คุณสมบัติทางชีวภาพของดินและจำนวนแบคทีเรียโคลิฟอร์มในน้ำจากสวนผลไม้บ้านโป่งแรด ตำบลพลับพลา อำเภอเมือง จังหวัดจันทบุรี

Biological Properties of Soil and Number of Coliform Bacteria in Water from Fruit Orchards of Pongrad area, Phlabphla subdistrict, Muang district, Chanthaburi province

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บทคัดย่อ

คุณสมบัติทางจุลชีววิทยาเป็นตัวบ่งชี้ความสมบูรณ์ของดินและคุณภาพน้ำทางชีวภาพ งานวิจัยนี้มีวัตถุประสงค์ในการศึกษาคุณสมบัติทางชีวภาพของดินสวนผลไม้และวิเคราะห์จำนวนแบคทีเรียโคลิฟอร์มในน้ำที่ใช้สำหรับการเกษตร โดยเก็บดินและน้ำจำนวน 10 ตัวอย่าง จากบ้านโป่งแรด ตำบลพลับพลา อำเภอเมือง จังหวัดจันทบุรี จำนวน 2 ครั้ง คือเดือนกันยายน 2557 (ภายหลังฤดูเก็บเกี่ยว) และเดือนธันวาคม 2557 (ช่วงที่ผลไม้ผลิดอก) เก็บดินรอบทรงพุ่มต้นผลไม้ที่ระดับความลึก 15 เซนติเมตร และนำมาศึกษาคุณสมบัติทางกายภาพและชีวภาพของดิน ผลการศึกษาพบว่าตัวอย่างดินที่เก็บในเดือนกันยายนและธันวาคมมีค่าพีเอชในช่วง 4.04 ถึง 6.99 และ 4.04 ถึง 6.66 ความชื้น 17.94 ± 0.36 ถึง 33.98 ± 0.57 และ 11.76 ± 0.29 ถึง 24.50 ± 0.75% อุณหภูมิดิน 25 ถึง 28 และ 26 ถึง 29 องศาเซลเซียส กิจกรรมของเอนไซม์คะตะเลสในเดือนกันยายนและธันวาคมมีค่าในช่วง 1.14 ± 0.04 ถึง 1.84 ± 0.12 และ 1.10 ± 0.03 ถึง 1.60 ± 0.07 มิลลิลิตร O_2 ต่อกรัมดินแห้ง ส่วนการหายใจของจุลินทรีย์ดินมีค่าในช่วง 0.03 ถึง 0.81 และ 0.03 ถึง 0.38 ไมโครกรัม CO_2 ต่อกรัมดินแห้ง ในการเก็บตัวอย่างเดือนกันยายนและธันวาคมมีปริมาณแบคทีเรียโคลิฟอร์มทั้งหมดในตัวอย่างน้ำที่ใช้ทางการเกษตรในช่วง 11000 ถึง 28000 และ 7400 ถึง 21000 MPN/100 มิลลิลิตร ปริมาณฟีคัลแบคทีเรียโคลิฟอร์มมีค่าในช่วง 3600 ถึง 9200 และ 3000 ถึง 7300 MPN/100 มิลลิลิตร ผลที่ได้จากงานวิจัยนี้พบว่าในการเก็บตัวอย่างทั้ง 2 ครั้ง คุณสมบัติทางกายภาพและชีวภาพของตัวอย่างดินจากสวนที่ได้รับการรับรอง GAP และสวนที่มีระบบการจัดการ

แบบดั้งเดิมมีค่าเฉลี่ยไม่แตกต่างกันทางสถิติ (*P* = 0.05) อาจเนื่องจากพื้นที่ในการเก็บตัวอย่างมีชนิดดินหรือรูปแบบการใช้ที่ดินซึ่งมีความแตกต่างกันน้อยมาก

