Effect of fertilizer rates on cassava grown on Yasothon soil amended with cassava stem base biochar and wastes from cassava starch manufacturing plant

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ABSTRACT: A field experiment was conducted to study the effect of organic wastes used as soil amendment and two rates, 312.5 and 625 kg/ha, of 15-15-15 formula chemical fertilizer on soil properties and yield of cassava grown on Yasothon soil. In this, a split plot of Randomized Complete block design with four replications was employed. Main plot consisted of organic soil amendments such as no soil amendment (control, T1), 200 kg/rai of cassava stem base biochar (T2), 6.25 t/ha of cassava starch waste (T3), 6.25 t/ha of cassava peel (T4) and 6.25 t/ha of tails and stalk (T5). Chemical fertilizer was applied in sub plot of cassava at four months of age. The higher rate of fertilizer significantly gave higher starch yield (31.3 t/ha) and above ground biomass (9.1 t/ha) than the one with lower rate. With no statistical differences, cassava yield tended to increase whereas starch content tended to decrease with increasing amount of chemical fertilizer. Cassava tails and stalk was likely to be the most suitable soil amendment for increasing cassava yield in this soil, especially when used with the addition of 625 kg/ha 15-15-15 formula chemical fertilizer, potentially giving the highest fresh root and starch yields of 34.6 and 10.4 t/ha, respectively. Tails and stalk reduced acidity more effectively than did other soil amendments, particularly when applied with the higher rate of chemical fertilizer as the soil significantly had the highest soil pH of 6.07. Cassava peel significantly promoted the highest soil cation exchange capacity of 3.12 $cmol_c$/kg whereas other soil amendments had no different effect from the control on this soil property, having values in the range between 1.50-1.66 $cmol_c$/kg.
Keywords: fertilizer, cassava starch waste, cassava peel, tails and stalk, biochar

Introduction

Cassava (*Manihot esculenta* Crantz.) is an economic crop, ranking third of exporting product in the world. Thailand earned 87,289 million bath in the current year (The Customs Department, 2012). Cassava growing areas are mostly distributed in the northeastern region, especially in Nakhon Ratchasima province, but the average yield is lower than in other regions (Office of Agricultural Economics, 2012). This is due to cassava having been grown on Paleustults of which most soil series in this great group of soil such as Yasothon, Warin and Satuk soil series are poor (Duangpatra, 1988). Theses soils are characterized by coarse and medium texture, low soil fertility level, low water and moisture retentions and poor physical properties. In addition, these soils have intensively been used for agricultural production without proper soil improvement practices, leading to a drastic decrease of plant nutrient stored in the soil. Furthermore, organic matter decreases rapidly and subsequently soil structure is destroyed. This could be the major reason that cassava yield diminishes in spite of growing plant receives sufficient chemical fertilizers. To maintain soil fertility, and in turn, sustain cassava productivity, improvements of soil management are necessary. Incorporation the soils with organic soil amendments has been

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proved successfully to improve soil productivity and to increase yield of many crops (Glaser et al., 2002; Major et al., 2010) as well as cassava (Changlek et al., 2006; Phuniam et al., 2012; Plengsuntia et al., 2012; Bovichain et al., 2013; Sinkumkoon et al., 2014).

In cassava production, there are large amounts of crop residues left after harvesting the plant, accounting for 27.56 million ton/year. Half of them is stem base that is left in the field (Department of Alternative Energy Development and Efficiency, 2013). The cassava stem base residues can re-grow and become weeds in the next crop. In starch manufacturing industry, the process that produces cassava starch from fresh cassava root leaves substantial industrial wastes such as tails and stalk, cassava peel and cassava starch waste. The tails and stalk derived from the first screening on the conveyer, comprising mainly dirt and part of cassava stem base. The cassava peel is skin and cortex of cassava root discarded during peeling and washing process while he cassava starch waste being from ensiling process. One ton of cassava fresh root produces 0.25-0.30 ton of starch with 0.50 ton of tails and stalk, 0.25-0.30 ton of cassava peel and 0.25-0.35 ton cassava starch waste being left as wastes (Chaornrath, 1982; North Eastern Tapioca Association, 2012). Cassava crop residues and organic wastes from starch manufacturing industry tend to increase annually and cause environmental problems. These materials have different properties but mostly contain relatively high plant nutrients (Changlek, 2006; Khungaew et al., 2010; Eneje and Nwosu, 2012). In the case of cassava stem base, it has high lignin concentration; therefore it suits to a production of biochar that can be used as soil amendment. The objectives of the study was to compare the effect of wastes from cassava starch manufacturing plant such as cassava starch waste, cassava peel, and tails and stalk, biochar and chemical fertilizers on growth, yield and plant nutrient uptake of cassava grown on Yasothon soil and to determine the residual effect of organic amendments and chemical fertilizer on soil property changes and plant nutrients availability in soil. Results obtained will be useful and transferable to cassava growers in the region where the soils are low fertile and cassava planted responds rather unrealistically to fertilization.

