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Soil Enzyme Activities and Their Relationship to Total Soil Bacteria, Soil Microbial Biomass and Soil Chemical Characteristics of Organic and Conventional Farming

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ABSTRACT

Soil properties such as physical, chemical, biological, microbiological and biochemical aspects affect on soil quality. Soil microbiological activities directly affect stability of ecosystems and soil fertility. The research aimed to determine soil microbial activities through soil enzyme activities and their relationship to total soil bacteria, soil microbial biomass, and soil chemical characteristics. The research was conducted at Laboratory of Soil Microbiology, Indonesian Soil Research Institute, Bogor from July 2015 to January 2016. Soil samples 0-10 cm depth were taken from organic and conventional farming of some commodities (tomato, carrot, maize, broccoli) from Bogor Regency, while those of rice were taken from Tasikmalaya Regency. Soil dehydrogenase, urease and cellulase activities were determined using some modified methods. The results showed that soil dehydrogenase and cellulase activities in organic farming were higher than those in conventional farming, whereas the soil urease activity in organic farming was lower than that in conventional farming. The total soil bacteria and soil microbial biomass were significantly and positively correlated with soil dehydrogenase, urease, and cellulose activities. Soil dehydrogenase, urease, and cellulose activities were very significantly and positively correlated with all soil characteristics tested, *i.e.* soil organic C, total N, potential P and K, available P and K, CEC, and pH, except that soil urease activity was very significantly and negatively correlated with soil pH. The results of this research indicated that organic farming is recommended for maintaining soil fertility and plant productivity; however, small use of urea fertilizer is still needed in the farming.

Keywords: Conventional farming, organic farming, soil chemical characteristics, soil enzyme activities, soil microbial biomass carbon

ABSTRAK

Sifat tanah seperti fisik, kimia, biologi, mikrobiologi dan aspek biokimia berpengaruh terhadap kualitas tanah. Aktivitas mikrobiologi tanah dapat mempengaruhi stabilitas ekosistem dan kesuburan tanah secara langsung. Penelitian ini bertujuan untuk menentukan aktivitas mikroba tanah melalui aktivitas enzim tanah dan hubungannya dengan total bakteri, biomassa mikroba, dan karakteristik kimia tanah. Penelitian ini dilakukan di Laboratorium Mikrobiologi Tanah, Balai Penelitian Tanah, Bogor dari Juli 2015 hingga Januari 2016. Sampel tanah pada kedalaman 0-10 cm diambil dari pertanian organik dan konvensional dari beberapa komoditas (tomat, wortel, jagung, brokoli) di Kabupaten Bogor, sedangkan tanah sawah (padi) diambil dari Kabupaten Tasikmalaya. Aktivitas enzim dehidrogenase, urease dan selulase tanah ditentukan dengan menggunakan beberapa metode yang dimodifikasi. Hasil penelitian menunjukkan bahwa aktivitas enzim dehidrogenase dan selulase tanah di pertanian organik lebih tinggi daripada di pertanian konvensional, sedangkan aktivitas enzim urease tanah di pertanian organik lebih rendah daripada di pertanian konvensional. Biomassa mikroba dan total bakteri tanah secara signifikan berkorelasi positif dengan aktivitas enzim dehidrogenase, urease, dan selulase. Aktivitas enzim dehidrogenase, urease, dan selulase tanah sangat signifikan berkorelasi positif dengan semua karakteristik tanah yang diuji, yaitu: C-organik, N total, P-potensial, K-potensial, P-tersedia, K-tersedia, CEC, dan pH. Sementara aktivitas enzim urease tanah sangat signifikan berkorelasi negatif dengan pH tanah. Hasil penelitian ini menunjukkan bahwa pertanian organik

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direkomendasikan untuk menjaga kesuburan tanah dan produktivitas tanaman; namun, penggunaan pupuk urea yang rendah masih dibutuhkan di pertanian.