ABSTRACT

Microbiological properties are indicators for soil fertility and biological water quality. This research aimed to study the biological properties of orchard soil and analyse for coliform bacteria in agricultural water. Ten soil and water samples were collected from Pongrad area, Phlabphla subdistrict, Muang district, Chanthaburi province by two times of samplings, in September 2014 (after harvesting) and in December 2014 (in flowering). Soil samples were taken from the bush at a depth of 15 cm and was investigated for soil physico-chemical and microbiological properties. In September and December sampling, the results showed that pH, moisture and temperature of soil samples ranged from 4.04 to 6.99, 4.04 to 6.66, 17.94 ± 0.36 to 33.98 ± 0.57%, 11.76 ± 0.29 to 24.50 ± 0.75%, 25 to 28 °C and 26 to 29 °C, respectively. Catalase activity of soil microorganisms in September and December sampling were ranged from 1.14 ± 0.04 to 1.84 ± 0.12, 1.10 ± 0.03 to 1.60 ± 0.07 ml O_2 g^{-1} dry soil, basal soil respiration were ranged from 0.03 to 0.81 and 0.03 to 0.38 µg CO_2 g^{-1} dry soil. The coliform numbers in agricultural water in September and December sampling were ranged from 11000 to 28000 and 7400 to 21000 MPN/100 ml for total coliform, 3600 to 9200 and 3000 to 7300 MPN/100 ml for fecal coliform. This study revealed that the physical and biological soils properties from the GAP-certified orchard and the conventional orchard were not significantly different (*P* = 0.05). Probably due to the collected sites had low degree of variability in soil type or land use pattern.

คำสำคัญ: สมบัติทางชีวภาพ กิจกรรมของเอนไซม์คะตะเลส การหายใจของจุลินทรีย์ดิน แบคทีเรียโคลิฟอร์ม

Keywords: Biological properties, Catalase activity, Soil respiration, Coliform bacteria

INTRODUCTION

Chanthaburi province has optimum conditions and suitable areas for growing the economically various kinds of tropical fruits with an average production of 500,000 tons and a total annual value of 150 billion bath (Shaanxi Sunboo IMP&EXP Co., Ltd., 2011). The characteristics practices of Chanthaburi fruit growers are always mixed several selected plants in their orchards (inter-cropping system) as well as application of synthetic chemical fertilizers, manures, herbicides and pesticides. However, there is a major concerns about the farmers and consumer health including environmental sustainability. As a result, the Good Agricultural Practices or GAP aiming to encourage the farmers to produce safety agricultural products for consumers is promoted to Thai farmers since 2003 (Pongvinyoo et al., 2015). From GAP methods, they can select only some easy control points to suit to their conventional farming (Wannamolee, 2008). In Chanthaburi, there are 1,968 active mangosteen growers certified by the Department of Agriculture (Department of Agriculture, 2009). However, there is some conflicts between GAP procedure and orchards management because the fruit growers mainly managed their orchards according to their conventional experiences such as fertilizing, watering, and input control (Hosono, 2007). Biological properties of soil and water database may be useful for a better management of Chanthaburi orchards. Anyway, this data is limited in this area.

Soil fertility and water quality are important biological factors influencing on gardening. These properties get altered with environmental and agricultural activities including activity of soil microorganisms (Wyszkowska, 2002). Soil enzymes that synthesized by microorganisms play an essential role in soil processes such as nutrient cycling, organic matter and pollutants decomposition and produce essential compounds for both soil organisms and plants (Igbinosa, 2015). The study of soil biological properties in terms of soil enzymatic activities is a sensitive bio-indicator and useful tool (Kizilkaya et al., 2012). When improperly managed however, surface water runoffs through fertilized and chemicalized agricultural soils can negatively affect water quality (EPA, 2015). High total coliform and fecal coliform counts in surface water implies that water should not be used for domestic and agricultural purposes (Latha and Mohan, 2013). Therefore, biological properties of orchard soil and agricultural water can be determined by using soil enzyme activities and total coliforms counts.

The aim of the studies was to investigate the biological properties of orchard soil in terms of microbial activity (basal soil respiration and catalase activity) and water quality by determine total coliform counts in Pongrad area, Phlabphla subdistrict, Muang district, Chanthaburi province. This is the suitable unique studied site since most of the gardeners in this area cultivate mangosteens. They manage their farms both as GAP mangosteen-certified orchard or conventional management orchard. This is the first report studying about the topic in this area. The obtained results may be useful for GAP cultivation management in Chanthaburi province.

MATERIALS AND METHODS

Soil collection

Ten soil samples were taken from 10 different mangosteens garden of 5 villages of Pongrad area, Phlabphla subdistrict, Muang district, Chanthaburi province in September and December 2014. Composite rhizospheric topsoil samples (0–15 cm) were obtained by mixing subsoil samples from the random points (1 rai/random point) in each sampling site (Fig. 1). The soil samples were packaged on ice during transported to the laboratory. After that, each soil sample was sieved through a 2-mm sieve and some physio-chemical properties (pH, moisture content) were measured according to standard procedures. The field moist soil samples were used for the microbiological analyses within 12 hours.

