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Decomposition, Nitrogen Release and Soil Fertility of Plant Residues Incorporation from Different Pre- Sugarcane Planting Management

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Abstract

The effect of decomposition, nitrogen release and soil fertility of upland rice-legume residues incorporation before sugarcane planting was investigated. The experimental design was randomized complete block design (RCBD) with 4 replications. The following residue and control treatments were implemented: i.e. i) control; no residues incorporation, ii) weed, iii) soybean (Glycine max), iv) sunn hemp (Crotalaria juncea) and v) upland rice. Soil samples and litter bags were collected at 1, 2, 4, 8, 12, 16, 24 and 32 weeks after incorporation. Soil mineral N was analyzed by Flow Injection Analyzer (FIA) and remaining dry weights of litter bag were recorded. Soil microbial biomass was measured by chloroform fumigation extraction method. The results revealed that weed residues treatment had the highest of remaining dry weight and % N remaining in litter bag in most sampling dates. Sunn hemp residues treatment had the highest soil mineral N and was significantly different from the other treatments ($p < 0.01$) at 4, 8, 12 and 16 weeks after residues incorporation. At final sampling date, the upland rice residues treatment gave the highest microbial biomass N and was significantly different from the other treatments ($p < 0.01$) and provided the highest relative microbial biomass N but not significantly different from soybean residues treatment. Moreover, soil organic matter could be improved by all residue treatments. However, sunn hemp may be a potential crop for soil N release but upland rice could support rice consumption demand. Thus, the effect of legume-upland rice residue incorporation on sugarcane yield should be further investigated under field conditions.
Keywords : *upland rice, soybean, sunn hemp, weed, plant residues*

1. Introduction

Despite sugarcane is one of the major exported crops of Thailand its average yield is quite low (1.6 t ha^{-1}) due to very poor soil fertility of harvested area. The northeast of Thailand is the largest sugarcane producing area having a sandy soil and low organic matter which leads to only one or two ratoon crops. Generally, the farmers plant sugarcane during October to December and harvest in December to April of the following year. Hence, the period between the last ratoon crop harvest and the next sugarcane planting, there is a 6–8 months time gap (1). This period will cover one whole rainy season and is considered to have a potential for crop rotation. Some farmer broadcasted green manure legume seed for instance sunn hemp, and incorporated when soil preparation for sugarcane planting. However, this practice could improve only soil fertility but not an economic income (2). Grain legume i.e. soybean is the alternatives crop due to it not only return an economic income but also soil fertility. According to (3) revealed soybean could fix 150 kg N ha^{-1} in Northeast Thailand. (4) found the highest cane yield was obtained when soybean was planted as a preceding crop compared to the fallow treatment. Moreover, soil fertility can be improved when legume crops are planted and ploughed during this time gap. However, harvesting the legume crops may not always provide sufficient major food especially for the small farmers.

Upland rice is one of the crops that can be grown under rainfed upland conditions and provides substantial yield to the farmers. If upland rice is grown and harvested before sugarcane planting in the late rainy season, the obtained yield will not only be used for home consumption but also provide cash income for the farmers. (5) reported that rice planted as a preceding crop provided significantly higher soil organic carbon content at final sugarcane harvest than that of Sesbania treatment. However, chemical properties of plant residue such as C:N ratio are the major causes of available nutrient release (6,7), upland rice and legume residues are different in such properties. Moreover, the decomposition and nitrogen release of upland rice residues have never been studied and compared to legume cropresidues. While understanding decomposition and nutrient release of plant residues is the main approach for sustainability management. Thus, the effect of decomposition, nitrogen release and soil fertility of upland rice-legume residues incorporation before sugarcane planting was investigated in our study.

