Relay-Intercropping of *Stylosanthes guianensis* in Rainfed Lowland Rice Ecosystem in Northeast Thailand

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Abstract: We evaluated the usefulness of the *Stylosanthes guianensis* (stylo)- rice relay-intercropping system for increasing agricultural productivity in Northeast Thailand. Although large production variability was observed, the relay-intercropping system produced an average of 350 g m\(^{-2}\) stylo dry matter during the dry season under non-irrigated and non-fertilized conditions in the experimental fields at the Ubon Rice Research Center. Utilization of the stylo production as green manure increased rice yield, but only slightly. The relay-intercropping also slightly improved soil chemical properties, but not significantly. The trial of the relay-intercropping in farmer's fields produced a maximum of 367 g m\(^{-2}\) stylo dry matter. Since the stylo production did not decrease the subsequent rice production, the rice-stylo relay-intercropping system is worth considering as one way to utilize the paddy fields during the dry season in Northeast Thailand.

Key words: Dry season, Forage production, Green manure, Nutrient deficit, Rainfed rice.

Rainfed agricultural regions without large-scale irrigation facilities are generally characterized by low productivity. In order to alleviate poverty, many organizations have invested considerably in attempts to increase the productivity in these regions. Northeast Thailand is such a rainfed agricultural region, in which the irrigation area occupies less than 5% of agricultural land, and agricultural productivity is much lower than in other regions in Thailand (Office of Agricultural Economics, Thailand, 2004). Constraints on agricultural production in Northeast Thailand are summarized by two factors. One is low yield of rainy season rice and the other is a lack of dry season crops.

Rainy-season rice in Northeast Thailand occupies 70% of the agricultural land, most of which is classified as rainfed fields. The average yield is 2.0 t ha\(^{-1}\), which is about 60% of average yield in the central plain. Although water shortage caused by erratic rainfall is one of the major constraints (Fukai et al., 1998), low soil fertility also strongly restricts rice productivity, even with sufficient water supply (Homma et al., 2001). The low soil fertility is often caused by low clay and organic matter contents in the soil (Willet, 1995). Organic matter content seems to be the best indicator of soil fertility (Homma et al., 2003). Therefore, many investigators have incorporated organic materials, such as farmyard manure, compost, and green manure, into soil and concluded that organic materials were effective for increasing soil fertility and rice productivity (Supapoj et al., 1998; Whitbread et al., 1999). Since the availability of farmyard manure and compost is often limited, green manure is recognized as a promising application (Garity and Becker, 1994). However, green manure practices such as crop establishment and residual incorporation (Palaniappan and Budhar, 1994) need to be established, as this technology has not been commonly used by farmers in Northeast Thailand.

The dry season in Northeast Thailand is from November to May. Low precipitation and lack of large-scale irrigation facilities restrict the area and the kind of dry season cropping. For example, rice production in the dry season in Northeast Thailand was only 0.4 million tons in 2003, 5% of that in the rainy season. Rice production in the dry season in the central plain was 3.7 million tons, which was 75% of that produced in the rainy season (Office of Agricultural Economics, Thailand, 2004). Although small-scale irrigation, including the use of tube wells and pumps, allows for cultivation of some vegetables during the dry season, the cultivation is limited by the small market in the area. In order to increase agricultural production in the dry season, new crops or new agricultural systems adapted to large-scale cultivation without irrigation are needed.

Water buffalos were traditionally kept for agricultural management, such as plowing and puddling. Rapid expansion of small tractors beginning in the 1990s dramatically decreased their agricultural use, and consequently, the number of buffalos decreased from 4.0 million head in 1993 to 1.5 million head in 2003 (National Statistical Office, Thailand, 1995, 2005). However, the buffalo was
still important for meat production (Simaraks et al., 2003). Recently, farmers in Northeast Thailand began raising cattle as an economic option (Simaraks et al., 2003; Phaowphaisal et al., 2005). Recent increases in consumption of meat and dairy products expanded the demand for cattle (Ohmomo et al., 2002; Simaraks et al., 2003), and the number of cattle increased from 3.3 million to 4.2 million in Northeast Thailand (National Statistical Office, Thailand, 1995; 2005). In the traditional methods of cattle raising, rice straw and grasses on non-agricultural fields were used for forage (Fukui, 1993). However, the amount of such forage is limited, and this constrains increases in the number of livestock (Fukui, 1993; Kawashima et al., 1998; Suzuki et al., 2006). In order for a small rice farmer to develop a stock-raising system, it is important to secure adequate feed.

