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Study of Soil Respiration And Nodulation of Green Beans Growing On Biochar and Dung Amandement On Vertisols

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Abstract: *Vertisols is a dominant suboptimal soils in Lombok. It is high soil chemical fertility, high organic matter, and deep solum. However, physically the Vertisols has limiting factors, namely cracking when dry, swelling when wet, sensitive to water logging, and aeration is limited. The latest factor directly influence soil respiration, and biological activities, e.g. roots growth and microorganism. A green house experiment with a Completely Randomized Design was carried out to study soil respiration and nodulation. These would indicate soil functionality. The results of research showed that soil respiration indicated by CO_2 released from soil was less affected by mixing biochar or dung on Vertisols Lombok. Nodulation on green beans increased on both biochar and dung treatment. Plant growth and gravimetric parameters of plant e.g. above soil biomass, either wet or dry, and roots volume, were not significantly affected under biochar or dung treatment. Soil physical nature e.g. soil moisture, bulk density, and specific density were relatively affected by the treatment. Chemical nature of soil, e.g. N-total, actual-pH, available P and exchangeable-K slightly improved. Bacteria population was higher at a rate of 20 tones biochar per hectare on Vertisols, i.e. 5.48×10^5 cells/gram compare to 3.44×10^5 cells/gram on control and 5.02×10^5 cells/gram on dung treatment.*

Keywords: *Vertisols, Biochar, Dung, and Green Beans*

I. Introduction

Vertisols is one of a dominant suboptimal soils in Lombok which comprises of 23% (12.643,23 ha) of total land (Bakosurtanal, 2009, Ma'shum *et al.*, 2003, Kusnarta *et al.*, 2011). It is fortunately that Chemical fertility of Vertisols is relatively high, i.e. CEC (Cation Exchange Capacity) ranges 25-45 me/100 g, base cation saturation is relatively high, soil pH is around 6.0 - 8,5 (Supriyo, 2008). Some physical factors are also beneficial for agriculture purpose, namely: soil solum is deep which ranges from 60 up to 150 cm, water holding capacity is high (Mahrup *et al.*, 2013). However, the Vertisols has limiting factors in term of physical characteristic, i.e. cracking when dry and swelling when wet. These are due to a high contents of clay fraction. It consists of more than 50% clay in Vertisols of Lombok. Domination of clay mineral, *monmorillonit* (Buckman dan Brady, 1982) influence soil aeration (Supriyo, 2008) which restricts respiration and soil microbial activities (Sutanto, R., 2005 dan Suwastika, *et al.*, 2009), as well as disturbing plant root growth and development (Ma'shum, 2003).

Soil respiration is an indicator to determine soil microorganism activities. This parameter is measured on the basis of CO_2 released from soils which represents microorganism activities (Anas, 1989), as well as roots's respiration (Hakim, *et al.*, 1986). The soil respiration could be an indicator of soil functionality (Raich & Tufekciogul, 2000). However, there are physical restrictions of Vertisols, in term of root growth and soil organism, namely dominant micro pores due to high clay fraction, so it is sensitive to waterlogging. This obstacle can be difficult in the plant cultivation activity. Like crops planted as 2d crop in dry season plant, horticulture and *leguminase* plants are sensitive to waterlogging condition. So that, this soils is favorable for rice, but it is very bad for non rice, e.g., legume, corn, chili, vegetables and horticulture.

The *legume* is crops which have nodules on its roots for nitrogen fixation from atmosphere. The dignification step on the land with this kind of Vertisol soil which has been done is: giving organic fertilizer, adding compost (residue of plant), giving mulching, and Raised beds system (Borrell *et al.*, 1998, Ma'shum, M.,2003). All of steps are aimed to increase the contents of soil organic material which can improve the soil natures (Nyangamara *et al.*, 2001). The use of soil decomposer with natural material experiences more and more higher of reorganizing and mineralization. The result is the necessary of natural material is increase continuously. However, the use of natural material which resist to the decomposition can use biochar. Biochar is a substance of porous charcoal posessing huge amount of micro and macro pores (Laine *et al.*, 1991).

Biochar has CEC, C-Organic and large of total surface area (Liang et al., 2006) and water absorption is relatively high. It resists to the microorganisms decomposition, so it persists in a long period of time in soils. . These particular nature of biochar have advantage, i.e., nutrient retention capacity is high, so it prevents nutrient leaching. Mixing biochar with Vertisols dominated by clay is able to allow respiration in soils (Quilliam *et al*., 2012 and Dariah, *et al.,2015*). In addition, Steiner *et al.* (2007) showed that biochar application can decrease soil solidity dan soil strength. Having wide surface area, biochar can adsorb plant nutrients, and act as media for soil microorganisms, as well as improving the physical nature of soils (Chan *et al.*, 2007).

