Effects of different quality organic residues applied yearly for the long term on dissolved organic matter dynamics in a sandy soil

Benjapon Kunlanit[1] and Patma Vityakon[1*]

Abstract: The objectives of this study were to investigate the effects of different quality (chemical composition) organic residues applied yearly for the long term on dissolved organic matter (DOM) dynamics in a sandy soil. This study consisted of five organic residue treatments: 1) no residue addition, 2) rice straw (low quality) which had low N, lignin, and polyphenols but high C/N ratio and cellulose, 3) groundnut stover (high quality) with high N but low lignin, polyphenols, and C/N ratio, 4) dipterocarp leaf litter (low quality) containing low N but high lignin, polyphenols, and C/N ratio, and 5) tamarind (leaf + petiole) litter (medium quality) with medium N, lignin, and polyphenols. The results showed that soil treated with tamarind residue yielded higher dissolved organic carbon (DOC) concentration than other treatments, while soil treated with rice straw had the lowest DOC concentration. For dissolved organic nitrogen (DON) concentration, soil treated with groundnut stover gave higher DON concentration than the other treatments. However, soil treated with rice straw residue which contained high cellulose content had the lowest DOC concentration (at 0-15 cm of soil depth). It was speculated that cellulose led to production of low molecular weight-DOC, which had low affinity for adsorption, and hence, may be leached into subsoil (>15 cm of soil depth). Therefore, future research should focus on identifying DOM forms (i.e., low and high molecular weight-DOM) and their respective contents, retention and movement in soils under different organic residue applications applied in the long term.

Key words: dissolved organic matter, chemical composition of organic residues, decomposition

Land Resources and Environment Section, Department of Plant Science and Agricultural Resources, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002

*Corresponding author: patma@kku.ac.th

Introduction

Sandy soils of Northeast Thailand have low fertility partly due to low soil organic matter (SOM). To improve soil fertility, an effective solution is organic residue management. The quality or chemical composition (i.e., carbohydrates, cellulose, lignin, and polyphenols) of organic residues is an important factor affecting decomposition rate and the accumulation of SOM. Soil organic matter consists of rapidly-changing (labile), and slowly-changing (stable) pools. The labile pool brings about nutrient release and cycling. Dissolved organic matter is a crucial part of the labile pool of SOM. It significantly contributes to the C and N cycles in terrestrial ecosystems, soil aggregate formation, and pollutant mobilization by chelation process in soils (Kalbitz et al., 2000)

Chemical composition of organic residue determines attributes of DOM. Upon degradation, recalcitrant compounds (i.e., lignin and polyphenols) provide higher quantity of high molecular weight (HMW) (> 10,000 Da) than low molecular weight (LMW) (< 10,000 Da)-DOM. Meanwhile, the degrading labile compounds (i.e., cellulose, sugars, and amino acids) yield higher quantity of LMW-DOM than HMW-DOM. In general, HMW-DOM has higher affinity to be adsorbed to soil solid phase than LMW-DOM. Puttaso et al. (2010) investigated SOC accumulation resulted from incorporation of different quality organic residues (e.g., groundnut stover, rice straw, tamarind, and dipterocarp). The highest soil organic carbon (SOC) accumulation was found in groundnut (added C of 3.88 Mg ha^{-1} $year^{-1}$), while the lowest SOC accumulation was found in rice straw (added C of 3.67 Mg ha^{-1} $year^{-1}$). Meanwhile, CO_2-C loss was highest in the groundnut treatment (91% of initial C added) followed by rice straw (71% of initial C added) (Puttaso, 2010). They hypothesized that most C from rice straw (high cellulose) may have been lost by leaching process in the form of low molecular weight-DOC; in particular, at the initial stage of the decomposition occurring during high soil moisture and high rainfall conditions. So far, few studies have focused on the effects of organic residues quality on *in situ* DOM dynamics in tropical sandy soils. Therefore, the aim of this study was to investigate the effects of different quality organic residues applied yearly for the long term on DOM dynamics in a sandy soil.

