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Nutrient Balance of Rainfed Highland Rice - Legume Crop Rotation in Northern Thailand

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Introduction

Upland areas in northern part of Thailand cover 90% of the Upper North. Rice is grown as a major crop in the highlands and it is relying on rainfed. The highland farmers have a lack of knowledge on soil maintenance and crop rotation in agricultural areas. Thailand's Royal Project Foundation (RPF) has promoted cultivation of navy bean and red kidney bean in rice fields after harvesting to increase income. A research result has shown that growing green manures in highland areas before rice (2 months) accumulated nitrogen by 223 - 416 kg N ha^{-1}. The rice yield after legume was increased by 15 – 44 % when compared to rice monoculture (Chaiwong et al., 2012).

Oikeh et al. (1998) reported that maize yield was 20 % and 24 % higher when grown after stylo and soybean than maize in spite of the removal of the standing legume biomass from the plots. Nutrient balance in the systems that exceeded the results indicated that the loss of nitrogen was probably due to leaching.

Whitbread et al. (2003) reported that after five years of wheat and two legume/fallow crops, negative N balance of up to -303 kg N ha^{-1} were calculated for the treatments where wheat was not retained and bare fallow leys were used. The nutrient balances were always significantly lower when the wheat crop residue were removed after harvest than when they were left on the pot.

Moreover, intercropping and rotation of cereal and legume had more advantage over monocultures (Bationo et al., 1998) and Stoorvogel and Smaling (1990) reported that nutrient output generally exceeded nutrient input. The report in maize - legume cropping systems in which the crops were grown for grain, most of N was removed from the field by harvesting, including in the N rich grain of legumes. Nevertheless, the intercrops left a positive N balance of 56.4 to 157.7 kg N ha^{-1} depended on efficiency in N fixation among legume species, as previously reported by others (Peoples et al., 2009) after the removal of maize-legume grain in the harvest. On the other hand, maize mono in farmers' practice left N negative balance -3.6 kg N ha^{-1} (Adirek, 2017)

The soil nutrient balance was calculated by the difference between the inputs and outputs. The experiment determined input in fertilizers and N fixation, output determined in crop production and crop residue. The objective was to evaluate yields and nutrient balance in rice – legume crop rotation.

Material and Methods

The study was conducted during April 2016 - March 2017 in the farmers' fields in Mae Wak village, Mae Chaem district, Chiang Mai, Thailand, at the altitude of 670 MSL (mean sea level).

The study applied RCBD to design the experiment which conducted 5 cropping systems and 3 replicates, as follows:

(1) Rice (*Oryze sativa*) monoculture or farmer's practice
(2) Rice - navy bean *(Phaseolus vulgaris),*
(3) Rice – kidney bean *(Phaseolus vulgaris),*
(4) Lablab (*Lablab purpureus*) – rice - navy bean
(5) Lablab – rice - kidney bean.

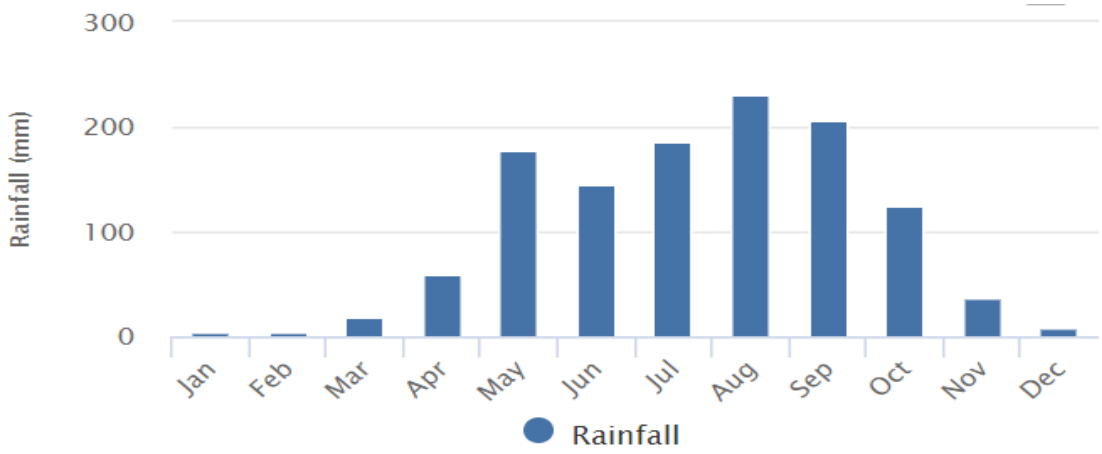

Figure 1. Monthly rainfall during the experimental period in 2016 in Mae Wak village, Mae Chaem district, Chiang Mai, Thailand

