Management of Groundnut Residue for Efficient Nitrogen Recycling in the Rice-Groundnut Cropping System

Banyong Toomsan[1], Wanwipa Kaewpradit[1], Saowakon Hemwong[1], Patma Vityakon[1], Viriya Limpinuntana[1],

Aran Patanothai[1] and Georg Cadisch[2]

[1]Department of Plant Science and Agricultural Resources, Faculty of Agriculture, Khon Kaen University, Khon Kaen, 40002, Thailand.

[2]Institute of Plant Production and Agroecology in the Tropics and Subtropics (380a), University of Hohenhiem, 70593 Stuttgart, Germany. Email Banyang@kku.ac.th

Abstract

Groundnut grown in the dry season after rice is an important cropping system in Thailand. Studies have been conducted at Khon Kaen University on the management of groundnut stover to improve the nitrogen recycling to benefit the following rice crop. In the studies, stover yield of groundnut obtained ranged from 4.0-7.6 Mg ha^{-1}. The amount of N_2 fixed, as measured by ^{15}N isotope dilution method, was found to be as high as 200 kg N ha^{-1}. Most of the nitrogen was retained in the stover (74-166 kg N ha^{-1}). Stored groundnut stover after harvest then reapplied by being ploughed under two weeks before transplanting of following rice crop was found to increase rice yield substantially. The application of 3.8 Mg ha^{-1} of stover dry matter plus 14.4 kg N ha^{-1} of nitrogen fertilizer at PI gave higher rice yield than the application of nitrogen fertilizer at the recommended rate. Groundnut stover left immediately after harvest (early application) tended to give lower growth, yield and N accumulation of the following rice crop compared to late application of the stored stover. Mixing groundnut stover with other high C:N ratio stover like rice straw was found to delay N release and increase rice yield over the non-mixing groundnut stover treatment. An increase in ^{15}N recovery percentage was also observed when groundnut stover was mixed with rice straw than when groundnut stover was applied alone. Thus, appropriate management of groundnut stover is required for efficient nitrogen recycling in this cropping system.

Media summary

The adoption of groundnut into rice-based cropping systems offers opportunities to increase and sustain soil fertility and productivity of smallholders in Thailand.

Key Words

Groundnut stover, N recycling, rice cropping system

Introduction

Groundnut after rice crop is usually grown in December to early January and harvested during April–May. Immediate incorporation of groundnut stover after a harvest results in a 1-2 month lag period before rice transplanting. During this lag period N loss in large amounts can occur, and hence not beneficial to the succeeding rice crop. This is because peak net N mineral accumulation from groundnut stover occurs at about 4 weeks after incorporation. However, this management option required extra labor and may not synchronize with labor availability for stover transportation and a lack of adequate storage facilities to keep groundnut stover during this time gap (Promsakha Na Sakonnakhon et al., 2005). Vityakon et al. (2000) mixed groundnut stover with rice straw and found that peak N mineralization of the mixture was delayed from 4 to 8 weeks after incorporation. However, there was no crop planted to verify if rice was able to effectively take advantage of the delayed N release in that experiment. The studies had been made at Khon Kean University with the aims to (i) to investigate the benefit of preceding groundnut to succeeding rice and (ii) approaching their management for efficiency N recycling in rice-groundnut based cropping system.

Methods

The studies were consisted of 4 experiments;

(i) To estimate the potential N_2 fixation of groundnut. Two groundnut varieties were grown in farmer's fields under rain-fed and irrigated conditions. They were evaluated for growth, yield and N_2 fixation using ^{15}N isotope dilution method with non-nod groundnut as a reference crop (Toomsan et al., 1995). Their residual nitrogen benefit to succeeding rice was also measured.

(ii) To investigate the benefit of groundnut stover rates to succeeding rice yield. Groundnut stover was applied, 10 days before rice transplanting, in different rates (1.9, 3.8, 4.7 and 7.6 Mg ha^{-1}) in combinations with NPK fertilizers. At final harvest rice yield was determined (Toomsan et al., 2003).