Dung in soil also contributes in stimulating soil biological activities and improving soil physical natures, particularly soil structure, so plant roots grow well in soils containing a relative high content of dung in it. There are some advantages of having dung in soils, namely: improving soil structure (Syekhfany, 2000), increasing water holding capacity or water retention (Hartatik and Widowati, 2010), improving microbial activity and providing nutrients for plants.

Therefore, it is worthy to study the effect of biochar and dung amendment to Lombok's Vertisols .on soil respiration activity and nodulation of the green beans at Lombok Vertisols.

II. Materials And Methods

The research was conducted at a Green House of Faculty of Agriculture, University of Mataram. Soil samples and plant tissue were analyzed at the Laboratory of Soil Science and Laboratory of Microbiology, Faculty of Agriculture, University of Mataram. This was taking place in August - October 2016.

2.1 Experimental design

This study used a Completely Randomized Design (CRD) with 5 treatments. The first treatment was without amendments as a control treatment (KO), The second treatment was biochar amendment at a rate of 20 of tons/ha (KB), the third treatment was dung amendment at a rate 20 tons/ha, the fourth treatment was combination of biochar and 10 tons/ha of dungs (BPK1), and the last treatment was combination of biochar and 20 tons/ha of dung (BPK). Each treatment was repeated 3 times, so that there are 15 units of pot experiments. Each unit of treatment had a serie of treatment, so that there were 30 pots of experiments.

2.2 Planting Media Preparation

Soil samples for planting media was air dried grounded Vertisols passing through a Ø 2 mm sieve. The soil samples were placed in cylinder plastic pots with dimension: pot diameter (Ø) was 10 cm, pot height was 25 cm. Soil depth in the pot was ± 20 cm. Soil weight per pot was approximately 3,61 kg of oven dried weight. The bottom part of the pot was inserted into a saturated fine sand media (± 5 cm) to keep capillary raise in the soil samples.

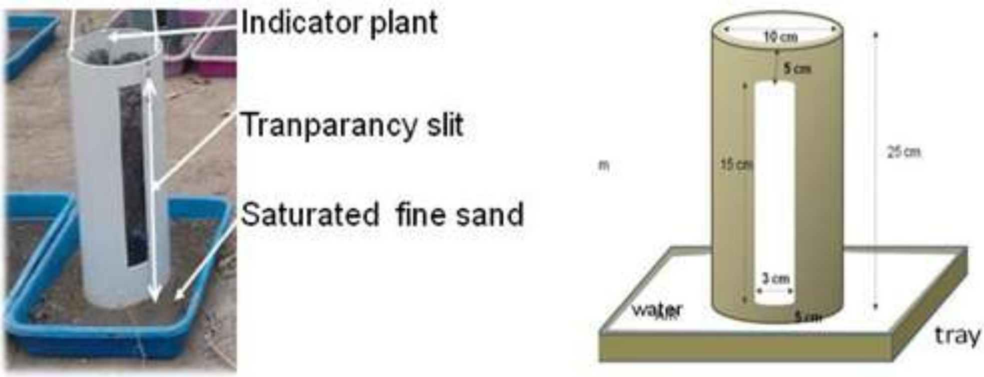


Figure 1. A cylindrical pot made of a PVC tube (left) and Pot Dimension (right)

2.3 Capillary Movement Observation

Capillary movement was observed through the slots on the pot side with 3 cm wide and 15 cm long. The slot was covered properly by transparant plastic, so that the capillary raise in the soil can be observed seen from outside. The limit of capillary water movement is scrutinized based on the different of soil colour, particularly *Value* and *chroma* using a munsell color chart. The limit of capillary raise is determined on transition between the color of moist soil and dry color.

The increasement of capillary was hourly measured from the surface of saturated fine sands upward until the transition point (base on color different). The measurement was read on a ruler whish was perpendiculary pasted at the slot side. The measurement is done everyday until the observation was ended (45 days fter planting).

2.4 Materials and Tools for Research
The materials and tools used in this experiment were Vertisols taken from Middle Lombok. The samples were air dried sifterred by a sifther with a diameter of Ø 2 mm. Some tools were: pots made of PVC- tube with Ø 10 cm, a hygrometer, a watering tool (water hose, measurement glass), soil sampling tool (modification bor, sample ring), soil moisture measurement tool, and soil physical measurer tool, roll gage, and stationary tools, aquades, chemical solution, such as: KOH, HCl, orange methyl, phenolphthalein, and other materials and tools.

2.5 Preparation for Biochar and Dung
Residue of rice husk was collected in a drum, then heated by using a heating furnace with temperature up to 300^0C (Rosidi, 2014). The heating was done until all of materials formed black charcoal and then it was cooled. After the biochar was cool, then it was grounded to fine powders. This biochar was ready to be be thoroughly mixed with soil sample as the recommended dosage. The application dosage was 20 tons of biochar per hectare.