Rice

Rice was grown in mid-June and harvested in mid-November. Fertilisers were applied with 156 kg ha^{-1} of urea (46% N) and 156 kg ha^{-1} of 16 – 20 - 0 (N - P - K) at 25 and 45 days after planting, respectively.

Legume

Navy bean (85 days) and kidney bean (85 days) were grown after the harvest in late-November with spacing 0.30 x 0.30 m and seed rate 75 kg ha^{-1}. Fertilisers applied were urea (46% N) and 16 – 20 – 0 (% N - P_2O_5 - K_2O) with 125 kg ha^{-1} at 25 and 45 days after planting respectively. Lablab was grown 25 days before land preparation for rice crop, while no fertiliser was applied in lablab and no pesticides or herbicides were applied in all legume.

Data collection

1. Grain yield: Rice was collected from 1 m^2 and legume was collected from 1 m^2. The grain yield was calculated at 14 % moisture.
2. Residues: Rice was collected from 1 m^2 and legume was collected from 1 m^2 in harvest stage. Samples were dried by hot air oven at 75 °C for 72 hours.
3. Yield and residue of rice and legume were analyzed for nitrogen (N) (The analysis was conducted by the Central Laboratory (Thailand) Co., Ltd.).
4. Statistical analysis was conducted by using Statistix version 8 (SXW)

Results and Discussion

Rice grain yield was non-significantly different between treatments range from 5.5 – 5.7 t ha^{-1}, rice grain yield was the lowest in rice monoculture and the highest in lablab – rice – kidney bean.

Legume grain yield was significantly different among the legume ($P < 0.01$) legume grain yield ranged between 1.0 – 1.6 t ha^{-1}. Grain yield of navy bean (1.5 to 1.6 t ha^{-1}) was higher than kidney bean (1.0 – 1.3 t ha^{-1}).

Total crop residue was significantly different between treatments ($P < 0.01$). Rice legume crop rotation was higher by 42.5 % – 57.5 % when compared to rice monoculture (farmers' practice).

Total nitrogen retaining into the soil was significantly different between treatments ($P < 0.01$). Rice - legume crop rotation was higher than rice monoculture (farmer's practice) by 99.2 % and 116 % in rice - navy bean and rice - kidney bean respectively, while added lablab before rice in lablab - rice - navy bean and lablab - rice - navy bean crop rotation increased by 165.0 % and 167.6 % respectively when compared to rice monoculture (farmers' practice) (Figure 2).