2. Materials and Methods

2.1 Experimental site

The plot study was conducted at Agronomy Unit's field site at Khon Kaen University, Khon Kaen, Thailand during January 2010 to mid of July 2010. Soil characteristics of the experimental site were (0-15 cm): soil texture was sandy with 90.91% sand, 5.48% silt and 3.61% clay, soil pH was 6.23 (1:2.5 water), CEC 4.13 me 100 g^{-1}, EC 0.04 mS cm^{-1}, organic matter 4.2 mg g^{-1}, available P 12.42 µg g^{-1}, exchangeable K 258 µg g^{-1} and exchangeable Ca 307.5 µg g^{-1}. The total rainfall received during the study period was 495 mm. Weekly rainfall and average temperature pattern during the experiment are presented in (Figure 1).

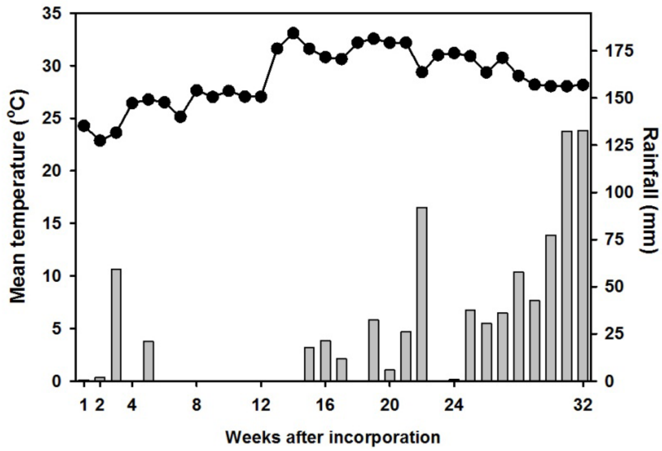

Figure 1. Weekly rainfall and average air temperature after residue incorporation throughout the experimental period.

2.2 Plant materials preparation

Plant residues were randomly collected from the farmer's field. The collected plant residues were cut into 10 cm and air dried. Sub-samples weighing 20 grams of the leaf litters were put in the oven at 70 ºC for 48 hours; after oven drying they were weighed and dry matter content was calculated. They were analysed to determine N, P, K contents, C:N ratio and acid detergent lignin. Chemical quality characteristics of plant residues are presented in (Table 1).

Table 1. Chemical quality of plant residues.

Plant residues	% N	C:N ratio	Lignin (%)	Lignin: N
Weed	1.14	33	4.41	3.87
Soybean	2.50	18	4.48	1.79
Sunn hemp	2.24	17	5.38	2.40
Upland rice	0.82	57	3.68	4.48

2.3 Decomposition study

Residues according to treatment were contained in nylon litter bags (20 x 20 cm^2, 2 mm mesh) and buried (10 cm soil depth) at the rate according to the received weight from the farmer's field in the border area of each treatmentand replicated four times. They were dug up at 1, 2, 4, 8, 12, 16, 24 and 32 weeks after residue incorporation. Sampled litter bags were washed briefly, oven dried at 70 ^{0}C, and dry weight and N content (Kjeldahl digestion) determined. Percent dry weight and nutrient remaining (%) were calculated on ash free basis.

X is the percent dry weight or nutrient remaining, where W_i is the initial dry weight or initial nutrient content and W_t is the oven dry weight or nutrient content at each sampling time.

2.4 Plot and plant residues preparation

The plots size was 1 m^2, and there were five treatments with four replications. Plant residues were incorporated to 10 cm soil depth in each plot. The following residue and control treatments were implemented: i) Control; no residues incorporation, ii) Weed; weed residues were incorporated at 2.38 t ha^{-1}, iii) Soybean; soybean (Glycine max) residues were incorporated at 2.60 t ha^{-1}, iv) Sunn hemp; sunn hemp (Crotalaria juncea) residues were incorporated at 3.94 t ha^{-1} and v) Upland rice; upland rice residues were incorporated at 1.10 t ha^{-1}.

