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Forage legume establishment in rice slash-and-burn systems

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Abstract

Increasing population pressures combined with government policies exert considerable pressure on traditional slash-and-burn farmers in northern Laos to change to other production systems. Replacing the natural fallow vegetation with fodder legumes could increase fodder availability, suppress weeds, and accelerate nutrient cycling. Establishment methods for potential forage species were evaluated at the Houay Khot station during 1992 and 1993. When broadcast into upland rice immediately after weeding in July, good or excellent establishment was observed for *Stylosanthes guianensis, S. hamata, Macroptlium atropurpureum, Pueraria javanica. P. phaseoloides, Calopogonium mucunoides, C. caeruleurn, Leucaena leucocephala, Centrosema pubescens,* and C. *plumieri*. Poor establishment was observed for Arachis pinto!, Flemingia congesta, Crowaria anagyroides, C. juncea, pigeon pea (Cajanus cajan), Tephrosia vogelil, and Lablab purpureus. July and August sowings resulted in better plant densities thaui June or September sowings. However,, early sowing of &ylosarzthes species reduced rice yield by 20-30% in 1993. Dibbling rice mixed (same hill) with leucaena resulted in good establishment without detrimental effect on rice yield, while dibbling race mixed with pigeon pea reduced rice yield by 55-65%.

Introduction

Slash-and-turn agriculture remains a dominant land-use system in many parts of the tropics (Warner 1991). Among other options, forage legumes which may be used in crop rotation, ley farming or pasture systems, have been widely recommended as alternatives to existing slash-and-burn systems (Nye and Greenland 1960; Spencer 1966; Sanchez 1987) and there is a strong interest in fodder legumes in cultivated upland environments (Thomas and Bennett 1975; Hulugalle 1988; Thomas et *al* 1992).

In the hilly regions of northern Laos, upland rice is the major crop, with an annual area of about 200 000 ha (National Statistical Center 1993), produced mainly in slash-and-burn systems (Fujisaka 1991). Slash-and-burn farmers consider weeds, insufficient rainfall, and rodent damage as the foremost constraints to upland rice production (Roder c/ at. 1994). Shorter fallow periods resulted in high labor requirements for weeding, and farmers are under pressure to change to other land-use systems. Considering the limited market opportunity for annual crops and horticultural products, the comparatively low population density, and the hilly topography, timber and livestock production are generally thought to be the best alternatives for the Lao upland farmer. Livestock production is the major source of cash income for farmers in much of Laos, relying on fallow land, waste land, and forest as the major grazing resources (Roder et at. 1993). There is potential for increased livestock production by replacing the fallow vegetation with fodder crops. Improved fallow systems combining the effects of fodder plants and the grazing animal may increase fodder availability, suppress weeds, and accelerate nutrient cycling (Roder et *al*. 1993). Furthermore, residues retained in systems without burning may improve soil and water conservation during the rice crop.

Potential forae species include: lablab (*Lablab purpureus*), pigeon pea (*Cajanus cajan*), Centre *sema pubescens*, *Stylosanthes gulanensis*, Pueraria phaseoloides, *Arachis pintoi*, !eucaena (*Leucoena leucocephala*,), and *Brachiaria* spp. (Thomas and Humphreys 1970; Shelton and Humphreys 1972; Roder et *al*. 1993). Farmers'

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acceptance of forage species partly depends on the availability of cheap and practical establishment methods.

Seeding forage species with a companion crop is a widely used practice in temperate as well as tropical conditions(Heath et at. 1973; Humphreys 1978). This method has several advantages, including: greater farmer acceptability, income from the companion crop, weed suppression, protection against adverse conditions, and an increase in forage quality and quantity after crop harvest (Thomas and Bennett 1975; Humphreys 1978). Successful establishment of S. guianensis in upland rice under slash-and-burn conditions of Laos has been reported earlier (Thomas and Humphreys 1970; Shelton and Humphreys 1972). Shelton and Humphreys (1972) showed that good stylo stands can be obtained by this method, without negative effects on rice yield, provided the seeding rate was kept low and the sowing of legumes delayed- Partly due to the lack of dissemination of the findings and the non-availability of S. guianensis seed, this method of legume establishment has not become popular in Laos. As a follow-up on the findings of Shelton and Humphreys (1972), there is a need to evaluate establishment techniques for a wider range of potential species, planting methods and environments.

Experiments were conducted during the 1992 and 1993 rice-growing seasons to: assess the suitability of simple methods of legume establishment in a growing rice crop; and evaluate the effect of planting date cm establishment success arid its interaction with rice yield.