The facts that huge areas of paddy fields are not utilized during the dry season, and that potential demand for cattle feed is quite large, suggest that farmers will produce forage crops if a system for production during the dry season is developed. Although the socioeconomic situation at present restricts the amount of input to dry season production, one method to overcome this restriction may be a relay-intercropping system. In such a system, residual water and nutrients from rice culture can be utilized for subsequent forage crops (Guldan et al., 1998; Caviglia et al., 2004). If the forage crops are not harvested, they may be grazed or used as green manure to the subsequent rice crop. Since farmers commonly leave livestock to graze residual rice straw, of which biomass and nutrients are low, in the fields during the dry season (Kawashima et al., 1998; Suzuki et al., 2006), forages may improve the nutrient status of livestock.

This study aimed to develop a forage production system by relay-intercropping on rainfed paddy fields in Northeast Thailand. Since a feasibility study showed that *Stylosanthes guianensis* (stylo) produced the most dry matter of several leguminous crops tested (*Vigna unguiculata*, cowpea; *Macroptilium atropurpureum*, siratro and *Centrosema pascuorum*, centro; Watatsu, 2002), thus, only stylo was tested as a forage crop for this system. We tested the system not only in experimental fields in the Ubon Rice Research Center (URRC; Ubon Ratchathani, Thailand), but also in farmer’s fields at three locations in Northeast Thailand. In the URRC, the biomass of stylo was tested as green manure as one of possible uses.

### Materials and Methods

1. **Experiment 1: Field experiment at the Ubon Rice Research Center**

The experiment was conducted in rainfed paddy fields of the URRC (15°20’N and 104°41’E, 123 m in altitude). Since soil fertility and water availability are greatly different at different toposequential positions in a mini-watershed in Northeast Thailand (Homma et al., 2003; 2004), two types of fields along a toposequence in a mini-watershed in the URRC were selected for the experiment: one was located in the upper toposequence (upper field), and the other in the lower toposequence (lower field). The lower field was classified as rainfed shallow, favorable subecosystem, and the upper field as rainfed shallow, drought-prone subecosystem. The difference in altitude between the upper and lower fields was 1.1 m. Soil properties of the fields before the experiment are shown in Table 1. Soil organic carbon (SOC) and clay contents in the lower field were slightly higher than those in the upper field. The upper field scarcely had standing water, while the lower field was submerged for most of the rainy season. Each field was divided into six plots, 10×10 m each. Three types of cropping systems were tested at each field in two replications from 2000 to 2003 (four seasons of rice and three seasons of stylo): Rice-*Stylosanthes guianensis* (stylo) relay-intercropping with chemical fertilizer (relay-intercropping), rice mono-cropping with chemical fertilizer (mono-fertilized) and rice mono-cropping without chemical fertilizer (mono-unfertilized). The effect of stylo can by examined by comparing relay-intercropping and mono-fertilized as the two were compared.

| Position       | Upper | Lower |
|----------------|-------|-------|
| pH             | 5.0   | 5.0   |
| SOC (g kg⁻¹)   | 3.3   | 4.4   |
| Texture (kg kg⁻¹) | 0.95 | 0.84  |
| Sand           | 0.01  | 0.11  |
| Silt           | 0.04  | 0.06  |

1) SOC: soil organic carbon.

### Fig. 1. Cropping calendar of rice-*Stylosanthes guianensis* (stylo) relay-intercropping system.
fertilized in the same way, while the mono-unfertilized treatment will provide the base rice productivity with no nutrient inputs to the crops.

A rice-stylo relay-inter cropping system was designed as shown in Fig. 1. Seedlings of rice cultivar KDML105, about 35 days old, were transplanted in mid-July each year, and grown in rainfed conditions. Planting density was 16 hills per square meter (0.25 m × 0.25 m) and two plants per hill. Fertilizer, at a rate of 2.5−2.5−1.25 g m\(^{-2}\) (N-P\(_2\)O\(_5\)-K\(_2\)O) was applied in the relay-inter cropping and mono-fertilized plots. The rate was a representative application rate for rainfed rice farmers in Northeast Thailand (Miyagawa et al., 1999). Half this amount of chemical fertilizer was applied as top dressing in late-July and the remaining half in mid-September every year. Rice plants were harvested in late-November. The seed of stylo cultivar CIAT-185 was soaked in water at 60ºC for 1 minute so that it would germinate uniformly. It was broadcast before rice harvesting, in early-November in the upper field, and immediately after standing water disappeared (around mid-November) in the lower field. Stylo survived during the dry season under non-irrigation and non-fertilized conditions, utilizing residual soil moisture and nutrients after the rice crop. At the end of the dry season, stylo started to grow rapidly as precipitation increased. In mid-June, one month before rice transplanting, the above-ground biomass was harvested and incorporated into the soil as green manure. The relay-inter cropping experiment was started in mid-July 2000, when rice was transplanted, and ended in late-November 2003, when rice was harvested.

