Chapter 4

RESULTS

1. Field survey

1.1. Rice-based intensive cropping systems in the Mekong Delta of Vietnam:

Cai lay District is one of the typical intensive land use areas in the Mekong Delta of Vietnam. Three crops per year have been practiced in this district for over 10 years. The dominant cropping pattern has been RICE (dry season) - RICE (early rainy season) - RICE (main rainy season) (Figure 2). Improved rice varieties with early maturity (about 100 days) have been used as the main crop throughout the year. Zero tillage has recently been a common practice for rice in the early rainy season when rice straw and stubble could be dried and burnt over the field before broadcasting dry or pre-soaked seeds. The field is then submerged for about 24 hours before drainage, and moisture is kept for seed germination. This is what farmers call "Sa chai" (direct seeding without tillage). This practice appears to be useful for farmers in intensive cropping systems when labour use reaches its peak during the transaction periods between two successive growing seasons. It is also considered as a "water-saving practice" for growing rice in the early rainy season when water, at the beginning of the growing season, is limited. In some areas, during the early and main rainy seasons, farmers transplant the 20-25 day-old seedlings into the field which is prepared in a similar way to "Sa chai", known as "Cay chai" (transplanting without tillage).

The main rainy and dry season rice crops are commonly transplanted in this area (Table 2), due to high water level on the field at the beginning of the growing seasons. A large amount of chemical fertilizers (more than 400 kg/ha, or more than 100 kgN/ha) are applied in order to obtain the average rice yield of 14.5 t/ha/year (6.0, 4.3 and 4.2 t/ha in dry season, early rainy season and main rainy season, respectively).

Some farmers intercrop certain kinds of upland crops, such as chili, cucumber, mungbean, okra, etc... with the early rainy season rice crop by growing them on the strip bunds across the field, and transplanting rice in between. This practice is highly profitable, but limited in area because very intensive labour use is required.

Table 2: The use of chemical fertilizer and rice yield in different planting methods and growing seasons practiced by farmers in Cai Lay district (Tien giang province), Vietnam.

Growing season	Planting method	Tillage	No. of observation	Fertilizer application(kg/ha)			Rice yield (t/ha)
				Urea46%N	DAP(1)	Others(2)	
Dry season	Broadcast	No	2	210	60	260	5.9
		Yes	2	220	105	225	6.1
	Transplant	No	0	-	-	-	-
		Yes	25	190	94	132	6.0
Early rainy season	Broadcast	No	14	219	103	155	4.3
		Yes	0	-	-	-	-
	Transplant	No	7	191	93	121	4.5
		Yes	8	196	112	61	4.1
Main rainy season	Broadcast	No	8	191	113	171	4.2
		Yes	0	-	-	-	-
	Transplant	No	7	186	83	149	4.1
		Yes	14	212	105	119	4.2
Grand mean			87	200	98	139	4.8
S.D.				66	39	104	1.0

(1) DAP : Diammonium Phosphate (18-46-0), (2) Non-N fertilizers.
S.D. : Standard deviation.

Analysis of soil samples from representative fields showed that there was no toxicity problem, and that total P, and N content, as well as organic matter (O.M), were from intermediate to high, as compared to the soil at the experimental station of the Multiple cropping Center, Chiang Mai University. N content and O.M. were higher in soil with tillage than in soil without tillage (Table 3). It can be explained by the fact that stubble and occasionally rice straw were incorporated into the soil by tillage instead of being burnt as in the case of zero tillage.

Table 3. Chemical properties of some representative soils in Cai lay (Tien giang) and Phong Hoa (Dong Thap), Vietnam.

Properties	Cai lay (Tien giang)[1]		Phong Hoa (Dong Thap)[2]	
	(+)Tillage	(-)Tillage	(+)Sesbania	(-)Sesbania
pH	6.36	6.06	6.02	6.36
O.M. (%)	4.13	3.45	2.35	2.09
N (%)	0.22	0.15	0.13	0.10
P_2O_5 (%)	0.05	0.05	0.04	0.04

1. Where 3 modern rice crops has been grown per year with (+) or without (-) tillage.
2. Where one traditional rice crop per year has been grown with (+) or without (-) *Sesbania* intercropped

In informal interviews, farmers revealed that more and more chemical fertilizer would be needed in order to maintain rice yield from year to year. However, they found many difficulties in incorporating green manure crops into their current cropping systems, and have never tried to do so, even though they know its benefits. Some have grown Azolla as green manure in paddy fields, but they found that pest damage on Azolla were very severe. However, the field survey showed that there was a period of time between main rainy season and dry season (about 4-6 weeks in September and October) when most fields were fallow because of the height of flood and rain (Figure 2). Therefore, there is the possibility that *S. rostrata* could be introduced to the systems via intercropping, to maintain soil fertility and to produce seeds for further use, with little or no disturbance to the systems.

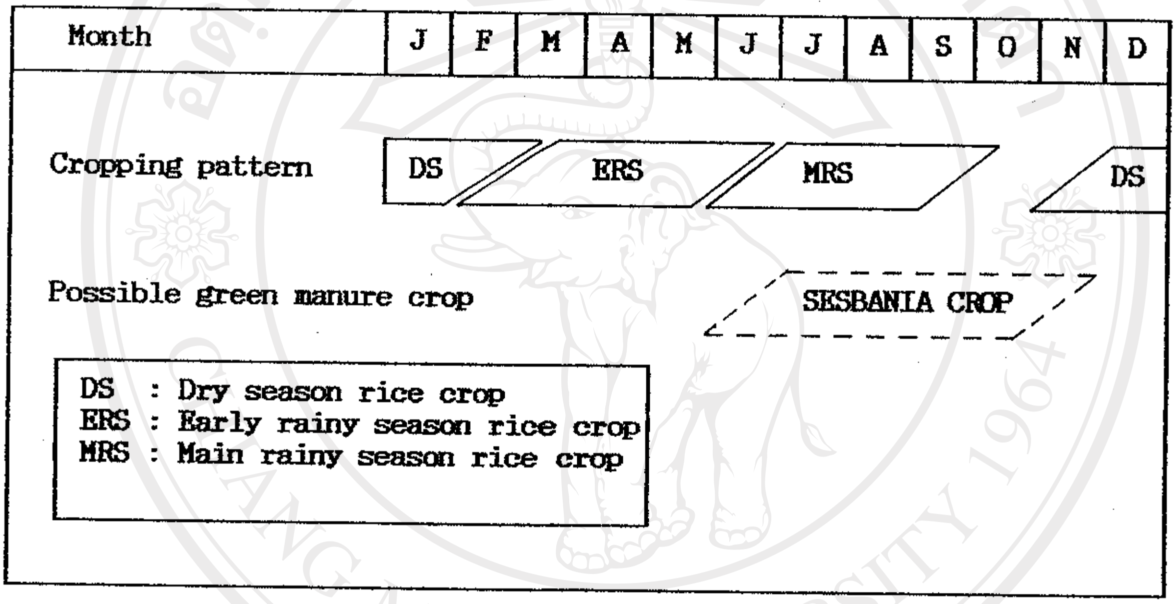

Figure 2. The major cropping pattern and the possible green manure crop in the target area of the study in the Mekong Delta of Vietnam.

1.2. Sesbania-Rice intercropping practice in the Mekong Delta of Vietnam:

In Phong Hoa village (Lai Vung district, Dong Thap Province), there are now more than 20 ha with more than 30 farmers still practicing *Sesbania sp.*-Rice intercrop. Of these, eleven farmers were randomly interviewed. This area is a fully rain-fed area where farmers can grow only one rice crop per year, using local traditional varieties. The fields are flooded in August, when there is enough water for land preparation to cultivate rice. The fields are left to fallow during the dry season, from December to April. No crop can be grown in the early rainy season (May to July) either, because of unreliable and unpredictable rainfall. Some farmers have more than 10 year's experience in intercropping a local species of *Sesbania* with traditional transplanted rice. Others have adopted this practice within the last 3-4 years. The main purposes of this type of intercropping are to produce *Sesbania* stems for firewood and to control weed growth during the early rainy season if fallowed.

Cuttings of the mature plants of *Sesbania sp.* (about 30-45cm long) are immediately transplanted into the rice field just 1 day before or 1-3 days after transplanting rice in August. Cuttings are arranged in rows at the spacing of 120-140 cm between rows and 20-50 cm within row (14,000-40,000 cuttings per ha). Young sprouts emerge from cuttings 1-2 weeks later and grow up together with rice. At the time of rice harvest (late December), *Sesbania sp.* with a height of 120-150 cm (20-50 cm above rice) is left on the field until the following July. It grows slowly during the dry season, but its growth rate increases rapidly when the rain comes. It reaches a height of 250-400 cm with 4-8 branches per cutting in late July. About 20 days before transplanting rice for the following season, *Sesbania* plants are cut down and left on the field to allow all leaves to drop. Afterwards, bare stems are collected for firewood. The period of time in which *Sesbania sp.* stands on the field is in total about 10-11 months. If farmers delay the harvest due to late monsoon, *Sesbania sp.* starts flowering in late August or early September.