Materials and Methods

Soil samples were collected (0-15 cm depth) from a long term SOM field experiment in Khon Kaen province, Northeast Thailand. Treatments consisted of five treatments: 1) no residue addition, 2) rice straw (low quality) with low N, lignin, and polyphenols but high C/N ratio and cellulose, 3) groundnut stover (high quality) with high N but low lignin, polyphenols, and C/N ratio, 4) dipterocarp leaf litter (low quality) containing low N but high lignin, polyphenols, and C/N ratio, and 5) tamarind (leaf + petiole) litter (medium quality) with medium N, lignin, and polyphenols. The contents of these compounds chemical composition of the residues varied to some extent in residues used from year to year. Those of year 10 and 13 are shown in Table 1. The residues were incorporated into the soil at approximately 15 cm depth at the rate of 10 Mg ha^{-1} $year^{-1}$. Soil samples from each treatment in year 2, 3, 4, 5, 6, 10, and 13 at week 0, 1, 2,4, 8, 16, 26, and 52 were extracted by K_2SO_4 for DOC and and KCl for DON. Dissolved organic carbon in the extract was determined by $K_2Cr_2O_7$ oxidation and DON was determined by the ninhydrin-reactive N method (Amato and Ladd, 1988).

Analysis of variance pertaining to a randomized complete block design (RCBD) and related statistical analysis were performed employing Statistics 8.0 (Analytical Software, 2003). Means comparisons of different treatments were done by least significant difference (LSD) and standard error of the difference (SED).

Results and Discussion

Dissolved organic carbon

Concentrations of DOC were higher in soils amended with residues than the control (no residue addition) (**Figure1a, b**). For year 10, the highest DOC concentrations were found in tamarind treatment throughout the decomposition period. DOC concentrations under all residue treatments peaked at week 8, at which tamarind had the highest DOC concentrations followed by groundnut, rice straw, and dipterocarp (**Figure 1a**). For year 13 at week 1 and 8, tamarind and groundnut treatments had higher DOC concentrations than rice straw and dipterocarp treatments, respectively. Thereafter, the DOC concentrations decreased in all treatments until week 16 in both years. After week 16 of both years, DOC concentrations slightly increased in all treatments. Among the treatments receiving residues, rice straw had the lowest DOC concentrations at week 52 (**Figure 1b**).

At the end of decomposition period (52 weeks) DOC concentrations were higher under tamarind than the other treatments at year 2, 5 and 13 (**Figure 2a**). The highest DOC concentrations under tamarind may have been due to the highest SOC accumulation in stable form (humic substances) which may have been a major source of high molecular weight-DOC. High molecular weight-DOC had high affinity for adsorption on soil colloid; therefore, soil treated with tamarind residue produced high DOC concentrations in topsoil. Meanwhile, rice straw treatment showed trend of lower DOC concentrations in topsoil than the other treatments receiving residues. This was likely due to the fact that the degrading rice straw produced high concentrations of low molecular weight-DOC with low affinity for adsorption on soil colloids and therefore, may have been leached into subsoil of soil profile.

Dissolved organic nitrogen

Concentrations of DON in year 10 were higher in soils amended with residues than the control (no residue addition) (**Figure 3a**). DON concentrations under groundnut residue treatment peaked at week 2. Second peaks of DON concentrations were found at week 16 under all residues; however, these peaks were than the first peak at week 2 under soil treated with groundnut residue. Thereafter, the DON concentrations decreased in all treatments until week 52. During the early phase of decomposition, groundnut had highest DON among all residue treatments although it was significant only at week 4. Groundnut also had the highest DON concentrations among all residue treatments in year 13 although they were significant in week 2 and 26 (**Figure 3b**).

At the end of decomposition period (52 weeks) of year 2 and 13, DON concentrations under groundnut treatment were higher than the other treatments (**Figure 2b**). The general higher DON concentrations under groundnut treatment than the other treatments were likely due to its highest nitrogen content and highest indigenous SON (Puttaso et al., 2010) which led to high soil DON concentrations.

Conclusions

Soil treated with tamarind yielded higher DOC concentrations than the other residue treatments because tamarind treatment produced high indigenous SOC, which was a major source of DOC. The DOC under tamarind is thought to have high molecular weight. However, the soil treated with high-cellulose rice straw produced low DOC concentration (at 0-15 cm of soil depth). This was because cellulose composition of rice straw led to production of low molecular weight-DOC, which had low affinity to adsorption, and hence may have been leached out to subsoil (>15 cm of soil depth) of soil profile. For DON concentration, soil treated with groundnut stover produced higher DON concentrations than the other residue treatments. This was because the highest nitrogen content in groundnut stover and the highest indigenous SON among all residue treatments may have resulted in high concentrations of both low and high molecular weight DON concentrations. Therefore, future research should focus on identifying DOM forms (i.e., low and high molecular weight-DOM) and their respective contents, retention and movement in soils under different organic residue applications applied in the long term.

Acknowledgments

The research reported here was funded by the Royal Golden Jubilee Ph.D. Program under the Thailand Research Fund (TRF), research grants of the government of Thailand to Khon Kaen University and TRF Targeted Research Program (sustainable agriculture) FY 2008.