(iii) To find the appropriate timing to return stored groundnut stover to the field on growth and yield of succeeding rice. Groundnut stover (7.5 Mg ha^{-1}) was applied at 45, 27, 13 and 6 days before rice transplanting, in combinations with NPK fertilizers. At final harvest rice yield was determined (Srichantawong et al., 2005).

(iv) To assess the impact of addition of groundnut stover and rice straw mixtures in different proportions on growth and yield of succeeding rice and ^{15}N balance from the plant-soil system. This experiment consists of 6 treatments (a) control (no stover), (b) NPK (at recommended rate), (c) groundnut stover 5 Mg ha^{-1}, (d) rice straw 5 Mg ha^{-1} (e) 1:0.5 mixed (groundnut stover 5 Mg : rice straw 2.5 Mg ha^{-1}), and (f) 1:1 mixed (groundnut stover 5 Mg : rice straw 5 Mg ha^{-1}) after groundnut harvesting. Stover was applied after groundnut harvesting and there was a 45 days time gap before rice transplanting. ^{15}N labeled groundnut stover was applied to 1x1 m micro-plot for ^{15}N recovery study. At final harvest, rice yield and ^{15}N recovery were determined.

Results

(i) Total dry matter of the two groundnut varieties were different. Stover yield ranged from 3.97-7.59 Mg ha^{-1}. The amount of N_2 fixed, as measured by ^{15}N isotope dilution method, was found to be as high as 200 kg N ha^{-1} (Table 1). Most of the nitrogen was retained in the stover (74-166 kg N ha^{-1}). Returning groundnut stover to the field gave better growth and yield of rice than stover removed treatment. In this experiment groundnut stover was stored and applied 10 days before rice transplanting. However, appropriate rate and timing of application were not known and these led to experiment 2.

(ii) In the second experiment, it was found that the application of 3.8 Mg ha^{-1} groundnut stover 10 days before rice transplanting combined with PK fertilizers (at transplanting) plus 14.4 kg N ha^{-1} at PI stage gave no statistically significant differences ($P>0.01$) from higher quantities treatments but was higher than that received only NPK fertilizers at recommended rate (Table 2). However, storing groundnut stover required extra labor and storage facilities and these led to experiment 3.

(iii) In the third experiment, it was found that incorporation treatment at 45 days before transplanting gave better rice growth and yield than surface application (mulching). A tendency of rice to respond to nitrogen application at PI stage was observed in early application treatments. Early stover incorporation had tendency to accumulate less nitrogen than late application and was due to rapidly decomposition of groundnut stover (Srichantawong et al., 2005). However, it has been reported mixing low- and high- C:N ratio materials (e.g. rice straw) could delay decomposition and N release (Vityakon et al., 2000) and thus led to experiment 4.

(iv) In the fourth experiment, improvement of rice yield and reductions in N losses could be achieved by adding 2.5 Mg ha^{-1} rice straw to 5 Mg ha^{-1} groundnut stover (Table 3).

Table 1. Seed and stover dry matter, total nitrogen content, %N derived from air (%Ndfa), N_2 fixed , net input from N_2 fixation of groundnut and rice yield increase due to stover return at two locations.

Crop/variety	Dry matter (Mg ha^{-1})		N content (kg ha^{-1})		%Ndfa	N_2 fixed (kg ha^{-1})	Net input of N from N_2 fixation (kg ha^{-1})	Rice yield increase due to stover returned (%)
	Stover	Seed	Stover	Seed				
a) Location 1: residual soil moisture								
KK 60-1	5.53	2.07	96	97	72	150	42	18
KK 60-3	7.59	1.57	166	61	73	172	100	26
Non-nod	3.42	1.28	37	25	-	-	-28	10
SED	0.29	0.40	9	21	3	20	10	-
b) Location 2: irrigation								
KK 60-1	3.97	2.94	74	168	77	197	21	14
KK 60-3	4.88	3.25	87	178	73	200	13	12
Non-nod	2.51	0.80	23	18	-	-	-21	7
SED	0.19	0.11	6	6	3	13	15	-

SED = standard error of the differences between means.