Kata kunci: Aktivitas enzim tanah, biomassa karbon mikroba tanah, pertanian konvensional, pertanian organik, sifat kimia tanah

INTRODUCTION

Conventional farming plays an important role in increasing food production, but most of its management practices rely on chemical fertilizers and pesticides (Tu *et al.* 2006). Use of agrochemical materials (fertilizers and pesticides) has increased yield of agricultural commodities. However, use of these materials could have negative impacts on environment (soil, water, and air). On the other hand, organic farming does not use chemical fertilizers and pesticides but emphasizes on organic inputs to meet nutritional needs for plants and biological control for pest management.

Agricultural cultivation in Indonesia consists of two kinds, namely organic and conventional farming. Organic farming is a system of agricultural cultivation that relies on the use of natural materials such as compost, manure, and biomass residues without using synthetic materials (agrochemicals). On the other hand, conventional farming is an agricultural cultivation system that relies on chemical inputs, especially chemical fertilizers and pesticides.

Soil microbiological activities directly affect stability of ecosystems and soil fertility (Dick and Tabatabai 1992; Bouma 2002). Dynamics of soil microbial biomass has a direct relationship to vegetation and established eco-physiological system relating to status of microbial metabolism (Anderson 2003; Burns *et al.* 2013). Use of organic material inputs into the soils affects microbial activities due to different substrate availability (Mondal *et al.* 2015). Therefore, dynamics of soil microbial are essential for plant growth. In its application, the soil microbes produce enzymes to decompose organic materials outside their cells.

Soil microbial activity can affect plant growth and soil fertility, because it can accelerate cycle of supplied nutrients, hormones and enzymes needed by plants (Agus 1997). Soil microbes produce enzymes related to nutrient cycling, soil microbiological activity, and are closely related to cultivation practices. The enzymes play an important role in supplying nutrients for plants because enzymes involved in the cycle of nutrients in the soil-plant system. The cycle can be seen through activity of microbes that are reflected in activity of enzymes contained in the soil (Pascual *et al.* 2000; Gil-Stores *et al.* 2005; Trasar-Cepeda *et al.* 2008; Giacometti *et al.* 2013; Mao *et al.* 2013).

Enzymes as catalysts in biochemical reactions in soil could be intracellular enzymes in living cells or dead organisms and extracellular enzymes. Soil enzymes are divided into three major groups, namely oxidoreductase, transferase and hydrolase groups. Enzymes are catalysts, substrate specific reaction to accelerate certain chemical reactions. Plant and microbes obtained their life needs by utilizing the products of enzymatic hydrolysis reactions such as ammonium, amino acids, and sugars. Enzymatic activity in soil is closely related to soil microbial activity. Changes in climatic, agronomic and environmental factors would influence soil microbial activities which in turn affect enzymatic reactions. Soil enzyme activity could serve as indicators of soil fertility or control various influences due to differences in soil management (Alef and Nanniperi 1995).

Based on the description mentioned above, this study aimed to: (1) determine soil microbial activities through soil enzyme activities, namely dehydrogenase, urease, and cellulose at several crops of organic and conventional farming; (2) determine relationship between soil enzyme activities and population of bacteria, and content of soil microbial biomass carbon; and (3) determine relationship between soil enzyme activities and soil chemical characteristics.

MATERIALS AND METHODS

Study Site

The experiment was conducted at Laboratory of Soil Microbiology, Indonesian Soil Research Institute, Bogor from July 2015 to January 2016. Soil samples were taken from organic and conventional farming in different locations and commodities. Soil samples of broccoli, tomato, maize, and carrot cultivations were taken from Bogor Regency-Indonesia, while those of rice cultivation were taken from Tasikmalaya Regency-Indonesia. Soil chemical and pesticide residue characteristics from both farms have been reported by Aziz *et al.* (2016).

Soil Sampling

Soil samples were taken from organic and conventional farming of some commodities (tomato, carrot, maize, broccoli) from Bogor Regency, while those of rice cultivation were taken from Tasikmalaya Regency. Interviews with the farmers in the respective sites showed that in each planting season, farmers usually provide fertilizer for conventional rice farming ranges from 100 kg ha^{-1} of urea and 250 kg ha^{-1} of NPK, while for organic rice farming, they provide input of organic matter, such as manure 7 Mg ha^{-1}, and compost 7 Mg ha^{-1}, as well as plant residues. Rice productivity of conventional farming ranges from 5-6 Mg ha^{-1}, while that of organic farming ranges from 7-8 Mg ha^{-1}.