References

Amato. M. and J.N. Ladd. 1988. Assay for microbial biomass based on ninhydrin reactive nitrogen in extracts of fumigated soil. Soil Biol. Biochem. 20 : 107-114.

Analytical Software. 2003. Statistix 8: User's Manual. Analytical Software, Tallahasse.

Kalbitz, K., S. Solinger, J.-H. Park, B. Michalzik, and E. Matzner. 2000. Controls on the dynamics of dissolved organic matter in soils: a review. Soil Sci. 165 : 277-304.

Puttaso, A. 2010. Changes in Soil Quality under Long Term Application of Different Quality Organic Residues in a Sandy Soil. Ph.D. Dissertation Graduate School, Khon Kaen University, Thailand.

Puttaso, A., P. Vityakon, P. Saenjan, V. Trelo-ges, and G. Cadisch. 2010. Relationship between residue quality, decomposition patterns, and soil organic matter accumulation in a tropical sandy soil after 13 years. Nutr Cycl Agroecosyst. DOI: 10.1007/s10705-010-9385-1.

Samahadthai, P., P. Vityakon, and P. Saenjan. 2010. Effects of different plant quality residues on soil carbon accumulation and aggregate formation in a tropical sandy soil in Northeast Thailand as revealed by a 10-year field experiment. Land Degrad. Develop. 21:463-473.

Table 1 Chemical composition of organic residues in year 10 and 13

Residues	C (g kg^{-1})		N (g kg^{-1})		C/N ratio		[a] L (g kg^{-1})		[b] Pp (g kg^{-1})		Cellulose (g kg^{-1})	
	Years		Years		Years		Years		Years		Years	
	10	13	10	13	10	13	10	13	10	13	10	13
Rice straw	390	367	5.6	4.7	69.6	78.4	19.4	28.7	8.0	6.5	474	507
Groundnut stover	415	388	22.3	22.8	18.6	17.1	39.1	67.6	12.5	12.9	372	178
Dipterocarp	450	453	6.2	5.7	72.6	79.5	255.8	175.5	94.4	64.9	325	306
Tamarind	439	427	10.0	13.6	43.9	31.5	198.0	87.7	50.0	31.5	356	143

[a] L, lignin

[b] Pp, Total extractable polyphenols

Sources: Samahadthai et al. (2010) and Puttaso et al. (2010)

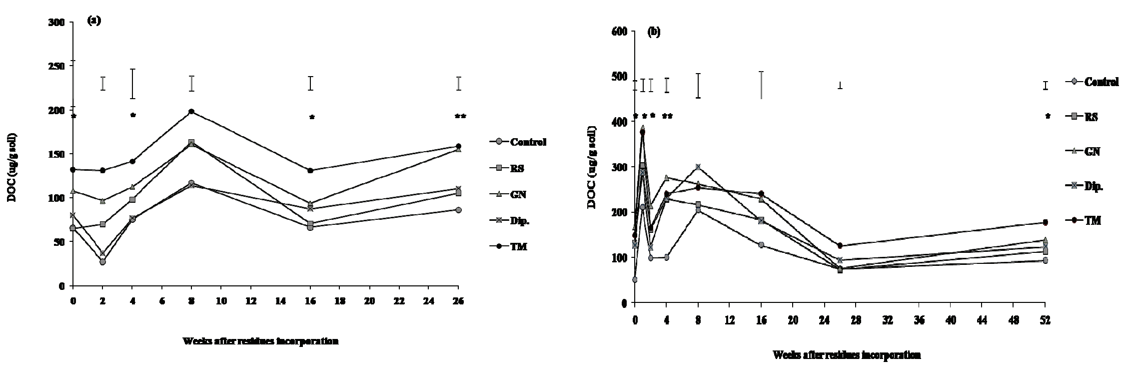

Figure 1 Changes in DOC concentrations at different periods after incorporation of organic residues into the soil **(a)** year 10 and **(b)** year 13. *Vertical bars represent SED*. *, ** significantly different at $P< 0.05, 0.001$, respectively

