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Soil Nitrogen Phosphorus and Tea Leaf Growth in Organic and Conventional Farming of Selected Fields at Sabah Tea Plantation Slope

Khim.Phin Chong (Corresponding author)
School of Sustainable Agriculture, Universiti Malaysia Sabah
88999, Kota Kinabalu, Sabah, Malaysia
Tel: 60-88-320-000 ext. 5655 E-mail: chongkp@ums.edu.my

Tek Yung Ho
School of Science and Technology, Universiti Malaysia Sabah
88999, Kota Kinabalu, Sabah, Malaysia

Mohamadu Boyie Jalloh
School of Sustainable Agriculture, Universiti Malaysia Sabah
88999, Kota Kinabalu, Sabah, Malaysia

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Abstract

A comparative study of organic and conventional farming system at three different slope sections was conducted in Sabah Tea Plantation to determine the effect of management practices and slope section on soil nitrogen, phosphorus and pH as well as tea leaves size. Soils from two selected fields; B29 (conventional field) and NO3 (organic field) in Sabah Tea Plantation were analyzed using selected soil analysis method with UV spectrophotometer. Organic farming system resulted in significantly higher level of soil pH (4.14), leaf length (15.14 cm) and leaf width (7.33 cm) than conventional farming system soil pH (3.38), leaf length (13.19 cm) and leaf width (5.58 cm). However, conventional farming system produced higher levels of ammonium content (166.16 µg ml^{-1}) than organic farming system (22.56 µg ml^{1}). No significant difference in soil Phosphorus and nitrate content were observed between two farming systems. Results also showed no significant effects of slope sections on all parameters studied. This study has provided basic knowledge on soil Nnitrogen, phosphorus as well as tea growth of organic and conventional farming in Sabah Tea Plantation.

Keywords: Nitrogen, Phosphorous, Conventional, Organic

1. Introduction

Tea has become increasingly popular nowadays due to its potential pharmacological properties such as antioxidative, antitumor and anticarcinogenic activities (Yamamoto et. al., 1997). Tea is consumed as part of daily diet to reduce the risk of cardiovascular disease and cancer, especially among men (Tsubono et. al., 2002). This has lead to the increase of about 6.2% of world tea production, from 3,146,000 metric tone in year 2003 to 3,342,000 metric tone in year 2004 (FAO 2007). Organic farming is replacing conventional farming gradually due to increasing demands for organic food and growing environmental concerns (Hansen et. al., 2001) Conventional farming often gives a lot of negative impacts such as soil erosion, nutrient runoff, loss of organic matter, impairment of environment quality, pollution of natural water by agricultural chemical and potential hazard to human and animal health from heavy use of pesticides (Diepeningan et. al., 2006) Studies reported that organic farming able to increase the level of total nitrogen, nitrate and available phosphorus in soil and preventing nutrients leaching (Hansen et. al., 2001). Slope effect on nutrients and soil fertility is closely related to soil erosion and run-off. Soil erosion often happens during rainfall at steep slopes and is a complex phenomenon resulting from soil detachment by raindrop impact and surface flow, and transport of particle by rain splash and surface flow (Anderson & Ingram 2001) Soil losses by erosion affect physical, chemical and biological soil properties. Erosion also selectively decreases the nutrient and organic matter content (Lobo et. al., 2005). Steep slopes (>25º) together with acid soil and high rainfall is not considered to be a sustainable land use system, due to high nutrient losses mainly through erosion (Fagerström et. al., 2002). Very little research was done on tea crop in Malaysia, especially in Sabah regarding its soil nutrients under organic and conventional farming system and their potential effect on tea leaf growth. Moreover, the potential effect of slope section on soil nutrients content and tea leaf growth in tea plantation still not well understood. Thus, study was done to compare soil nitrogen and phosphorus content as well as tea leaf growth of two factors; first, different farming system (organic or conventional) and second, different slope sections at Sabah Tea Plantation.

2. Research merhods

2.1 Study site

Sabah Tea Plantation (STP) is located at Kampung Nalapak (5º 55' 58.53" North, 116 º 46' 22.44" East) of Ranau, Sabah with approximate 6,200 acres tea plantation area. The mean temperature of the study site ranges from 25 to 31 ºC and the annual rainfall is approximately 2,000 mm year^{-1}. Soil used in tea plantation mainly consists of sandy loam texture with pH range from 4.0 – 4.5. Two fields were selected for this study; Field B29 (conventional farmed field) and Field NO3 (organic farmed field), which share the same characteristics such as size of area, altitude, date of tea planting, time of fertilizer application and type of tea planted.