The above-ground biomass and paddy yields of rice were measured for two 1-m\(^2\) areas in each plot at maturity. The aboveground biomass of stylo was measured for two 0.5-m\(^2\) areas in each plot just before incorporation into soil. Additional plant materials were also collected from each plot to determine the nitrogen (N) content. The N content of these materials was measured by the Kjeldahl method after drying for 72-h in an oven.

Soil in each plot was sampled from the plow layer (0−15 cm) before and after rice cropping, and before incorporation of the above ground biomass of stylo every year. Soil organic carbon (SOC) content was measured for all the soils, and ammonium-nitrogen (NH\(_4\)-N) and extractable phosphorus (P) contents were measured for the soils sampled in December 2001 and June 2002. SOC content of soil was determined by the Walkley method (Walkley, 1947). NH\(_4\)-N was determined by the indophenol method after extracted by potassium chloride (Dorich and Nelson, 1983). Extractable P was measured by the Bray 2 method (Bray and Kurtz, 1945).

2. Experiment 2: Application of the relay-inter cropping to farmer’s fields

The rice-stylo intercropping system was tested at farmer’s fields in three locations in Northeast Thailand: Udon Thani (17º15’N, 102º31’E), Chum Phae (16º39’N, 102º00’E) and Buri Rum (14º58’N, 103º12’E). In each location, two types of field were selected for the test along a toposequence in a mini-watershed: one was located in the upper and another in the lower toposequence. The selection was in accordance with Exp. 1: the lower field was classified as rainfed shallow, favorable subecosystem, and the upper field as rainfed shallow, drought-prone subecosystem. Each field was divided into four experimental plots.

| Site          | Management | Rice  | Stylo |
|---------------|------------|-------|-------|
|               | Site       | Upper     | Lower     | Management         |                      |                      |
| Udon Thani    | TP: late-June | late-June | BC: early-Nov. |                      |                      |
|               | HV: late-Nov. | late-Nov. | UT: harvested to feed cattle |                      |                      |
|               | CF: 2.6-1.3-1.3 | 1.5-0.8-0.8 |                      | (splited into 2 applications) |                      |
| Chum Pae      | TP: mid-Aug. | mid-July | BC: early-Nov. |                      |                      |
|               | HV: late-Nov. | late-Nov. | UT: green manure |                      |                      |
|               | CF: 3.1-3.9-0.0 | 0.6-0.7-0.0 |                      | (one application) |                      |
| Buri Ram      | TP: early-Aug. | early-Aug. | BC: early-Nov. |                      |                      |
|               | HV: late-Nov. | late-Nov. | UT: grazed water buffalo |                      |                      |
|               | CF: 1.5-1.5-0.8 | 1.8-1.8-0.9 |                      | (splited into 3 applications) |                      |

TP: transplanting; HV: harvesting; CF: application rate of chemical fertilizer (N-P\(_2\)O\(_5\)-K\(_2\)O g m\(^{-2}\)); BC: broadcasting; UT: utilization of stylo biomass.
and each plot was about 10×10 m in area. We used two treatments: rice mono-cropping (mono-fertilized) and rice-stylo relay-intercropping (relay-intercropping), with two replications, from transplanting of rice in mid-July 2002 to harvesting of rice in late-November 2004. The aboveground biomass and paddy yield of rice and aboveground biomass of stylo were measured by the same protocol as in Exp. 1.

Rice cropping both in mono-fertilized and relay-intercropping fields was managed by farmers according to their usual practices. The management is summarized in Table 2.

3. Weather data and statistical analysis

Precipitation was measured at the URRC, the Udon Thani Rice Experiment Station, the Chum Pae Rice Experiment Station, and the Buri Ram Meteorological Station. Table 3 shows the precipitation during the experiment. Seasons are divided into the wet season (June to October) and the dry season (November to May).