The soil samples were taken compositely from a depth of 0-10 cm (near root zone) which contains of a high microbial population and activity, and more significant effects of land use. The samples, then, were sieved with sieve size of 9 mesh (2 mm), stored in plastic clips, and placed in a cold room (16 °C) in order to prevent changes of soil biological properties prior to analysis.

Analysis of Soil Biological Properties

Analysis of soil biological properties was carried out in the Laboratory of Soil Microbiology, Indonesian Soil Research Institute, Bogor from July 2015 to January 2016. The parameters included soil dehydrogenase, urease, and cellulase activities, soil microbial biomass C (C-mic), and total soil bacteria.

Soil Dehydrogenase Activity

Soil dehydrogenase activity was determined using a modified method of Casida *et al.* (1964) and Ohliger (1995). Soil samples were weighed 5 grams and transferred into a glass vial, then 2 mL triphenyltetrazoliumchloride (TTC) and 2 mL of Tris HCl buffer were added. The samples were homogenized, incubated for 24 hours at a temperature of 37ºC, then methanol was added and shaken for 2 hours at shaker of 125 rpm. After filtering the suspension, the filtrate was adjusted to 50 mL, and measured with a spectrophotometer at a wavelength of 485 nm.

Furthermore, triphenylformazan (TPF) was calculated using the equation: $Y = aX + b$, $R^2 = 0.99$, in which Y is absorbance, X is concentration of TPF, and R^2 is coefficient determinant. While the value of dehydrogenase activity (DHA) was calculated using the following equation:

$$\mathrm{DHA} = (X \times V)/(m \times fa)$$

in which X is the concentration of Triphenylformazan; V is the final volume of filtrate of soil extracts; m is the weigh of soil sample; *fa* is factor correction for water content.

Soil Urease Activity

Soil urease activity was determined using a method of Schinner *et al.* (1996). Soil samples were weighed 5 grams and transferred into a bottle, incubated at 37°C for 2 hours. Then, 50 mL of KCl was added into the bottle, shaken for 30 minutes and filtered. Nessler reagent was added to the filtrate, then, solution was homogenized, allowed to stand for 10 minutes and measured with a spectrophotometer at a wavelength of 420 nm.

Furthermore, soil urease activity was calculated using the formula:

$$\text{Urease activity} = ((S\text{-}C).10.A.100) / (B.\%\ \mathrm{dm}.a.b)$$

S = concentration of sample (g NH_4^+), C = concentration of control (g NH_4^+), 10 = dilution factor, A = volume of extract (mL), B = weight of soil (g), % dm = factor for soil dry weight, a = molecular weight of NH_4^+ (g mol^{-1}), and b = incubation time.

Soil Cellulase Activity

Soil cellulase activity was determined using a method of Hope and Burns (1987). Soil samples were weighed 1 gram and put into a centrifuge tube, added with 0.5 mL of carboxylmethylcellolose (CMC) substrate, incubated at 40°C for 16 hours, shaken on a shaking water bath incubator and then centrifuged for 10 minutes at 2500 rpm. One mL of filtrate was inserted into a test tube, 1 ml of 3.5 dinitrosalicylic acid (DNS) and 2 mL of distilled water were added and then heated in boiling water at 100ºC for 15 minutes to enable reaction between glucose and DNS. After cooling, the samples were added with aquadest up to 10 mL, shaken, and then the absorbance was measured with a spectrophotometer at a wavelength of 540 nm.

Soil cellulase activity was calculated using the formula: $Y = aX + b$, in which Y is absorbance and X is concentration of glucose. While cellulose activity was calculated using this formula:

$$\text{Cellulose activity} = (\text{glucose concentration (sample - control)})/(\text{incubation period}) \times 10$$

Soil Microbial Biomass Carbon

Soil microbial biomass C was determined using fumigation-incubation method (Kuhnert and Finkemagel 1995). Fifty grams of soil samples were weighed and transferred into a 50 ml glass beaker and pure chloroform was added. After fumigation, the samples were transferred into a PVC for incubation processes. Further, soil samples in PVC columns were transferred into incubation jars using the vial containing 10 mL of 0.5 *N* KOH, and 10 mL of distilled water was added. The jar was sealed and incubated for 10 days at room temperature in dark room. On the 10th day, the samples were titrated with 0.5 *N* HCl and added with phenolphthaleine (pp) indicator until the color of the solution disappeared. Then the samples were added with methyl orange (MO) indicator and titrated again with 0.5 *N* HCl until the color of the solution turned into pink.

