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Soil Chemical Characteristics of Organic and Conventional Agriculture

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ABSTRACT

Use of chemical fertilizers and pesticides on intensive land of both lowland and upland food crops have been shown to increase agricultural productivity significantly. Research aimed to study soil chemical characteristics and soil pesticide residues at some crops of organic and conventional farms. The research was carried out in Laboratory of Soil Chemistry, Indonesian Soil Research Institute and in Laboratory of Agrochemical Residue, Indonesian Agricultural Environment Research Institute, Bogor from February to July 2015. Soil samples at 0-10 cm depth were taken compositely from broccoli (*Brassica oleracea*), carrots (*Daucus carota*), maize (*Zea mays*), and tomatoes (*Solanum lycopersicum*) farms in Bogor Regency as well as from rice field in Tasikmalaya Regency at both organic and conventional farms. Soil chemical characteristics were analyzed include: soil organic-C (Walkey and Black), total-N (Kjeldahl), potential-P (HCl 25%), available-P (Olsen), potential-K (HCl 25%), available-K (NH_4OAc 1 *N* pH 7), CEC (NH_4OAc 1 *N* pH 7), and pH (soil : water = 1: 5), while pesticide residues included levels of organochlorine (lindane, aldrin, heptaklor, dieldrin, DDT, endosulfan); organophosphates (diazinon, fenitrotin, metidation, paration, profenofos); and carbamates (carbofuran, MIPC, BPMC) in the soil by using Gas Chromatography method. Results showed that levels of soil organic-C, total-N, potential and available-P, potential and available-K, CEC, pH at organic farms were higher than those at conventional farms. Some pesticide residues compound (organochlorines, organophosphates, and carbamates) were detected at conventional farm, while those at organic farm were not detected (trace).

Keywords*:* Conventional farm, organic farm, pesticide residues, soil properties.

ABSTRAK

Penelitian yang bertujuan untuk mempelajari karakteristik kimia dan residu pestisida tanah beberapa komoditas tanaman pada pertanian organik dan konvensional telah dilaksanakan di Laboratorium Tanah Balai Penelitian Tanah dan Laboratorium Residu Agrokimia, Balai Penelitian Lingkungan Pertanian, Bogor. Contoh tanah kedalaman 0-10 cm diambil secara komposit dari Kabupaten Bogor untuk komoditas brokoli, wortel, jagung, dan tomat serta dari Kabupaten Tasikmalaya untuk komoditas padi. Karakteristik kimia tanah yang dianalisis meliputi: C-organik (Walkey and Black), N-total (Kjeldahl), P-potensial (HCl 25%), P-tersedia (Olsen), K-potensial (HCl 25%), K-tersedia (NH_4OAc 1 *N* pH 7), KTK (NH_4OAc 1 *N* pH 7), dan pH tanah (tanah : air = 1 : 5), sedangkan analisis residu pestisida meliputi kadar organoklorin tanah (lindan, aldrin, heptaklor, dieldrin, DDT, endosulfan); organofosfat (diazinon, fenitrotin, metidation, paration, profenofos); dan karbamat (karbofuran, MIPC, BPMC) dengan metode Gas Kromatografi. Hasil penelitian menunjukkan bahwa kadar C-organik, N-total, P-potensial, P-tersedia, K-potensial, K-tersedia, KTK, pH tanah pada pertanian organik lebih tinggi dibandingkan pertanian konvensional. Demikian pula kadar residu pestisida tanah (organoklorin, organofosfat, dan karbamat) pada pertanian organik lebih baik (trace) daripada pertanian konvensional.

Kata Kunci: Karakteristik kimia tanah, pertanian organik, pertanian konvensional

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INTRODUCTION

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Use of chemical fertilizers and pesticides on intensive land of both lowland and upland food crops have been shown to increase agricultural productivity significantly. However, the use of agrochemicals in conventional system can cause serious environmental problems, including soil, water, or air environment. Along with the increasing of human consciousness on health and safety of agricultural products, it is recognized that the use of organic materials in soil nutrient management to replace the use of chemicals is very important. It is intended that the agricultural environment will not be polluted and crops are also free from pollutants.

Organic farm systems are different from conventional farm systems. In production process, conventional farm is relied on chemical fertilizers and pesticides (Tu *et al.* 2006), whereas organic farm avoided to use agrochemicals. Organic farm emphasized the organic input to meet nutritional needs and biological processes as well as pest management. Since with proper management, the yields of organic farms was not inferior to conventional farm, while quality of the result was much better than conventional farms.