The experimental data were subjected to analysis of variance with least significant difference (LSD) and test of residuals using IRRISTAT 5.0 (IRRI).

Results

1. Experiment 1: field experiment at the Ubon Rice Research Center

(1) Dry matter production of *Stylosanthes guianensis* (stylo)

The maximum dry matter production of stylo was recorded in the first season in the field experiment at the URRC (Table 4). In particular, the production in the field located in the lower toposequence (lower field) was 950 g m⁻² under non-fertilized and non-irrigated conditions during stylo production in the dry season. Stylo produced less dry matter in the second and the third seasons, but, with the exception of the upper field in the second season, more than 200 g m⁻² of dry matter was produced. No significant relationship was observed between stylo production and precipitation in the dry season.

(2) Effects of relay-intercropping on rice paddy yield

More precipitation during the wet season in 2002 increased rice yield in the upper field, but it did not increase rice yield in the lower field (Table 5). Although rice yield was not significantly different between the relay-intercropping and mono-fertilized treatments, relay-intercropping fields tended to produce more rice yield and more biomass than mono-fertilized fields for three continuous years. The relay-intercropping caused greater N uptake by the subsequent rice crop. Without fertilizer application, rice biomass production was lowest, and the yield was only about 70% of that in the relay-intercropping treatment where fertilizer and green manured stylo was applied.

2. Effect of the relay-intercropping on chemical properties of soil

Soil organic carbon (SOC) content increased with time in the relay-intercropping system (Fig.2). In the lower field, it also increased in the mono-cropping systems and hence the advantage of relay-intercropping was not clear. However, in the upper field, the SOC content after 3 years of relay-intercropping was significantly higher than that after the 3 years of mono-cropping, where the SOC content of soil was almost constant for three years.
Ammonium nitrogen (NH$_3$-N) and extractable phosphorus (P) contents of soil in the relay-intercropping tended to be higher in the early stage and at the end of the second cropping season of stylo than they were in the mono cropping (Table 6). The stylo in relay-intercropping tended to increase soil NH$_3$-N, but to decrease extractable P. However, these values had large deviations and the differences were not statistically significant.

2. Experiment 2: Application of the relay-intercropping to farmer’s fields

In the first cropping season, 2002–2003, we obtained little biomass of stylo at the beginning of June because of submergence in the lower field in Chum Pae and grazing by water buffalo in the upper and lower fields in Buri Rum. However, the standing biomass exceeded 150 g m$^{-2}$ in the other three fields and the maximum was 367 g m$^{-2}$ in the upper field in Udon Thani (Table 7). In the second cropping season, 2003–2004, the standing biomass of stylo hardly exceeded 100 g m$^{-2}$. Since we left management of stylo to farmers, they used the stylo biomass for themselves. The farmer in Udon Thani harvested the aboveground biomass to raise cattle. The farmer in Chum Pae plowed the stylo into the soil as green manure. In Buri Rum water buffalo grazed it.

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**Table 5.** Grain yield, aboveground biomass and nitrogen (N) uptake by rice in four cropping seasons in a relay-intercropping system, rice monoculture (mono-fertilized) and rice monoculture without chemical fertilizer (mono-unfertilized).

| Position | Treatment                  | 2000  | 2001  | 2002  | 2003  | Average |
|----------|----------------------------|-------|-------|-------|-------|---------|
| Grain (g m$^{-2}$) | Upper Relay-intercropping | 214 ns | 204   | 320   | 43    | 189 a   |
|          | Mono-fertilized           | 233   | 222   | 274   | 35    | 177 ab  |
|          | Mono-unfertilized         | 167   | 160   | 212   | 45    | 139 b   |
|          | Lower Relay-intercropping | 372 ns| 330   | 237   | 354   | 307 a   |
|          | Mono-fertilized           | 353   | 218   | 235   | 332   | 262 ab  |
|          | Mono-unfertilized         | 295   | 181   | 174   | 333   | 229 b   |
| Biomass (g m$^{-2}$) | Upper Relay-intercropping | 583 ns| 383   | 828   | 321   | 510 a   |
|          | Mono-fertilized           | 579   | 427   | 755   | 235   | 473 a   |
|          | Mono-unfertilized         | 364   | 387   | 560   | 163   | 370 b   |
|          | Lower Relay-intercropping | 1066 ns| 845   | 826   | 927   | 866 a   |
|          | Mono-fertilized           | 1021  | 648   | 785   | 828   | 754 b   |
|          | Mono-unfertilized         | 781   | 530   | 611   | 783   | 641 c   |
| N uptake (g m$^{-2}$) | Upper Relay-intercropping | 3.3 a | 4.2   | 5.9   | 2.2   | 4.1 a   |
|          | Mono-fertilized           | 3.5 a | 3.0   | 4.4   | 1.6   | 3.0 b   |
|          | Mono-unfertilized         | 1.1 b | 2.2   | 3.0   | 1.3   | 2.2 b   |
|          | Lower Relay-intercropping | 6.1 ns| 6.7   | 5.7   | 7.4   | 6.6 a   |
|          | Mono-fertilized           | 6.1   | 3.8   | 5.5   | 6.4   | 5.2 b   |
|          | Mono-unfertilized         | 5.1   | 3.1   | 5.2   | 5.8   | 4.7 b   |