Total green biomass was approximately 4-10 kg/cutting or 50-200 t/ha (as estimated by farmers). According to the farmers, to get the same rice yield as those with *Sesbania sp.* intercropped (4-5 t/ha), an extra amount of 50 kg of Urea (equivalent to 23 kgN/ha) and about 15 kg/ha of other chemical fertilizers needed to be applied to the fields without *Sesbania sp.* (Table 4). In additions, farmers could gain an additional amount of 400-800 thousand VN. dong (equivalent to 1.4-1.8 ton of paddy rice) per ha from selling *Sesbania sp.* stem as firewood.

However, soil analysis showed that organic matter and N content in soil with *Sesbania sp*-rice intercropping were not much higher than those in soil with rice alone, even though the practice of intercropping had been done for 10 years (Table 3). This indicated that if only leaves and roots of *Sesbania sp.* were returned to the soil, as currently practiced by farmers, the contribution of *Sesbania sp.* to soil fertility would be less important.

Table 4: The use of chemical fertilizer and *Sesbania sp.* intercrops related to rice yield in Phong Hoa, Lai Vung (Dong Thap).

Cropping systems	No. of observation	Fertilizer application(kg/ha)			Sesbania biomass (t/ha)	Rice yield (t/ha)
		Urea(46%N)	DAP(1)	Others(2)		
Sole rice	2	215 (65)*	55 (25)	25 (25)	- -	4.4 (0.3)
Rice-*Sesbania* intercrop	9	164 (20)	57 (15)	9 (7)	136.5 (21.1)	4.7 (0.2)

(1) DAP : Diammonium phosphate, (2) Non-N fertilizers.
* Numbers in parentheses are standard errors.

2. Field experiment

2.1. Agronomic characteristics:

2.1.1. Growing period:

RD7 (an improved rice variety) took about 125 days to harvest. Intercropping with *Sesbania rostrata* did not considerably affect its growth duration (days from sowing to maturity). However, the presence of *S. rostrata* could cause a slight delay in the days to flowering and the flowering period of rice by 1-3 days and 1-16 days, respectively, depending on the proportion and sowing date of *S. rostrata* (Table 5). The early introduction of *S. rostrata* had more effect on flowering period of rice.

Table 5. Growth duration of rice and *S. rostrata* as affected by intercropping and sowing date.

Cropping systems	Time of Introduction	Days to flowering		Flw. period (day)		Days to maturity	
		Rice	Sesbania	Rice	Sesbania	Rice	Sesbania
Sole rice		89	-	5	-	125	-
Intercrop							
75R : 25S	Simultaneous	91	63	12	39	125	134
	Intermediate	89	50	7	30	125	133
	Late	89	41	6	30	125	107
50R : 50S	Simultaneous	92	63	16	39	125	138
	Intermediate	90	50	6	30	125	130
	Late	90	41	6	30	125	106
Sole Sesbania							
	Simultaneous	-	63	-	39	-	131
	Intermediate	-	44	-	36	-	133
	Late	-	41	-	30	-	106
Grand mean		90	51	8	34	125	124
S.D.		1	10	4	4	-	14

Days to flowering: Days from sowing to 5% flowering.
Flowering (Flw.) period : Days from 5 % to 80% flowering.
Days to maturity : Days from sowing to 80% of grains per panicle turn yellow for rice and to the last harvest for *S. rostrata*.
S.D. : Standard deviation.

Days from sowing to flowering of *S. rostrata* varied largely depending on the sowing dates. When sown on June 30th (simultaneous sowing) its vegetative stage and flowering period (63 and 39 days, respectively) were longer than those in intermediate sowing (July 30th) and late sowing (August 30th) (Table 5). Pods matured at about 45-50 days after flowering. Later sowing resulted in poorer growth rates and a shorter duration. Sowing after July caused the growth rate and duration of *S. rostrata* to be severely reduced because it flowered early in 41-50 days after sowing. Generally, the growth duration of *S. rostrata* fits to the current cropping systems in the target area when intercropped during the main rainy season (Figure 3).

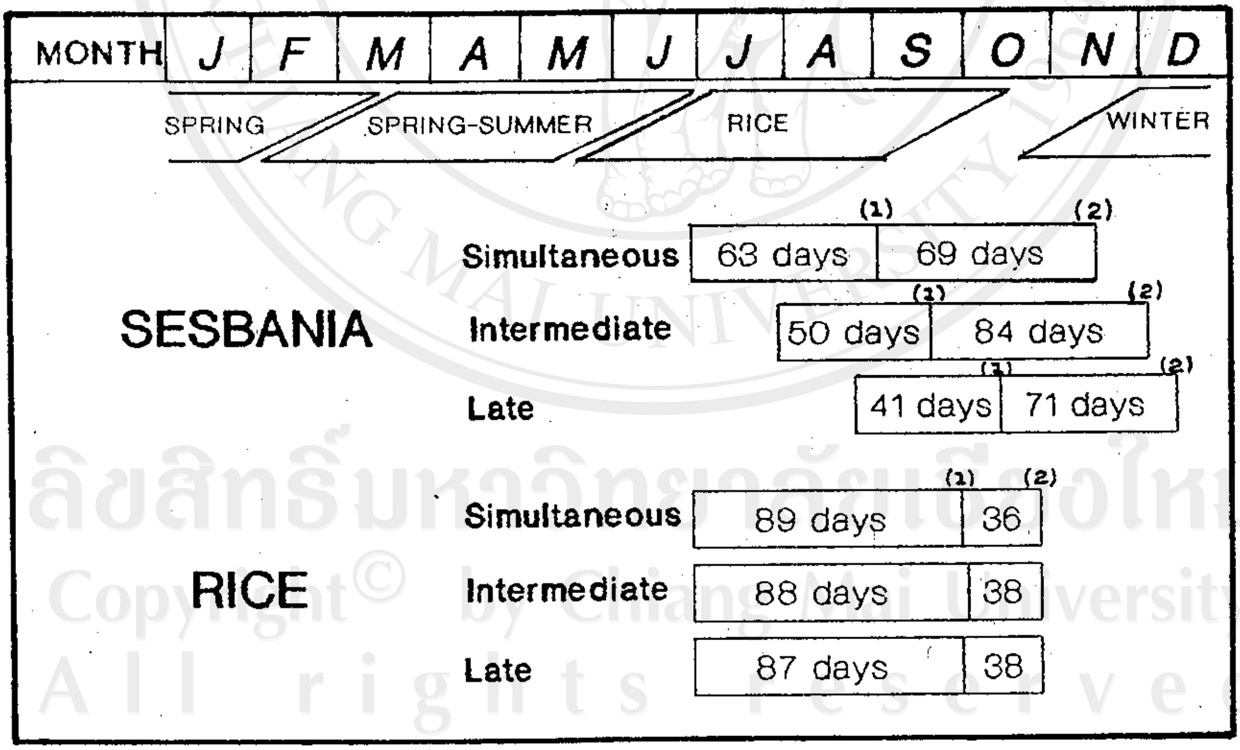

Figure 3: Growth duration of rice and *S. rostrata* in different mixtures related to current cropping system in the target area (1) onset of flowering, (2) finish of harvesting.

2.1.2. Plant height:

Rice increased its plant height slowly from transplanting to panicle initiation stage, but then increased more rapidly at the booting stage (45 days after transplanting-DAT until 60 DAT). Plant height of rice in intercrops, especially with simultaneous sowing of *S. rostrata*, increased faster than that in sole rice crop since 30-45 DAT (Fig. 4).