Table 2. Dry matter yield of rice cultivar KDML 105 as affected by some selected treatments at final harvest.

Treatment	Dry matter (Mg ha^{-1})			HI
	Straw + Stubble	Seed	Total	
-stover -NPK (control)	2.45 f	2.60 f	5.05 e	0.51
+3.8 Mg stover ha^{-1} + PK	3.56 bcd	3.43 bcd	6.99 bc	0.49
+3.8 Mg stover ha^{-1} + PK+N_p	4.09 abc	3.77 ab	7.86 ab	0.48
+7.5 Mg stover ha^{-1} + PK	4.35 ab	3.78 ab	8.13 ab	0.47
+7.5 Mg stover ha^{-1} + PK+N_p	4.39 a	4.07 a	8.46 a	0.48
-stover + PK	2.53 ef	2.68 f	5.21 e	0.51
-stover + (N_t + N_p)+PK	3.14 def	3.26 cde	6.39 cd	0.51
F-test	**	**	**	ns
C.V. (%)	15	10	11	6

ns = non significant, ** = significant at $P \leq 0.01$; means in the same column followed by the same letters are not significant by DMRT at $P \leq 0.05$; N_t = 25 kg N ha^{-1} at transplanting, N_p = 14.4 kg N ha^{-1} at panicle initiation as urea, PK = 10.9/10.4 kg ha^{-1} at transplanting.

Table 3. Dry matter yield of rice cultivar KDML 105 as affected by different mixing treatments.

Residue management	Rice dry weight (Mg ha^{-1})		
	Straw+ Stubble	Seed	Total
Control	3.7	2.8	6.5
NPK	4.1	3.0	7.0
GN	4.6	3.1	7.7
RS	4.3	3.0	7.3
1:0.5 (GN:RS)	5.0	3.5	8.5
1:1 (GN:RS)	5.5	3.7	9.2
SED	0.2**	0.1**	0.2**
C.V.	6	3	4

SED = Standard error of the differences between means.
** = significantly different at $P \leq 0.01$.

Conclusion

Groundnut stover contains substantial required nutrients for rice growth. Proper groundnut stover management at final harvest can provide enough nutrients for rice growth and yield or reducing chemical fertilizer application. When labor and storage facilities are available, farmers can store and reapply groundnut stover shortly before rice transplanting at the rate of 3.8 Mg ha^{-1}. This plus 14.4 kg N ha^{-1} application (PI stage) can reduce the cost of N fertilizer application at the time of transplanting. In another hand, when storage facilities are not available, farmers can leave the stover in the field immediately after groundnut harvest but it should be mixed and incorporated with rice straw (1:0.5 ratio) which is locally available in order to reduce N loss and thus leads to improve growth and yield of succeeding rice.

References

Promsakha Na Sakonnakhon S, Toomsan B, Cadisch G, Baggs EM, Vityakon P, Limpinuntana V, Jogloy S, Patanothai A, 2005. Dry season groundnut stover management practices determine nitrogen cycling efficiency and subsequent maize yields. Plant Soil 272: 183-199.

Srichantawong M, Toomsan B, Limpinuntana V, Cadisch G, Jogloy S, Patanothai A. 2005. Evaluation of groundnut stover management strategies in a legume-rice rotation. Biol Agr Hort. 23:29-44.

Toomsan B, Cadisch G, Srichantawong M, Thongsodsaeng C, Giller KE, Limpinuntana V. 2000. Biological N_2 fixation and residual N benefit of pre-rice leguminous crops and green manures. Neth J Agr Sci. 48:19-29.

Toomsan B, Srichantawong M, Jogloy S, Limpinuntana V, Sri-ngarn S, Patanothai A. 2003. Effect of groundnut stover application rates on growth and yield of rice cultivar KDML 105. Proceedings of the 16th national groundnut workshop, held at Krungsri river hotel, Ayutthaya, Thailand, 1-3 May 2002. Khon Kaen Field Crops Research Center, Field Crop Research Institute, Department of Agriculture, Ministry of Agriculture and Cooperatives.

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. Neth J Agr Sci. 48:75-90.