Comparison of soil physical and chemical properties and soil invertebrate communities between organic and conventional tea plantation in Taiwan

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Abstract

In this study, we investigated whether organic agricultural practices can improve soil health, in terms of soil properties and fertility and soil invertebrate community in the Fenghuang Tea Plantation of Central Taiwan. Soil physical (soil bulk density and moisture content), chemical (soil pH and soil carbon, nitrogen, phosphorus concentrations) and biological (diversity and composition of soil invertebrates and pest communities) data were collected from a conventional, a transitional, and an organic farming site (which was previously conventionally managed) in June 2017. The results showed that the conventional site had the lower soil bulk density (0.79 g/cm3) in top soils, as compared to the transitional and the organic ones. Organic site had higher organic carbon (%), nitrogen and phosphorus content in 5-15 cm deep soil. Composition of soil invertebrate communities from pitfall trap samples significantly differed between agricultural managements (MANOVA; p<0.0001). Organic site had more predators (i.e. Araneae) and herbivores (i.e. Hemipetra and Orthoptera). Transitional site had more collembolans and a lower abundance of oribatid mites. Our results indicated a gradual yet significant transformation in soil nutrients and invertebrate community during the transition process from conventional to sustainable practices.

Introduction


Figure 1. Fenghuang Tea Plantation (photo taken by Dr. Chen)

Farming practices for tea plantations vary from intensive application of chemical pesticides and fertilizer (conventional) to no agrochemical application at all (organic). The usage of pesticides and synthetic chemical fertilizers causes inhabitable soil environment (e.g., high soil acidity, soil toxicity and heavy soil compaction) for many soil organisms (such as beetles, mites, collembolan, spider, ants, etc.). Disturbing soil communities disrupts many important biological processes performed by these organisms, such as pest and weed control, improved soil aggregate stability, and better nutrient cycling efficiency. In recent years sustainable agricultural management (i.e., organic practice) is encouraged for tea plantations in Taiwan (Chen et al 2016). Assessment and comparison of changes in soil properties, soil nutrients and soil invertebrate community during the transition from conventional to organic practices could provide sufficient information to prepare tea farmers for such transformation.

Methods and Materials

Study Area

The experiment was conducted at the Fenghuang Tea Plantation (鳳凰茶園; Fig. 1), National Taiwan University Experimental Forest, Nantou County, Taiwan. The study area receives an average of 2,250 mm annual precipitation with an average temperature of 18.5 oC. It is located at 800-900 meters in elevation with 20º slope. The soil is clay loam and acidic (pH 3.2-3.9). Oolong tea (and one of its varieties: Jinxuan) is one of the main tea varieties grown in this area. This project was conducted in May-June, 2017.

Experimental design

Three sampling sites were selected from different farming management (conventional, transitional, and organic) (Fig. 2).

- Conventional site: tea plantation that continuously receives agrochemical application (synthetic fertilizers and pesticides)
- Transitional site: tea plantation has just recently converted from conventional management into organic practice for 2 years
- Organic site: tea plantation has been implemented with organic practice consecutively for 4 years


Figure 2. The tea plantation under conventional (left), transitional (middle), and organic (right) practices. There is little ground vegetation cover in the conventional site due to application of the herbicide.

Experimental design

Five rows of tea crops (6 m apart from each other) were randomly selected at each studying site. At each row two sampling plots were established for collection of soil properties (soil bulk density, moisture content and pH; 0-5 cm and 5-15 cm), soil nutrients (carbon, nitrogen and phosphorus; 0-5 cm) and soil biological community (soil invertebrates and flying pest community).

Pitfall traps (D=7.6 cm and H= 9.5 cm) filled with 75% ethanol were buried into the ground for 100 hours to evaluate diversity and activity of soil dwelling invertebrate. Two sticky pad traps (16 cm × 22.5 cm) were set above the tea tree plants (1 meter in height) and 3 meters apart from each pitfall trap for 52 hours. Upon collection, the traps were wrapped with saran wrap allowing for the traps to be stacked. Traps were refrigerated before the pictures were taken for further specimen identification. Soil invertebrates and insects collected from the traps were identified to the Order to evaluate invertebrate activity and diversity among different managements. Data from sticky traps is not included in this presentation.