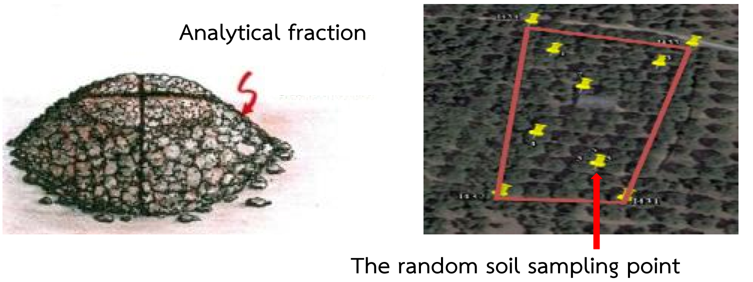

Figure 1 Soil sampling methods.

Water sample collection

Surface agricultural water samples (ponds, wells, canals, streams) were also collected from the sampling sites. Physical parameters of water consist of temperature and pH were measured directly in the water body. The sterilized 500 ml glass bottles were used for grab water sampling. The collected water samples were kept on ice and transported to the laboratory with the caution to avoid contamination by other microbes and analyzed within four hours.

Soil microbiological characteristics

Basal soil respiration

Basal soil respiration (BSR) of the collected soil samples were performed for quantifying CO_2 evolution by alkali absorption method according to Watcharathai (2008) with some modifications. Briefly, moist soils (300 g dry weight equivalent) were spread on the bottom of 500 ml glass jars and then placing a beaker containing 10 ml NaOH (0.5 M) solution. After incubation at room temperature for 24 h, 10 ml of 3 M $BaCl_2$ and 3-4 drops of phenolphthalein indicator were added into the beaker, and then titrated with

0.5 M HCl. The jars with autoclaved soils served as a control. The quantified of CO_2 evolution from soil microbes was calculated from the difference of consumed volume of HCl between the treatment and the control in titration. Data were expressed as µg CO^2-C g^{-1} dry soil.

Catalase activity

Catalase activity (CA) was measured by the method of Beck (1971) as cited in Kizilkaya (2009). Tube containing moist soil (5 g dry weight equivalent) was added with 10 ml of phosphate buffer (pH 7) and 5 ml of a 3% H_2O_2 substrate solution. The volume (ml) of O_2 released within 3 minutes at room temperature was determined. Three replicates of each soil were tested. The tube containing sterile soil served as control was tested as the same way. Results were expressed as ml O_2 g^{-1} dry soil.

Water analysis

The Most Probable Number (MPN) method was used for determining the coliform content of water samples. The 3 tube MPN test for detection of total coliform bacteria and fecal coliform bacteria was performed in two stages: i. Presumptive coliform test, ii. Confirmed coliform test.

Statistical analysis

All experiments were established in a 2x2 Factorial experimental in CRD, fixed effect model. Univariate was performed with SPSS statistical package version 16.0 (SPSS Inc., Chicago, USA) and the means compared by Duncan's multiple range test (P = 0.05).

RESULTS AND DISCUSSION

Related information about the studied area

Pongrad area consist of 5 villages (Moo 1 - Moo 5) which has the suitable climatic and terrain conditions for cultivating and growing tropical fruits. The gardeners in this area cultivate a single crop (mangosteens) or mixed crops (e.g. mangosteens and durians, mangosteens and long-kongs) in their farms. They manage their orchards in two ways, the GAP-certified orchards which decrease the chemical use in their gardens by joining the Good Agricultural Practice (GAP) as well as making the fermented organic fertilizers and plant hormones using EM, while the fruit growers of the conventional management orchards manage their farms as the conventional methods by using chemical fertilizer, manure, pesticides and herbicides. The ten soil and water samples were taken from 4 GAP-certified orchards (sample code O) and 6 conventional management orchards (sample code I). Most of the soil samples are loamy soil while water samples were mostly collected from ponds which the farmers used for watering plants (Table 1).

Table 1 Type of soil and water and land use pattern in the studied area.