2.5 Soil mineral N and microbial biomass N analysis

Soil samples were taken from 0-15 and 15-30 cm with an auger at 1, 2, 4, 8, 12, 16, 24 and 32 weeks after residue incorporation. Mineral N (NH_4^+ and NO_3^-) was determined on 20 g fresh soil samples immediately after sampling. The soil samples were extracted with 100 ml of 2 M KCl and mineral N determined colorimetrically using a FIA (8).

Microbial biomass N was measured in fresh soil immediately after sampling by chloroform fumigation-extraction technique (9). Chloroform was washed and distilled before use, to remove ethanol, and samples incubated for 36 hours. For microbial biomass N 10 g of fumigated and unfumigated soil were extracted with 50 ml of 1 M KCl. Microbial biomass N was determined by the ninhydrin-reactive N method and calculated as the difference between the fumigated and the unfumigated value and using a k_{EN} factor of 0.32 (9).

Soil samples taken at final sampling was analyzed for soil texture using the hydrometer method and chemical properties were determined, i.e. pH by 1:2.5 H_2O, C.E.C. by 1 M ammonium acetate extraction, organic matter by Walkley and Black wet oxidation, total N by Kjeldahl, available P by Bray II and exchangeable K and Ca by using 1 M ammonium acetate extraction at pH 7.

2.6 Data analysis

Data were subject to a randomized complete block design (4 replications) analysis of variance. Statistical analyses were done using MSTAT-C (Version 1.42) developed by Crop and Soil Science Division, Michigan State University, USA. One factor ANOVA was used to analyze the main effect of the treatments and standard error of the difference (SED) between treatment means are presented. Simple correlations were computed to determine the relation between mineral N and the mount of N added; net mineral N and the amount of N added, lignin: net microbial biomass N and the amount of N added, and initial residue C:N ratio.

3. Results

3.1 Decomposition study

Weed residue treatments had the highest remaining dry weight in most sampling dates (Figure 2a). While, remaining dry weight of soybean residues treatment was significantly lowest ($p< 0.01$) in most sampling dates. At the last sampling date, upland rice residues treatment had zero percentage of remaining dry weight but not significantly different from these of soybean and sunn hemp treatments ($p< 0.01$). According to remaining dry weight, weed treatment had the highest of percentage of N remaining in litter bag (Figure 2b) and soybean residues treatment had the lowest of percentage of N remaining in litter bag ($p< 0.01$).

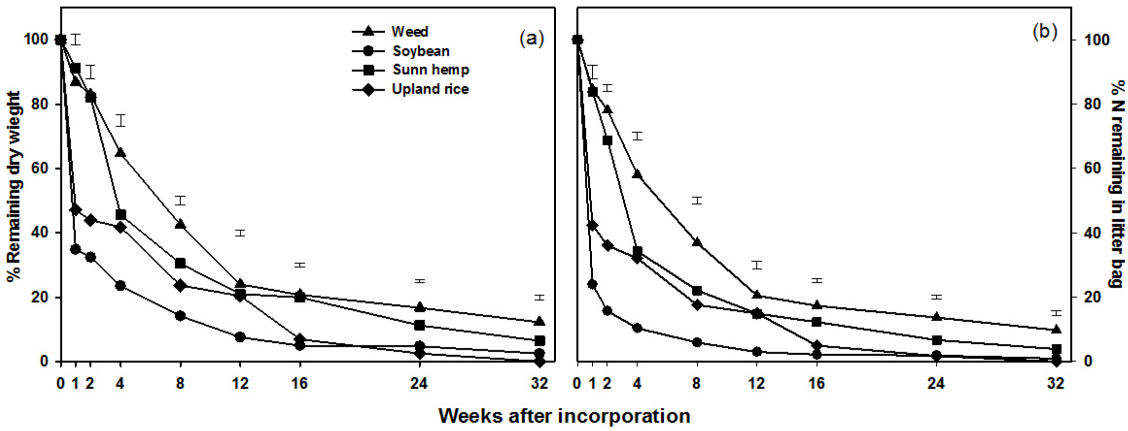

Figure 2. (a) Dry weight, (b) N remaining (% of original) in the litter bags after residues incorporation into the soil. Vertical bars represent standard error of the difference (SED).