The soil microbial biomass C (C-mic) was calculated using the equation:

Soil microbial biomass (SMB) =
(Fumigation - Non Fumigation)/0.41

The amount of C in the non fumigated and fumigated soil samples were calculated using the formula of soil respiration as follows:

$$r = (a-b) \times t.6$$

a = mL HCl of sample, b = ml HCl of control (jar without soil), t = Normality HCl, and 6 = correction factor mg $C\text{-}CO_2$, SMB = Soil microbial biomass (mg $C\text{-}CO_2$ kg^{-1})

Total Soil Bacteria

The population of soil bacteria was calculated using plate count method and nutrient agar media after one day of incubation.

Data Analysis

The data were analyzed and correlation analysis was tested. The student's t-test was made to see the significant difference between organic and conventional farming and the correlation analysis was made to see the relationship between soil chemical characteristics (Aziz *et al*. 2016) and soil enzyme activities using Microsoft Excel at the significance level of 5% and 1%.

RESULTS AND DISCUSSION

Soil Dehydrogenase Activity

Soil dehydrogenase activity (DHA) of 5 crops of organic and conventional farming is presented in Table 1. The results showed that there were significant differences between organic farming and conventional farming of the commodities based on student's t-test. The results also showed that the soil DHA of all crops on organic farming was higher than that on conventional farming. Soil DHA on organic farming of tomato, carrot, maize, broccoli, and rice commodities were 10.89, 7.78, 9.57, 15.71, and 20.35 μg TPF g^{-1} dry sample $hour^{-1}$, respectively; while those of conventional farming were 4.28, 0.99, 1.88, 2.16, and 1.46 μg TPF g^{-1} dry sample $hour^{-1}$ for tomato, carrot, maize, broccoli, and rice, respectively.

Soil DHA is closely related to soil organic matter content. The higher levels of soil organic matter, the higher the soil DHA is. Organic matter (manure, compost, local microorganisms (MOL), etc.) in organic farming is much higher than those in conventional farming (Aziz *et al*. 2016). The results of interviews with farmers indicated that each manure, biomass residues, and compost 7 Mg ha^{-1} was used before planting in intensive organic farming.

Soil DHA is an indicator of oxidative metabolism of microbes that takes place in intracellular of living cells (viable). In soils,

Table 1. Soil Dehydrogenase Activity (DHA) of five commodities in organic and conventional farming.

Farm	DHA (μg TPF $g^{-1}h^{-1}$)				
	Tomato	Carrot	Maize	Brocolli	Rice
Organic	10.89	7.78	9.57	15.71	20.35
Conventional	4.28	0.99	1.88	2.16	1.46
t-test	3.64^{*}	5.44^{**}	14.03^{**}	4.55^{**}	8.55^{**}

Note: $t_{0.05} = 2.57$; $t_{0.01} = 4.03$

dehydrogenase becomes an integral part of intact cells and does not accumulate in extracellular. It indicates an average activity of active microbial population. An indicator of soil biology to look at the level of soil fertility is the activity of soil dehydrogenase that oxidizes organic matter by transferring protons and electrons from substrate to acceptor. It is part of soil microbial respiration cycle paths which gives an indication of potential fertility of soil biology related to biochemical processes.

Agricultural practices at both organic and conventional systems basically are affected by enzymatic activity in soils (Garcia *et al.* 2010). Average of soil DHA showed that dehydrogenase activity in organic farming was higher than those in conventional farming (Table 1). This is because of differences in organic-C content in both agricultural cultivations. At Diana site (organic farming) with tomato and broccoli commodities contained soil organic-C of 5.38% which was higher than that at Megamendung site (conventional farming), *i.e.* 4.50%. The content of soil organic-C could describe the use of organic matter in the soil.