Sample code (orchard)*	Soil type**	Water type	Land use pattern
$O_{1.1}$	loam	pond	GAP-certified orchards
$O_{1.2}$	loam	pond	
O_3	loam	pond	
O_4	sandy clay	pond	
I_1	loam	pond	conventional management orchards
I_2	sandy loam	stream	
I_3	loam	canal	
$I_{4.1}$	sandy clay loam	well	
$I_{4.2}$	loamy sand	stream	
I_5	loam	well***	

*O: sample code for GAP-certified orchard; I: sample code for Conventional management orchard, the first number 1-5: sample code for village 1-village 5, the second number 1-2: sample code for the first and the second sample of same village e.g. $O_{1.2}$ mean the second sample taken from the GAP-certified orchards of Moo (village) 1

$I_{4.2}$ mean the second sample taken form the integrated management orchards of Moo 4

**Naked eye observation

Soil physico-chemical properties

Physical properties of soils (e.g. pH, moisture, temperature) influence the soil microbial activity. The soil characteristics were given in Table 2. There were the differences of pH, moisture and temperature between the soil samples under study. It is noticeable that the pH range in 10 soil samples was very broad (4.04 to 6.99, 4.04 to 6.66) since there were the differences in the soil type of collecting points. The high pH value during September sampling (6.99) and December sampling (6.66) were obtained from the loamy soil in the GAP-certified orchards ($O_{1.2}$, $O_{1.1}$). From our observations and interviewed with the fruit growers, we found that the gardeners in the GAP-certified orchards had spreading organic fertilizers including compost, manures and organic wastes in their farms for maintenance of fruit trees after harvesting of fruit crop. Furthermore, they had stopped the use of pesticides and herbicides before harvesting which was restricted by the GAP requirements. This might be contribute to the loamy soil structure of the neutral pH soil in these orchards. Since the biofertilizers are live formulates of microorganisms that increased physico-chemical properties of soils such as soil structure, texture, water holding capacity, cation exchange capacity and pH by providing several nutrients and sufficient organic matter (Abbasniayzare et al., 2012). The continuous use of chemical fertilizers by the ordinary gardeners in Pongrad area might lead to a decrease in soil pH since the acid-forming nitrogen fertilizers increasing feature of acid irrigation (Savci, 2012). For soil moisture measurement, the result showed that the December sampling had lower percentage of soil moisture than the September sampling since there was a heavy rainfall before collecting soil samples in September.

Table 2 Physico-chemical properties in the studied soils.

Soil sample code	pH		Soil moisture (%)***		Temperature (îC)	
	A*	B**	A*	B**	A*	B**
$O_{1.1}$	6.15 ± 0.02	6.66 ± 0.04	24.32 ± 0.65	18.29 ± 1.39	25 ± 0.57	29 ± 0.57
$O_{1.2}$	6.99 ± 0.04	6.60 ± 0.08	19.31 ± 0.57	16.98 ± 2.65	27 ± 0.40	28 ± 0.57
O_3	6.80 ± 0.07	5.57 ± 0.09	29.61 ± 0.36	24.50 ± 0.75	27 ± 0.57	29 ± 0.20
O_4	6.02 ± 0.03	4.06 ± 0.10	24.78 ± 0.57	12.77 ± 1.78	28 ± 0.30	29 ± 0.46
I_1	6.44 ± 0.01	6.51 ± 0.20	19.44 ± 0.65	15.83 ± 0.46	26 ± 0.57	28 ± 0.57
I_2	4.93 ± 0.02	4.26± 0.44	22.21 ± 0.57	17.83 ± 0.53	27 ± 0.57	26 ± 0.36
I_3	5.54 ± 0.10	5.38 ± 0.35	17.94 ±0.36	11.76 ± 0.29	26 ± 0.65	27 ± 0.57
$I_{4.1}$	6.13 ± 0.20	4.48 ± 0.05	25.19 ± 0.57	23.80 ± 1.85	26 ± 0.57	26 ± 0.70
$I_{4.2}$	4.04 ± 0.75	4.04 ± 0.04	24.14 ± 0.65	22.78 ± 1.90	27± 0.48	29 ± 0.48
I_5	5.99 ± 0.07	6.20 ± 0.20	33.98 ± 0.57	20.57 ± 1.30	27 ± 0.29	26 ± 0.57

*September sampling **December sampling ***Values are means of triplicate ± standard deviations (SD)