Results

Soil properties

The conventional site had the lower soil bulk density and the higher soil water content than the transitional site (Table 1).

Table 1. Soil pH, bulk density (g/mL) and soil moisture content (%) from tea plantations receiving conventional, transition and organic practices. Data is presented in mean value (± standard error).

		Management			
Soil Measurement	Soil depth	Conventional	Transitional	Organic	Statistic Results
Soil pH	0-5cm	3.6 ± 1.0	3.8 ± 0.6	3.6 ± 0.3	*Management* F= 2.0; *p*= 0.14 *Depth* F= 0.2; *p*= 0.6
	5-15cm	3.2 ± 0.5	3.7 ± 0.4	3.9 ± 0.5	*Management*Depth* F=2.0; *p*= 0.14
Soil Bulk Density (g/mL)	0-5cm	0.79 ± 0.09[a]	0.95 ± 0.08[b]	0.92 ± 0.08[b]	*Management* F= 6.3; ***p*= 0.004** *Depth* F= 28.9; ***p*< 0.001**
	5-15cm	1.00 ± 0.11	1.06 ± 0.11	0.99 ± 0.10	*Management*Depth* F=3.0; *p*= 0.06
Soil Moisture (%)	0-5cm	61.6 ± 9.3[a]	46.8 ± 10.8[b]	53.9 ± 4.8[ab]	*Management* F= 11.9; ***p*< 0.001** *Depth* F= 28.9; ***p*< 0.001**
	5-15cm	44.9 ± 4.9[ab]	38.6 ± 4.7[a]	48.6 ± 6.2[b]	*Management*Depth* F=3.2; ***p*= 0.05**

Soil nutrients

- For the top 5 cm soil, transition site had the lowest organic carbon (%), nitrogen and phosphorous contents in the top 0-5 cm soil among all three managements (Fig. 3).
- Organic site had the highest organic carbon (%), nitrogen and phosphorous contents in the 5-15 cm soil.

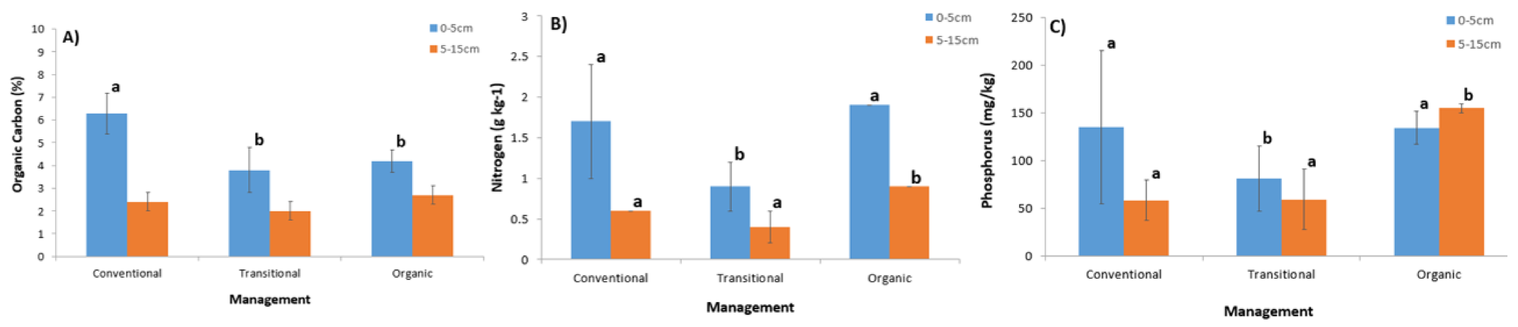
Figure 3. Organic carbon (%), nitrogen (g/kg) and phosphorus (mg/kg) contents in the top (0-5 cm) and 5-15 cm soils from the tea plantations receiving conventional, transition and organic practices. Different letters indicate a significant difference between different managements (p< 0.05; Tukey's HSD)

Soil invertebrates (Pitfall trap)

- Composition of soil invertebrate communities was significantly different between tea plantations with different managements (MANOVA; p <0.05; Fig. 4).