Materials and Methods

All experiments were conducted at the Houay Khot Research Station (19 0N), under typical upland conditions. Soil at the station is class-Lied as Eutric Cambisol with a pH of 6.1, and an organic C content of 1.6%. The station is Located in the drier zone of northern Laos with an average annual rainfall of about 1300 mm. Annual rainfall for 1992 and 1993 recorded at the station was close to the long-term average for the region, but was unusually low for the last 3 months of 1993 (Table 1).

Field preparation consisted of slashing the shrub vegitation in January and burning the dry above-ground biomass in March. As far as possible, areas with termite mounds and tree stumps were excluded from the experiment. Nevertheless, soil conditions were highly heterogeneous, as is common in slash-and-turn fields (Andriesse and Schelhaas 1987; Pushparajah and Chan 1987). Rice was dibbled in hills with a spacing of 20 by 25 cm. Approximately 10 rice seeds were placed in 3-5 cm deep holes made with a dibble stick following the traditional planting method. The medium-duration, glutinous, local cultivar "Vieng" was used for all experiments. Seeds of C. *pubescens, Stylosanties hamata, S. gulanensis, P. phaseoloides, Pueraria javanica, Calopogonium caeruleum,* and leucaena were dipped in boiling water for 15 seconds prior to planting to break the dormancy. Rice arid legume seeds were treated with Carbaryl (85%) immediately before planting. Seeding rates used for legumes were generally higher than the recommended rates, in an endeavour to get more uniform establishment and help reduce the high variation expected due to heterogeneous soil conditions. Following the results of the first year, the experimental designs were modified in the second year. Combined statistical analysis over the 2 years was therefore not possible. Rice yields, adjusted to 14% moisture, were measured from whole plots after removing the border rows.

Table 1. Rainfall (mm) at Houay Khoi Station.

Month	1992	1993
January	50	-
February	62	-
March	-	92
April	53	66
May	68	133
June	232	97
July	316	220
August	177	222
September	131	113
October	91	67
November	41	-
December	28	2
Total	1249	1012

Establish by broadcasting in a sanding rice crop

Planting date experiment, 1992. The experimental design was a split-plot, with legume planting date as the main treatment, 4 replicates and a plot size of 6 m^2. Rice was planted on May 21. Seed of the legumes [lablab, pigeon pea, *Calopogonium mucunoides*, *C. pubescens*, *P. phaseoloides*, and sun hemp *(Crotalaria juncea)*] was broadcast into the rice crop at the rate of 80, 60, 20, 30, 20 and 30 kg/ha, respectively, on 4 occasions at monthly intervals from June 16. Weeding was done in all plots before each legume planting date. Legume density and/or cover was recorded one month after legume broadcast, at the time of rice harvest, and at the end of the dry season from the area between 3 centre rows of rice. Rice was harvested on October 19.

Planting date experiment, 1993. The experimental design was as for 1992. Rice was planted on June 4. Legume seed was broadcast into the rice on 3 occasions at monthly intervals from July 6, at 15 kg/ha. The legume treatments consisted of: control (no legume); *P. phaseoloides*; *C. mucunoides*; *S. hamata* (cv. Amiga); and *S. guianensis* (cv. Cook). All plots were weeded before each planting date. Legume density, cover, and height were recorded one month after legume broadcast (density and cover only) and at the time of rice harvest from the area between the 3 centre rows of rice. Rice was harvested on October 21. Legume dry matter yield and cover were estimated visually at the end of the dry season on May 5, 1994.

Establishment of various legume species. The experimental design was a randomised complete block with 4 replicates and a plot size of 7 m^2. Rice was planted on June 14. The legumes [green leaf desmodium *(Desmodium intortum)*, Siratro *(Macroptilium atropurpureum)*, *P. javanica*, *P. phaseoloides*, leucaena, *C. caeruleum*, *Centrosema plumieri*, *Crotalaria anagyroides*, *Flemingia congesta*, *Tephrosia vogelii*, and *Arachis pintoi* (cv. Amarillo)] were broadcast into the rice crop on August 10 at the rate of 15, 25, 25, 25, 30, 30, 50, 25, 15, 25 and 60 kg/ha, respectively. Plots were weeded in July and immediately before broadcasting legume seeds. Legume density, cover and height were recorded from 3 randomly placed frames of 0.05 m^2 on August 28 (density only) and at the time of rice harvest on October 26. With the late sowing date for legumes, no effect of legume treatment on rice yield was expected, and rice yield was not measured for individual plots.