Moeskops *et al.* (2010) stated that organic matter can improve soil dehydrogenase activities. This is evident from activity of soil respiration and release of carbon dioxide from rhizosphere. Salazar *et al.* (2011) also argued that soil organic matter content has a significant effect on soil enzyme as well as microbial activities. Soil dehydrogenase activity from organic rice farming is higher than that of conventional farming. This indicated that use of inorganic fertilizers and pesticides that are not prudent in conventional agriculture could affect soil enzymatic activity. Macci *et al.* (2012) stated that application of inorganic fertilizers could increase nutrient availability, but fertilizer and pesticide application could affect populations of soil microorganisms and soil enzymatic activity as well. Furthermore, they argued that the decline of dehydrogenase enzyme activity is directly proportional to the level of intensity of fertilizer and pesticide applications on a crop management. Jastrzebska and Kucharski (2007) stated that the soil dehydrogenase activity is inhibited with the increase of fungicide doses. Higher dehydrogenase activity was measured in the organic farming than in the conventional farming (Chu *et al.* 2007). Potential hydrogen is also one of the factors that affect soil dehydrogenase enzyme activity. The soil pH of organic farming is higher than that of conventional farming (Aziz *et al.* 2016). Dehydrogenase activity is directly proportional to soil pH value (Moeskops *et al.* 2010).

Soil Urease Activity

The results of student's t-test showed that soil urease activities (UR) of some crops (carrot, maize, broccoli, and rice) on organic agriculture were significantly lower than those of conventional farming (Table 2). The results also showed that soil UR activities of the crops in conventional agriculture were 10.13, 4.35 , 10.23, 13.06, and 6.17 units gram^{-1} of tomato, carrot, maize, broccoli, and rice respectively; whereas those in organic agriculture were only 5.8, 3.83, 7.92, 6.4, and 0.36 units gram^{-1} of tomato, carrot, maize, broccoli, and rice respectively.

Soil UR activity is closely related to substrate of urea in the soils. Source of N in conventional farming is frequently derived from urea, whereas in organic farming is originated from organic materials. Results of interviews with farmers showed that urea fertilizer in conventional agriculture was applied intensively before planting, *i.e.* urea 100 kg ha^{-1} and NPK 250 kg ha^{-1}.

One source of N used in agriculture is commonly urea. Organic fertilizer also contains N, especially organic fertilizer derived from urine and feces of cattle. Urea is hydrolyzed enzymatically by urease in the soil to form ammonia and carbon dioxide, then ammonia can be further hydrolyzed into ammonium. This ammonium can be absorbed by plants (Rosmarkam and Yuwono 2002; Winarso 2005). Soil urease serves to hydrolyze urea contained in soil into ammonium, which is readily absorbed by plants, or could be converted to nitrite and nitrate

Table 2. Soil Urease Activity (UR) of five comodities in organic and conventional farming.

Farm	UR (unit g^{-1})				
	Tomato	Carrot	Maize	Broccoli	Rice
Organic	5.80	3.83	7.92	6.4	0.36
Conventional	10.13	4.35	10.23	13.06	6,17
t-test	16.14**	0.55	0.93	10.14**	9.22**

Note: $t_{0.05} = 2.57$; $t_{0.01} = 4.03$

Table 3. Soil CMCase Activity of five commodities in organic and conventional farming.

Farm	CMCase (unit g^{-1})				
	Tomato	Carrot	Maize	Brocolli	Rice
Organic	17.86	27.24	24.80	22.35	97.93
Conventional	4.32	12.02	13.34	1.31	0.53
t-test	5.01^{**}	10.27^{**}	3.47^{**}	19.83^{**}	41.70^{**}

Note: $t_{0.05}$ = 3.18; $t_{0.01}$ = 5.84

compounds. Thus the enzyme urease plays an important role in soil N cycle (Burn *et al.* 2013).

High or low urease activity depends on the presence of substrates and products of reaction catalyzed by this enzyme, *i.e.* urea and ammonium (Askin and Kizilkaya 2005). The high activity of urease in conventional farming of the commodities was obviously due to the presence of urea in soil substrate that was still abundant in beginning of observation period. Level of enzyme reactions is limited by the extent of enzyme and substrate if other environmental factors considered are constant. Keep in mind that substrate availability in soil, especially urea affects specific enzyme induction by microbial or enhanced microbial growth, which all affect the level of soil urease activity (Cattaneo *et al.* 2014).