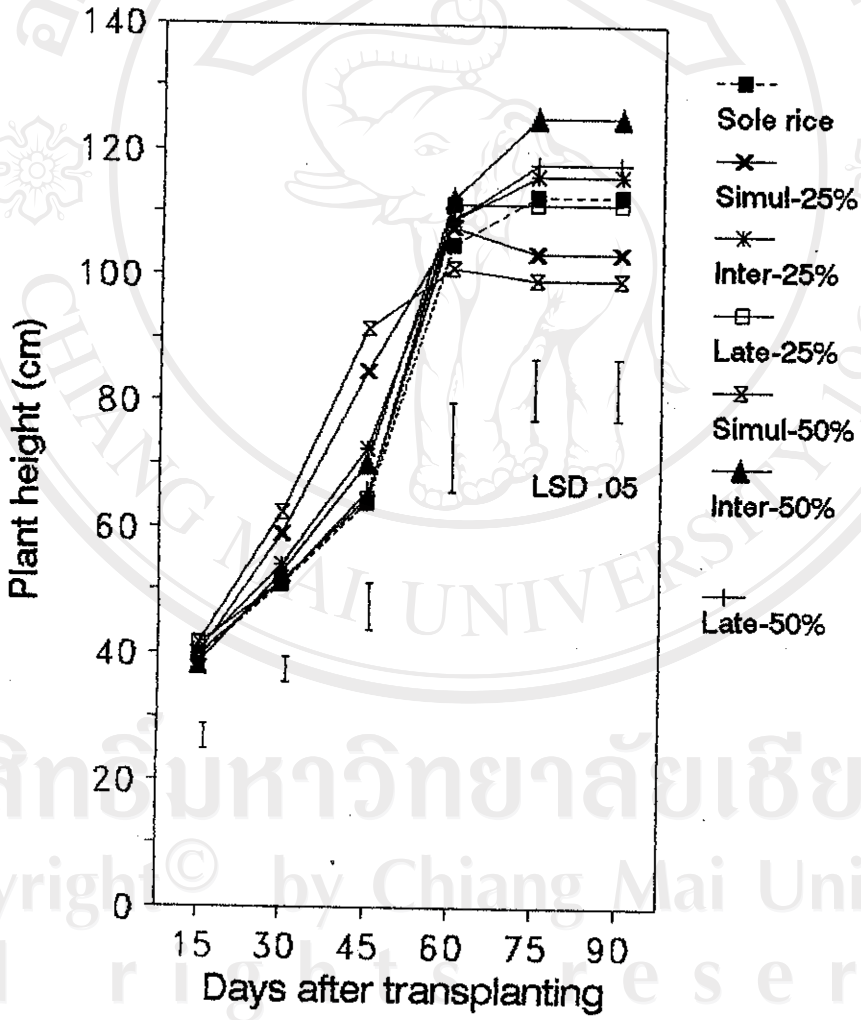

Figure 4. Plant height of rice as affected by intercropping and sowing date of *S. rostrata*.

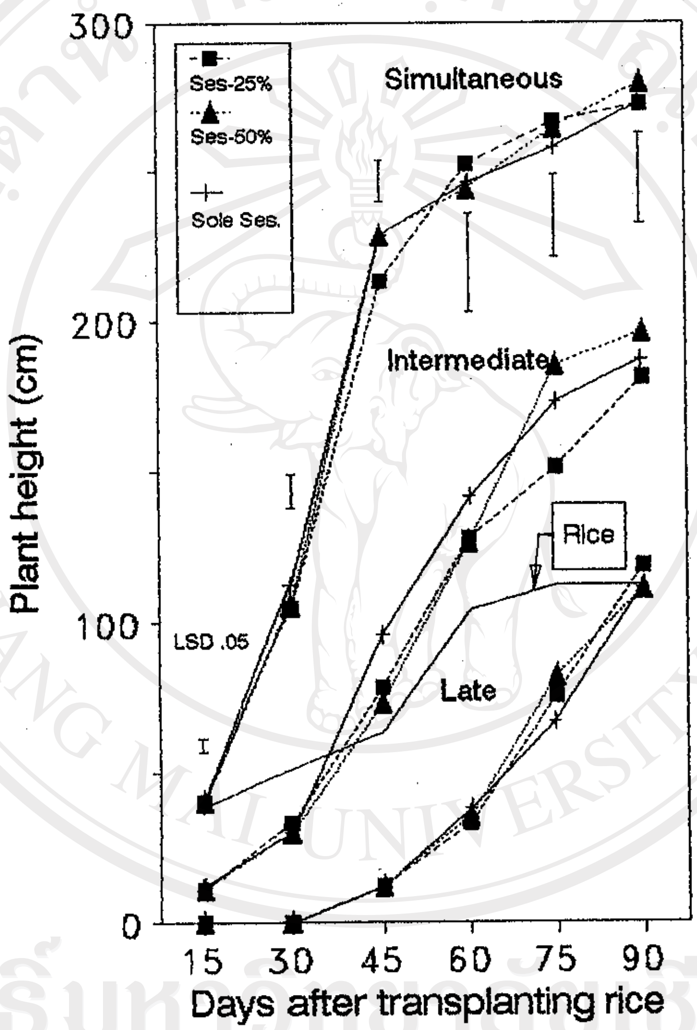

Figure 5. Plant height of *S. rostrata* as affected by intercropping and sowing date, compared with rice (———).

However, the differences in plant height were not significant at the flowering stage. At harvesting stage, the average plant height of rice was 100-125 cm, and was affected by the introduction date of *S. rostrata*. Only rice plants which were intercropped with a 50 % population in intermediate sowing of *S. rostrata* were significantly taller than the rice plants in sole crop. Simultaneous sowing both at 25 % or 50% of *S. rostrata* significantly reduced the plant height of rice (Fig. 4). In these treatments, *S. rostrata* started covering rice as early as 20 DAT (Fig. 5). In intermediate sowing plots, *S. rostrata* plants rose up over rice only after the completion of panicle initiation stage of rice (45 DAT). Late sowing of *S. rostrata* has no effect on plant height of rice. *S. rostrata* began to cover the rice when the rice was near maturity (90DAT). The maximum plant heights of *S. rostrata* were significantly reduced with the delay of sowing dates (275, 188 and 114 cm with simultaneous, intermediate and late sowing, respectively).

2.1.3. Tiller numbers:

Maximum tiller numbers of RD7 were reached at 30 DAT in all treatments. The maximum tiller numbers per hill were 12-13 when intercropped with 25% of *S. rostrata* (75% of rice population compared to sole crop) and 13-15 when intercropped with 50% of Sesbania (50% rice compared to sole crop). These numbers were significantly higher than that of rice in sole crop (9 tillers /hill) (Fig. 6). No interaction effect between intercropping density and sowing date of *S. rostrata* on tillering ability of rice was found. In the early introduction of *S. rostrata* (simultaneous sowing), the tillering ability of rice was severely depressed in both two intercropping treatments. The numbers of tillers per hill in these two intercropping proportions were similar to those in sole rice crop.

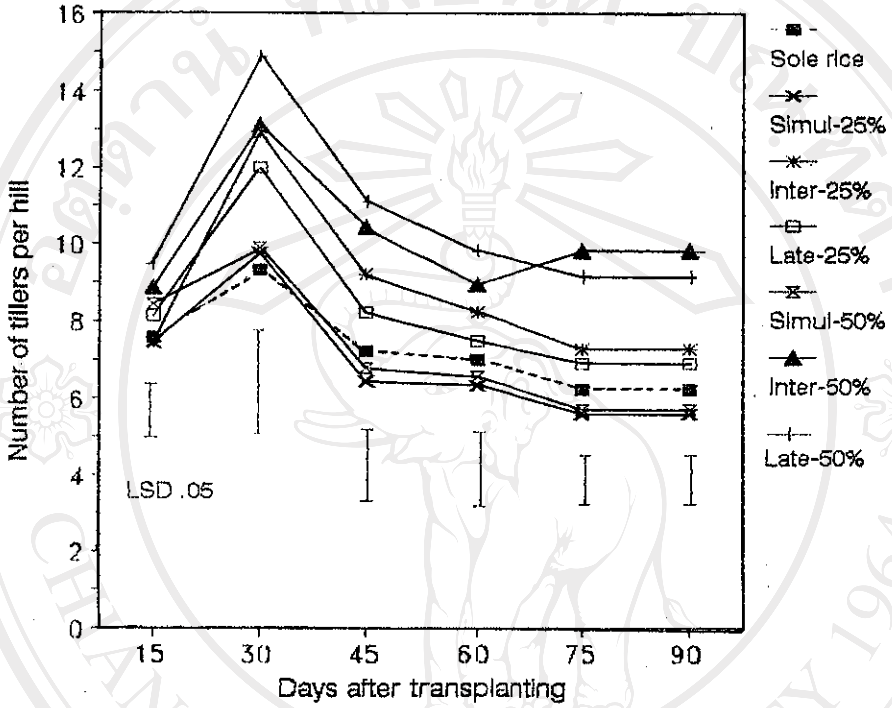

Figure 6. Tillering ability of rice as affected by intercropping and sowing date of *S. rostrata*

2.1.4. Leaf area index:

RD7 in sole crop produced maximum LAI at panicle initiation stage (45 DAT) when its leaves reached maximum size whereas, maximum LAI of rice in intercrop treatments were obtained at 60 DAT (Fig. 7). There was no significant difference in LAI of rice among treatments throughout the growing season. However, LAI tended to be less when more *S. rostrata* plants were added to the rice stands.