Methodology

Field experiment was carried out on Yasothon soil in a farmer field at Ban Subplu Noi, Huay Bong subdustrict, Dan Khun Thot district, Nakhon Ratchasima province. The experimental area is undulating with 3% slope with an elevation of 245 m above MSL. Average annual rainfall and temperature in the area were 1,212 mm/yr and 28.2^{o}C, respectively.

The trial was carried out during June 2012 and May 2014 using cassava, Huay Bong 80 variety as a major plant. Split plot in randomized complete block design (RCBD) with four replications was employed. Main plot consisted of organic soil amendments including no soil amendment application as the control (T1), 1.25 t/ha of stem base biochar (T2), 6.25 t/ha of cassava starch waste (T3), 6.25 t/ha of cassava peel (T4) and 6.25 t/ha of tails and stalk (T5). Sub plot comprised two rates of 15-15-15 formula chemical fertilizer, 312.5 kg/ha (F1) and 625 kg/ha (F2). Cassava stem base biochar was applied in the form of dry material, thus the amount was five times lower than wastes from the cassava starch manufacturing plant. Other organic wastes used in this experiment were fresh and their properties are shown in **Table 1**. Main plot size was 8×10 m with the spacing of 1 m between plots. Soil amendments were applied onto soil surface and incorporated to the approximate of 30 cm at the first plough using three-disc plough. The field was left for two week and then using seven-disc plough to loosen the soil and ridge was produce across the slope right after that. Cassava was planted with a spacing of 80×120 cm on the top of the ridge. Each main plot was separated into two equal subplots (4×5 m in size). Two rates of 15–15–15 complete fertilizer were applied at four months after planting. Cassava yield and plant parameters were harvested and recorded when cassava was at 10 months old.

Site characterization of the study area was also carried out basing on standard field methods (Soil Survey Division Staff, 1993). Soil samples at three following depths; 5-10, 15-20 and 25-30 cm were collected from each plot at one week before harvesting time. Laboratory analyses of physico-chemical properties of soils were conducted basing on standard methods (National Soil Survey Center, 1996).

Cassava characters and yield, and properties of soil as affected by soil amendment and chemical fertilizer were analyzed for statistical significance using the analysis of variance (ANOVA). Mean separation was done using SPSS program ver.16.0 (SAS Institute, 2003) and Duncan's multiple range test (DMRT), respectively at a significant level of $P<0.05$ (Steel and Torrie, 1987).

Results and Discussion

1. Characterization of Soil in the Studied Area

The soil in the experimental area was derived from sandstone therefore it was dominated by sand particle (>700 g/kg), indicating its textural narrowness that ranged from loamy sand in topsoils to sandy loam in subsoil horizon. Soil pH was strongly to very strongly acid with the values ranging from 4.9-5.5. The soil had very poor fertility status as reflected by very low amount of organic matter, total nitrogen, available phosphorus, available potassium and low cation exchange capacity (**Table 2**). According to a presence of clay accumulation and base saturation percentage of lower than 35 percent in an argillic horizon, the soil was classified as a Typic Paleustult.

2. Effect of Organic Soil Amendment and Rate of Fertilizer on Cassava

The rate of 15-15-15 formula chemical fertilizer had the effect starch yield and above ground biomass (**Table 3**). The higher rate significantly gave the higher starch yield and above ground biomass than did the lower rate (9.1 compared to 7.4 t/ha and 26.3 compared to 25.4 t/ha, respectively). With no statistical difference, cassava yield tended to increase whereas the starch content decreased when applied chemical fertilizer at the higher rate. This agrees with previous reports (Changlek et al., 2006; Samutthong et al., 2010; Parkes et al., 2012). The higher rate of chemical fertilizer released larger amounts of major plant nutrients than did the lower rate, therefore These nutrients could enhance cassava growth and subsequently gave better yield and above ground biomass but the trend of starch content in cassava tuber was in opposition decreased as generally reported (Changlek et al., 2006; Kandi et al., 2011; Bovichain et al., 2013; Sinkumkoon et al., 2014).