3.2 Mineral N, Net mineral N and Microbial biomass N

After residue incorporation, mineral N (Figure 3) values were significantly different at 4, 8, 12 and 16 weeks after residue incorporation. Sunn hemp residue treatment gave the highest mineral N and net mineral N significantly different from the other treatments ($p < 0.01$) (Table 2). Microbial biomass N values were significantly different among treatments in most sampling dates with the exception at the first week after residue incorporation (Figure 4). The residue treatments had higher microbial biomass N than the control treatment at 8 weeks after residues incorporation. At the last sampling date the upland rice residue treatment provided the highest microbial biomass N which was significantly different from the other treatments ($p < 0.01$).

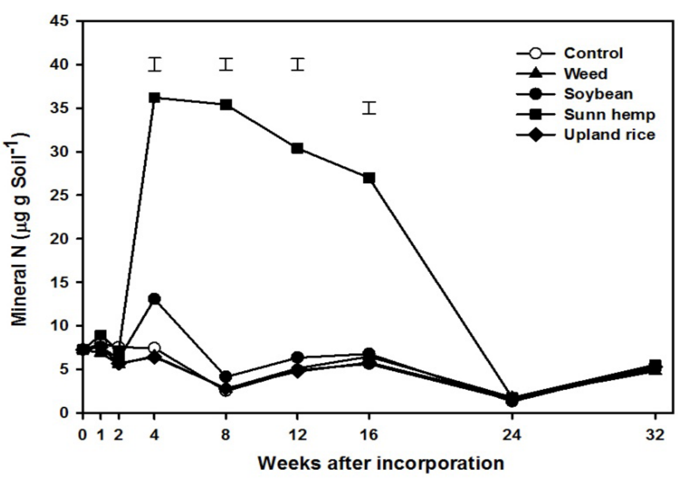

Figure 3. Soil mineral N (μg g^{-1}Soil) after residues incorporation into the soil. Vertical bars represent standard error of the difference (SED).

Table 2. Mineral N (μg N g^{-1} Soil) and net mineral N (μg N g^{-1} Soil) at 4, 8, 12 and 16 weeks after residues incorporation.

Treatments	Mineral N				Net mineral N[1/]			
	Weeks after residues incorporation							
	4	8	12	16	4	8	12	16
Control	7.45 bc	2.54 b	4.92 b	5.65 b	nd[2/]	nd	nd	nd
Weed	6.53 c	2.77 b	5.14 b	6.49 b	-0.93 b	0.23 b	0.22 b	0.84 b
Soybean	13.08 b	4.15 b	6.36 b	6.79 b	5.63 b	1.61 b	1.44 b	1.14 b
Sun hemp	36.19 a	35.39 a	30.37 a	27.00 a	28.74a	32.85a	25.45a	21.35a
Upland rice	6.43 c	2.84 b	4.77 b	5.80 b	-1.03b	0.30b	-0.15b	0.15b
F-test	**	**	**	**	**	**	**	**
CV (%)	21.24	27.49	25.52	27.31	40.83	32.53	43.61	54.63