Soil Cellulase Activity

Soil cellulase activity of Endo-1,4-â-D-glucanase (carboxymethyl cellulose or CMCase) for five crops of organic and conventional farming is presented in Table 3. The results of student's t-test showed that soil cellulase activities for all crops of organic farming were significantly different from those of conventional farming. The soil cellulase activities for all crops of organic farming were higher than those of conventional farming. Table 3 also showed that soil CMCase for tomato, carrot, corn, broccoli, and rice commodities of organic farming was 17.86, 27.24, 24.8, 22.35, and 97.93 units gram^{-1} respectively; whereas that of conventional farming was just 4.32, 12.02, 13.34, 1.31, and 0.53 units gram^{-1}, respectively.

Soil CMCase activity is closely related to cellulose content in the soil which is reflected in the levels of soil organic matter content (Aziz *et al.* 2016). The higher levels of soil organic matter content, the higher level of soil cellulase activity is. Straw decomposition, especially in paddy soil produced high level of cellulose thereby the cellulase activity was high.

One factor affecting activity of soil cellulase is organic matter. Organic farming has higher soil organic-C content than that at conventional farming (Aziz *et al.* 2016). It is directly proportional to

Table 4. Total soil bacteria of five commodities in organic and conventional Farming.

Farm	Total Bacteria (Log CFU g^{-1})				
	Tomato	Carrot	Maize	Broccoli	Rice
Organic	8.15	8.52	8.48	8.46	7.69
Conventional	7.42	7.14	6.32	7.46	6.95
t-test	7.77^{**}	20.02^{**}	31.26^{**}	12.87^{**}	4.68^{**}

Note: $t_{0.05}$ = 3.18; $t_{0.01}$ = 5.84

Table 5. Soil microbial biomass in organic and conventional farming with five commodities.

Farm	Soil Microbial Biomass (mg C-CO$_2$ kg^{-1})				
	Tomato	Carrot	Maize	Broccoli	Rice
Organic	393.09	279.09	440.96	323.03	320.25
Conventional	128.14	170.89	115.14	143.27	121.95
t-test	17.42^{*}	2.61	8.71^{*}	73.74^{**}	5.07^{*}

Note: $t_{0.05}$ = 4.30; $t_{0.01}$ = 9.92

cellulase activity. Inductive enzyme elevations (urease and cellulase) in the soil are caused by the substrates (organic C and total N) which are available in the soil. Previous studies showed that the urease and cellulose activities are positively correlated with soil organic C and total N (Clegg 2006; Bastida, *et al*. 2007; Jangid *et al*. 2008; Meriles *et al*. 2009; Udawatta *et al*. 2009; Vallojo *et al*. 2010).

Total Soil Bacteria and Soil Microbial Biomass

Total soil bacteria and soil microbial biomass carbon in organic and conventional farming of five crops are presented at Table 4 and Table 5, respectively. Based on the results of student's t-test, total soil bacteria (Table 4) and soil microbial biomass (Table 5) of tomato, carrot, maize, broccoli, and rice of organic farming were significantly different from those of conventional farming. The variables in organic farming were higher than those of conventional farming. This is reflected on soil organic C content (Aziz *et al.* 2016) that influences soil microbial population and soil microbial biomass.

Soil microbial biomass is an important attribute of soil biological quality and also serves as an indicator of changes in soil management or land use (Danielle *et al.* 2012). Soil microbial biomass depends on soil organic material content as food source or substrate (Zhang *et al.* 2008; Santos *et al*. 2012). Therefore, farm management greatly affects the dynamics of organic matter and microbial biomass.

Relationships between Soil Enzyme Activities with Total Soil Bacteria, Soil Microbial Biomass, and Soil Chemical Characteristics

Correlations between soil enzyme activities with total soil bacteria and soil microbial biomass (C-mic) are presented in Table 6. The total soil bacteria and soil microbial biomass were significantly and positively correlated with soil dehydrogenase, urease, and cellulase activities. Soil organic matter can increase biomass of soil microbes (Haney *et al.* 2010) that is accompanied by increasing soil enzyme activity (Zhang *et al.* 2008), soil urease activity (Cattaneo *et al*. 2014), and soil cellulase activity (Acosta *et al.* 2014).

