86.84 a	46.34 a	173.40 a	73.40 a	277.90 a
T2	117.73 bc	137.10 b	286.48 cd	936.77 bc	14.83 bc	64.21 c	25.33 c	179.97 b	81.23 c	300.23 bc	134.94 d	519.14 cd
T3	91.42 ab	152.64 b	242.37 bc	864.38 bc	10.60 a	51.45 bc	22.36 c	124.65 a	55.76 ab	319.00 bc	116.51 bc	439.34 bc
T4	141.27 c	159.10 b	318.72 d	1073.93c	18.00 c	59.66 bc	26.18 c	176.72 b	114.36 d	375.87 c	146.92 d	576.39 d
T5	78.55 a	106.69 ab	198.11 ab	737.53 ab	9.63 a	40.88 bc	16.54 ab	122.20 a	61.72 abc	289.60 abc	93.84 ab	406.39 bc
T6	89.32 ab	137.74 b	280.11 cd	734.37 ab	11.16 ab	39.56 ab	24.76 c	125.56 a	49.51 ab	213.22 ab	146.96 d	372.41 ab
CV (%)	2.90	3.86	1.85	2.73	2.99	3.82	1.84	2.73	2.73	4.00	1.85	2.66

Figures in a column having common letters do not differ significantly at 5% level of DNMRT. Notes: T1=$N_0P_0K_0OP_0$ kg ha^{-1} (native nutrient, control), T2=$N_{90}P_{108}K_{240}OP_0$ kg ha^{-1}, T3=$N_{67.5}P_{36}K_{180}OP_{500}$ kg ha^{-1}, T4=$N_{45}P_{36}K_{120}OP_{1,000}$ kg ha^{-1}, T5=$N_{22.5}P_{18}K_{120}OP_{2,000}$ kg ha^{-1}, and T6=$N_0P_0K_0OP_{5,000}$ kg ha^{-1}.

Table 4. Correlation between NPK sorption and a total root and plant dry weight of cassava (*Manihot esculenta* Crantz.).

Correlation	Correlation equation		r value	
	2012-2013	2013-2014	2012-2013	2013-2014
Root N sorption and total root dry weight	y = 7.38 + 0.32x	y = 17.99 + 0.225x	0.92 *	0.74 *
Root P sorption and total root dry weight	y = 12.74 + 2.19x	y = 38.25 + 0.134x	0.90 *	0.92*
Root K sorption and total root dry weight	y = 14.56 + 0.36x	y = 5.155 + 0.691x	0.96 *	0.98 *
Plant N sorption and total plant dry weight	y = -7.176 + 0.17x	y = 18.45 + 0.047x	0.89 *	0.93 *
Plant P sorption and total plant dry weight	y = -3.704 + 1.82x	y = 23.59 + 0.247x	0.92 *	0.91 *
Plant K sorption and total plant dry weight	y = -2.503 + 0.32x	y = 20.86 + 0.084x	0.89 *	0.93 *

agreement with Silva *et al*. (2013) and Streck (2014).

Effect of Fertilizers on the Yield of Cassava

Total root fresh weight of cassava was significantly influenced by the application of fertilizers (Table 2). The highest total root fresh weight was found in a combination dose of inorganic and organic fertilizers of T4 ($N_{45}P_{36}K_{120}OP_{1,000}$ kg ha^{-1}) both for 2012-13 and 2013-14 growing seasons and the lowest was at control (T1). Application a combination dose of 1,000 kg Organonitrophos ha^{-1} with 45-36-120 of N-P-K, respectively (T4) increased total root fresh weight of cassava by 39.48 and 13.36% for 2012-13 and 2013-14, respectively than application of 90-108-240 of N-P-K ha^{-1} only (T2), by 71.02 and 44.76% for 2012-13 and 2013-14, respectively than application of 5,000 kg Organonitrophos ha^{-1} only (T6), and by 73.38 and 70.94% for 2012-13 and 2013-14, respectively than application of control (T1). FAO (2013) had done trials in Indonesia and Vietnam, a combination of 5 t ha^{-1} compost or farmyard manure with N and K in Vietnam and with N only in Indonesia produced high crop yields of cassava and the highest net income compared to control or a single treatment only. Application a combination of 135 kg N ha^{-1} with 5 Mg compost ha^{-1} increased cassava fresh root yield by 73.33% than application of 5 Mg compost ha^{-1} only, by 9.86 % than application of 135 kg N ha^{-1} only, and by 271.43 % than control.