[1/] = Mineral N of residues treatments- mineral N of control treatment

[2/] = not detectable

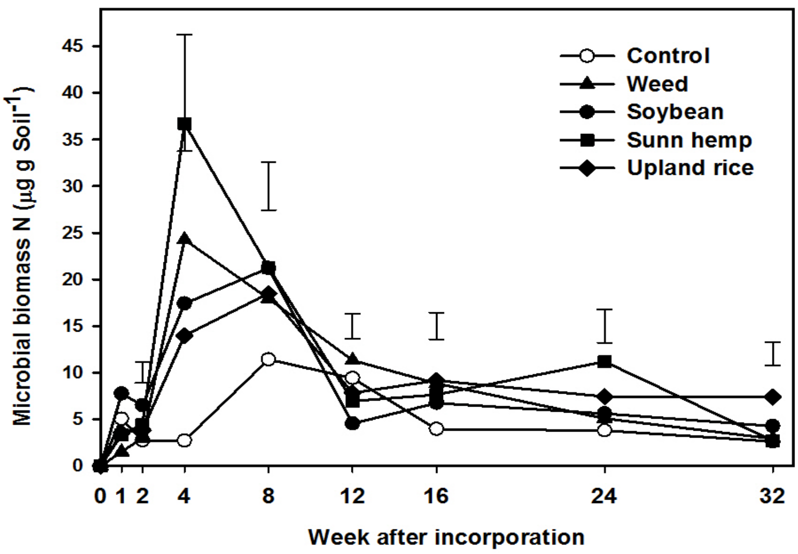

Figure 4. Microbial biomass N (μg g^{-1}Soil) after residues incorporation into the soil. Vertical bars represent standard error of the difference (SED).

3.3 Relative microbial biomass N and apparent microbial efficiency

Relative microbial biomass N values were significantly different among treatments in most sampling dates except at 8 and 16 weeks after residue incorporation (Table 3). The control treatment had the highest relative microbial biomass N than other treatments at 12 weeks after residue incorporation ($p < 0.01$). At 24 weeks after residue incorporation, the sunn hemp residue treatment gave the significantly highest value while upland rice residue treatment provided the highest relative microbial biomass N at the last sampling date but not significantly different from the soybean residue treatment ($p < 0.05$). The control treatment had significantly highest apparent microbial efficiency at 4 weeks after residues incorporation but such values were significantly highest in the sunn hemp residues treatment at 8, 12 and 16 weeks after residues incorporation (Table 4).

Table 3. Relative microbial biomass N[1/] (µg N mg^{-1} N added).

Treatments	Weeks after residues incorporation							
	1	2	4	8	12	16	24	32
Weed	-3.54 b	0.25 b	21.56 ab	6.53	1.90 a	4.90	1.29 b	0.30 b
Soybean	2.70 a	3.77 a	14.71 ab	9.79	-4.88 c	2.79	1.81 b	1.65 b
Sunn hemp	-1.71 b	1.73 ab	34.03 a	9.86	-2.47 bc	3.69	7.38 a	0.10 b
Upland rice	-1.51 b	1.10 b	11.28 b	7.08	-1.59 b	5.21	3.63 b	4.76 a
F-test	#	#	**	ns	**	ns	**	*
CV (%)	307.09	97.67	48.49	45.42	91.91	52.88	53.64	112.89

[1/] = (Microbial biomass of residues treatments-microbial biomass of control treatment)/ the amount of N added

= significantly different at P<0.10

Table 4. Microbial biomass N (µg N g^{-1} Soil) and Apparent microbial efficiency (µg N µg^{-1} N added) at 4, 8, 12 and 16 weeks after residues incorporation.

Treat-ments	Microbial biomass N				Apparent microbial efficiency[1/]			
	Weeks after residues incorporation							
	4	8	12	16	4	8	12	16
Control	2.70 c	11.42 b	9.42 ab	3.95 b	5.63 a	0.23 b	0.54 b	1.61 b
Weed	24.26 ab	17.95 a	11.32 a	8.85 a	0.31 b	0.16 b	0.49 b	0.85 b
Soybean	17.41 bc	21.21 a	4.54 c	6.74 ab	0.75 b	0.20 b	1.44 b	1.09 b
Sun hemp	36.73 a	21.28 a	6.96 bc	7.64 a	1.11 b	1.70 a	5.93 a	3.64 a
Upland rice	13.97 bc	18.49 a	7.82 ac	9.15 a	0.53 b	0.16 b	0.62 b	0.65 b
F-test	**	*	**	*	**	*	**	*
CV (%)	46.53	20.02	23.87	27.68	144.90	28.12	112.70	43.22

[1/] = Microbial biomass N/ the amount of N added

3.4 Soil chemical properties at the last sampling date

In upper soil depth (0-15 cm), only organic matter were significantly different ($p < 0.05$) among the treatments. The residue treatments could increase soil organic matter which led to the significantly higher values than that of the control treatment (Table 5).