Dung used in the experiment was livestocks' feces, such as: goat and cow with ratio 1:1. The dung must be dark brown in coloured as indication of maturity. The dung was sifterred by a sifter with Ø 2 mm to get uniformity size. The treatment dosage was 20 ton of air dried dungs per hectare.

2.6 Preparation of seeds and Planting
Specific density of soil sample was 1.2 g/cm^3 . Samples were sifterred and placed in to the cylindrical pots. Soil samples were filled with a soil as thick as ± 20 cm. The pot was filled with the soil samples are perpendiculary placed above a base that can receive water (tray) with water thickness is ± 5 cm. The same thing is done on the each of treatment, i.e., KN (Vertisol as much as 2000 g/pot and biochar as much as 17 gram/pot equal to 20 ton/ha), PK (Vertisol as much as 2000 g/pot and dung as much as 17 gram/pot equal to 20 ton/ha), B+PK1 (Vertisol as much as 2000 g/pot, biochar and dung as much as 8.333 gram/pot of each of them equal to 10 ton/ha) and B+PK (Vertisol as much as 2000 g/pot, biochar and dung as much as 17 gram/pot of each of them). The fertilizer with mixtures of N, P, and K with recommendation dosage as basic fertilizer as much as 0.08 g/pot is entered into a hole with 5-6 cm of distance. Then, each of treatment is done an incubation, incubation process is done by the paralons/pots have been filled with soils are covered with plastics and then perforated and done a watering on the width capacity and incubated during 3 weeks. The same thing is done on the each of treatment which the further is done planting indicator plants. Then, it is done planting the indicator plants, i.e., green beans.

2.7 Observation Variable
Soil variables were soil properties namely, physical, chemical, and soil biology properties. Plant variables were plant height after 45 days of planting, and fresh and oven dried weight of shoots and roots. The soil physical variables included: bulk density (BV), particle density (BJ) of soil, soil total porosity (η) using a formula: $\eta = (1 - (BV/BJ)) \times 100\%$. The variables of soil chemistry included: Particulat Organik Carbon (POC), soil organic carbon using Walkley Black method (Nelson and Sommers, 1982), soil pH-potential and actual. Biologycal variable included: soil respiration test was carried out by measuring the evolution of CO_2 at 0 day after planting (DAP), 15 DAP, and 45 DAP. This measurement was directly done to the planting media after cutting the indicator crop. Soil respiration rate was counted as follows: CO_2 (gas) released per 10 hours^{-1} (mg) = (W – V) N.E; where B is volume of HCl used for blank titration, V is volume of HCl used for titration of treatment sample, N is normality of HCl and E = 22 is gram-equivalent from the released CO_2.

2.8 Variables of Plant
Plant height was regularly measured at age of 7 DAP, 14 DAP, 28 DAP, 35 DAP, and 45 DAP as a final stage of vegetative phase for green beans. Shoots (above soil part of plant) and roots were weighed in the fresh and oven dried conditions. Root length was measured from beginning of root branch until the tip of longest root.
The observation and counting of root nodules was done at age of 45 DAP. The observation was done by lifting the plants from the pots and separating soil from roots. Amount of root nodules was manually counted.

***2.9 Data analysis*.**
Observed data in this study were analyzed by analysis of variance (ANOVA) at 5% level ($P \leq 0.05$). Further statistical test for significantly different between treatment was carried if F-test indicated significantly different. This further test using *Duncan Multiple Range Test* (DMRT) at 5% significance level.

III. Results And Discussion

Spectral analysis of infrared absorption by biochar and dung was carried out to identify type of organic compounds contained in the biochar and dung. Graph of clusters for biochar and dung functional compounds are displayed in picture 3.1. The infrared absorption (*band assignment*) shows that the biochar contains the function cluster shape which indicates the presence of aldehyde, cetone, carboxylate acid, and esther. These organic compounds cause the biochar has heterogenous functional (Van Zwieten *et al.*, 2010), which contains oxygen (Lehmann, 2007), so their presence in soils, could experience hydrolysis and oxidation process (Lehmann, 2007, Cheng et al.,2006:174, Hammes et al, 2006:175). The oxidation of biochar particles could produces negative charge in the form of carboxyl and phenol on the surface of biochar (Zackrisson et al, 1996). The higher of the negative charge of biochar, the higher will be the soil CEC (Liang et al., 2006). Thus, the biochar has ability to increase retention of soil nutrients.