Establishment by planting rice and legume seed in the same hill

The treatments were: control (rice only); pigeon pea (ICP 11298) mixed with rice; pigeon pea (ICP 8094) mixed with rice; leucaena mixed with rice; ICP 11298 and rice separately; ICP 8094 and rice separately; and leucaena and rice separately. The experimental design was a randomised complete block with 4 replicates and a plot size of 13.5 m^2. Both rice and legume were planted on June 3. Where legumes were mixed with rice, they were dibbled at a distance of 1 m with the rice seed (same hill, every fourth row); and where rice and legume were dibbled separately, every fourth row was sown to legume. Seeding rate was 4–6 seeds per hill. Rice planting density was 25% lower where legumes were dibbled separately. ICP 11298 (erect type) and ICP 8094 (prostrate type) were obtained from ICRISAT. Rice was harvested on October 20. In December, the number of hills with leucaena present was recorded as well as the height of 10 randomly selected plants per plot . Pigeon pea plants showed vigorous growth with all treatments but no additional observations were taken on their performance.

Results and discussion

Establishment by broadcasting in a standing rice crop

Planting date experiment, 1992. Mean rice yield was 3.8 t/ha and was not affected by the legume or planting date treatments (Table 2). Best legume establishment was achieved from the July sowing. Good establishment was obtained for *C. mucunoides*, *C. pubescens*, and *P. phaseoloides*, while irregular or insufficient establishment of pigeon pea, sun hemp and lablab was observed for all planting dates. The poor results obtained for the latter 3 species may be due in part to insect damage, sensitivity to shading and establishment problems with large seed when placed on the soil surface. Pigeon pea (8 entries) and lablab (2 entries) cultivars were tested in a separate experiment in 1992 (W. Roder, unpublished data) but no pigeon pea and very few lablab plants established.

Plant cover and density followed similar trends. Planting date by legume treatment interactions were significant for most observations,

Table 2. Planting date and species effect on rice yield, legume density, and cover in 1992.

Category	Rice yield	Legume			
		Density		Cover	
		30 d[1]	19.30.92[2]	19.10.92[2]	24.4.93[3]
	(t/ha)	(plants/m²)		(%)	
Planting date					
June 16	3.7	26	37	11	14
July 16	3.7	41	25	18	35
August 16	4.0	19	9	1	2
September 16	4.0	6	6	0.2	1
Legumes					
Lablab		3.8	9	5	2
Pigeon pea	3.9	5	4	5	
C. mucunoides	3.9	35	22	17	7
C. pubescens	3.8	30	20	7	14
P. phaseoloides	4.0	38	26	14	20
C. juncea	3.7	22	8	2	1
Anova summary: (PR> F)					
Planting date (A)	NS	<0.01	<0.01	<0.01	<0.01
Legume (B)	NS	<0.01	<0.01	<0.01	<0.01
AxB	NS	<0.01	<0.01	<0.0!	<0.01
CV (%)	16.6	42.5	56.3	82.5	83.5

[1] Observations taken 30 days after broadcasting legume seeds.
[2] Observations taken at the time of rice harvest.
[3] Observations taken at the end of the dry season.

but these are shown only for the plant density estimates at the time of rice harvest (Figure 1). In contrast to other species, establishment rate for pigeon pea and sun hemp increased again with the last planting date. This may be the result of a decline in shading effects in the last phase of the rice crop. interactions for other observations did not reveal any particular trend, nor did they affect the conclusions drawn from the means shown in Table 2.

At the end of the dry season, *P. phaseoloides* and C. *pubescens* had the best plant cover. Planting date effects on plant cover of individual legume species remained constant through the dry season. Plant cover for the drought-resistant species, C. *pubescens* and pigeon pea, increased dramatically, but decreased for C. *mucunoides*.

Planting date experiment. 1993. Soil conditions were more variable in 1993, resulting in higher variation in rice yield data (Tab]e 3). As in 1992, the best establishment was observed for the July planting date, but establishment was still good for fir August and September sowings. Early sowing of stylo species reduced rice yield for S. *hamata* to 75% and S. *gulanensis* 70% of that of the control treatment. S. *guianensis* is the most competitive species tested arid has the best establishment rate but is also the legume most likely to reduce the yield of the companion rice crop. Shelton and Humphreys (1972) suggested that the negative effects of S. *guianensis* on the yield of the companion rice crop could be minimised by low seeding rates and delayed legume planting.