Table 5. Soil chemical properties (0-15 cm) at the last sampling date.

Treatments	OM (mg g Soil^{-1})	Total N (%)	Available P	Exchangeable K	Exchangeable Ca
			(µg g Soil^{-1})		
Control	7.04 b	0.043	25.39	22.49	290.00
Weed	7.62 ab	0.045	19.91	22.96	235.00
Soybean	8.54 a	0.046	23.98	23.43	277.50
Sunn hemp	8.57 a	0.047	23.58	26.24	312.50
Upland rice	8.07 a	0.045	18.68	26.11	230.00
F-test	*	ns	ns	ns	ns
CV (%)	8.09	5.69	25.25	20.75	22.36

4. Discussion

Different chemical properties of heterogeneous plant resides led to the variety decomposition. (10) suggested that the degradability of organic residues was affected by initial N concentration or C:N ratio. In our study, despite upland rice residue had highest C:N ratio but the highest remaining dry weight was obtained from the weed residue treatment in most sampling dates. While, sunn hemp and soybean residues had similar lowest C:N ratio but the remaining dry weight of soybean residues treatment was always lower than that of the sunn hemp treatment ($p < 0.01$) in most sampling dates. The result was contradictory to (7) who reported the higher C:N ratio residue had higher remaining dry weight in most sampling dates than the lower C:N ratio residue. Nevertheless, such experiment was conducted under anaerobic condition. Moreover, our results revealed that, there are positive correlations between mineral N and the amount of N added at 4, 8, 12, and 16 weeks after residue incorporation ($R^2 = 0.89, 0.76, 0.77$ and 0.76, respectively). The positive correlations were also found between net mineral N and the amount of N added at such sampling dates, indicating that N mineralization was encouraged by the amount of N added. Positive correlations were found between net microbial biomass N and the amount of N added at the early sampling dates (4 and 8 weeks after residue incorporation, $R^2 = 0.63$ and 0.76, respectively) but negative correlations were found at the later of sampling period (12 and 16 weeks after residue incorporation; R^2 = -0.2 and -0.5, respectively).

C:N ratio was the litter quality parameter widely used to predicted rate of litter decomposition and nutrient release (11). This study presented the negative correlation between net microbial biomass N and C:N ratio at initial of sampling period (8 weeks after residue incorporation; R^2 = -0.60) but positive correlation at the later of sampling period (12 and 16 weeks after residue incorporation; R^2 = 0.15 and 0.70, respectively). This indicates that the low C:N ratio residue encourage activity of microbial biomass N at initial of sampling period but retard such activity at the later of sampling period, and high C:N ratio residue had vice versa. The results suggested that C:N ratio could be a parameter predicting N release from the residues. According to, (12) reported that N content and the C:N ratio were the best predictors of decomposition rather than lignin: N ratio. Although, reducing C substrate accessibility is protected by lignin (13). Surprisingly, we found positive correlation between net mineral N and lignin in our study (at 4, 8, 12, and 16 weeks after residue incorporation; R^2 = 0.81, 0.75, 0.76 and 0.76, respectively).

In this experiment, sunn hemp residue had the lowest C: N ratio (18) presented significantly highest mineral N at 4, 8, 12, and 16 weeks after residue incorporation (Figure 3) while upland rice residue (C: N ratio = 57) showed negative net mineral N at 4 and 12 weeks after residue incorporation indicating immobilization occurrence (Table 3). However, the effect of higher rate of residue application of sunn hemp treatment should also be considered.