2.2 Samples

A total number of 18 soil samples (each soil samples constitute from five sub-soil samples) and 108 middle tea leaves were randomly sampled from the slope of two selected field in STP. The slope of each field was divided into three section; top, middle and low, using Random Complete Block Design (RCBD). Three soil replicates (sampled at depth of 0 – 15 cm) and 18 leaves were sampled from each section of slope. Soil samples were air-dried as soon as possible after sampled at temperature 30 – 35 ºC. Soil samples were ground and sieved through a two mm mesh before analysis take part (Dang 2004).

2.3 Physical measurement and chemical analyses

Tea leaves were measured manually for their length and width using ruler. Soil pH was determined using pH meter with soil-water ratio, 1:2.5 (Anderson & Ingram 1993). Soil available ammonium, nitrate and phosphorus were determined following the method as described by Page et. al., 1982, Cataldo et. al., 1975 and Mehlich-3 test with the use of Varian 50 Win UV Spectrophotometer. The concentration of nutrient in filtrate (µg ml^{-1}) was converted into kg ha^{-1} by multiplying with 2.0 x 10^6 (one hectare of soil at the depth of 15 cm is equivalent to 2.0 x 10^6 kg).

3. Results and discussion

3.1 Effects of farming systems

Figure 1 show that farming systems only significantly affecting soil ammonium ($p = 0.020$), soil pH ($p = 0.000$), leave length ($p = 0.001$) and leaf width ($p = 0.000$). Soil phosphorus ($p = 0.128$) and nitrate ($p = 0.065$) are not significantly affected by any farming systems. Organic farming system (OFS) resulted in higher soil pH (4.14), leaf length (15.1 cm) and leaf width (7.3 cm) while conventional farming system (CFS) resulted in higher soil ammonium content (166.2 µg ml^{-1}).

3.2 Effect of farming system on soil ammonium

Higher concentration of soil ammonium in CFS may due to excessive application of nitrogen fertilizers. Moreover, organic fertilizer nutrient availability to plants depend on many environmental factors such as soil aeration, soil moisture, soil pH, temperature as well as the C: N ratio of the organic materials before decomposition and mineralization can take place. In other words, organic fertilizers require more time before nutrients become available for plant use as compared to chemical fertilizers (Assouline & Ben-Hur 2006, Tisdale and Nelson 1975, Zech et. al., 1997). Higher content of ammonium in CFS soil may also due to the decrease in soil nitrogen absorption by tea plants due to plant toxicity. In tea plantations, excessive amounts of nitrogenous fertilizers are usually applied to ensure nitrogen is available for tea crop use (Oh et. al., 2006) Salisbury and Ross, 1992 reported that excessive supply of nitrogen in soil can leads to N toxicity in plant and nitrogen toxicity was an inhibitory to plant growth and development (Caicedo et. al., 2000).

3.3 Effect of farming system on tea leaf growth

Excessive amount of nitrogen were present in the soil, the positive response progressively declined and even became negative. This could be the reason for the lower tea leaf size in the CFS which had very high level of soil nitrogen. Willson and Clifford, 1992 reported, for unshaded tea, the increase in crop yield is directly proportional to the amount of nitrogen applied. Studies also showed OFS can produce higher yield of tea compared to CFS due to its ability to improve soil quality such as increase in nutrient, microbial biomass content and reduced soil acidity (Flieβbach et. al., 2007, Marinari et. al., 2006). Acidic soil such as in the CFS is not a favorable condition for tea plant to maximize its yield production as acidification can result in plant root damage and reduce plant productivity (Kauppi et. al., 1986) Besides, recommended soil pH for tea cultivation is 5.0-5.6 (Willson & Clifford 1992) and the pH in CFS is far below this range, indicating the unsuitability of CFS acidity level for tea productivity at STP. Moreover, excessive amount of ammonium in soil was considered potentially inhibitory to plant growth and development due to plant toxicity (Caicedo et. al., 2000). Plant toxicity can retard the growth and development of tea leaf and might consequently resulted in lower leaves size.