Plant height at the time of rice harvest decreased with planting date (Table 3). All legumes from the last planting were small at the time of rice harvest, but in spite of' the extremely dry period from October 1993-February 1994 (Table 1), a few plants survived for all species. In early May 1994, S. *gulanensis* had dry matter yields of 3.5, 2.5 and 0.3 t/ha for the July, August and September planting dates, respectively. Weed growth was inversely related to legume growth. The weed biomass, consisting mostly of Chromolaena odorata and *Crassocephalum crepidioides,* was 15, 21 and 91% of the total above-ground biomass for the S. *guianensis* planting dates of July, August arid September, respectively. Planting in August thus resulted in a competitive plant cover of stylo without affecting the rice yield.

Table 3. Effect of planting date and legume species on rice yield, legume density, cover, height, and dry matter yield in 1993.

Category	Rice yield	Legumes - 1993				Legumes - 1994[3]	
		Density		Cover[2]	Height[2]	Yield	Cover
		30 d[1]	20.10[2]				
	(t/ha)	(plants/m²)		(%)	(cm)	(t/ha)	(%)
Planting dale							
July 6	1.32	54	40	55	71	1.5	55
August 6	1.58	44	32	21	33	1.0	38
September 6	1.44	21	28	2	1	0.3	11
Legumes							
Control	3 .59						
C. *mucunoides*	2.33	25	23	18	42	0.3	14
P. *phaseolaides*	L55	17	16	18	36	0.5	20
S. *hamata*	1.44	52	42	25	32	0.9	41
S. *guianensis*	130	64	51	43	40	2.1	64
Anova summary (PR>F)							
Planting date (A)	0.09	<0.01	0.06	<0.01	<0.01	<0.01	<0.0!
Legume (B)	NS	<0.01	<0.01	<0.01	NS	<0.01	<0.01
A x B	NS	<0.01	NS	<0.01	NS	<0.01	<0.01
CV (%)	36.2	32.4	38.9	61.1	52.1	59.0	51.0

[1] Observations taken 30 days after broadcasting legume seeds.
[2] Observations taken on October 20. 1993, at the time of rice harvest.
[3] Observations taken on May 5, 1994.

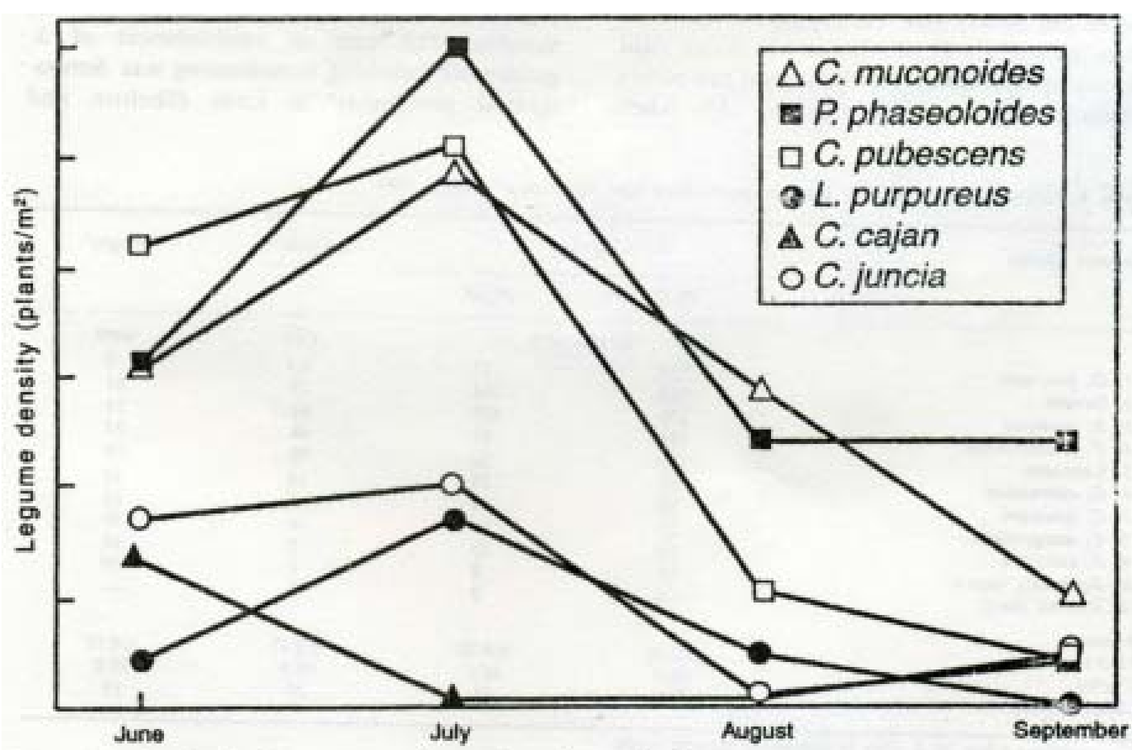

Figure 1. Planting date by legume treatment interactions on legume density.

