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【Short Report】

Nutrient Deficiency in the Rice-Stylo (*Stylosanthes guianensis*) Relay-Intercropping System in Rainfed Lowland Rice Ecosystem in Northeast Thailand

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Abstract : The rice-stylo (*Stylosanthes guianensis*) relay-intercropping system in paddy fields has previously been shown to increase agricultural productivity in Northeast Thailand, but successive relay-intercropping conducted without irrigation and fertilization during the stylo cropping has resulted in reduced production of stylo. The aim of this study was to determine the effect of nutrient deficiency on the stylo production. The experiment was conducted using pots to control fertilization accurately. The results showed that, after three successive relay-intercroppings, the soil was severely deficient in sulfur, phosphorus, and molybdenum. Sulfate application to the soil after the successive relay-intercroppings was suggested to improve stylo production. We recommend the use of a rain-fed shallow, favorable subecosystem as a field for stylo production in relay-intercropping and the stylo production with a cycle of several years.

Key words : Dry season, Restoration trial, Successive cropping, Sulfur deficiency.

In tropic and sub-tropic regions, agricultural productivity is generally low due to low soil fertility, small amount of chemical fertilizer applied and other similar factors. To overcome such constraints, relay or intercropping of cereals and legumes has been recommended by previous studies (Reddy and Willey, 1981; Saito et al., 2006). We examined the capacity of the rice-stylo (*Stylosanthes guianensis*) relay-intercropping system to increase agricultural productivity in a rain-fed lowland rice ecosystem in Northeast Thailand (Fig. 1; Homma et al., 2008). Stylo is a tropical leguminous forage crop, fallow crop or green manure crop (Becker and Johnson, 1998; Saito et al., 2006). In the relay-intercropping system that we examined, stylo was grown by utilizing residual water and nutrients from rice cropping under non-irrigated and non-fertilized conditions during the dry season, when other crops were not cultivated. Homma et al. (2008) reported that stylo produced plenty of biomass under such conditions in the first cropping season, up to 950 g m^{-2}, but the production in the second and the third cropping seasons was substantially decreased.

This may be caused by the nutrient deficiency, because rain-fed paddy fields in Northeast Thailand generally have low soil fertility, and nutrient deficiency has been reported even in rice mono-cropping systems (Haefele et al., 2006). Relay-cropping in unfertile soil sometimes requires additional fertilizer such as phosphorus (P) and sulfur (S). Herrera et al. (1997) reported that P application significantly increased

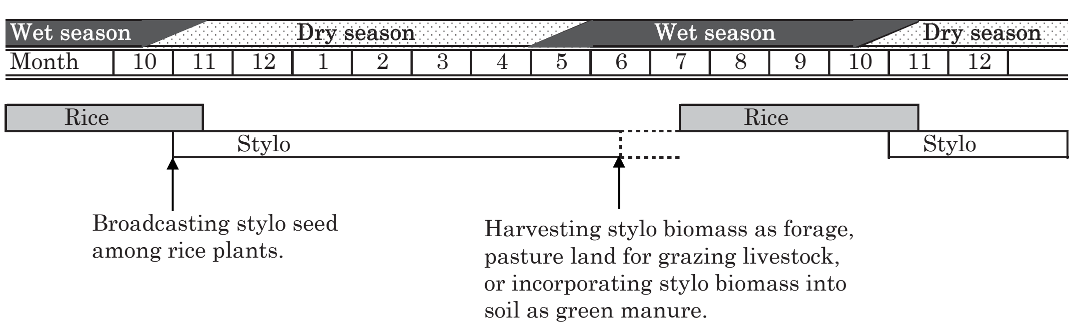

Fig. 1. Cropping calendar of the rice-stylo (*Stylosanthes guianensis*) relay intercropping system (adapted from Homma et al., 2008).

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Table 1. Production of stylo in the fields at different toposequential positions (upper and lower).

Field	Plot	Stylo production (g m^{-2})			
		2000–2001	2001–2002	2002–2003	2003–2004
Upper	RI2000	415±136	77±15	211±13	96±70[1)]
	RI2002			243±115	20±16
Lower	RI2000	950±339	229±13	236±9	427±69[1)]
	RI2002			938±183	445±251

Means ± standard error (n=2); RI2000, the stylo production was started in 2000; RI2002, the stylo production was started in 2002; [1)] 2.9 g m^{-2} of sulfur was applied on 1 Dec. 2003, as sodium sulfate.

the biomass production of *Sesbania rostrata*, cultured prior to planting of lowland rice as a green manure in Northeast Thailand. Ali et al. (2000) reported that sulfur and micro-nutrient fertilization was effective for leguminous crops in a cereal-legume relay cropping system in India.