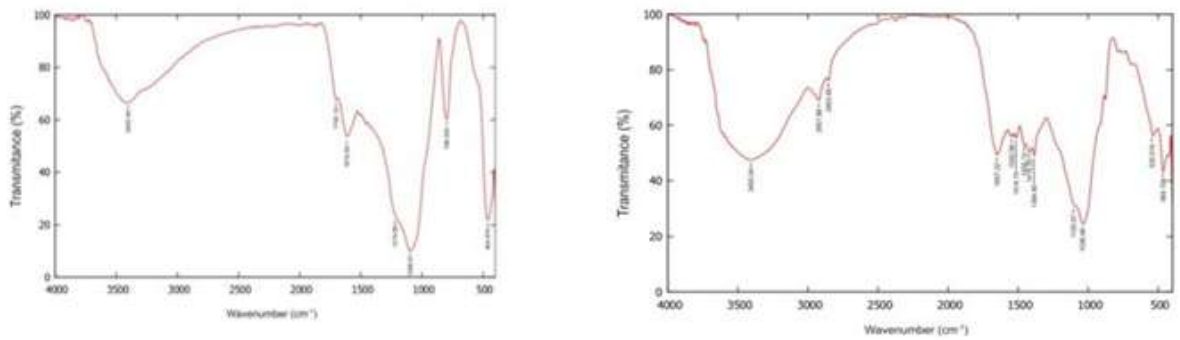


Figure 3.1. Fourir Transformation Infra Red (FTIR) for Biochar of Rice Husk (Left) and Dung Spectra (right)

Main group of organic compounds in biochar and dung are presented in Table 3.2. As it is shown in the Table 3.2 that biochar and dung contain similar types of organic compounds, except for aldehyde which was only found in biochar. Aldehyde is one of carboxyl compounds possessing a hydrogen atom on the tip of its primary chain (Oeda, 1934). It is produced through an oxidation process of alcohol with a typical physical property of relative high boiling point (Reuss, et al.,2005) among other carboxyl compounds. Therefore, the presence of aldehyde in the rice husk biochar was due to oxidation (pyrolysis) during its production. Furthermore, there should be beneficial effect of having aldehyde in biochar, i.e. it would provide exchangeable-H which enable to be replaced by any cations in soil solution.

Table 3.2 The Main Group of Compound Functional Cluster in the Rice Husk Biochar and Dung

	Wavenumber (cm^{-1})	Infrared Absorption (Chemical Bond)*)	Type of Compound
Rice Husk Biochar	464.974-798.555	C=C-H (aromatic H)	Alkene
	1098.91-1219.89	C-O	Alcohol, ether, carboxylate acid, esther
			Alkene
	1616.95	C=C	Aldehyde, ketone, carboxylate acid, esther
	1700.10	C=O	
			Amine, amide
	3405.49	N-H	
Dung	464.154-535.019		
	1036.48-1100.07	C-O	Alcohol, ether, carboxylate acid, esther
	1384.90-1455.12	C-H	Alkane
	1514.74-1542.56	C=C	Aromatic Ring
	1674.22	C=C	Alkene
	2853.48-2921.98	C-H	Alkane
	3400.04	N-H	Amine, amide

*)**Source:** *Principle of Instrumental Analysis,* Skoog, Holler, Nieman (1998)

Table 3.3. Chemical Properties of of Biochar and Dung

Parameters	Unit	Biochar	Dung
pH-H_2O	-	7.01	8.3
C-organik	%	28.35	26.2
CEC	me.$100g^{-1}$	-	-
Total-N	%	0.39	2.02
Total-P	%	0.07	1.49
K	%	0.03	2.42
C/N		71.96	13.9

3.2. Characteristics of Vertisols

Soil samples were taken from an agricultural field at Batujai Village, West Praya Subdistrict of Central Lombok. Characteristics of Vertisols is shown in Table 3.4. It can be seen from the Table that soil pH was neutral, concentration of total Nitrogen and available Phosphate were low, C-organic content was very low , and total porosity was about 56.72%.

Table 3.4. The Characteristics of Vertisol Soil

Parameters	Method	Unit	Value	Criteria*)
Soil Physics a. BV (Bulk density)	Candle	g/cm^3	1,27	
b. BJ (Specific Weight)	Phycnometer	g/cm^3	2,25	
c. Total Porosity (%)		%	56.72	
Soil Chemical				
pH-H_2O	Electrode Glass		7.09	Neutral *
N-Total (%)	Kjeldhal	%	0,12	Low*
P-Available (ppm)	Olsen	Ppm	10.80	Low*
K-Exchangable	(NH4-Acetate)	Me/100g/%	3,57	Very high*
C-Organic	(Walkey & Black)	%	0,92	Very low*

*)*Source: Soil Research Center (1983) in Hardjowigeno (2003)*

3.3 Respiration Activity

Soil microbiology activity in this study was detected by means of soil respiration. It could be measured through evolution analysis of CO_2 released from soils. This measurement was done at age of 0 DAP (as an initial stage), 15 DAP, and 45 DAP (as a last stage). Amount of CO_2 released at various of treatments are presented on Figure 3.3.