Since relay-intercropping (cultivation of *Stylosanthes guianensis*) was started after heading of rice in the 2000 cropping season, statistical analysis was conducted separately for 2000 and for the period from 2001 to 2003. Numerals followed by a common letter are not significantly different a 5% level. ns denotes not significantly different at 5% level.

**Table 6.** Ammonium nitrogen (NH$_3$-N) and extractable phosphorus (P) content of soil at the early stage (Dec. 2001) and at the end (June 2002) of the second cropping season of stylo in relay-intercropping, mono-fertilized and mono-unfertilized plots.

| Position | Treatment                  | NH$_3$-N (mg kg$^{-1}$) | Extractable P (mg kg$^{-1}$) |
|----------|----------------------------|-------------------------|-----------------------------|
|          |                            | Dec-01 | Jun-02 | Increase | Dec-01 | Jun-02 | Increase |
| Upper    | Relay-intercropping        | 2.8   | 3.9    | 1.0 ns   | 43    | 41    | −2 ns    |
|          | Mono-fertilized            | 1.8   | 2.7    | 0.9      | 38    | 39    | 1        |
|          | Mono-unfertilized          | 2.2   | 2.7    | 0.5      | 26    | 26    | 1        |
| Lower    | Relay-intercropping        | 2.9   | 7.9    | 5.0 ns   | 39    | 32    | −7 ns    |
|          | Mono-fertilized            | 4.0   | 5.8    | 1.8      | 44    | 44    | 0        |
|          | Mono-unfertilized          | 3.3   | 4.6    | 1.3      | 22    | 26    | 4        |

ns denotes not significantly different at 5% level.
The relay-intercropping system tended to increase the grain yield of rice more than the mono-fertilized cropping (Table 8). However, the difference was not significant because of the relatively large variability. The percentage of the increase of grain yield in the relay-intercropping system compared to that in the mono-fertilized cropping was approximately 20, 10, and 0% in Chum Pae, Buri Rum, and Udon Thani, respectively, with an average of 10%.

**Discussion**

*Stylosanthes guianensis* were proposed as leguminous pasture crops in Thailand (Guodao et al., 1997) and as fallow crops in Lao PDR (Roder and Maniphone, 1995; Saito et al., 2006). The present results show that stylo can be produced in paddy fields during the dry season in Northeast Thailand in rice-stylo relay-intercropping. The relay-intercropping did not need irrigation or fertilization during the stylo cropping, which utilized residual water and nutrients from the rice cropping. Under such conditions, the maximum stylo production was 950 g m\(^{-2}\) on the experimental field at URRC and 367 g m\(^{-2}\) at the farmer’s field in Udon Thani. However, the stylo production showed a large variability. In order to introduce the relay-intercropping system to farmer’s fields, the production variability must be decreased.

The largest difference in the stylo production was observed between the first and the second cropping seasons. The production decreased in the second cropping season in both the experimental fields and the farmer’s fields. In order to reveal the production constraints, we conducted a pot experiment. The decrease in the production may be caused in part by sulfur deficiency, but the details will be published elsewhere. Craswell and Karjalainen (1990) also stated a risk of sulfur deficiency in paddy field in Thailand. In spite of sulfur deficiency, the relay-intercropping still produced more than 200 g m\(^{-2}\) dry matter in the