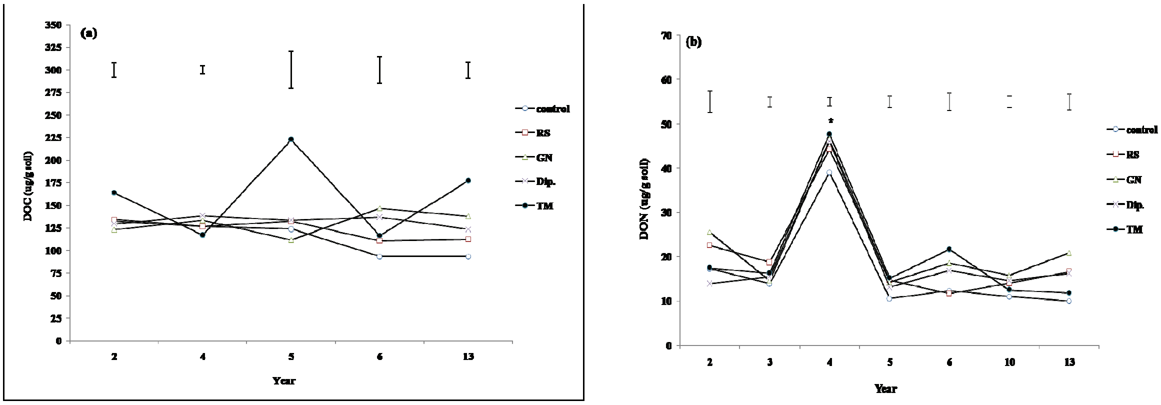

Figure 2 Changes in DOC concentrations at week 52 after residue incorporation of year 2, 4, 5, 6, and 13 **(a)** and changes in DON concentrations at week 52 after residue incorporation of year 2, 4, 5, 6, and 13 **(b)** as affected by different quality organic residues incorporated into the soil. *Vertical bars represent SED*. * significantly different at *P*< 0.05

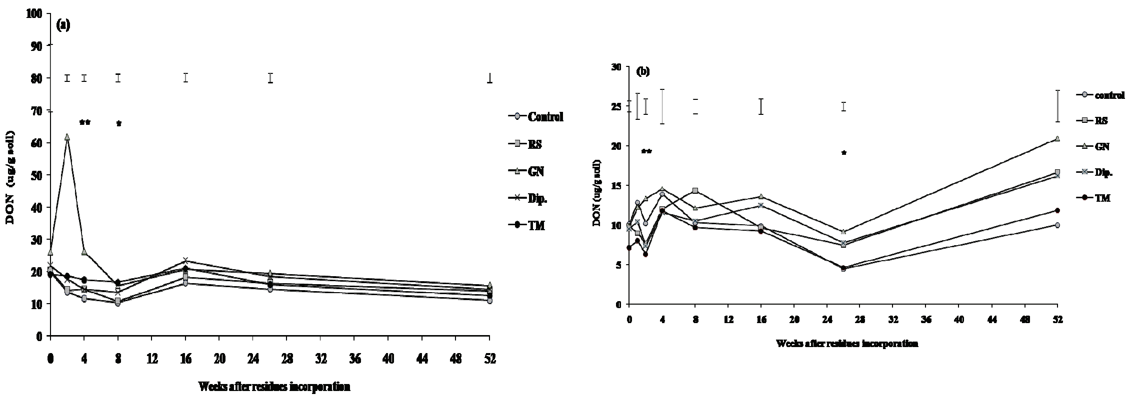

Figure 3 Changes in DON concentrations at different periods after incorporation of organic residues into the soil **(a)** year 10 and **(b)** year 13. *Vertical bars represent SED*. *, ** significantly different at *P* < 0.05, 0.001, respectively.

Soil biological activity and greenhouse gas production in salt-affected areas under tree plantation

Aung Naing Oo[1], Chuleemas Boonthai Iwai[1]*, Patcharee Saenjan[1] and Bubpha Topark-ngarm[1]

Abstract: Soil salinity is likely the most important abiotic factor that constrains the crop production in Northeast Thailand. This study aimed to evaluate impacts of soil salinity on the soil biological activity and greenhouse gas evolution in salt-affected areas under tree plantation, at Amphur Borabue, Mahasarakam province, Northeast Thailand. The study area was divided into two zones based on the plant community found in each area which linked with the flooding situation and soil salinity. Soil samples were collected from the two different zones at the same depth (0-20cm) with three replications during the rainy season of 2010, in order to analyze soil salinity and biological properties. The results showed that the soil biological activity in terms of soil respiration, microbial biomass carbon and microbial biomass nitrogen in the upper site were greater than in the lower site. Moreover, metabolic quotient was higher in the lower site than the upper site. Field evolution of CH_4 varied with different location. It could be concluded that tree plantation covered with native grasses in salt-affected areas increased soil biological properties and reduced the greenhouse gas production.

Key words: soil biological activity, salinity, methane

[1] Department of Plant Science and Agricultural Resources, Land Resources and Environment Section, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002

* Corresponding author: chulee_b@kku.ac.th