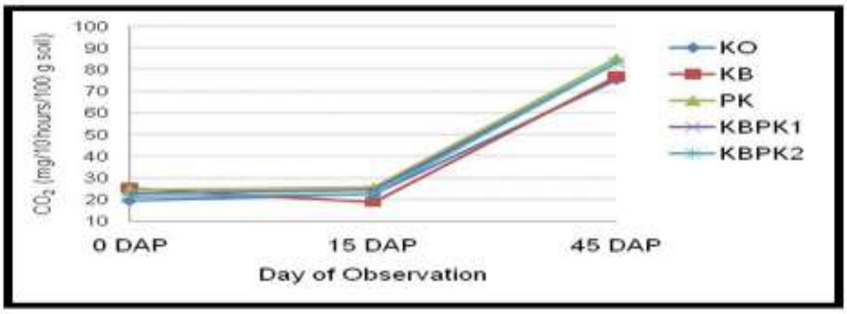


Figure 3.3. Evolution of CO_2 at age of 0 DAP, 15 DAP, and 45 DAP (mg/10 hours/2kg)

Figure 3.3 shows that respiration of microbiology in Vertisols sharply increased temporally after 45 days of treatment. At the initial stage (0 DAP) CO_2 released from soil was the same for all treatments. It ranged from 19.5 to 25. 4 mg/10 hours/100 gr soil. This figures remained constant within two weeks after planting (15 DAP). A relatively high CO_2 was observed at 45 DAP when all treatments performed a similar trend without significant difference between treatments. At this stage, evolution of CO_2 for all treatments ranged from 75.4 to 85.3 mg/10 hours/100 gr soil. There was a slightly difference evolution of CO_2 from soil with amendment, e.g. dung and combination of dung plus biochar. The different was about 10 mg/10 hours/100 gr soil compared to solely biochar or control. The same result was reported by Biederman and Harpole (2013), that on the combination of biochar and dung was found any enzymes which triggered increasement of microbiology activities in soils. The releasing of relatively high CO_2 in the period of observation could be an indicator of soil amendment role on soil functionality, such as on microbial activities. Murphy (2014) reported that soil organic materials, particularly humous, are the best providers for the highest energy sources for soil microorganisms. So they are able to increase soil respiration.

3.4 Root Nodules

Tabel 3.5 shows that amendment of biochar (KB) or dung (PK) on Vertisols at rate of 20 ton/ha, respectively and combination of both at rate of 10 tons/ha for each could stimulate nodulation of green bean. The highest numbers of total nodules and effective nodules per crop were performed on combination of biochar and dung at rate of 10 tons/ha each (KBPK1). This result suggest that if biochar and dung are combined, then favorable growth for nodules will be reach at a minimum rate. In other words, combining biochar and dung can reduce an optimum rate of biochar or dung required to gain an optimum growth of nodules. However, there was a clue that an increasing rate of dung tends to increase number of ineffective nodules. The highest number of ineffective nodules was found in the dung treatment, either on solely dung (PK) or on its combination with biochar at a rate 10 tons/ha (KBPK1). It might be because of a high content of nitrogen in the dung applied to the soils. Laboratory test shows that nitrogen content of the dung was 2.02%. This means that dung amendment enriched concentration of soil nitrogen. As a results, growth and *Rizhobium* sp activity for nitrogen fixation were depressed. Previous research conducted by Kurniaty, et al.(2013), concluded that nitrogen play role as starter at early vegetative stage of legume. However , high concentration of nitrogen in soils can reduce activity of nitrogen fixation by *Rizhobium sp* (Lynch, J.M.,1983), which can be indicated by increasing number of ineffective nodules.

Table 3.5. Effective Root Nodules, Ineffective Root Nodules, The Amount of Root Nodules On The Green Beans Plant

Treatment	Root Nodules			Root Volume (cm^3)
	Effektive	Ineffective	Total	
KO	8.00a	2.00a	10.00a	0.4a
KB	12.33b	3.33ab	15.66a	0.4a
PK	12.67bc	6.00b	18.67a	1.33a
KBPK1	15.67a	5.67b	21.34a	1.43a
KBPK2	9.67b	3.67ab	13.34a	0.67a
DMRT 5%	1.16	1.19	4.62	0.41

*) The numbers followed by the same letters on each treatment was not significant different at 5% level of Duncan Multiple Range test (DMRT)

3.5 Parameter of Plant

Table 3.6. Effect of Treatment to Crop Parameters

Treatrment	Wet Stover Weight (gr)	Dry Stover Weight (gr)	Root Volume (cm3)	Plant Height (cm)
KO	125.98^{a}	35.21^{a}	2.37^{a}	58.00^{a}
KB	127.03^{a}	34.03^{a}	2.37^{a}	58.33^{a}
PK	129.19^{a}	36.23^{a}	3.33^{b}	66.00^{a}
KBPK1	129.80^{a}	35.64^{a}	3.43^{b}	65.93^{a}
KBPK2	122.78^{a}	37.12^{a}	2.67^{ab}	56.83^{a}
DMRT 5%	13.63	3.17	0.41	5.21