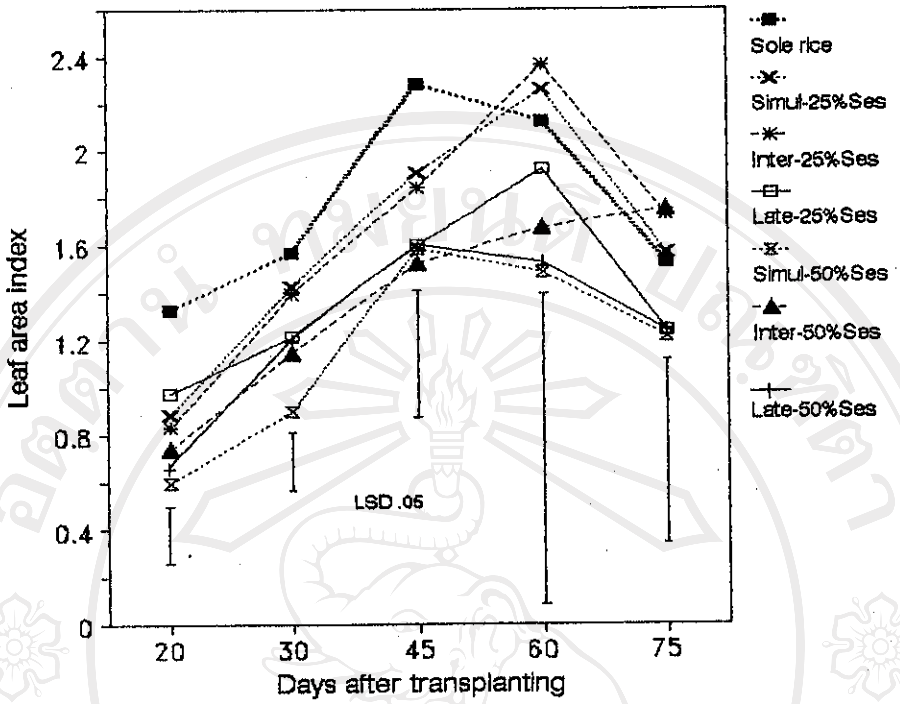

Figure 7. Leaf area index of rice as affected by intercropping and sowing date of *S. rostrata*.

2.2. Light penetration:

Figure 8 shows that, with the early introduction of *S. rostrata* (simultaneous sowing), rice was covered early by *S. rostrata* canopy. As early as 30 DAT, only 30-50% of light could reach to rice canopy, and the lowest light penetration (5-20% of maximum light interception) to the rice canopy occurred at 45 DAT (at booting stage). Although shading was alleviated after rice flowering, because *S. rostrata* littered its leaves, the light penetration was still low (about 30-40%). When *S. rostrata* was sown at transplanting time of rice (intermediate sowing), rice was almost free for tiller and panicle formation (before 45 DAT). But light penetration was significantly reduced in plots with high density of *S. rostrata*. In late sowing plots, more than 80% of solar radiation could reach rice canopy throughout the growing season.

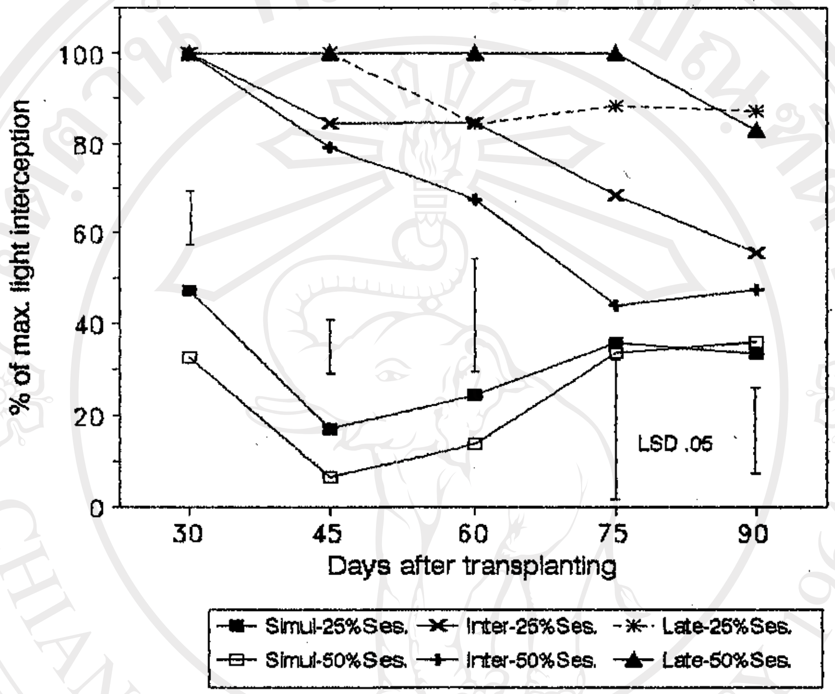

Figure 8. Light penetration on top of rice as affected by intercropping and sowing date of *S. rostrata* (% from the maximum light interception on the field at around noon).

2.3. Dry matter yield:

Rice:

The maximum dry matter of rice was obtained in sole crop (8.08 t/ha) at harvesting stage . Early sowing of *S. rostrata* markedly depressed dry matter of rice in intercrops with *S. rostrata* at either 25% or 50% of the population (Fig. 9). Delay of sowing *S. rostrata* (intermediate and late sowing) reduced the depressive effect of *S. rostrata* on the dry matter of rice.

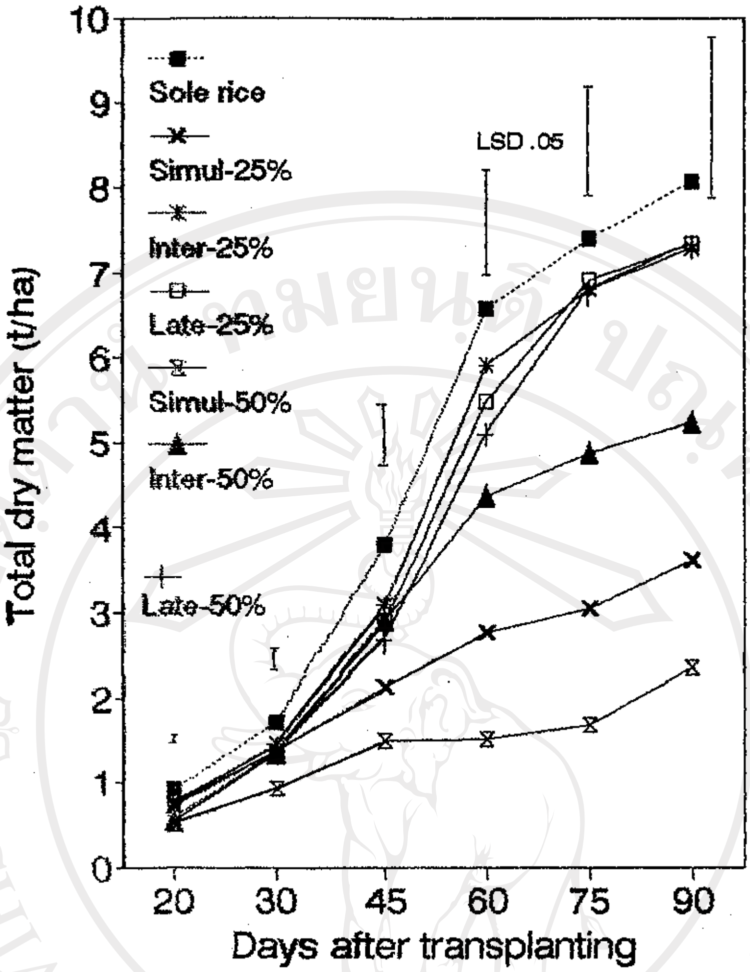

Figure 9. Total dry matter of rice as affected by intercropping and sowing date of *S. rostrata*.

At harvest, dry matter of rice was considerably depressed by the presence of *S. rostrata* (Table 6). In the case of intercropping, early sowing both at 25% or 50% of *S. rostrata* showed its significant negative effect on rice as compared to the other treatments. Total dry matter of rice was significantly depressed when *S. rostrata* was sown at the transplanting time of rice (intermediate) at 50% of the population, but the effect was not significant when intercropped with a lower proportion of *S. rostrata* (25%).

Table 6. Dry matters of rice and *S. rostrata* at harvest of rice as affected by intercropping and sowing date of *S. rostrata*.

Cropping systems	Time of Introduction	Rice (t/ha)	Sesbania Leaf (t/ha)	Sesbania Nodule (t/ha)	Sesbania Stem (t/ha)	Sesbania Total (t/ha)
Sole rice	-	8.08	-	-	-	-
Intercrop						
75R : 25S	Simultaneous	3.62	0.36	0.13	8.43	8.91
	Intermediate	7.29	0.28	0.06	2.61	2.96
	Late	7.34	0.11	0.02	0.40	0.52
50R : 50S	Simultaneous	2.36	0.33	0.18	11.41	11.93
	Intermediate	5.24	0.58	0.11	5.50	6.20
	Late	7.42	0.21	0.04	0.76	1.00
Sole Sesbania						
	Simultaneous	-	0.58	0.27	16.56	17.42
	Intermediate	-	0.59	0.18	9.19	9.96
	Late	-	0.58	0.08	2.25	2.91
Grand mean		5.91	0.40	0.12	6.35	6.87
CV (%)		17.7	38.0	27.1	32.5	31.8
LSD .05		1.86	0.27	0.06	3.57	3.79
LSD .01		2.60	0.37	0.08	4.92	5.22

75R:25S: 75 % Rice and 25 % *S. rostrata* intercropped;
50R:50S: 50 % Rice and 50 % *S. rostrata* intercropped.

Sesbania

Dry matter of *S. rostrata* increased very fast from 30 DAT (or 60 days after sowing) with the early sowing date; about 45 days after sowing with the intermediate and late sowing dates when *S. rostrata* plants were about to flower. When compared at the same age, growth rates of *S. rostrata* in different sowing dates were similar at the early stage. The differences in dry matter began after 75 days from sowing. Delaying the sowing date reduced growth rate and dry matter yield of *S. rostrata* (Figure 10).