3.4 Effect of farming system on soil pH

Studies showed that nitrogenous fertilizers used in tea cultivation (CFS) such as ammonia sulphate, ammonium nitrate, ammonium sulphate nitrate, urea, calcium ammonium nitrate and ammonium chloride, are acid producing (Ma et. al., 1990, Tee et. al., 1987) Long-term tea cultivation even caused serious soil acidification (77% of 70 tea fields having pH below 4.0) as a consequence of heavy nitrogen (N) application (Oh et. al., 2006). Study also shows the continuous use of ammonium sulphate without the addition of lime will reduce the soil pH to level that is unsuitable for economic production of crops (Tisdale & Nelson 1975) Vogt et. al., 2006 showed that substantial part of the potential acidity was represented by deposition of ammonium ($NH4^+$). These facts are consistent with the result obtained from this study, where CFS was produced higher level of soil acidity.

3.5 Effect of farming on soil nitrate

No significant different of soil nitrate content in any farming system may due to low content of nitrate in both fields as a result of leaching and denitrification. Nitrate is known to be very mobile in soil and moves largely with the soil water. Under conditions of excessive rain it will leach out from the upper horizons of the soil into deeper layers (Tisdale & Nelson 1975). Furthermore, through denitrification process, nitrate may be lost in the form of nitrous oxide at pH level 4.9 to 5.6 (Wilson & Clifford 1992) as a result of excessive nitrogen application (Oh et. al., 2006). Diepeningen et. al., 2006 also reported similar results in their study comparing the effects of organic and conventional management on chemical and biological parameters in agricultural soil. They suggest that soil type (clay or sandy soil) has a stronger effect on the soil characteristics rather than management type.

3.6 Effect of farming system on soil phosphorus

No significant differences in soil phosphorus content in both farming systems were observed. Ionic forms of phosphorus ($H_2PO_4^-$) readily react with oxides (hydroxide), iron and aluminium which are abundant in acid soil, to form insoluble compounds that is hard to be extracted from soil (Tisdale & Nelson 1975, Wilson & Clifford 1992). The incomplete extraction of phosphorus (P) from soil can some how lead to the inaccurate result. However, Diepeningen et. al., 2006 also reported the similar result in their study, suggesting that soil type (clay or sandy soil) has a stronger effect on the soil characteristics rather than management type.

3.7 Effect of slope sections

Table 1 show that none of the parameters studied show significant difference at different slope sections; ammonium ($p = 0.646$), nitrate ($p = 0.711$), phosphorus ($p = 0.686$), leaf length (0.202), leaf width ($p = 0.684$) and soil pH (0.174).

3.8 Effect of slope sections on all parameters

Results from this study showed no significant differences for all parameters for the different slope sections. The dense tea canopies in Sabah Tea Plantation reduce the impacts of raindrop that can cause soil detachment, surface flow and transport of particle by rain splash (Anderson & Ingram 1993). Minimum soil loss by erosion does not have a significant impact on soil properties (Lobo et. al., 2005) and this was consistent with the result obtained from this study, wherein no significant differences in all parameters for the different slope sections were observed. This can be explained by the presence of dense tea canopies.

4. Conclusion

In conclusion, types of farming systems do significantly affecting soil pH, ammonium and leave length and leaves width. OFS promotes better soil pH (4.14), leaf length (15.1 cm) and leaf width (7.3 cm) but lower ammonium content (22.6 µg ml-1). CFS produces higher ammonium content (166.2 µg ml-1), but lower soil pH (3.38) and leaf length (13.2 cm) and leaf width (5.6 cm). Phosphorus and nitrate were not affected by any of the farming system. Slope levels, on the other hand, show no influence on any parameters studied.This study has provided basic knowledge about soil N, P and pH as well as tea leaves growth of Sabah Tea Plantation (STP).

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Table 1. Means values and standard deviation for six parameters studied under different farming systems and slope sections. Means with the same letter indicate no significance difference ($p < 0.05$).