Sutanto (2002) also stated that increase of agricultural production at conventional farm systems did not last long, because of soil degradation and accumulation of pesticide residues that might be toxic to plants. Another study also explained that the excessive use of chemical fertilizer could accelerate land degradation threatening the sustainability of farming systems (Zhen *et al.* 2006). In addition, the provision of chemical fertilizers in large amounts could also harm soil flora and fauna and might cause contamination of soil, groundwater, and water bodies. Results of monitoring wells around water bodies in Citarik (West Java) and Kaligarang (Central Java) watershed showed that the water samples from the wells contained nitrates (NO_3^-) that exceeded value threshold (Nursyamsi *et al.* 2005). Meanwhile, organic farming systems, also called sustainable agriculture contributed in increasing agricultural production in the long term.

Organic farm systems give priority to the use of organic materials main activities in this farm. The use of organic materials are able to improve soil physical, chemical, and biological properties that support plant growth better. So, the study of changes in soil properties after several rounds of organic farm systems was necessary to be conducted to know the benefits of this system on improvement of soil properties to warrant further use (Isnaini 2006).

Based upon this research aimed to study chemical characteristics related to the availability of soil nutrients and soil pesticide residues at some crops of organic and conventional farms system.

MATERIALS AND METHODS

The research was conducted at Laboratory of Soil Chemistry, Indonesian Soil Research Institute, and Laboratory of Agrochemical Residue, Indonesian Agricultural Environment Research Institute, Bogor from February to July 2015. The soil samples were taken from the cultivation of organic and conventional farm in some places for some commodities. Soil samples from cultivation of broccoli, tomatoes, maize, and carrots were taken in Bogor Regency, while the samples from rice field were taken in Tasikmalaya Regency at both organic and conventional farms (Table 1).

Soil samples were taken compositely at a depth of 0-10 cm (near the roots) because at the soil depth, there was a very high microbial population and activity, as well as the effects of land use and processing more significant. The samples, then, were aired dried, sieved with a sieve of 9 mess size (2 mm) and stored in a plastic labeled, and placed in sample room.

Soil sampling sites were in Tasikmalaya Regency covered two cropping index in conventional farm, namely CI 2 and CI 3 while in organic farming only covered CI 3. The intensity of fertilization was

Table 1. Location of soil sampling.

Sub Distric	District	Owner	Farm system	Crops
Megamendung	Bogor	Pertanian Diana	Organic	Broccoli and Tomato
Megamendung	Bogor	Pertanian Diana	Conventional	Broccoli and Tomato
Cisarua	Bogor	Permata Hati	Organic	Maize and Carrot
Cisarua	Bogor	Permata Hati	Conventional	Maize and Carrot
Cisayong	Tasikmalaya	Kribo	Organic	Rice
Rajapolah	Tasikmalaya	Kribo	Conventional CI 3	Rice
Manonjaya	Tasikmalaya	Kribo	Conventional CI 2	Rice

also related to cropping index. Interviews results with farmers in the soil sampling sites showed that farmers provided fertilizer for conventional rice ranged from 100 kg ha^{-1} of urea and 250 kg ha^{-1} of NPK, while for organic rice provided input in organic material form, included manure of 7 Mg ha-1 and compost of 7 Mg ha^{-1}. Conventional rice field had productivity ranged from 5-6 Mg ha^{-1}, while organic rice field had productivity 7-8 Mg ha^{-1}. Soil sampling sites in Bogor only covered CI 3 at both organic and conventional farms. Fertilizer given in conventional farm was urea and NPK, while that in organic farm was animal manure, compost and green manure.

Analysis of Soil Characteristics

The soil samples were analyzed at Laboratory of Soil Chemistry, Indonesian Soil Research Institute, Bogor to establish soil chemical characteristics. Analysis of soil chemical characteristics included: soil organic-C (Walkey and Black), total-N (Kjeldahl), potential-P (HCl 25%), available-P (Olsen), potential-K (HCl 25%), available-K (NH_4OAc 1 *N* pH 7), CEC (NH_4OAc 1 *N* pH 7), and pH (soil: water = 1: 5).

Analysis of Soil Residue

The soil samples were analyzed at Laboratory of Agrochemicals Residue, Indonesian Agricultural Environment Research Institute, Bogor to establish levels of soil pesticide residues. Analysis of soil pesticide residue was carried out on levels of soil organochlorine (lindane, aldrin, heptaklor, dieldrin, DDT, and endosulfan); organophosphates (diazinon, fenitrotin, metidation, paration, and profenofos); and carbamates (carbofuran, MIPC, and BPMC). Furthermore, Gas Chromatography was used as a method of analysis the pesticide residues in the soil.