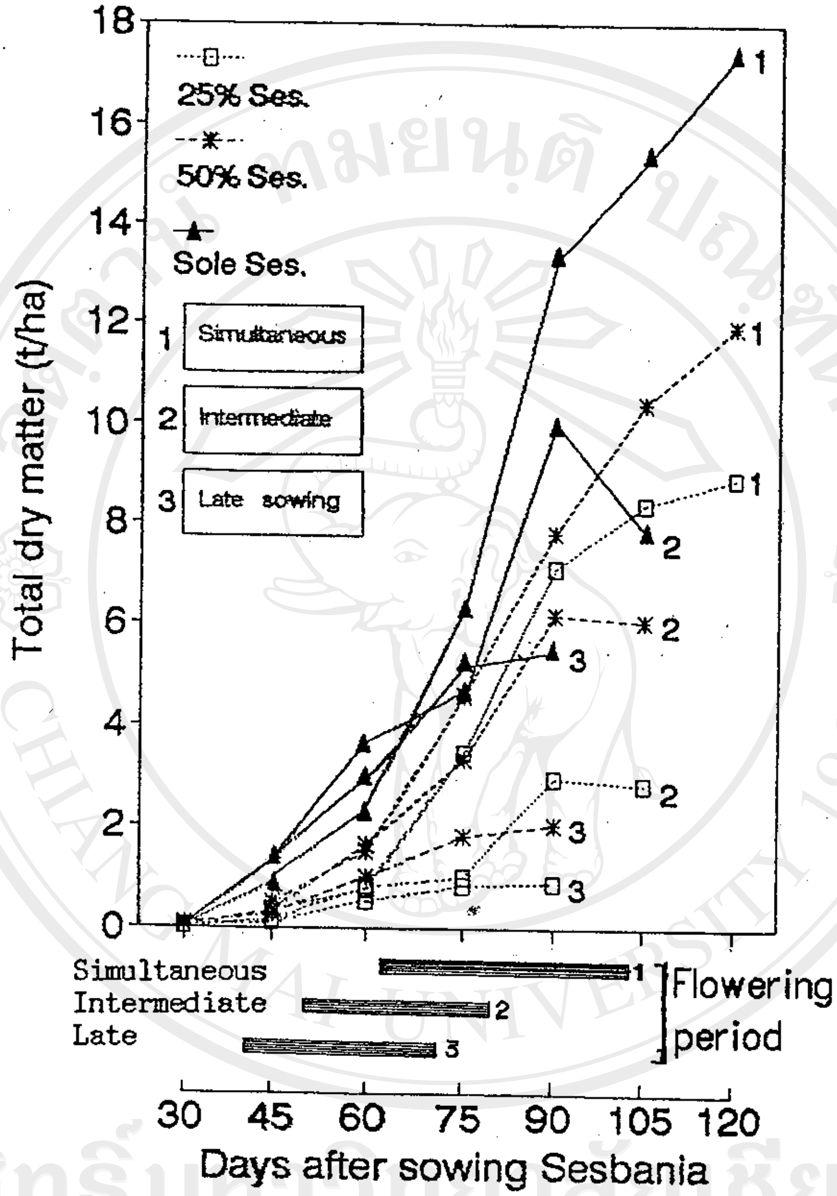

Figure 10. Total dry matter of *S. rostrata* as affected by intercropping and sowing date.

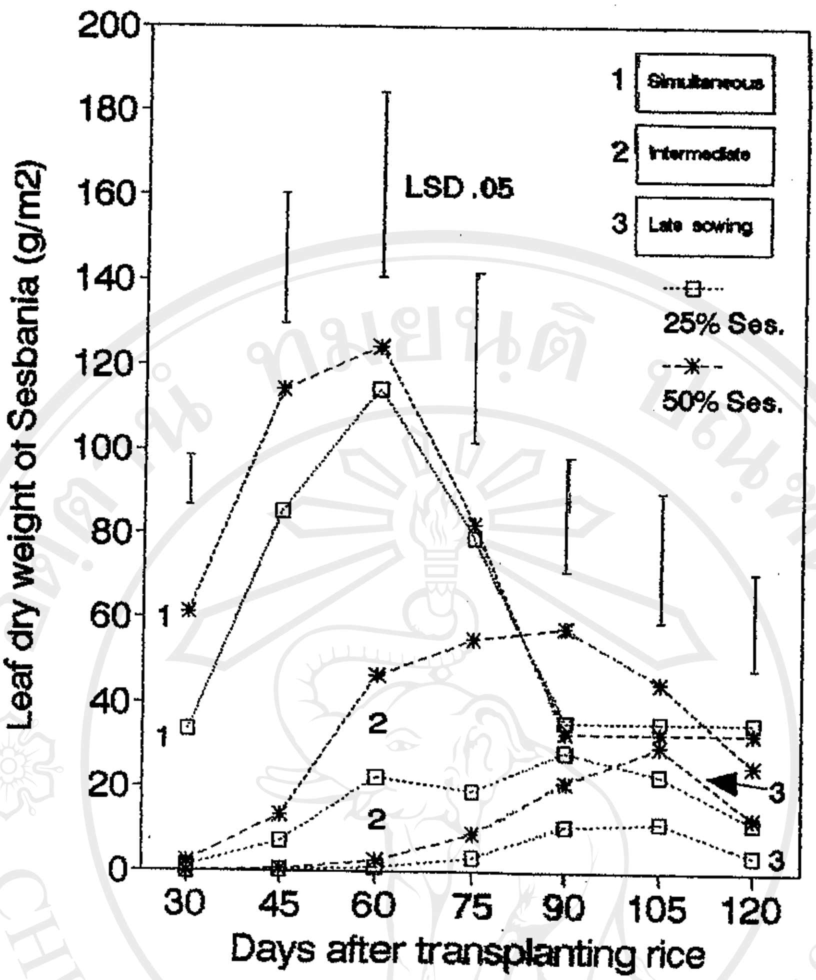

Figure 11. Leaf dry weight of *S. rostrata* as affected by intercropping and sowing date.

The maximum dry matter of *S. rostrata* which was obtained from early sowing and sole cropping was significantly greater than that from late sowing and intercropping (Table 6).

Research has tended to focus on leaf dry matter of *S. rostrata* because it has a high content of nitrogen, and almost all leaves are littered on the field. *S. rostrata* started littering its leaves by 45 DAT in simultaneous sowing, and 60 DAT in intermediate sowing (Fig. 11). The amount of leaves littered during the growing period could not be exactly estimated. However, the actual amount of littered leaves was thought to be much higher because the *S. rostrata* plants continuously produced new leaves while the old leaves dropped. At the time of rice harvest, leaf dry matter of *S. rostrata* was about 100-600 kg/ha (Table 6). Intercropping caused the decrease in leaf and shoot dry matter per ha as compared to sole crop.

2.4. Yield and yield components:

Rice:

The higher the density of *S. rostrata* intercropped, the greater the reduction in the number of panicles /m2, and the percentage of filled grains and grain weight. Additionally, a lower yield of rice could be observed (Table 7). It is also noted that the presence of *S. rostrata* in intercrops caused some difficulties in harvesting rice.

Table 7. Grain yield and yield components of rice as affected by intercropping and sowing date of *S. rostrata*.

Cropping systems	Time of Introduction	Panicle number /m2	Spikelet number /panicle	Filled grains (%)	1000grain weight (g)	Grain yield (t/ha)	Harvest index
Sole rice	-	197	95	68.1	29.9	3.47	0.43
Intercrop							
75R : 25S	Simultaneous	120	51	42.7	24.8	0.79	0.18
	Intermediate	192	97	64.3	29.0	2.76	0.38
	Late	166	101	72.5	29.9	3.42	0.47
50R : 50S	Simultaneous	53	49	30.6	24.8	0.29	0.08
	Intermediate	146	98	52.8	28.5	1.71	0.33
	Late	158	115	70.8	30.0	3.36	0.45
Sole Sesbania		-	-	-	-	-	-
Grand mean		147	87	57.4	28.1	2.26	0.35
CV (%)		13.2	23.0	25.2	5.7	22.6	18.5
LSD .05		35	35	25.7	2.8	0.91	0.11
LSD .01		49	50	36.1	4.0	1.27	0.16

75R:25S: 75 % Rice and 25 % *S. rostrata* intercropped;
50R:50S: 50 % Rice and 50 % *S. rostrata* intercropped.

At early sowing date of *S. rostrata* (simultaneous sowing) all yield components of rice were severely depressed, especially those with 50% of *S. rostrata*, and rice yield was almost nil (0.29 t/ha).

The number of spikelets/panicle was markedly reduced by intercropping with simultaneous sowing of *S. rostrata*. Delaying of *Sesbania* establishment could reduce the negative effects of *S. rostrata* on most yield components, and on grain yield of intercrop rice. Sowing *S. rostrata* at 30 DAT (late sowing), either with 25% or 50% of the population, gave the same rice yield as sole crop; even though the number of panicles/m2 were low, the number of spikelets /panicle, and the percentage of filled grains and grain weight of rice were high.