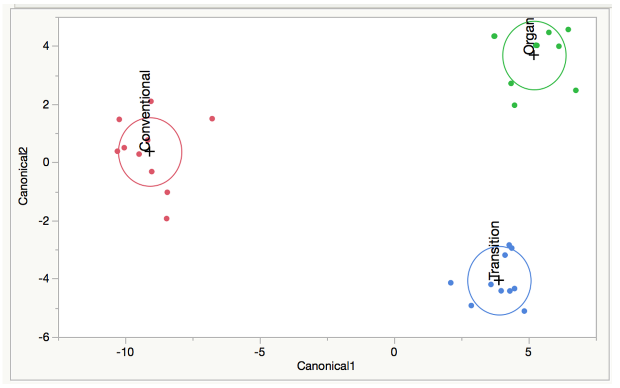
Figure 4. The canonical plot for soil invertebrate community of pitfall trap samples from tea plantations with conventional, transitional and organic practice.

Table 2. Soil invertebrate community from pitfall trap samples in the tea plantations receiving conventional, transition and organic practices. Data is presented in mean values with data range included in the parentheses. Log-transformed data was used for MANOVA and ANOVA statistical analyses.

Invertebrate groups	Management			Statistical Results (log-transformed data)
	Conventional	Transition	Organic	
Acarina	18.0[a] (8-32)	8.4[b] (1-16)	14.7[a] (6-27)	F=6.3 ***p*= 0.0056**
Araneae	0.5[a] (0-2)	8.6[b] (0-27)	14.0[b] (9-36)	F= 39.3 ***p*< 0.0001**
Chilopoda	1.0[ab] (0-3)	0.3[b] (0-2)	0[bc]	F= 4.2 ***p*= 0.03**
Collembola: *Entomobryomorpha*	225.6[ab] (95-459)	427.1[a] (53-987)	156.5[b] (16-503)	F=4.6 ***p*= 0.02**
Collembola: *Symphypleona*	12[a] (4-65)	146.3[b] (1-566)	51.1[ab] (14-97)	F= 3.7 ***p*= 0.04**
Collembola: *Poduromorpha*	0.1[a] (0-1)	3.7[b] (0-12)	12.8[c] (1-31)	F= 19.9 ***p*< 0.0001**
Dermaptera	1.0[a] (0-3)	0.3[ab] (0-2)	0[b]	F= 4.2 ***p*= 0.03**
Diptera	26.0[a] (0-84)	5.9[ab] (0-11)	4.9[b] (1-12)	F= 3.9 ***p*= 0.03**
Hemipetra	0.1[ab] (0-1)	0[a]	1.1[b] (0-5)	F=4.1 ***p*= 0.03**
Isopoda	0[a]	0.3[ab] (0-2)	1.0[b] (0-3)	F=5.7 ***p*= 0.0083**
Orthoptera	0.3[a] (0-2)	3.9[b] (0-8)	6.0[b] (0-24)	F= 14.5 ***p*< 0.0001**

- Conventional site has a higher abundance of oribatid mites and Diptera than the transitional and organic ones.
- There were more collembolans (Entomobryomorpha and Symphypleona) in the transitional site.
- Organic site had more collembolans (Poduromorpha), isopoda and Orthopetra (e.g., grasshoppers). (Table 2)

Conclusions and Discussion

1. We observed the changes in soil nutrients and soil invertebrate community during the transition from conventional to organic practice.
2. The lower organic carbon in top 5 cm soil at the transition and organic sites might be due to disturbance on the top soil during the transition process.
3. Higher organic carbon, nitrogen and phosphorus contents in 5-15 cm soils at the organic site might be a result of improved soil microbial communities, increased root secretion, increased plant debris from natural vegetation cover.
4. There is a significant change in soil invertebrate community during the conventional-organic transition process. Changes in the composition of soil invertebrate community could be attributed to the lack of pesticide application, availability of food resources, and predator-prey dynamic. Further research is needed to monitor the recovery and changes in dynamic of soil invertebrate community during the transition from conventional to sustainable, organic practice.

Reference

Chen, C., Ming-Jer, T., Chuang-Wen,P. 2016. Study on Soil Properties of Fenghuang Tea Plantation in Experimental Forest, National Taiwan University. Journal Exp. For. Nat. Taiwan Univeristy. 30(3): 187-198.

Acknowledgments

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