RESULTS AND DISCUSSION

Soil Chemical Characteristics

Soil organic carbon (org-C) and total nitrogen (total-N) are presented at Figure 1, cation exchange capacity (CEC) and pH at Figure 2; potential

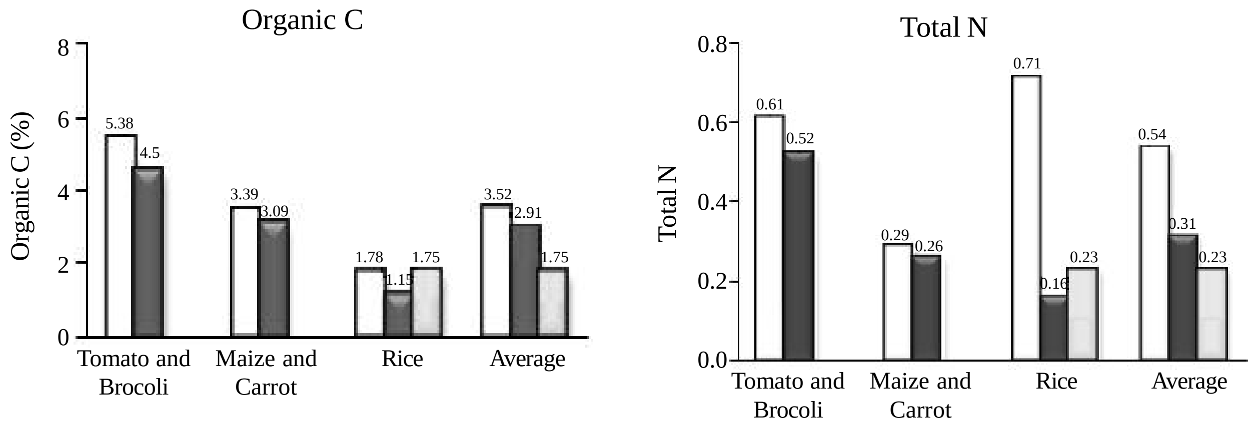

Figure 1. Levels of soil organic-C and total-N at some crops of Organic and Conventional Farms.
□: organic; ■: CI3; ▣: CI2.

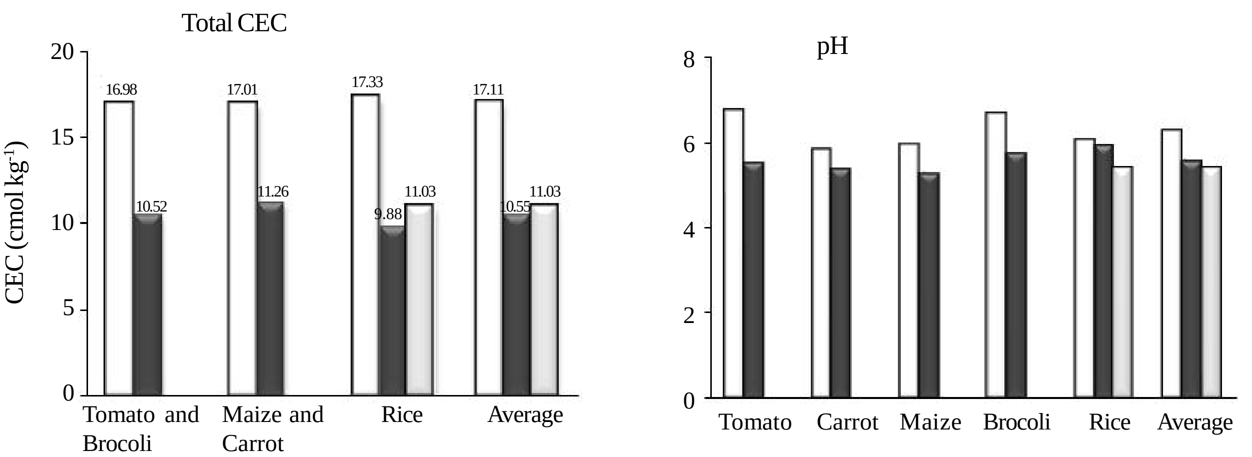

Figure 2. Soil CEC and pH at some crops of Organic and Conventional Farms.□: organic; ■: CI3; ▣: CI2.