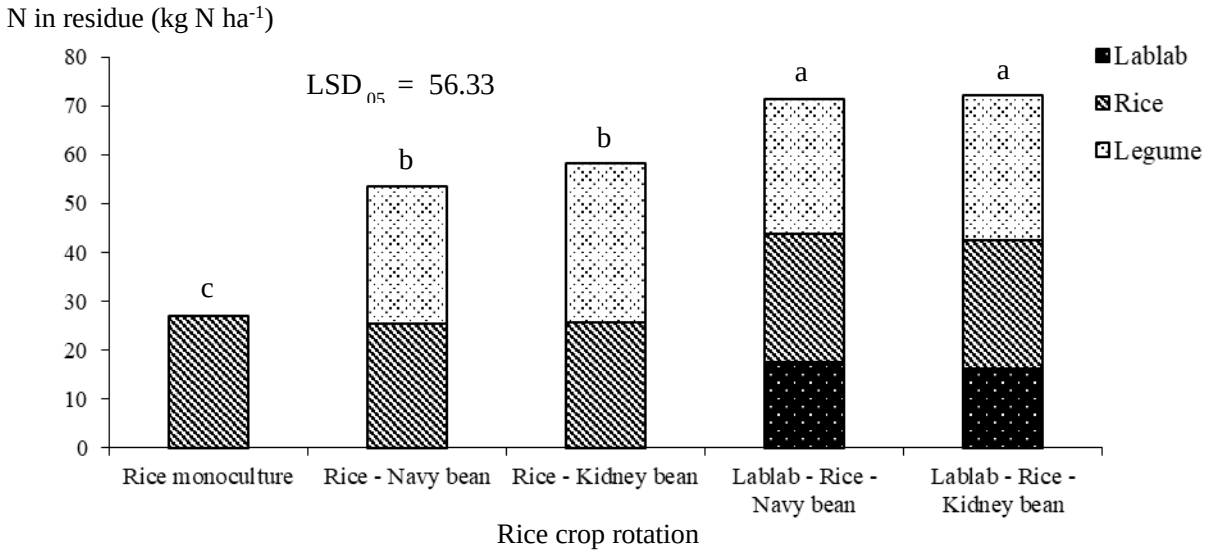

Figure 2. N in crop residue in rice- legume crop rotation (kg N ha^{-1}) at Mae Wak village, Mae Chaem district, Chiang Mai, Thailand

Total N input was significantly different among the rice –legume crop rotation ($P < 0.01$) ranging from 96.9 to 190.0 kg N ha^{-1}. The total N input was increased in rice - navy bean and rice- kidney bean by 1.8, 1.9 and 2.0 times in lablab - rice - navy bean and lablab - rice – kidney bean respectively when compared to farmers' practice (Table 1).

Total N output was significantly different among the rice –legume crop rotation ($P < 0.01$) ranging from 148.8 to 199.4 kg N ha^{-1}. The total N output was increased in rice - kidney bean by 20.9%, 334.0 %, 31.1 % and 29.7% in lablab - rice - navy bean, rice - navy bean and lablab - rice- kidney bean respectively when compared to farmers' practice (Table 1).

Nitrogen balance showed a negative balance in the experiment and there was significantly different among the rice –legume crop rotation ($P < 0.01$) ranging from - 3.8 to - 51.9 kg N ha^{-1}, while in rice monoculture the highest N was removed out of the plot (Table 1).

As the result shown, rice grain yield in the treatment that was non-significant in rice – legume crop rotation indicated that the loss of nitrogen was probably due to leaching (Oikeh et al. 1998). Nutrient balance in the systems was a negative balance as the related result (Bationo et al. (1998) reported that intercropping and rotation of cereal and legume had more advantage over

mono-cultures and Stoorvogel and Smaling (1990) reported that nutrient output generally exceeded nutrient input.

Table 1 N balance in rice – legume based cropping systems at Mae Chaem district, Chiang Mai province.

Treatment	**N Input (kg ha^{-1})**			**N Output (kg ha^{-1})**			**N balance (kg ha^{-1})**
	Fertilizer	**Fix**	**total**	**yield**	**residue**	**total**	
1. Rice monoculture	96.9	-	96.9 c	128.8 c	20.0	148.8 c	-51.9 c
2. Rice - Navy bean	174.4	-	174.4 b	175.6 a	19.4	195.0 a	-20.6 b
3. Rice - Kidney bean	174.4	-	174.4 b	160.6 b	19.4	180.0 b	-5.6 a
4. Lablab - Rice - Navy bean	174.4	14.6	188.8 a	180.0 a	20.0	199.4 a	-10.6 ab
5. Lablab - Rice - Kidney bean	174.4	15.6	190.0 a	173.8 ab	19.4	193.1 a	-3.8 a
mean	158.9	5.9	164.8	163.8	19.4	183.1	-18.1
f-test			**	**	ns	**	**
$LSD_{.05}$			5.3	13.8		12.0	12.4

** = significant different $P < 0.01$, mean in the same column follow by different letter indicate significant different $P < 0.05$

Conclusions and Outlook

Rice - legume crop rotation reduced the nutrient removal from the rice field in the highland. Moreover, rice – legume crop rotation was a sustainable highland farming system requiring that crop yield was stable through the maintenance of soil fertility and the balance nutrient in the system. Furthermore, future work has to evaluate the adoption of crop rotation by highland farmers and has to explore the local knowledge on sustainable agriculture.

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