*) The numbers followed by the same letters on each treatment was not significant different at 5% level of Duncan Multiple Range test (DMRT)

Table 3.5 shows effect of treatment, i.e., KO, KB, PK, KBPK1, and KBPK2 to green bean growing on Vertisols. It can be seen from table 3.5 that dung plays significant role in the plant growth, e.g. weight of wet and dry stover (above ground of plant part), volume of root and plant height. Over all, these parameters indicate higher values on solely dung treatment (PK) and its combination with biochar compare to biochar treatment (KB). This results are reasonable, because dung can serve as a nutrient source for plant (Hartatik dan Widowati, 2010), while biochar does not provide nutrients (Lehmann, 2007). Laboratory test shows that dung used in the experiment contained a relatively high concentration of plant nutrient, i.e. 2.02% N, 1.49% P ,and 2.42% K (Table 3.3). In contrast, biochar contain a low concentration of plant nutrient, i.e. 0.39 % N, 0.07% P ,and 0.03 % K (Table 3.3). In addition, Vertisols used in this experiment was infertile soils where essential nutrient content was very low, namely total N 0.12%, available P 10.8 ppm, and C-organic 0.92% (Table 3.4). Except for available K, the soils contain a very high concentration, i.e. 3.57 me/100 gr soils (Table 3.4). Buckman and Brady, (1982) stated that macro nutrient, such as N, P and K is essential nutrients for crops to grow well. This result is similar with other studies conducted by Pujisiswanto dan Pangaribuan, 2008, Ariyanto,2011) revealed that dung applied to soils can provide nutrients which are available for plants.

3.6. Changes of Soil Properties

Some soil physical parameters of Vertisols slightly changed, though statistically the changes in BV, BJ, COLE of Vertisols were not significant. Significant change was performed by soil moisture and porosity.

Soil moisture at wilting point significantly decreased, if both biochar and dung were mixed. However, if they were separately applied, then the effect on soil moisture was insignificant. Lowering in the wilting point resulted in increasing of available water in soil. It was due to a high capacity of biochar and dung to hold water(Lehmann, 2009; Hartatik and Widowati, 2010), within micro pores which provide more readily available water for root system (Sutanto, R.,2005). In addition, total porosity of water indicates a maximum water of soils. Amendment of biochar, or dung at a rate of 20 tons/ha on to Vertisols could increased total porosity.

Table 3.6 The Changes of Soil Physical Nature

Treatment	Variables of soil physical Properties				
	Moisture (%)	BV (g/cm^3)	BJ (g)	Porosity (%)	Value of COLE (gr/cm3)
KO	22.50^{a}	1.27^{a}	2.15^{a}	40.93^{a}	0.16 a
KB	22.30^{a}	1.16^{ab}	2.13^{a}	45.53^{b}	0.11b
PK	21.64^{a}	1.13^{ab}	2.15^{a}	52.33^{a}	0.10b
KBPK1	14.15^{b}	1.10^{b}	2.09^{a}	52.55^{a}	0.09b
KBPK2	14.22^{b}	1.09^{c}	2.06^{b}	52.91^{a}	0.09b
DMRT 5%	3.13	0.04	0.04	2.54	0.008

*) The numbers on each of line followed by the same letters in each of treatment is not real different according to DMRT test of 5% level.

The percentage of soil porosity is n indicator of soil ability in holding water. Table 3.6 shows that the soil porosity increased on biochar and dung amendment. Furthermore, combining biochar and dung had significantly improved total porosity of vertisols. The highest porosity was achieved on the mixture of biochar and dung at rate of 20 tons/ha each. Though the total soil porosity was statistically the same as those at level 10 tons/ha (KBPK1), and solely dung (PK). Dariah and Rahman (1989) reported that dung gave the highest total porosity of 67.2% by applying it as a mulch to Vertisol at Citayam. In this study, incorporated dung and biochar contributed to the highest soil porosity of 52.9% at the rate of 20 tons/ha each.

Value of Coefficient Linear Extensibility (COLE) slightly changed among various of treatments. It seems that COLE decreased as a result of dung or biochar amendment to Vertisols. There was 34,5 % of COLE lowering after applying biochar or dung and 43,7% lowering if biochar and dung were mixed in Vertisols. Krisnayanti (1996) found that Vertisols in Lombok was dominated by *montmorillonite* mineral from group *smectite* possessing high value of COLE.