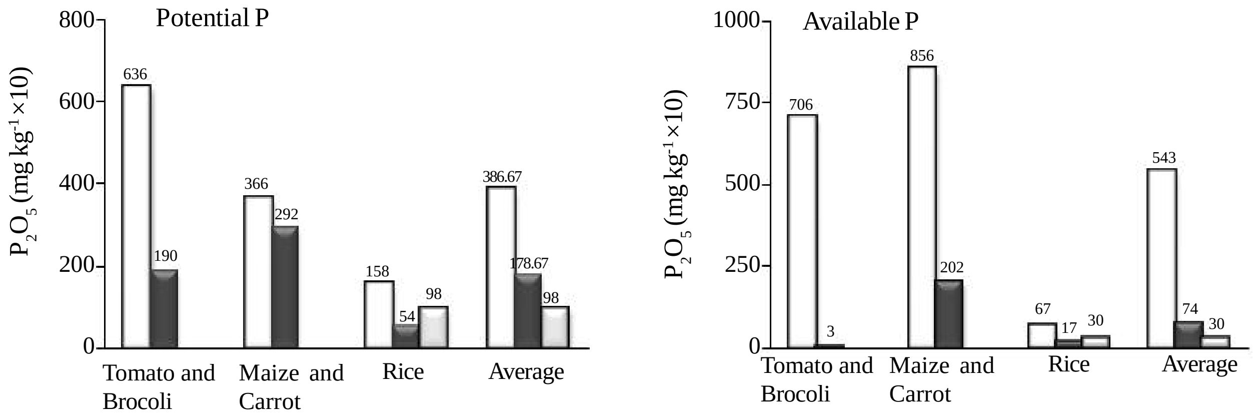

Figure 3. Levels of soil potential and available-P at some crops of Organic and Conventional Farms. □: organic; ■: CI3; □: CI2.

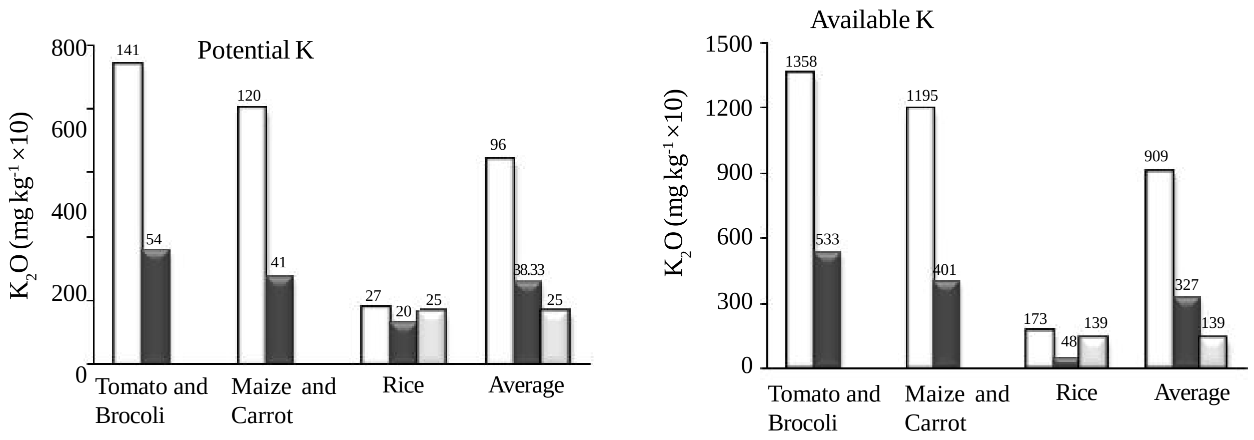

Figure 4. Levels of soil potential and available-K at some crops of Organic and Conventional Farms. □: organic; ■: CI3; □: CI2.

phosphorus (potential-P) and available phosphorus (available-P) at Figure 3; and potential potassium (potential-K) and available potassium (K-provided) at Figure 4.

Figure 1 shows that levels of soil org-C and total-N in organic farming was higher than that in conventional farm. This fact was because farmers used organic matter (animal manure, compost and green manure etc.) at organic farm in a large amount while that at conventional farm was only in a small amount. Interviews result on farmers showed that farmers used organic matter about 7-20 Mg ha^{-1} season^{-1} at organic farm, whereas at conventional farm, farmers relied on inorganic fertilizers. In addition, this also shows that the organic materials used in organic farming is a source of C-org and N-total ground.