When *S. rostrata* was sown at the time of transplanting rice (intermediate sowing), rice yield in plots with 50% of *S. rostrata* (1.71 t/ha) was markedly reduced, but the yield of those with 25% of *S. rostrata* (2.76 t/ha) was comparable to sole rice yield (3.47 t/ha).

Harvest index had the same response pattern among treatments as grain yield. An average of 45% of assimilation materials was accumulated in grains of sole rice. Simultaneous sowing of *S. rostrata* caused a significant decrease in the harvest index of intercrop rice. Fewer productive tillers, lower numbers of spikelets per panicle, and small hull size limited the sink of rice plants in these plots.

Sesbania:

Seed yield of as much as 3 t/ha or more of *S. rostrata* could be obtained with simultaneous sowing. Delayed sowing of *S. rostrata* caused a significant reduction in all yield components, as well as seed yield of *S. rostrata*, due to poor plant growth and short duration (Table 8).

Table 8. Seed yield and yield components of *S. rostrata* as affected by intercropping and sowing date.

Cropping systems	Time of Introduction	Pods /m2	Seeds /pod	1000seed weight (g)	Seed yield (t/ha)	Shelling (%)
Sole rice	-	-	-	-	-	-
Intercrop						
75R : 25S	Simultaneous	488	29	21.2	3.00	64.1
	Intermediate	251	25	19.8	1.30	58.3
	Late	53	21	12.3	0.14	42.9
50R : 50S	Simultaneous	582	30	21.0	3.55	63.3
	Intermediate	355	24	22.4	1.98	61.0
	Late	114	17	14.5	0.29	42.0
Sole Sesbania						
	Simultaneous	616	28	21.3	3.68	66.5
	Intermediate	600	26	20.9	3.32	61.9
	Late	363	25	20.0	1.82	61.4
Grand mean		380	25	19.3	2.12	57.9
CV (%)		23.7	9.2	7.5	25.5	4.7
LSD .05		156	4	2.5	0.94	4.7
LSD .01		215	5	3.4	1.29	6.4

75R:25S: 75 % Rice and 25 % *S. rostrata* intercropped;
50R:50S: 50 % Rice and 50 % *S. rostrata* intercropped.

S. rostrata sole crops gave higher seed yield than intercrops due to higher density. With low density in intercrops, the *S. rostrata* plants were bigger, and the number of pods per plant was higher. However, the number of pods per m2 were still low.

Intercropping with rice caused a reduction in all yield components of *S. rostrata*, especially when sown late in August. Seed yield of *S. rostrata* in late sowing treatments were extremely low (140 kg with 25% and 290 kg/ha with 50% intercropped); the seeds were also small in size (less than 15 g/1000 seeds) and of questionable viability. Low number of pods per m2 and small seeds were the main reasons for the low yield from these treatments.

Seed yields of intercrop *S. rostrata* sown at the time of transplanting rice (intermediate) were significantly lower than those of sole cropping, and all simultaneous sowing treatments. However, they were still high enough for seed production purposes (1.30 and 1.98 t/ha with 25% and 50% of intercrop *S. rostrata*, respectively).

Shelling (% of seed weight/pod weight) was higher in early sowing intercropping and sole cropping than in other treatments.

All combinations of intercrops showed the advantages of intercropping over sole cropping (RYT > 1) in terms of dry matter and seed yield, regardless of population ratios or sowing date of *S. rostrata* (Table 9). However, the contribution of each component crop to total dry matter and seed yield depended especially on the time of *Sesbania* establishment (Figure 12).

When time was taken into account, only early sowing of Sesbania (simultaneous) showed advantage (ATER > 1) from all proportions of intercropping. However, sowing *S. rostrata* into rice field at transplanting time (intermediate) with 25% of Sesbania population gave an acceptable ATER (0.91) (Table 9).

Table 9. Relative Yield Total (RYT) and Area Time Equivalent Ratio (ATER) in different proportions and times of *Sesbania* introduction to rice stand related to seed yield.

Proportion of Rice:Sesbania	Time of introduction					
	Simultaneous		Intermediate		Late	
	RYT	ATER	RYT	ATER	RYT	ATER
75R : 25S	1.06	1.04	1.16	0.91	1.06	0.77
50R : 50S	1.06	1.05	1.09	0.87	1.12	0.82
Mean	1.06	1.04	1.12	0.89	1.09	0.79
LSD .05	ns	0.11	ns	0.11	ns	0.11
LSD .01	-	0.15	-	0.15	ns	0.15

75R:25S: 75 % Rice and 25 % *S. rostrata* intercropped;
50R:50S: 50 % Rice and 50 % *S. rostrata* intercropped.

2.5. Nodulation and nitrogen yield:

2.5.1. Nodulation:

Table 6 also showed that nodule dry matter of *S. rostrata* depended mainly on the age of *Sesbania* plants, as nodule dry matter was greater in the earlier sown treatments of each cropping system. At the time of rice harvest, *Sesbania* plants were at the ages of 120, 90 and 60 days-old in simultaneous, intermediate and late sowing treatments, respectively.

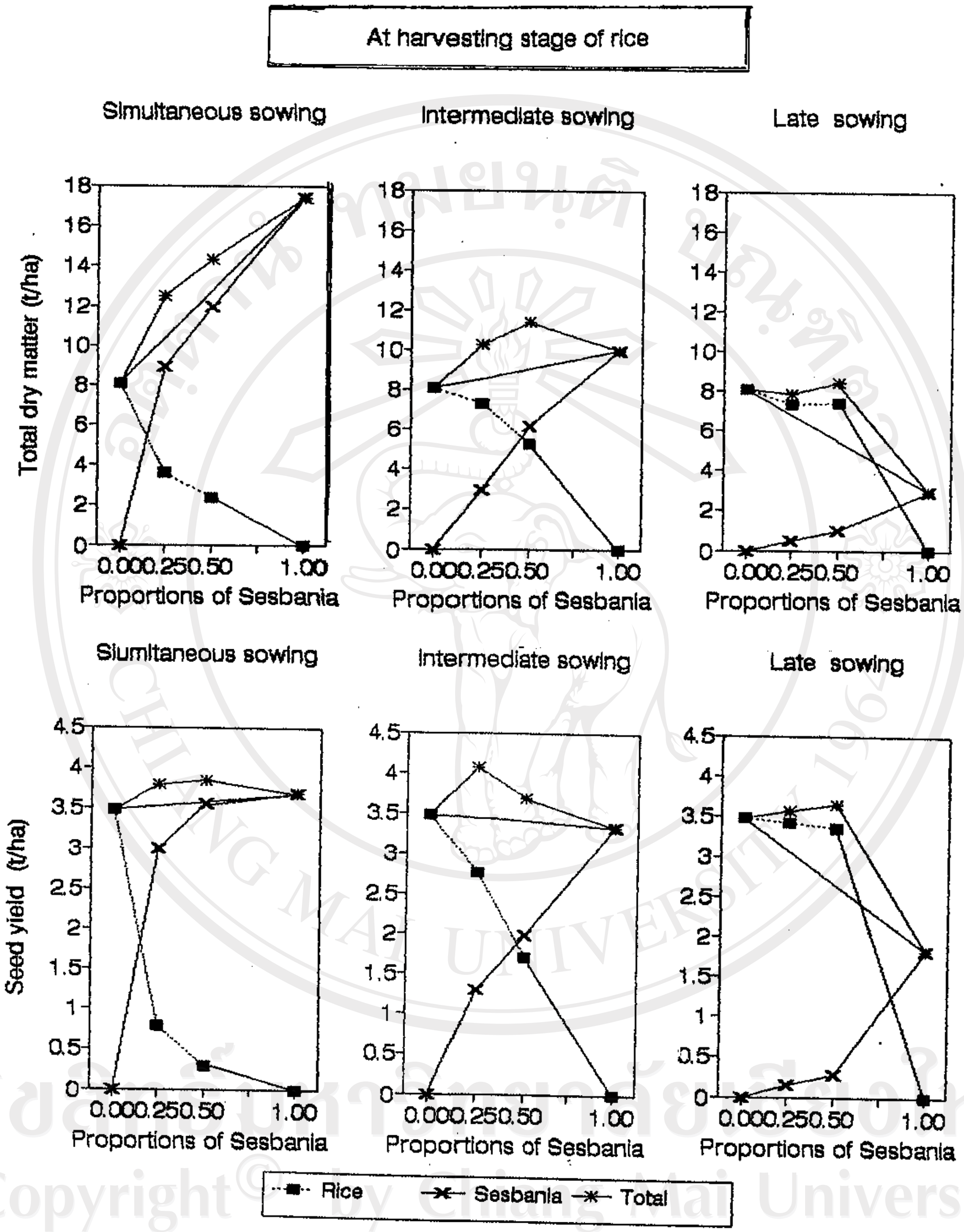

Figure 12. Shoot dry matter and seed yield of rice and *S. rostrata* as affected by intercropping and sowing date of *S. rostrata*.