**Table 7. Dry matter production of stylo (g m\(^{-2}\)) at the beginning of June in 2 cropping seasons at different toposequential positions (upper and lower) in Udon Thani, Chum Pae and Bri Rum experimental sites.**

| Site         | Position | 2002−2003 | 2003−2004 |
|--------------|----------|-----------|-----------|
| Udon Thani   | Upper    | 367±27    | 103±27    |
|              | Lower    | 176±21    | 90±11     |
| Chum Pae     | Upper    | 322±103   | 92±44     |
|              | Lower    | 2±1\(^{1}\) | 20±11     |
| Buri Ram     | Upper    | 7±1\(^{2}\) | 41±4      |
|              | Lower    | 1±0\(^{2}\) | 57±20     |

\(^{1}\) Stylo was extremely damaged by submergence.
\(^{2}\) Water buffalos grazed.

**Table 8. Grain yield of rice (g m\(^{-2}\)) for 3 cropping seasons in the relay-intercropping system and rice monoculture (mono-fertilized).**

| Site          | Position | Treatment       | 2002  | 2003  | 2004  | Average |
|---------------|----------|----------------|-------|-------|-------|---------|
| Udon Thani    | Upper    | Relay-intercropping | 225   | 67    | 166   | 117     |
|               |          | Mono-fertilized  | 231   | 54    | 178   | 116     |
|               | Lower    | Relay-intercropping | 220   | 123   | 217   | 170     |
|               |          | Mono-fertilized  | 241   | 112   | 211   | 162     |
| Chum Pae      | Upper    | Relay-intercropping | 375   | 320   | 444   | 382     |
|               |          | Mono-fertilized  | 366   | 231   | 408   | 320     |
|               | Lower    | Relay-intercropping | 333   | 258   | 301   | 280     |
|               |          | Mono-fertilized  | 337   | 201   | 284   | 243     |
| Buri Ram      | Upper    | Relay-intercropping | 255   | 154   | 224   | 189     |
|               |          | Mono-fertilized  | 259   | 142   | 178   | 160     |
|               | Lower    | Relay-intercropping | 293   | 160   | 206   | 183     |
|               |          | Mono-fertilized  | 313   | 148   | 195   | 172     |
| Average       | Upper    | Relay-intercropping | 285 ns| 180   | 278   | 229 ns  |
|               |          | Mono-fertilized  | 285   | 142   | 255   | 199     |
|               | Lower    | Relay-intercropping | 282 ns| 80    | 242   | 211 ns  |
|               |          | Mono-fertilized  | 297   | 154   | 230   | 192     |

Since relay-intercropping (cultivation of *Stylosanthes guianensis*) started after heading of rice in the 2002 cropping season, statistical analysis was conducted separately for 2002 and for the period from 2003 to 2004. ns denotes not significantly different at 5% level.
third cropping season at the experimental fields. Since urea is commonly used as nitrogen fertilizer for rice cropping in Northeast Thailand (Author’s observation; also see Craswell and Karjalainen, 1990), a change to ammonium sulfate may increase the stylo production.

Another factor affecting the production variability seems to be water conditions. The production decrease of stylo in the upper field in the second cropping season may have been caused by drought. The lower production in the lower fields than in the upper fields in Udon Thani and Chum Pae may be associated with excessive soil moisture. Such constraints can be avoided to some extent by changing the broadcast time of stylo seed. Earlier sowing benefits from more available water, while later sowing alleviates injuries from excessively wet conditions. In order to determine the optimum time of sowing, more trials are necessary.

In the experimental field, we used the stylo biomass as green manure. The green manure tended to increase rice yield and to improve the soil chemical properties. The relay-intercropping system may cause sulfur deficiency, although it seems not to affect rice yield. Significant effect of fertilizer on green manure biomass has been reported (Arunin et al., 1994; Herrera et al., 1997). Accordingly, the stylo crop which received only residual nutrient of rice cropping may not be suitable for green manure production. In Udon Thani and Buri Rum, the farmers fed the stylo biomass to livestock. The feeding did not decrease rice yield, suggesting that stylo biomass produced in relay-intercropping can be utilized for livestock production without affecting subsequent rice production.

In order to introduce the relay-intercropping system to farmer’s fields, many problems remain to be solved, such as low seed supply and high cost. If the stylo production is used for cattle raising, a stable supply of seed is required. However, the increased amounts of agricultural products on the many paddy fields not currently used during the dry season, would be of value. The products, forage in this case, can increase livestock production and be converted to barnyard manure. The manure contributes to improved soil fertility and agricultural productivity.

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