Parameters	OFS (mean ± standard deviation)			CFS (mean ± standard deviation)		
	Top	**Middle**	**Low**	**Top**	**Middle**	**Low**
Ammonium (µg/ml)	27.37 [a] ± 17.27	18.90 [a] ± 1.57	21.40 [a] ± 7.61	218.97 [b] ± 98.09	178.20 [b] ± 246.12	101.30 [b] ± 79.24
Nitrate (µg/ml)	11.73 [a] ± 2.61	9.38 [a] ± 7.02	7.57 [a] ± 2.78	22.10 [a] ± 3.49	14.43 [a] ± 15.86	22.00 [a] ± 17.96
Phosphorus	20.97 [a] ± 10.65	28.03 [a] ± 17.80	8.53 [a] ± 1.70	35.33 [a] ± 15.83	23.20 [a] ± 9.99	33.03 [a] ± 22.67
Soil pH	3.83 [a] ± 0.25	4.10 [a] ± 0.37	4.48 [a] ± 1.67	3.43 [b] ± 0.44	3.42 [b] ± 0.55	3.28 [b] ± 0.23
Leaf length (cm)	14.57 [a] ± 0.92	15.20 [a] ± 1.51	15.67 [a] ± 1.17	12.67 [b] ± 0.25	13.37 [b] ± 0.38	13.53 [b] ± 0.49
Leaf width (cm)	7.10 [a] ± 0.20	7.43 [a] ± 0.81	7.47 [a] ± 0.55	5.67 [b] ± 0.58	5.33 [b] ± 0.15	5.73 [b] ± 0.64

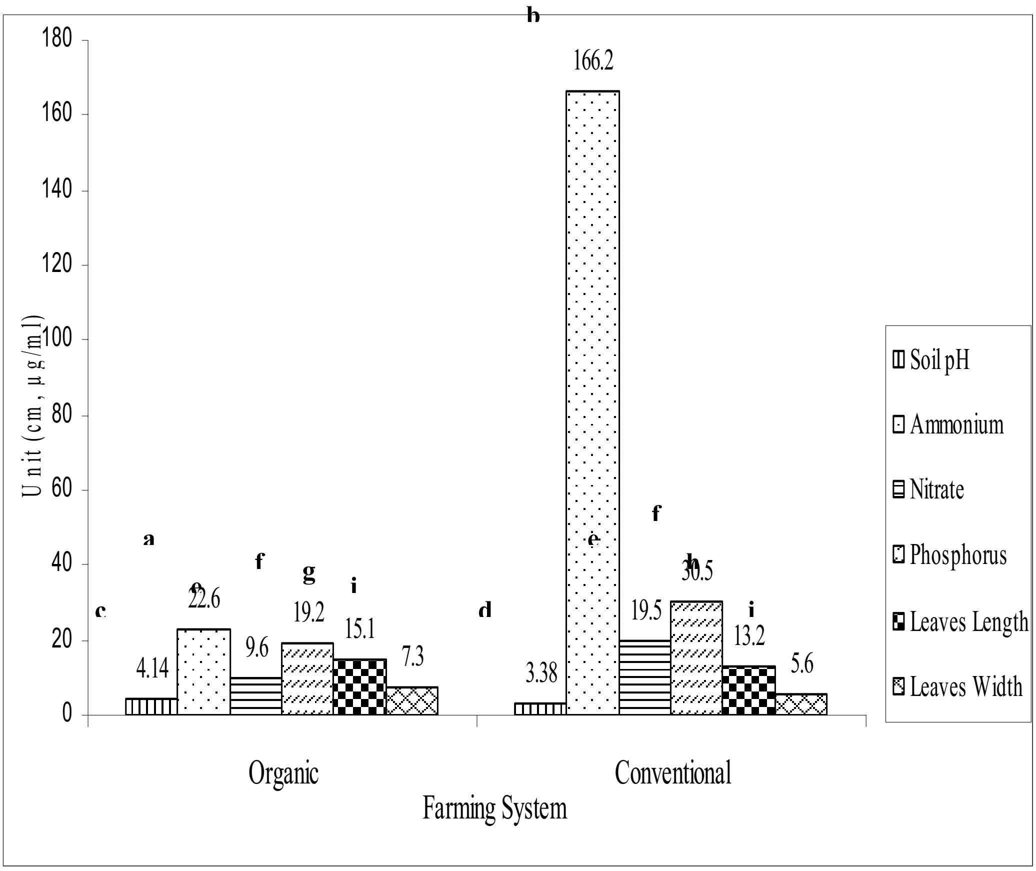

Figure 1. Mean values for six parameters studied under two different farming systems.

Bars with the same letter indicate no significant differences ($p < 0.05$).