3.7 Soil Chemical Properties

Table 3.7 The Treatment Influence To The Change of Soil Chemical Natures

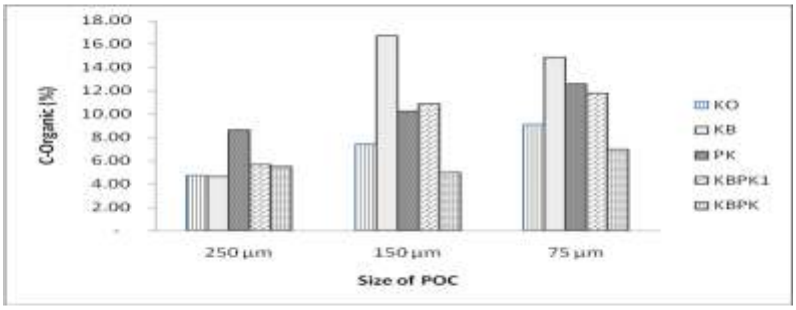
Treatments	Variable of Soil Chemistry			
	Actual pH	N-Total (%)	K-Exchangable (Me/100g/%)	P-Available (ppm)
KO	7.09 ^{a}	0.12^{a}	3.52 ^{bc}	10.80 ^{a}
KB	7.24 ^{c}	0.15 ^{b}	3.37 ^{b}	12.10 ^{b}
PK	7.24 ^{c}	0.16 ^{bc}	3.69 ^{c}	18.80 ^{c}
KBPK1	7.17 ^{b}	0.16 ^{bc}	3.40 ^{b}	16.73 ^{d}
KBPK2	7.13 ^{b}	0.17 ^{c}	3.10 ^{a}	16.00 ^{e}
DMRT 5%	0.02	0.006	0.09	0.25

Table 3.7 shows that actual pH ranges between 7.09-7.24 which is neutral. It seems that the soils had capacity to buffer pH at a range optimum for plant growth. This might be because of parent material of the Vertisols which is limestone ($CaCO_3$) or dolomite ($CaMgCO_2$) (Kusnarta, et al., 2011). These compound are alkaline or base in nature and they can play a role as buffer for soil reaction (Sutanto, 2009). N-total is between 0.12-0.17% which is categorized as low category. It means that state of nitrogen content in soil did not change, though total N slightly increased as result of biochar and dung amendment. Exchangeable-K is between 3.10-3.69 me/100g/% which is in a medium category and P-available is between 10.80-18.80 ppm which is in a low category. It seems that dung treatment on Vertisols resulted in the highest concentration of exchangeable K. This finding was supported by Chan *et al.* (2007) who stated that a huge amount of negative charges belong to organic matter can replace domination of clay mineral in cation adsorption in heavy clay soils. Furthermore, Syekhfani, 2000 revealed that organic matter can reduce cation fixation by clay mineral. While biochar could increased CEC at application rate of more than 50 tons /ha (Chan *et al.*, 2007).

As it was expected that dung would be a nutrient source in soils (Hazelton and Murphy, 2007). It had been proved from this result that the highest concentration of available phosphate was the highest in dung treatment. It was also performed by nitrogen which was relative high concentration in the dung treatment and on its combination with biochar.

3.8. Distribution of Particulate Organik Carbon

Size distribution of particulate organic carbon (POC) in soils (medium) varied in according to source of carbon being applied to the soils. In this study, POC was classified in to three categories of size, namely 75µm, 150 µm, and 250 µm. It can be seen from Pic. 3.4 that POC in the original Vertisols was mostly of size 75µm to 150 µm. Dominant POC in biochar was 150 µm, and it was followed by 75µm. There was a very small percentage with size of 250 µm. Dung shows a different distribution which dominant size was 75µm and successively followed by 150 µm and 250 µm with relatively high percentage.



Picture 3.4 Particle Size Distribution of *Particulate Organik Carbon* (POC)

3.9. Population of Soil-born Bacteria

Soil biology in this study was represented by observing population of bacteria. It can be seen from Figure 3.4 that population of bacteria was relatively high at biochar (KB) and dung treatment (PK). On the other hand, population of bacteria was relatively low in combination of biochar and dung. Population of bacteria in the *rhizosphere* was 5,48 x 10^5 cell/gram in the biochar treatment at rate of 20 ton/ha (KB), and 5.02 cell/gram in the dung treatment at rate of 20 ton/ha (PK). However, population of bacteria was depressed to 1.56 x 10^5 cell/gram, if biochar and dung were mixed at a high dosage (20 tons biochar + 20 tons dung/ha). It seems that application of biochar in infertile Vertisols of Lombok could stimulate competition in energy use by bacteria. It was stated by Handayanto and Hairiah (2007), that any organic matters supplied into soils must fulfill its C:N ratio which is favorable for soil micro organism. Organic matters with high C:N ratio tend to cause nutrient detioration or depletion, because more energy is required by microorganism to decompose the organic matter with high content of carbon (Hardiwinoto, et al., 2005). So, if nutrient is not enough in soils then population of bacteria will decrease because of malnutrition (Gibson, 1981).