Soil microbiological characteristics

Basal soil respiration

Basal soil respiration (BSR) is a useful parameter in measuring a soil's biological activity (Kizilkaya, 2009). The higher soil respiration, is an indicative of high biological activity, suggesting rapid decomposition of organic residues that make nutrients available for plant growth (Araújo et al., 2009). The pattern of BSR (Fig. 2A) was varied between the collected sites during September and December sampling and was not correlated with the physico-chemical properties of soils (pH, moisture, temperature) reported in this study. In which the maximum basal respiration at 0.81 µg CO_2 g^{-1} dry soil was found in the GAP-certified orchard ($O_{1.2}$) in September sampling (soil properties: pH 6.99, moisture 19.31%, 27 °C), but in the O_3 soil, the BSR decreased to 0.03 µg CO_2 g^{-1} dry soil (soil properties: pH 6.80, moisture 29.61%, 27 °C). As a result, future experiment such as determination of soil organic matter should be conducted. In comparison with BSR value between the GAP-certified orchards and the conventional management orchards in Pongrad area, the obtained results did not differ. The maximum BSR during the samplings were both obtained from the $O_{1.2}$ and I_3 orchards. This result showed that there were some little differences between the GAP-certified orchards and the conventional orchards in this area. Our finding was not according to the previous studies that reported the higher basal respiration rates in the organic farming than in the conventional farms (Araújo et al., 2009).

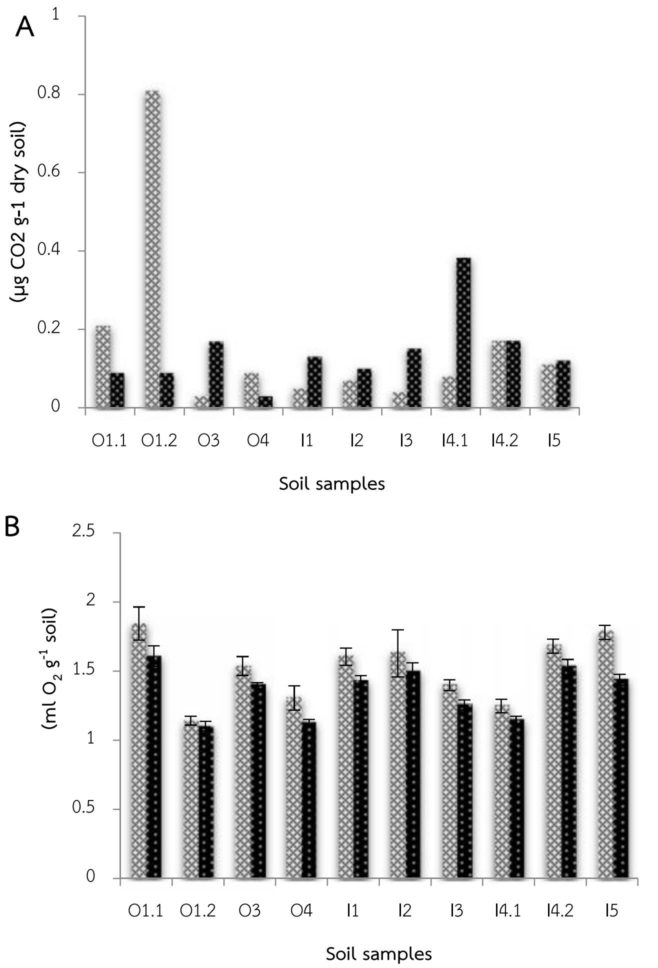

Figure 2 **A.** Basal soil respiration and **B**. catalase activity of ten soil samples collected from Pongrad area in September and December sampling of 2014.