Cassava root yield, starch yield and above ground biomass in plots incorporated with cassava stem base biochar, cassava tails and stalk, cassava peel and cassava starch waste tentatively increased when compared to the plot without using soil amendment. The soil amended with tails and stalk gave the highest root yield of 32.4 t/ha and above ground biomass of 27.1 t/ha but with no statistical difference ($P>0.5$) (**Table 3**). There were no interaction between soil amendment and rate of chemical fertilizer applied. However, soil amendments combining with the higher rate of chemical fertilizer tended to give higher yield than did combining with the lower rate.

3. Effect of Organic Soil Amendment and Rate of Fertilizer on Soil Properties

There was no statistical difference on bulk density at the depth between 0-30 cm with or without soil amendment application (**Table 4**). Bulk density values were still quite high with measured values ranging between 1.53-1.7 Mg/m^3. The addition of cassava tails and stalk somehow had a trend of decreasing bulk density, particularly at the depth between 25-30 cm whereas other soil amendments seemed to have no effect. This coincided with greater yield retrieved, although the statistical analysis did not show any difference.

Organic soil amendment and rate of fertilizer had a slight effect on the change in chemical properties of the soil. Incorporation of cassava peel significantly resulted in the highest cation exchange capacity of 3.12 $cmol_c$/kg after growing cassava for one crop (**Table 4**). It means this organic waste is efficiently able to increase an ability of the soil to absorb plant nutrient. Nonetheless, the result was inconsistent with cassava root yield obtained. The range of 1.62 to 1.81 $cmol_c$/kg cation exchange capacity value was obtained from the plots incorporated with other soil amendments but without any statistical difference comparing to the control plot (1.56 $cmol_c$/kg). It was quite surprising that the higher rate of chemical fertilizer applied significantly gave the higher organic matter content in soil than did the others, indicating that the higher the major nutrients being applied, the more the underground growth such as small roots was produced, and subsequently decomposed to give more organic matter remaining in the topsoil. Soil pH was significantly affected by organic soil amendment and rate of fertilizer. The application of tails and stalk combining with the higher rate of 15-15-15 formula chemical fertilizers significantly induced the highest soil pH of 6.1 (**Table 4**). This result coincided with the yield obtained. This is because soil pH increase may subsequently have increased the availability of plant nutrients, especially phosphorus that can be fixed under acidic condition (Brady and Weil, 2008), particularly in case of the soil in the experimental area that was strongly to very strongly acid.

After one crop, soil in the experimental area still contained low amounts of organic matter, total nitrogen, available phosphorus and available potassium contents with the amount ranging from 0.30-0.47 g kg, 0.26-0.36 g kg, 4.68-57.58 mg/kg and 29.62-77.66 mg/kg (**Table 4**). However, these contents were still higher in the plots incorporated with organic soil amendment than in the control plot without soil amendment added. This reflects the nature of these coarse-textured soils that have very low amount of organic matter and cation exchange capacity (**Table 4**). Additional, good aeration nature of this Yasothon soil due to the soil having mainly macropores also accelerated the decomposition rate of organic material, thus the effect of the addition of organic soil amendment in this study was very slightly detectable. It may also be because of the rate of soil amendments used in this experiment was too little to be able to change soil properties. Consecutive incorporation may be needed to improve this chemical property of the soil in search of getting the soil to be capable of retaining plant nutrients against leaching.

Table 1 Properties of soil amendments used in the experiment.