5. Conclusion

Sunn hemp provided significantly highest N release at 4-16 weeks after residue incorporation, which was according to the recommended time for fertilizer application in sugarcane. Thus, sunn hemp may be promising treatment as a synchrony crop for the lag period before sugarcane planting. Nevertheless, at the final sampling date, all residue treatment could increase organic matter. Hence, upland rice planting during such period could be an alternative crop for the farmer due to the potential of economic return and the ability to maintain soil fertility. However, the effect of legume-upland rice residue incorporation on sugarcane yield should be more investigated further under field conditions.

6. Acknowledgement

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7. References

(1) Hemwong S, Cadisch G, Toomsan B, Limpinuntana V, Vityakon P, and Patanothai A. 2008. Dynamics of residue decomposition and N_2 fixation of grain legumes upon sugarcane residue retention as an alternative to burning. Soil and Tillage Research 99: 84-97.

(2) Whitmore AP, Cadisch G, Toomsan B, Limpinuntana V, Noordwijk MV, Purnomosidhi P. 2000. An analysis of economic values of novel cropping systems in N.E. Thailand and S. Sumatra. Journal of the Royal Netherlands Society for Agricultural Sciences 48: 105-114.

(3) Toomsan B, McDonagh JF, Limpinuntana V, Giller KE. 1995. Nitrogen fixation by groundnut and soybean and residual nitrogen benefits to rice in farmers' fields in Northeast Thailand. Plant Soil 175: 45-56.

(4) Shoko MD, Zhou M, and Pieterse PJ. 2009. The use of Soybean (Glycine max) as a breake crop affect the cane and sugar yield of sugarcane (Saccharum officinarum) variety CP 72-2086 in Zimbabwe. World Journal of Agricultural Sciences 5 (5): 567-571.

(5) Yadav RL. 1995. Soil organic matter and NPK status as influenced by integrated use of green manure, crop residues, cane trash and urea N in sugarcane – based crop sequences. Bioresource technology 54: 93-98.

(6) Vityakon P, Meepech S, Cadisch G, Toomsan B. 2000. Soil organic matter and nitrogen transformation mediated by plant residues of different qualities in sandy acid upland and paddy soils. Journal of the Royal Netherlands Society for Agricultural Sciences 48: 75-90.

(7) Kaewpradit W, Toomsan B, Cadisch G, Vityakon P, Limpinuntana V, Saenjan P, et al. 2008. Regulating mineral N release and green house gas emissions by mixing groundnut residues and rice straw under field conditions. European Journal of Soil Science 59: 640-652.

(8) Tecator. 1984. Determination of ammonium nitrogen (ASN 65-32/84) or nitrate nitrogen (ASN 65-31/84) in soil sample extractable by 2 M KCl using flow injection analysis. Application notes. Tecator, Höganas, Sweden.

(9) Amato M, and Ladd JN. 1988. Assay for microbial biomass based on ninhydrin-reactive nitrogen in extracts of fumigated soils. Soil Biology and Biochemistry 20: 107-114.

(10) Melillo JM, Aber JD, and Muratore JF. 1982. Nitrogen and lignin control of hardwood leaf litter decomposition dynamics. Ecology 63: 621–626

(11) Heal OW, Anderson JM, and Swift MJ. 1997. Plant litter quality and decomposition: An historical overview. (eds Cadisch G & Giller KE), pp. 3-30. CAB International, Wallingford, UK.

(12) Taylor BR, Parkinson D, and Parsons WFJ. 1989. Nitrogen and lignin content as predictors of litter decay rates: A microcosm test. Ecology 70: 97-104.

(13) Hammel KE. 1997. Fungal degradation of lignin. In: Driven by nature: Plant residue Quality and Decomposition (eds Cadisch G & Giller KE), pp. 33-46. CAB International, Wallingford, UK.