The aim of this study was to evaluate the effect of nutrient deficiency on stylo production in field and pot experiments.

Materials and Methods

1. Field experiment

The experiment was conducted in rain-fed paddy fields at the Ubon Rice Research Center (URRC) in Northeast Thailand. Since the management of rice-stylo relay-intercropping has been described in detail in a previous report (Homma et al., 2008), we only briefly describe the method here.

The relay-intercropping system was designed as in Fig. 1. Seeds of stylo cultivar CIAT-185 were broadcast at a rate of 2.5 g m^{-2} after rice heading and before harvesting. Stylo grew slowly during the dry season under non-irrigated and non-fertilized conditions, utilizing residual soil moisture and nutrients after rice cropping. As precipitation increased at the beginning of the rainy season, stylo grew rapidly. The above-ground biomass of stylo was harvested in mid-June, 1 month before rice transplanting. The biomass was incorporated into the soil as green manure in this experiment. Rice was grown under custom management for transplanting, chemical fertilizer application (N-P_2O_5-K_2O=2.5-2.5-1.25 g m^{-2}) and rain-fed conditions.

Two types of fields in URRC were selected for the experiment. One was located in the upper toposequence of a mini-watershed (upper field), and another was located in the lower toposequence (lower field). The upper field was classified as a rain-fed shallow, drought-prone subecosystem, and the lower field was classified as a rain-fed shallow, favorable subecosystem, depending on the definition of classification by IRRI (Khush, 1984). Each field was divided into 6 plots, 10×10 m^2 each. Two plots with the same management were used as replications. The relay-intercropping started with the rice transplanting in mid-July 2000 for 2 of the 6 plots (RI2000) and was followed in 2002 by another 2 plots (RI2002). In the remaining 2 plots, rice was cultivated by mono-cropping (MN). The above-ground biomass of stylo was measured for two 0.5-m^2 sections in each plot in mid-June.

The effect of sulfur (S) application was evaluated by applying sodium sulfate into RI2000 plot on 1 December 2003. Sulfur was applied at the rate of 2.9 g S m^{-2}, which corresponds to the amount of S contained in 11.6 g m^{-2} of ammonium sulfate (2.5 g m^{-2} of nitrogen). Nitrogen is generally applied at the rate of 2.5 g m^{-2} as urea for the rice cultivation in Northeast Thailand (Author's observation; also see Craswell and Karjalainen, 1990; Miyagawa et al., 1999).

2. Pot experiment

The pot experiment was conducted in 2003 to examine nutrient deficiency in the relay-intercropping system. Plow-layer soils (20 cm in depth) in the lower fields were collected on 2 and 10 July 2003, from the plot where the relay-intercropping had been started in 2000 (RI2000) and from the rice mono-cropping (MN) plot. The same amount of soil was collected from two points for each replication plot, and soil samples were mixed for each treatment. The mixed soils were air-dried, cracked, and passed through 1-mm-mesh sieves to remove plant residues. Dry soil was put into 7.0 L pot at the rate of 5.0 kg per pot. Six different fertilizers were applied to the soils: (1) P-K-S-Mo=0.84-2.24-0.70-0.112 g pot^{-1} (P-K-S-Mo), (2) no fertilizer, (3) K-S-Mo (-P), (4) P-S-Mo (-K), (5) P-K-Mo (-S) and (6) P-K-S(-Mo). The composition and the amount of nutrients were based on a study by Suriya-arunroj et al. (2000). Ten seeds per pot of stylo cultivar CIAT-185 were sown on 20 July 2003, and thinned to 6 plants per pot after 1 mo. The pots were protected from rain water with a transparent roof and watered thoroughly 200 mm per wk. The above-ground biomass was measured on 14 November 2003. The experiment was conducted with three replications, and the analysis of variance was carried out using IRRISTAT 5.0 (IRRI).

Results

1. Stylo production under successive relay-intercropping

In the lower field, the stylo production in the first cropping season was more than 900 g m^{-2} of dry matter both in RI2000 and RI2002 (Table 1). Stylo production was, however, substantially decreased in successive cropping seasons.

In the upper field, stylo production was 415 g m^{-2} in the first cropping season in the RI2000 plot but was only 243 g m^{-2} in the RI2002 plot. This was almost the same as the production for the RI2000 plot in the third cropping season. The production in the second cropping season was much lower than that in the first cropping season in both the RI2000 and RI2002 plots.