Cation exchange capacity of the soil in organic farming was higher than conventional farming. Similarly, the pH of the soil in organic farming was higher than conventional farming. It has been argued previously that levels of C-org soil in organic farming was higher than conventional farming (Figure 1). Organic materials can donate the value of soil CEC significantly, so the higher the C-org ground higher the soil CEC.

Figure 3 shows that the levels of soil potential and available-P at organic farm was higher than that at conventional farm. Similarly, Figure 4 also shows that the levels of soil potential and available-K at organic farm was higher than that at conventional farm. It had been argued previously that levels of soil org-C at organic farm was higher than conventional farm (Figure 1). Decomposition of organic matter might supply nutrient availability in the soil including N, P and K.

According to Agus (2000), there was a difference between organic and chemical fertilizers. Organic fertilizers could provide different elements both macro and micro nutrients, while chemical fertilizers provided only one or more of certain nutrients. Ruskandi and Odih (2003); Wiwik and Widowati (2006); and Abdul (2009) also argued that the organic fertilizer contributed macro nutrients (N, P, K, Ca, Mg and S) and micronutrients (Cu, Mn, Zn and Fe).

Table 2. Contributions of nutrients from animal manure, green manure, and compost at Organic Farm.

Nutrients	Nutrient Content (%)			Nutrient Content (kg ha^{-1})			Total (kg ha^{-1})
	Animal Manure[1)]	Green Manure[2)]	Compost[3)]	Animal Manure	Green Manure	Compost	
C	16	20	35.11	1120	1400	2457.7	4978
N	0.3	0.92	1.86	21	64.4	130.2	216
P	0.2	0.29	0.21	14	20.3	14.7	49
K	0.15	1.39	5.35	10.5	97.3	374.5	482

Note: animal manure = 7 Mg ha^{-1}, green manure = 7 Mg ha^{-1}, and compost = 7 Mg ha^{-1}. [1)]Wiwik and Widowati 2006; [2)]Ruskandi and Odih 2003; [3)]Abdul Munif 2009.

Table 3. Contributions of nutrients from Urea and NPK fertilizers at conventional farm.

Nutrient	Nutrient Content (%)		Nutrient Content (kg ha^{-1})		Total (kg ha^{-1})
	Urea	NPK	Urea	NPK	
C	-	-	-	-	-
N	45	15.0	45	37.5	83
P	-	6.5	-	16.4	16
K	-	12.5	-	31.3	31

Note : Urea = 100 kg ha^{-1} and NPK = 250 kg ha^{-1}.

Table 4. Soil pesticide residue from tomato and rice crops at organic and conventional farms.

Pesticide residues	Content of Pesticide Residues (mg kg^{-1})				
	Organic Tomato	Conventional Tomato	Organic Rice	Conventional Rice (CI 2)	Conventional Rice (CI 3)
ORGANOCHLORINE					
Lindan	Trace	Trace	Trace	Trace	Trace
Aldrin	Trace	Trace	Trace	Trace	Trace
Heptaklor	Trace	Trace	Trace	Trace	Trace
Dieldrin	Trace	Trace	Trace	Trace	Trace
DDT	Trace	Trace	Trace	Trace	Trace
Endrin	Trace	Trace	Trace	Trace	Trace
Endosulfan	Trace	Trace	Trace	Trace	0.01
ORGANOPHOSPHATE					
Diazinon	Trace	Trace	Trace	Trace	Trace
Fenitrotin	Trace	Trace	Trace	Trace	Trace
Metidation	Trace	0.034	Trace	0.01	0.018
Paration	Trace	Trace	Trace	Trace	Trace
Profenofos	Trace	Trace	Trace	Trace	Trace
KARBAMAT					
Karbofuran	Trace	0.025	Trace	Trace	Trace
MIPC	Trace	Trace	Trace	Trace	Trace
BPMC	Trace	Trace	Trace	Trace	Trace

Table 2 and Table 3 shows that the contribution of nutrients from organic matter due to organic farm management was higher than that from inorganic fertilizers to conventional farm. Organic matter from organic farm management contributed nutrients C, N, P, and K were 4978, 216, 49, and 482 kg ha^{-1} respectively (Table 2), whereas artificial fertilizers contributed C, N, P, and K only 0, 83, 16 and 31 kg ha^{-1} respectively (Table 3). In addition, the level of nutrient availability at organic farm was slowly (slow release) because of the level of nutrient availability depended on degree of decomposition of organic matter (Sacco *et al.* 2015). While the availability of nutrients at conventional farm, especially N and K from urea and NPK fertilizers were readily soluble in water so easily leached. It was already reported by Stopes *et al.* (2002) and Benoit *et al.* (2014) who stated that organic farm systems had levels of leaching (30-50%) lower than conventional farm systems.