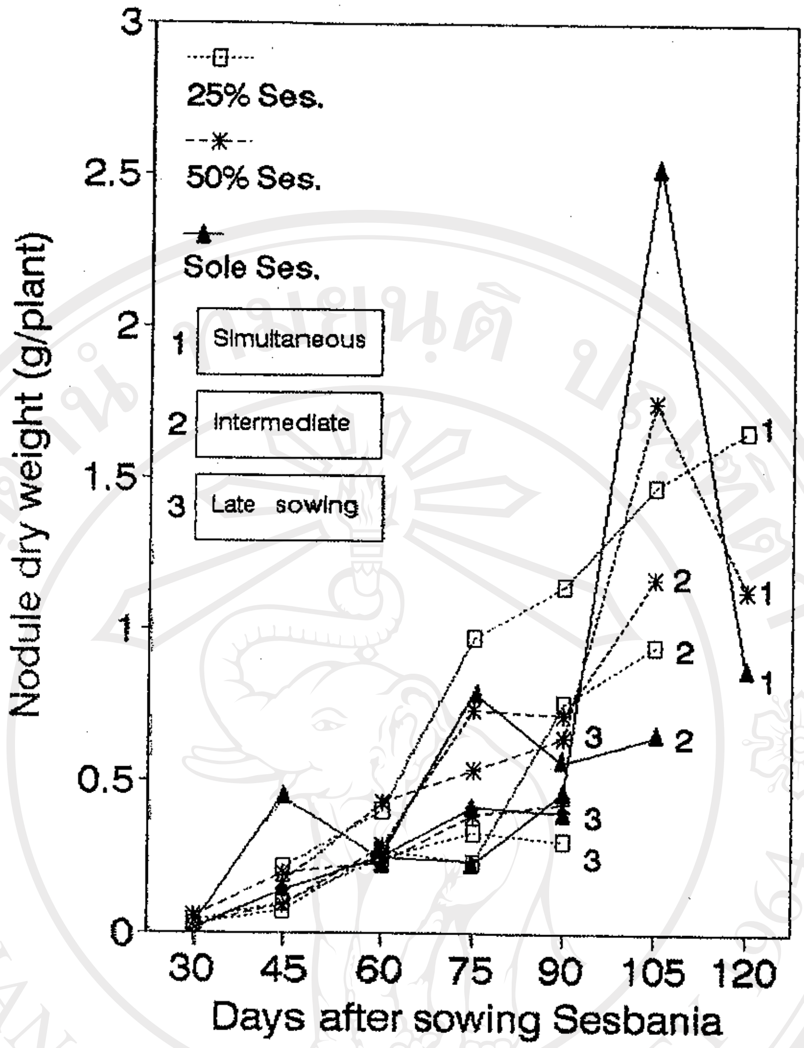

Figure 13. Nodulation of *S. rostrata* varied with ages and affected by intercropping and sowing date.

One month differences in age resulted in significant differences in nodule dry weight means (196, 118 and 45 kg/ha from simultaneous, intermediate and late sowing, respectively). At the same plant age in different sowing dates and plant proportions of intercropping, the nodule dry weight of individual plants was slightly depressed by the presence of rice in the case of intercropping (Fig. 13). Nodule dry weight per plant increased slowly at first with the presence of rice. The rate of increase in nodule dry weight rose sharply after harvesting rice.

Table 10. Nitrogen content (%) in rice at harvesting stages as affected by intercropping and sowing date of *S. rostrata*.

Cropping systems	Time of Introduction	Parts of plant		
		Straw	Grain	Total
Sole rice		0.55	1.15	0.81
Intercrop				
75R : 25S	Simultaneous	1.50	1.87	1.58
	Intermediate	0.68	1.27	0.90
	Late	0.58	1.09	0.82
50R : 50S	Simultaneous	1.59	1.82	1.61
	Intermediate	0.91	1.40	1.07
	Late	0.58	1.08	0.81
Sole Sesbania		-	-	-
Grand mean		0.91	1.33	1.02
CV (%)		27.2	14.6	19.0
LSD .05		0.44	0.36	0.34
LSD .01		0.62	0.50	0.46

75R:25S: 75 % Rice and 25 % *S. rostrata* intercropped;
50R:50S: 50 % Rice and 50 % *S. rostrata* intercropped.

2.5.2. Nitrogen yield:

Rice:

Analysis of nitrogen content in rice at harvesting stages indicated that nitrogen content in the shoot and grain of rice intercropped with *S. rostrata* was significantly higher than that in sole rice. Furthermore, early sowing of *S. rostrata* provided more N content in associated rice crop than did intermediate and late sowing (Table 10). Field observers also noticed the differences in the color of the rice leaves: dark green in intercrop and pale green in sole crop treatments.

Total amount of N-uptake of rice was about 65 kgN/ha in sole cropping and less than 55 kgN/ha in intercropping plots (Table 11). N-uptake of rice in intercropping with 50% *S. rostrata* sown simultaneously was significantly lower than that of the others. The effects of intercropping on N-uptake of rice were more severe in simultaneous sowing but less or none in intermediate and late sowing of *S. rostrata*. The interaction effects between intercrop density and sowing date of *S. rostrata* were apparent on N yield in grain. The earlier the establishment of *S. rostrata* took place, and the denser the *S. rostrata* plants intercropped, the lower the amount of N was transferred into rice grains. More than 60% of N-uptake was transferred into grains in intercrop rice with late sowing of *S. rostrata*, which was the same as that in sole rice. Approximately 43-53% of N-uptake was deposited in grains of intercrop rice with intermediate sowing and only 12-23% with simultaneous sown *Sesbania*.

Table 11. Nitrogen yield (kg/ha) of rice at harvesting stage as affected by intercropping and sowing date of *S. rostrata*.

Cropping systems	Time of Introduction	Parts of plant		
		Straw	Grain	Total
Sole rice		25.3	40.0	65.4
Intercrop				
75R : 25S	Simultaneous	39.8	12.0	51.8
	Intermediate	31.0	35.0	66.0
	Late	22.6	37.4	60.0
50R : 50S	Simultaneous	30.5	4.2	34.7
	Intermediate	31.8	23.7	55.5
	Late	23.8	36.2	60.1
Sole Sesbania		-	-	-
Grand mean		29.3	26.9	56.2
CV (%)		23.6	24.2	16.6
LSD .05		12.3	11.6	16.6
LSD .01		17.2	16.2	23.3

75R:25S: 75 % Rice and 25 % *S. rostrata* intercropped;
50R:50S: 50 % Rice and 50 % *S. rostrata* intercropped.

Sesbania:

Average N-contents were 4.27 % in Sesbania leaf, 1.97 % in stem, 5.05 in seed (Table 12). Intercropping with different proportions had no effect on N-content of *S. rostrata*. No interaction effect was found between sowing date and proportion of *S. rostrata* on N-content in leaf and stem. Nitrogen content in seed was significantly higher in simultaneous and intermediate sowing than in late sowing of *S. rostrata*. However, the younger plants, due to delayed sowing, contained higher N in stem.

Table 12. Nitrogen content (%) in *S. rostrata* at harvesting stage of rice as affected by intercropping and sowing date.

Cropping systems	Time of Introduction	Parts of plant		
		Leaf	Stem	Seed
Sole rice	-	-	-	-
Intercrop				
75R : 25S	Simultaneous	4.24	1.60	5.27
	Intermediate	3.92	2.20	5.52
	Late	4.40	2.10	4.27
50R : 50S	Simultaneous	4.44	1.21	5.11
	Intermediate	3.83	1.92	5.28
	Late	4.89	2.43	4.52
Sole Sesbania				
	Simultaneous	4.55	1.32	5.13
	Intermediate	3.60	2.24	5.35
	Late	4.59	2.68	5.05
Grand mean		4.27	1.97	5.05
CV (%)		11.71	13.54	20.02
LSD .05		ns	ns	0.44
LSD .01		ns	ns	0.60

75R:25S: 75 % Rice and 25 % *S. rostrata* intercropped;
50R:50S: 50 % Rice and 50 % *S. rostrata* intercropped.

N-yield of *S. rostrata* reached maximum points at about 90 days after sowing. Delayed sowing caused the decrease in N-yield of *S. rostrata* due to the decrease in total dry matter (Table 13). Intercropping with rice reduced the plant populations of *S. rostrata* and then caused the significant reduction in N-yield of *S. rostrata* as compared to sole cropping. There was no significant difference in N-yield from all parts of *S. rostrata* plants when intercropped at 25% to 50% of overall population.

Table 13. Nitrogen yield (kg/ha) of *S. rostrata* at harvesting stage of rice as affected by intercropping and sowing date.