2. Nutrient deficiency in successive relay-intercropping

In 2003, stylo was cultivated in the pots containing the soil collected from MN and RI2000 plots in the lower field. Stylo production in the soil from the MN plot was not significantly influenced by fertilizing with P-K-S-Mo, showing that P, K, S and Mo were adequate for stylo production in the MN plot (Table 2). Stylo production in the soil from the RI2000 plot, however, was very low, and was greatly increased by fertilizing with P-K-S-Mo. Application of P-K-Mo without S (-S) did not significantly improve stylo production, indicating that S was deficient in the soil after the relay-intercropping. The stylo production under application of -P or -Mo fertilizer was more than that under non-fertilized condition, but less than that under application of P-K-S-Mo. The result suggests that P and Mo were deficient in RI2000 plot, but not as severely as S.

3. Restoration trial from nutrient deficiency by sulfate application

Sodium sulfate (S) was applied to the RI2000 plot in the fourth cropping season (2003-2004) (Table 1). In the lower field, S increased the stylo production to almost double the production in the third cropping season and to the same level as that observed in the second cropping season for plot RI2002. In the upper field, S applied to the RI2000 plot in the fourth cropping season failed to increase stylo production above the level observed in the third cropping season, but it did increase stylo production above the level observed in the second cropping season for plot RI2002.

Table 2. Stylo dry-matter production in the pot experiment.

Treatment	Dry matter weight (g pot^{-1})	
	MN	RI2000
P-K-S-Mo[1)]	8.86	8.51
non-fertilized	9.32	4.57
-P[2)]		6.19
-K[2)]		9.70
-S[2)]		3.83
-Mo[2)]		6.04
L.S.D. (0.05)	ns	1.37

L.S.D. (0.05), Least significant difference at 5% level; The soils were collected in July 2003 from the plots where the relay - intercropping had been started in 2000 (RI2000) or where rice mono-cropping had been conducted (MN); 1) P-K-S-Mo = 0.84-2.24-0.70-0.112 g pot^{-1} was applied; 2) -P, -K, -S and -Mo means P, K, S and Mo deficits from P-K-S-Mo treatment, respectively.

Discussion

This study revealed that the rice-stylo relay-intercropping system in rain-fed paddy fields in Northeast Thailand led to S deficiency. This deficiency in S greatly decreased stylo production, as production in successive cropping seasons was less than half of that seen in the first cropping season. Craswell and Karjalainen (1990) have previously warned that adoption of urea and triple super phosphate induces sulfur deficiency in lowland rice in Southeast Asia.

Generally, deficiency of N and P is seen in rain-fed rice production and P deficiency in leguminous crop production in Northeast Thailand (Herrera et al., 1997; Suriya-arunroj et al., 2000). The pot experiment in this study indicated that P deficiency also occurred during stylo production in relay-cropping but that the degree of P deficiency was significantly less than that of S deficiency. We proposed the relay-intercropping to produce stylo without fertilization, but the fertilizer was applied for the rice production. Therefore, the P deficiency in stylo may have been relieved by P contained in the chemical fertilizer prior to the stylo production. Application of a combined chemical fertilizer containing P as one of the main ingredients is common in rain-fed rice production in Northeast Thailand (Miyagawa et al., 1999).

Application of S is predicted to improve stylo production, although the improvement was not much effective in the field experiment. In Japan, about 80 % of nitrogen fertilizer is supplied as ammonium sulfate, which is an industrial by-product. When and if such a situation becomes common in Thailand, the application of ammonium sulfate for rice production may relieve S deficiency for stylo production in relay-intercropping. However, since a low pH is one of the major problems of soils in Northeast Thailand, the application of sulfate might not be acceptable. Even if S deficiency were restored by sulfate application, the results from the pot experiment suggest that P or Mo deficiency might also occur. Ali et al. (2000) recommended fertilizer application of sulfur and micro-nutrients such as Zn, Mo, B and Fe to leguminous crops in a cereal-legume relay cropping system in India. To obtain high and stable stylo production, fertilizer that included several minerals would also be necessary in the rice-stylo relay-intercropping system.

Although some nutrient deficiency occurred, the relay-intercropping in the lower fields that were classified as a rain-fed shallow, favorable subecosystem, produced at least 200 g m^{-2} of stylo dry matter. In the first cropping season, the relay-intercropping produced more than 900 g m^{-2} in the favorable subecosystem and more than 200 g m^{-2} even in the drought-prone subecosystem, which was the classification of the upper field in this study. Such production was obtained without irrigation or fertilization in paddy fields during the dry season, when no agricultural production was generally obtained. Moreover, the production of stylo did not decrease rice production (Homma et al., 2008). The production of stylo in relay-intercropping will increase the total amount of agricultural products produced per field. This system may increase the capacity for feeding livestock as well. Numerous paddy fields in Thailand and elsewhere are not currently used for agricultural production during the dry season and can be considered to be suitable for the relay-intercropping system. Therefore stylo production once every several years in a field may increase the yield per unit land area, and it may be an acceptable method for increasing agricultural production.

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