	Cassava starch waste	Cassava peel	Tails and Stalk	Stem base biochar
Dry weight (%)	21.14	26	22.6	59.31
pH (1:1 H_2O)	5.8	6.2	4.6	6.8
EC (dS m^{-1} 1:1 H_2O)	0.62	1.06	1.5	0.54
C:N ratio	63.1	33.1	40.1	60.1
cation exchange capacity ($cmol_c$/kg)	0.62	1.06	1.5	0.54
Organic matter (g/kg)	433	354	269	200
Total N (g/kg)	3.5	6.3	3.9	1.8
Total P (g/kg)	660	596	0.3	52.1
Total K (g/kg)	2.8	5.2	6.2	21.9
Total Ca (g/kg)	5.6	6.2	9.7	22.6
Total Mg (g/kg)	1.4	1.3	1.9	3.5
Total Na (g/kg)	2.9	2.9	0.5	0.1
Total Mn (mg/kg)	28	105	290	35
Total Zn (mg/kg)	21	29	77	11
Total Fe (mg/kg)	71	2121	5085	99.50
Total Cu (mg/kg)	0.44	3.14	42.11	2.78

Remark: Ec = Electrical conductivity, OM = organic matter, CEC = cation exchange capacity

Table 2 Properties of Yasothon soil representing the experimental area.

Depth	Hor.	pH 1:1 H_2O	OM	Avail. P	Extractable				CEC	BS	BD	Particle size distribution			Textural class
					K	Ca	Mg	Na				Sand	Silt	Clay	
(cm)			(g/kg)	(mg/kg)	(---------------- $cmol_c$/kg -------------)					(%)	Mg/m^3	(------- g/kg-----------)			
Ap	0-18/21	5.1	0.43	4.3	0.01	0.15	0.01	0.30	1.0	33	1.6	831	80	89	LS
Bt1	21-43	5.5	0.16	1.0	0.01	0.15	0.03	0.36	0.8	22	1.8	780	122	97	SL
Bt2	43-68	5.2	0.16	2.7	0.01	0.18	0.03	0.34	0.7	22	1.6	769	148	84	SL
Bt3	68-90	5.3	0.10	2.6	0.02	0.18	0.05	0.28	0.6	15	1.6	747	156	97	SL
Bt4	90-118	5.3	0.17	4.0	0.01	0.12	0.10	0.28	0.8	11	1.6	721	198	81	SL
Bt5	118-150	5.4	0.19	3.9	0.01	0.12	0.14	0.29	1.1	16	1.6	704	194	102	SL
Bt6	150-175	5.2	0.17	2.5	0.01	0.09	0.12	0.09	0.8	13	1.6	736	177	88	SL
Btc	175-200	4.9	0.21	2.0	0.01	0.04	0.14	0.26	0.8	13	1.7	718	173	109	SL

Remark: Hor. = horizon, OM = organic matter, CEC = cation exchange capacity, BS = base saturation, BD = bulk density, LS = loamy sand, SL = sandy loam

Table 3 Effect of fertilizer rates and organic soil amendments on yield of cassava grown on Yasothon soil.

Treatment	Root yield	Starch yield	Aboveground biomass	Starch content	Survival rate
	(------------------------ t/ha	------------------------)		(----------------- %	--------------------)
Soil amendment					
T1	28.1	7.6	25.3	29.1	86.6
T2	27.4	7.3	25.3	28.8	86.6
T3	29.7	7.9	26.1	29.4	94.6
T4	28.1	8.5	25.7	25.5	92.0
T5	32.4	9.9	27.1	28.8	92.0
F-test	ns	ns	ns	ns	ns
Fertilizer rate					
F1	26.9	7.4b	25.4b	29.2	90.7
F2	31.3	9.1a	26.3a	28.7	90.0
F-test	ns	**	*	ns	ns
Soil amendment × Fertilizer rate					
T1F1	26.1	6.6	25.0	29.6	87.5
T1F2	30.1	8.5	25.4	28.6	85.7
T2F1	24.6	6.3	24.8	29.0	92.9
T2F2	30.1	8.4	25.9	28.7	80.4
T3F1	28.1	7.1	25.9	29.4	92.9
T3F2	31.3	8.7	26.4	29.4	69.4
T4F1	25.8	7.8	25.4	29.0	87.5
T4F2	30.3	9.3	26.0	28.0	96.4
T5F1	30.3	9.3	26.3	29.0	92.9
T5F2	34.6	10.4	27.9	28.7	91.1
F-test	ns	ns	ns	ns	ns
CV (%)	11.7	10.7	3.9	2.4	13.8

Remark: ns: non-significant, *, **: significant difference at 0.05 and 0.01 probability levels, respectively, means with the different letters in column are significantly different from each other according to DMRT.