The correlation between soil enzyme activities and soil characteristics is presented in Table 7. Soil dehydrogenase activity was very significantly and

Table 6. Correlation between Soil Dehydrogenase (DHA), Urease (UR) and Cellulase (CMCase) Activities with total soil bacteria and soil microbial biomass.

Variable	Total Soil Bacteria	Soil Microbial Biomass
	......................r......................	
DHA	0.723^{**}	0.489^{**}
UR	0.409^{**}	0.875^{**}
CMCase	0.5561^{**}	0.905^{**}

Note: $r_{0.05} = 0.280$ and $r_{0.01} = 0.388$

Table 7. Correlations between Soil DHA, UR and CMCase Activities with soil chemical characteristics.

Soil Variables	Soil DHA	Soil UR	Soil CMCase
	....	r.....................	
Org. C	0.282^{*}	0.411^{**}	0.336^{*}
Total N	0.574^{**}	0.849^{**}	0.471^{**}
Potential P	0.453^{**}	0.564^{**}	0.806^{**}
Potential K	0.446^{**}	0.353^{*}	0.288^{*}
Available P	0.419^{**}	0.974^{**}	0.739^{**}
Available K	0.289^{*}	0.423^{**}	0.858^{**}
CEC	0.886^{**}	0.949^{**}	0.790^{**}
pH	0.666^{**}	-0.523^{**}	0.522^{**}

Note: n = 33, $r_{0.05} = 0.280$ dan $r_{0.01} = 0.388$

positively correlated with soil organic C, total N, potential P and K, available P, available K, CEC, and pH. Soil urease activity was very significantly and negatively correlated with soil pH; significantly and positively correlated with potential K; very significantly and positively correlated with soil organic C, total N, potential P, available P and K, and soil CEC. Soil cellulase activity was significantly and positively correlated with soil organic C and potential K; very significantly and positively correlated with total N, potential P, available P and K, CEC, and pH.

All the enzyme activities tested are positively and significantly correlated with soil organic C, total N, potential P and K, available P and K, as well as soil CEC. The results indicated that the enzyme activities are closely related to nutrient cycling in the soil. According to Acosta *et al*. (2014), soil enzyme activity is critical to soil ecosystems in transforming nutrients and biochemical cycles of carbon, nitrogen, phosphorus, and sulfur. In addition, soil enzyme activity is a sensitive indicator of changes in soil quality due to different land uses (Kong *et al*. 2011; Wallenstein and Burns 2011).

Implication

Soil DHA (Table 1) and soil cellulase (Table 3) activities at organic farming were higher than those of conventional farming, while soil urease activity (Table 2) at organic farming was lower than that of conventional farming. Since both soil DHA and soil cellulase activities are indicators of soil fertility, then organic farming is recommended for maintaining soil fertility and plant productivity. The urease activity is also as an indicator of soil fertility, particularly in releasing N for plant growth. Since soil urease activity at organic farming is lower than that of conventional farming, therefore, organic farming still needs small addition of urea fertilizer. Soil enzyme activity is significantly correlated with total soil bacteria, soil microbial biomass, and soil chemical characteristics (Table 6 and 7). It means that soil enzyme activities are very good indicators for predicting soil fertility, thus we could use those parameters to predict the level of soil fertility.

CONCLUSIONS

Soil dehydrogenase and cellulase activities in organic farming were higher than those in conventional farming, whereas the soil urease activity in organic farming was lower than that in conventional farming. The total soil bacteria and soil microbial biomass were significantly and positively correlated with soil dehydrogenase, urease, and cellulase activities. Soil dehydrogenase, urease, and cellulase activities were very significantly and positively correlated with all soil characteristics tested, *i.e.* soil organic C, total N, potential P and K, available P and K, CEC, and pH, except that soil urease activity was very significantly and negatively correlated with soil pH. The results of this research indicated that organic farming is recommended for maintaining soil fertility and plant productivity, however, small use of urea fertilizer is still needed in the farming.

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