Establishment of various legume species. Plant densities observed were largely a result of seeding rate. Furthermore, differences in initial establishment were influenced by seedling vigor, a variable that was not measured in the experiment. Excellent establishment was observed for Siratro, *P. javanica*, *P. phaseoloides*, *C. caeruleum*, leucaena, and C. *plumieri* (Table 4). Between the observation taken 18 d after broadcasting seed and the time of rice harvest, the loss of plants was 0-45% for all legumes except green leaf desmodium. Green leaf desmodium had a very high plant density 18 d after broadcasting seed, but only a few weak plants survived at the time of rice harvest. Combined effects of shading and diseases may be responsible for the heavy loss of desmodium plants. Similar observations were made for green leaf desmodium seedings in 1992 (W. Roder, unpublished data), but green leaf desmodium sown in a nursery, without a companion crop, developed well.

Establishment by planting rice and legume seed in the same hill

Leucaena and *pigeon pea*, 1992. Rice yields were low with only 1.7 t/ha for the control treatment. Both legumes established well. Leucaena developed slowly and was always much shorter than the rice plant, with no effect on rice yield. Strong competition from the pigeon pea plants, however, depressed rice yield by 55% where pigeon pea was mixed with rice and 66% where pigeon pea and rice were dibbled separately (P cc 0.05). The vigor of pigeon pea was slightly reduced when dibbled together with rices but difference in rice yield was not significant due to high variation (CV 24.6%) Leucaena established in 73% of the hills and was not affected by planting method (CV 11%). Leucaena height in December was 50 cm when dibbled with rice and 78 cm when dibbled in separate rows (CV 14%, P<0.02).

Conclusions

Results were consistent over both years. Both broadcasting and sowing mixed with rice offer considerable potential for selected species. These methods are well adapted for upland rice systems such as those in Laos. Establishment success or failure will be influenced by many factors, including: soil, climate, pests, diseases, weed control, weed competition. planting date, rice variety, rice cover, rice vigor, legume seed quality and legume shade tolerance. S. *guianensis*, S. hamata, C. *mucunoides*, C. *pubescens*, P. *phaseoloides*, P. *javanica* and Siratro are well suited for broadcasting, while others such as pigeon pea, sun hemp and lablab are less suitable. The ease of establishment of' S. *guianensis* following broadcasting was demonstrated previously in Laos (Shelton and

Table 4. Establishment of various legume species broadcast into rice in August 1993.

Legume Species	Density		Cover[2]	Height[2]
	28.8[1]	26.10[2]		
	(plants/m^2)		(%)	(cm)
1. D. *intortum*	525	11	<1	5
2. Siratro	350	298	73	6)
3. P. *javanica*	228	125	41	23
4. P. *phaseoloides*	128	88	48	27
5. Leucaena	110	88	10	19
6. C. *caeruleum*	45	28	18	16
7. C. *plumieri*	33	28	15	22
8. C. *anagyroides*	23	15	4	39
9 F. *congesta*	15	25	3	14
10. *Tephrosia vogelii*	12	8	1	29
11. *Arachis pintoi*	0	0	0	-
Anova				
PR>F	<0.01	<0.0!	<0.01	<0.0!
Cv (%)	38.3	46.4	58.5	39.0
LSD(P <0.05).	100	59	22	19

[1] Observations taken 18 d after broadcasting legume seeds.
[2] Observations taken on October 26, at the time of rice harvest.

Humphreys 1972). Delayed broadcasting combined with low seeding rates will result in good establishment without negative effects on rice yield, as demonstrated in this and earlier experiments. The vigor and heavy seed production of S. *guianensis* may, however, become a serious problem if farmers must use the same fields again for rice production. Further studies are warranted o clarify the potential for S. *guianensis* in rice rotation systems under Lao upland conditions.

Planting a mixture of legume and rice seed is probably the best approach for the establishment of slow-growing shrubby or tree species, of which leucaena is the most promising species presently available. Advantages of this method include: no extra labor requirements; young seedlings growing in a rice hilt will be protected during farmers' weeding operations; less weed competition compared with establishment in fallow land; and reduced competition effects on the companion rice crop.

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