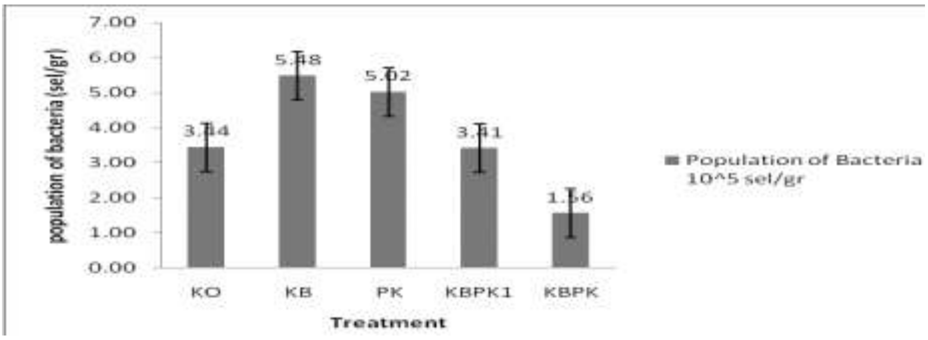


Figure 3.4 Population of Soil Bacteria at Various Treatments

Same results had been reported by Graber, et al., (2010), and Santi and Gunadi (2012) that the application of biochar increased bacteria population compare to compost. It was due positive effect of biochar on enzyme activities in *rhizosphere* (O'neill et al, 2009). The same result was found by Nurida, et al.(2011) that viability of bacteria after applying biochar in 12 months on Ultisols at Bogor Park.

3.10. Capillary Movement

The observation of capillary movement was done in Laboratory after green house experiment. The result shows that capillarization, i.e., vertical water movement in Vertisols was faster in biochar treatment (KB) than other treatment, e.g. dung (PK), mixing dung and biochar (KBPK1 and KB PK2) and control (KO). The fastest capillary rate was 1.83 cm/hour on biochar treatment (KB). This figure was followed in a successive order of 1.64 cm/hour on control (KO), 1.60 cm/ hour on KBPK2, 1.58 cm/hour on PK and 1.53 cm/hour on KBPK2. There was 11.6 % increase in capillary rate on biochar compare to ordinary Vertisols (control treatment). However, dung did not accelerate the vertical movement of water in Vertisols.

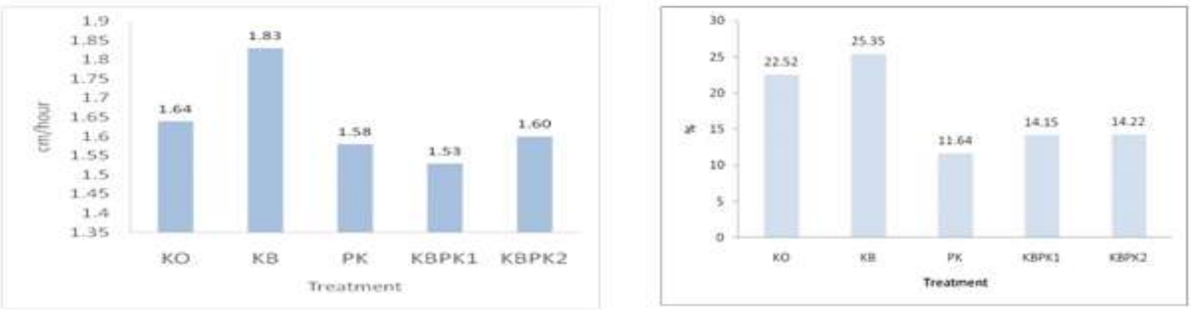


Figure 3.5 Capillary Rate (left) and Soil Moisture (right) on five tested treatments.

This fenomena was clearly explained by Ricigliano (2012) that physically, biochar consists of porous structured material, very fine texture, and very large total surface area. This physical characteristics are directly related to soil moist dynamics (Murphy, 2014), in which porous structure means that biochar tend to provide dominant micro pores (Downie, et al, 2009) where a contact corner between water meniscus and capillary wall is getting small, so the adhesive force lifting water up is increasing (Cetin, et al., 2004) In addition. Large surface area of biochar can increase water holding capacity of soils (Troeh and Thompson,2005) therefore *water retention increases* and more water will be conserved in soils.

IV. Conclusion

Incorporation of biochar or dung as a single or mixed ameliorant in Vertisols Lombok has not performed yet significant contribution to soil respiration based on CO_2 released from the soils. In spite the fact that nodulation on green bean, and soil-born bacteria population were significantly affected by biochar or dung. The highest amount of nodules and effective nodules were found on mixed biochar and dung at rate 10 tons/ha each. It was followed lower in successive order by dung and biochar. In short term, chemical and physical nature of Vertisols have not been significiantly changed yet by biochar or dung. Exception for capillary rate, it was accelerated due to biochar.

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