Catalase activity

Catalase activity (CA) has been effectively used as an indicator of soil fertility (Kizilkaya et al., 2012; Li et al., 2014). In this study we investigated on the CA of 10 surface soil samples taken in mangosteen orchards from Pongrad areas of Chanthaburi province, Thailand. The reported data may be related to the metabolic activity of aerobic organisms because catalase is an intracellular enzyme found in all aerobic bacteria and most facultative anaerobes (Trasar-Cepeda et al., 2000 cited in Li et al., 2014). The maximum CA was found in the same GAP-certified orchard ($O_{1.1}$) for the first (1.84 ml O_2 g^{-1} dry soil) and second (1.60 ml O_2 g^{-1} dry soil) samplings. This was according to the fact that the owner of this orchard strictly manage his land according to GAP protocols. It was the orchard without the use of chemical substances for more than 10 years. The gardener used the fermented liquid organic fertilizers made by himself for crops maintenance and pest removal as well as using the fermented bio-fertilizers. The result was consistent with Ahmed et al. (2010), they reported that application of organic manures and bio-fertilizers increase catalase and peroxidase activities in sorghum. However, the CA values obtained in this studied varied very little between the GAP-certified orchards and conventional management orchards in September and December sampling. In which the maximum CA at 1.84 and 1.78 ml O_2 g^{-1} dry soil were obtained from the GAP-certified orchards ($O_{1.1}$) and the conventional management orchards (I_5) in September sampling, respectively. This was probably due to the two land use pattern in this area not quite different, resulting in the non-different in O_2 level because catalase is oxygen sensitive (Kizilkaya et al., 2012). According to Pongvinyoo et al., 2015, we had observed that the GAP-certified orchards in Pongrad area still managed their orchards according to their conventional experiences such as fertilizing, watering, and input control. Our observations was in agreement with other studies (Liu et al., 2006; Li et al., 2014). Nevertheless, our results disagreed with the previous findings that catalase differ under different land uses (Shi et al., 2008; Kizilkaya et al., 2012). Since they studied about the effect of soil contamination with pesticides and found the variations in CA for the different doses of chemical at different sampling times. Because the CA shows a quick response to induced changes (Sardar et al., 2007; Kizilkaya et al., 2012). As a result, CA determination is a useful indicator of aerobic microbial activity.

Effect of orchards management and soil sampling time on soil quality

Table 3 showed the mean soil physical and biological properties of the selected pairs of orchards and sampling time. The soils properties were not significantly different. However, it might be the interaction effect between orchards management and/or sampling time on soil quality evaluating by soil physical and biological indicators. Soil moisture and temperature in the September sampling of the GAP-certified orchards (moisture 24.51 %, 26.75 °C) were similar to the conventional management orchards (moisture 23.82%, 26.50 °C). It might be due to the effect of a heavy rainfall before soil sampling. Guntiñas et al. (2013) reported that soil moisture and temperature is greatly affect soil respiration. In contrast, soil moisture in the December sampling of the two orchards management was lower than that in the September sampling. This was due to the winter season of December sampling.

Table 3 Effect of orchards management and sampling time on the quality of soils.

Soil properties	GAP-certified orchards		Conventional management orchards	
	September sampling	December sampling	September sampling	December sampling
pH	6.49 ± 0.47	5.72 ± 1.23	5.51 ± 0.89	5.15 ± 1.05
Soil moisture (%)	24.51 ± 2.45	18.14 ± 2.46	23.82 ± 2.01	18.76 ± 2.01
Temperature (^{o}C)	26.75 ± 0.49	28.75 ± 0.49	26.50 ± 0.39	27.00 ± 0.39
Basal soil respiration (µg CO_2 g^{-1} dry soil)	0.29 ± 0.09	0.09 ± 0.08	0.09 ± 0.06	0.17 ± 0.06
Catalase activity (ml O_2 g^{-1} dry soil)	1.47 ± 0.06	1.38 ± 0.07	1.34 ± 0.07	1.51 ± 0.07

Soil temperature was depend on the sampling time and orchard type. Since the temperature of the two management orchards were higher in December than September sampling. And also soil temperature of the GAP-certified orchard (28.75 °C) was slightly higher than the conventional management orchards (27.00 °C). These phenomena could be related to different activities of the two orchards management system. Fruit-growers of the GAP-certified orchards were commonly applied organic fertilizers to fruit trees during flowering seasons. Larney and Angers (2012) reported that soil microbial biodegradation and mineralization of organic carbon fertilizers might lead to an increase of soil temperature. On the other hand, fruit growers of the conventional management orchards always applied more water because they used the synthetic fertilizer which poorly water soluble than organic amendments.

Most agricultural soils have a pH in the range of 5.5 to 8.0, the optimal pH range for most crops is 6.0 to 7.5 (Kyveryga et al., 2004). However, the pH values either increase or reduce under different treatments or perturbations of agricultural soils (Ayansina and Oso, 2006). In our study, soil pH of the GAP-certified orchard had the highest pH value at 6.49 in rainy season of September sampling after applying organic fertilizers by the fruit growers, while the conventional management orchard showed the lowest pH values at 5.15 to 5.51 during the two sampling times. These results agree with previous study that observed a reduction in soil pH treated with herbicides (Trimurtulu et al., 2015). The increased pH could have been due to the decomposition of soil organic (Haynes and Mokolobate, 2001).