Cropping systems	Time of Introduction	Parts of plant			Total
		Leaf	Stem	Seed	
Sole rice	-	-	-	-	-
Intercrop					
75R : 25S	Simultaneous	14.4	143.3	158.4	316.1
	Intermediate	11.1	58.6	74.3	144.0
	Late	4.8	8.6	6.3	19.7
50R : 50S	Simultaneous	14.2	142.0	180.7	337.0
	Intermediate	12.6	110.0	105.3	237.8
	Late	10.3	19.2	13.3	42.8
Sole Sesbania					
	Simultaneous	27.0	224.1	189.0	440.2
	Intermediate	20.8	226.4	177.7	424.9
	Late	26.1	62.1	92.1	180.3
Grand mean		16.8	110.5	110.8	238.1
CV (%)		39.5	48.3	25.8	31.4
LSD .05		11.5	92.3	49.4	129.6
LSD .01		15.8	127.2	68.1	178.6

75R:25S: 75 % Rice and 25 % *S. rostrata* intercropped;
50R:50S: 50 % Rice and 50 % *S. rostrata* intercropped.

At the end of growing season, RYT and ATER for nitrogen yield were calculated. Table 14 shows the advantages of all intercropping combinations over sole cropping, when *S. rostrata* was sown simultaneously and intermediately with rice (RYT and ATER > 1). Late sowing of *S. rostrata* did not perform well, and took longer to complete the growing period (low values of RYT and ATER < 1). *S. rostrata* was the main N-contributor to the systems with simultaneous sowing. In intermediate sowing, *S. rostrata* became dominant only after rice flowering. However, in late sowing of *S. rostrata*, rice took a large share of the N-yield in the systems (Figure 14).

Table 14. Relative Yield Total (RYT) and Area Time Equivalent Ratio (ATER) in different proportions and times of *Sesbania* introduction to rice stands related to total nitrogen yield.

Proportion of Rice : Sesbania	Time of introduction					
	Simultaneous		Intermediate		Late	
	RYT	ATER	RYT	ATER	RYT	ATER
75R : 25S	1.50	1.46	1.34	1.04	1.02	0.75
50R : 50S	1.31	1.28	1.43	1.12	1.15	0.85
Mean	1.32	1.29	1.33	1.04	1.08	0.80
LSD .05	0.16	0.14	0.16	0.14	0.16	0.14
LSD .01	0.22	0.19	0.22	0.19	0.22	0.19

75R:25S: 75 % Rice and 25 % *S. rostrata* intercropped;
50R:50S: 50 % Rice and 50 % *S. rostrata* intercropped.

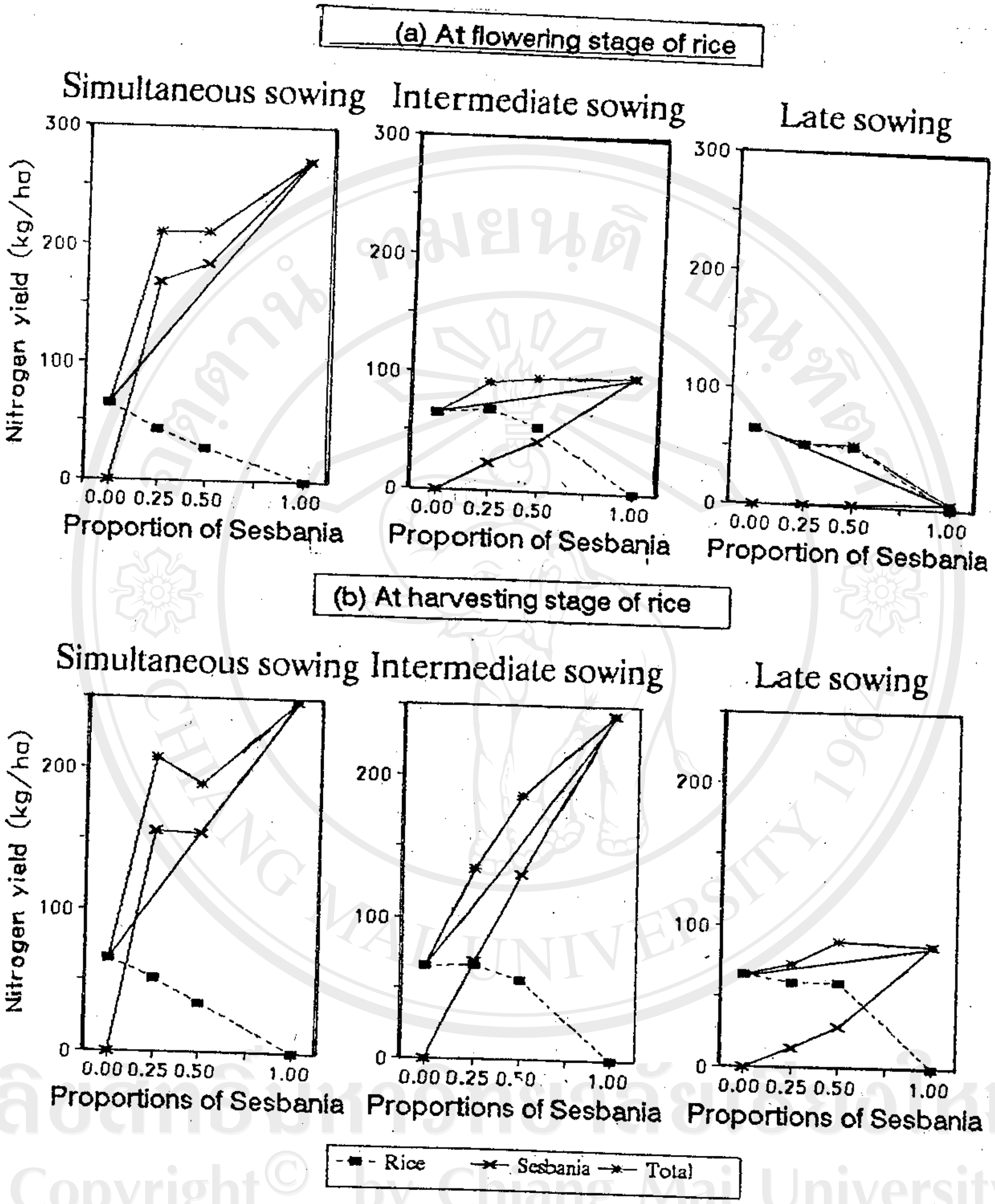

Figure 14. Nitrogen yield of the systems at flowering and harvesting stages of rice as affected by intercropping.

2.5.3. Nitrogen fixation:

The amount of N-fixed by a certain system was estimated from the difference between the total N-yield of that system and the soil N-budget which was absorbed by sole rice crop as a control treatment.

Column (a) in table 15 shows that *S. rostrata* with simultaneous sowing could fix as much as 300 kg N/ha or more, even in the case of intercropping with rice. With intermediate sowing at as low as 25 % of the population, *S. rostrata* could also yield more than 140 kg N/ha. However, intercrops with late sowing have shown very low potential of N-fixation.

2.6. Simple N-balance:

If all crop residues were returned to and retained within the soil after harvesting seeds, N-balance would be shown as in column b table 15. Intercropping *S. rostrata* with rice enriched soil fertility, represented by positive N balance of 36-132 kgN/ha (excepting the treatments with late sowing). However, *S. rostrata*-Rice intercrop with late sowing still seemed better than sole rice treatment, even though it had a negative N-balance. Early sowing can produce higher amounts of N to improve soil fertility. N gained from the systems depended mainly on the proportion of *S. rostrata*.

In the case that all stems of *S. rostrata* were removed and used as firewood, and only rice straws and *Sesbania* leaves were returned to the soil, all treatments had the negative N-balance (Column (c)). However, the absolute values of N-balance showed that intercropping with simultaneous and intermediate sowing of *S. rostrata* had less depletion impact to the soil than did sole rice or sole *S. rostrata.*

Table 15. Total nitrogen yield, nitrogen fixation and nitrogen balance of different cropping systems.

Cropping systems	Time of Introduction	Nitrogen yield (kg/ha)			N-fixed (kg/ha)	N-balance (kg/ha)	
		Straw	Seed	Total	(a)	(b)	(c)
Sole rice		25	40	65	-	-40	-40
Intercrop							
75R:25S	Simultaneous	197	170	367	302	132	-11
	Intermediate	101	109	210	145	36	-23
	Late	36	44	80	15	-29	-38
50R:50S	Simultaneous	187	185	372	307	122	-21
	Intermediate	164	129	293	228	99	-11
	Late	53	50	103	38	-12	-31
Sole Sesbania							
	Simultaneous	251	189	440	375	186	-38
	Intermediate	247	178	425	360	182	-45
	Late	88	92	180	115	23	-39
Grand mean		135	119	254	188	70	-30
CV (%)		41	22	29	39	51	31
LSD .05		96	44	125	125	96	16
LSD .01		131	61	172	172	131	22

(a) N-fixed = Total N-yield from the whole system - Total N-yield from sole rice.

(b) In the case of all crop residues returned to the soil:
N-balance = N-yield in straw of the whole system - N-uptake by sole rice
= N-fixed - N-removed by seeds

(c) In the case of only rice straw and Sesbania leaves returned to the soil:
N-balance = (N-yield in straw of rice
+ N-yield in leaf of *S. rostrata*)
- N-uptake by sole rice (65 kgN/ha)