Total root fresh weight of cassava cv UJ-5 (*Cassesart*) in these experiments ranged from 32.57 to 56.47 Mg ha^{-1} and from 35.00 to 59.83 Mg ha^{-1} for 2012-13 and 2013-14, respectively. These results were still low compared to the potential yields of the same variety which were 45 to 60 Mg ha^{-1} (BPTP 2008). Although, the results were in agreement with Puslittan (2013) which reported that average yields of cassava cv UJ-5 were 25-38 Mg ha^{-1}.

While, the effectively of fertilizer combination was found at T4 ($N_{45}P_{36}K_{120}OP_{1,000}$ kg ha^{-1}) based *Relative Agronomic Effectiviness* (RAE) of cassava root yield with RAE e"100% which were 301 and 139.69 % for 2012-13 and 2013-14, respectively (Table 2). It means that a combination dose of 45-36-120-1,000 N-P-K-Organonitrophos kg ha^{-1} can be recommended as the best combination of inorganic and organic fertilizers to get the optimum yield of cassava grown in ultisol Bandarlampung soil.

Effect of Fertilizers on the NPK Sorption of Cassava

NPK sorption in a total root and total plant of cassava is presented in Table 3. For the two growing seasons (2012-2013 and 2013-2014), the highest NPK sorption in total root and total plant of cassava were generally in T4 ($N_{45}P_{36}K_{120}OP_{1,000}$ kg ha^{-1}) followed by T2 ($N_{90}P_{108}K_{240}OP_{0}$ kg ha^{-1}) although there was not significantly different between T4 and T2 but they were significantly higher than T1 (control). Application of fertilizers (inorganic only (NPK), organic only (OP), or combination of inorganic and organic (NPK-OP)) increased NPK sorption of total root and total plant of cassava compared to control. The major nutrients required by cassava for optimum top growth and tuber yields are nitrogen (N), phosphorus (P), and potassium (K) (Obigbesan and Fayemi 1976). Moreover, Agbaje

and Akinlosotu (2004) reported that NPK fertilizer affected tuber yields of cassava grown in a forest alfisol of south-western Nigeria.

There were significantly correlations between NPK sorption of roots and plants with total root and total plant dry weight of cassava of 2012-13 and 2013-14 with r values ranged from 0.89 to 0.92 and from 0.74 to 0.98 for 2012-13 and 2013-14, respectively (Table 4). Increasing NPK sorption of cassava plant would increase total plant dry weight of cassava. Similarly, increasing NPK sorption of cassava root would increase total root dry weight of cassava. The growth and yields of cassava had been reported to respond to adequate fertilizers (Gomez *et al*. 1980, Agbaje and Akinlosotu 2004, FAO 2013).

CONCLUSIONS

The difference combination of NPK and Organonitrophos fertilizers showed significant effects on the plant height, the NPK sorption of total plant and total root, and the yields of cassava. The highest cassava yields (56.47 and 59.83 Mg ha^{-1} for 2012-2013 and 2013-2014, respectively) were found in $N_{45}P_{36}K_{120}OP_{1,000}$ kg ha^{-1} combination. Based on Relative Agronomic Effectiveness (RAE) of cassava root yield, it can be concluded that 45-36-120-1,000 N-P-K-Organonitrophos kg ha^{-1} was the best combination dose of inorganic and organic fertilizers for the production of cassava in ultisol soil of Bandarlampung.

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