Soil microbial activity and biomass was greater in high yield organically managed orchards (Huang et al., 2013). This was according to our study in which the BSR of the GAP-certified orchard showed the highest value in September sampling. Furthermore, the range of CAT values between the two sampling time was narrower in the GAP-certified orchard than the conventional management orchard. This finding was consistent with other physical factors of the GAP-certified orchards in September sampling. We observed a positive correlation between physical and biological properties of the GAP-certified orchard. As a result, it was possible to conclude from our study that the soil quality of GAP-certified orchard from Pongrad area was slightly better than the conventional management orchard. Since earlier reports revealed the enhancement of soil microbial functional diversity in organically managed farms soil (Kremer et al., 2015; Huang et al., 2013).

Water analysis

The microbiological quality of water is measured by the analysis and enumeration of indicator coliforms. The obtained data was shown in Table 4. In September sampling total coliforms count was minimum at 11000 MPN/100 ml in the $O_{1.2}$ water sample and maximum of 28000 MPN/100 ml in the I_1 water sample. The average was 18800 MPN/100 ml. Fecal coliforms were counted as minimum of 3600 MPN/100 ml (I_1, I_2, I_3, $I_{4.2}$) and maximum of 9200 MPN/100 ml (O_3). The average fecal coliforms count was 6170 MPN/100 ml. In December sampling total coliforms count was minimum at 7400 MPN/100 ml ($O_{1.2}$) and maximum of 21000 MPN/100 ml ($I_{4.2}$). The average was 13480 MPN/100 ml. Fecal coliforms were counted as minimum of 3000 MPN/100 ml in 4 water samples (I_1, I_3, $I_{4.1}$, $I_{4.2}$) and maximum of 7300 MPN/100 ml ($O_{1.1}$). The average fecal coliforms count was 3990 MPN/100 ml. It was seen from the result that both total coliforms and fecal coliforms counts were higher in September sampling (wet season) than December sampling (dry season). Furthermore, it was shown that most of the bacterial counts in water samples in September sampling exceeded the Type III of The Surface Water Standard for Agriculture and Water Quality for Protection of Aquatic Resources (20000 MPN/100 ml for total coliform, 4000 MPN/100 ml for fecal coliform). This might be because there was a heavy rainfall in September 2014, one week before samples collection.

Moreover, the gardeners had spreading the organic fertilizers (manure, dung) into their orchards for maintenance of the trees after harvesting. Hence, rains wash organic fertilizers from the land into the receiving waters. Coliform bacteria which commonly found in soil and manure can enter the surface agricultural water through direct discharge of manure. Since the coliforms are indicative of the general hygienic quality of the water and potential risk of infectious diseases through water (Sivaraja and Nagarajan, 2014). On the basis of this data, the water samples was considered to be unsatisfactory for agricultural purposes.

Table 4 Levels of total and fecal coliforms in 10 agricultural water samples collected from Pongrad area of Chanthaburi province.

Water sample code	Total coliforms (MPN/100 ml)		Fecal coliforms (MPN/100 ml)	
	September sampling	December sampling	September sampling	December sampling
$O_{1.1}$	14000	11000	9000	7300
$O_{1.2}$	11000	7400	7300	3600
O_3	15000	11000	9200	6200
O_4	14000	7400	7300	3600
I_1	28000	21000	3600	3000
I_2	20000	15000	3600	3600
I_3	15000	11000	3600	3000
$I_{4.1}$	20000	15000	7300	3000
$I_{4.2}$	23000	21000	3600	3000
I_5	28000	15000	7200	3600

CONCLUSION

Soil is the habitat for many species of microorganisms such as bacteria and fungi. The activity of these microbes play an important role in the soil fertility. In addition, coliform bacteria resides in agricultural water is also an index of water quality. This was the first report to investigate the biological properties of soil and water collected from the fruit orchards in Chanthaburi province. However, the obtained results could not indicate the state of soil fertility and water quality since the invariable data obtained from the two times of samplings. This might be due to the land use pattern and soil type determined in this study was not quite different. Nevertheless, the results of the soil quality assessment suggesting that the GAP-certified orchard possessed good microbial activity since it had the optimum soil conditions for growth of microorganisms especially in rainy season of the September sampling. It's possible that the obtained results will be useful data for sustainable orchards managements in Chanthaburi and we have planned to study about the diversity of plant growth promoting rhizobacteria (PGPR) in orchard soils of Chanthaburi. After the culture collection of this microbes, the usage of this PGPR as inoculants in bio-fertilizers may be promoted.

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