F1 = 312.5 kg/ha of 15-15-15, F2 = 625 kg/ha of 15-15-15

T1 = control, T2 = 1.25 t/ha of stem base biochar, T3 = 6.25 t/ha of cassava starch waste, T4 = 6.25 t/ha of cassava peel, T5 = 6.25 t/ha of tails and stalk

Table 4 Effect of fertilizer rates and organic soil amendments on chemical properties of soil.

Treatment	pH	OM	Available		Ca	Extractable		CEC	Bulk density (Mg/m^3)		
			P	K		Mg	Na		5-10 cm	15-20 cm	25-30 cm
	1:1 H_2O	(g/kg)	(-- mg/kg --)		(--------- $cmol_c$/kg ----------)						
Soil amendment											
T1	5.6	4.4	2.3	14.0	0.74	0.06	0.49	1.6b	1.55	1.63	1.70
T2	5.5	4.6	2.3	13.8	0.86	0.06	0.51	1.7b	1.54	1.64	1.70
T3	5.8	4.7	3.6	16.4	0.95	0.06	0.39	1.6b	1.59	1.26	1.67
T4	5.4	4.1	2.5	15.4	0.80	0.06	0.47	3.1a	1.59	1.60	1.68
T5	5.8	4.8	3.9	17.0	1.81	0.06	0.62	1.8b	1.55	1.61	1.62
F-Test	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	*
Fertilizer rate											
F1	5.6	4.3b	2.6	14.7	0.86	0.06	0.49	2.0	1.58	1.63	1.69a
F2	5.6	4.8a	3.3	16.0	1.20	0.06	0.50	2.0	1.55	1.61	1.66b
F-Test	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns
Soil amendment × Fertilizer rate											
T1F1	5.7abc	4.1	2.2	13.7	0.62	0.05	0.47	1.8	1.57	1.63	1.74
T1F2	5.5bc	4.7	2.4	14.3	0.85	0.06	0.51	1.4	1.53	1.62	1.66
T2F1	5.5bc	4.5	2.7	12.5	0.91	0.06	0.42	1.6	1.54	1.66	1.72
T2F2	5.5bc	4.6	1.9	15.1	0.81	0.06	0.61	1.8	1.54	1.62	1.67
T3F1	5.8ab	4.3	2.2	15.5	1.06	0.06	0.38	1.7	1.64	1.66	1.66
T3F2	5.7bc	5.1	4.9	17.3	0.84	0.07	0.39	1.6	1.54	1.59	1.69
T4F1	5.5bc	4.1	1.7	16.2	0.78	0.06	0.47	3.1	1.57	1.58	1.70
T4F2	5.4c	4.1	3.2	14.7	0.81	0.06	0.47	3.1	1.60	1.62	1.67
T5F1	5.5ab	4.2	4.0	15.5	0.91	0.07	0.73	1.6	1.56	1.63	1.63
T5F2	6.1a	5.3	3.7	18.5	2.70	0.07	0.52	2.0	1.53	1.59	1.61
F-Test	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	4.3	13.9	76.2	33.0	104.4	0.0	36.0	40.8	2.9	3.9	2.7

Remark: ns: non-significant, *, **: significant difference at 0.05 and 0.01 probability levels, respectively, means with the different letters in column are significantly different from each other according to DMRT.

F1 = 312.5 kg/ha of 15-15-15, F2 = 625 kg/ha of 15-15-15

T1 = control, T2 = 1.25 t/ha of stem base biochar, T3 = 6.25 t/ha of cassava starch waste, T4 = 6.25 t/ha of cassava peel, T5 = 6.25 t/ha of tails and stalk

Conclusions

Cassava stem base biochar, cassava starch waste, cassava peel, cassava tails and stalk, and different rates of 15-15-15 formula chemical fertilizer hardly affected cassava root yield differently. Applied chemical fertilizer tended to have more influence on vegetative growth of cassava than did the organic soil amendments. The cassava tails and stalk applied at the rate of 6.25 t/ha with the addition of 625 kg/ha of 15-15-15 formula chemical fertilizer was likely to produce the highest fresh root and starch yields. This waste also had the effect on increasing soil pH while cassava peel increased cation exchange capacity of the soil. Further research needs to be undertaken, especially in trying to use higher rates of cassava peel, and cassava tails and stalk in combination with adjusted ratio and rate of chemical fertilizer.

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