Although level of nutrient in organic fertilizer was relatively low, but application of organic matter was very large so that it could contribute nutrients greater. In addition, organic matter contributed to soil chemical properties higher than artificial chemical fertilizers did. Role of organic fertilizer to soil chemical properties were: (a) to provide macronutrients (N, P, K, Ca, Mg and S) and micronutrients (Zn, Cu, Mo, Co, B, M n and Fe), (b) to increase cation exchange capacity (CEC), and (c) to form complex compounds with toxic metal ions such as Al, Fe, and Mn so that these metals are not toxic. Duxbury *et al.* (1989) also suggested that decomposition of organic material produced a residue in form of humus, where this fraction was able to combine soil organic colloidal minerals into aggregate. The organic material adsorbed a cation higher than colloidal clay did, so addition of organic matter to the soil would increase its soil CEC.

Average of soil pH at organic farms was higher than at conventional farm. Organic fertilizer can increase soil pH in acid mineral soils. According to Waalewijn-Kool PL *et al.* (2014), organic matter might reduce concentration of Zn with increasing soil pH. It was also presented by Nursyamsi and Suprihati (2005), organic fertilizer had very significant effect on increase of soil pH in Andisols. Organic matter contained in compost (manure) could produce humic and fulvic acids which were able to form complex compounds with Al^{3+} in soil solution which caused increase in soil pH.

Soil Pesticide Residues

Soil pesticide residue from tomato and rice crops at organic and conventional farms are presented in Table 4. Pesticide residues were found in soil from tomatoes of conventional farm, rice of conventional CI 2, and rice of conventional CI 3. It was closely related to use of pesticides (herbicides, fungicides, and insecticides) which were not wise in these crops of conventional farm.

Conventional farm or modern farm was often criticized as did not environmentally friendly, reduced biodiversity, and production system too dependent on inorganic inputs from outside the ecosystem that might affect sustainability of production systems (Soemarno 2001). Ohorella *et al.* (2013) also showed that use of pesticides to control pests and plant diseases also had a negative impact on environment in form of pesticide residues. Pesticides that were often used in Indonesia were a group of organochlorine which was chronic toxic and extremely harmful to environment.

Furthermore, Sakung (2004) stated that pesticide residues were not only from materials, but also came from absorption of roots on soil. In addition, excessive used of insecticides might cause negative impact for environment, such as destruction of natural enemies and other insects, as well as appearance of symptoms of pest resistance to insecticides that also might reduce quality of crop. Its application in the field of agriculture, not all pesticides came in contact with target. Approximately only 20% of pesticide achieved on target while the other (80%) might fall to the soil. The accumulation of pesticide residues resulted contamination of agricultural land. Since entering into the food chain, toxic material from pesticide could cause various diseases.

The soil pesticide residues detected from tomato and rice of both CI 2 and 3 at conventional farm were pesticide residues compounds that were a group of organochlorines, organophosphates and carbamates. On conventional tomatoes crop was detected 0.034 mg kg^{-1} of metidation (organophosphate group) and 0.025 mg kg^{-1} of carbofuran (carbamate group), on conventional rice of CI 2 was detected 0.01 mg kg^{-1} metidation (organophosphate group) and conventional rice of CI 3 was also detected 0.01 mg kg^{-1} of endosulfan (organoclorine group) and 0.018 mg kg^{-1} of metidation (organophosphate group). It was also been investigated by Helen *et al.* (2016) who stated that pesticide residues were detected from maize and tomato crops of conventional farm in Greece. The soil pesticide residues compounds of the three group, however, were not detected at both of rice and tomato crop of organic farm. Stanislaw *et al.* (2013) found pesticide residues in organic farm significantly lower than that at conventional farm. Based on interviews to farmers, conventional farmers location used herbicides and insecticides at growing season progresses.

CONCLUSIONS

Levels of soil organic-C, total-N, potential and available-P, potential and available-K, CEC, pH at organic farms were higher than those at conventional farms. In the other hand, some pesticide residues compound (organochlorines, organophosphates, and carbamates) were detected at conventional farm, while those at organic farm were not detected (trace).

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