CHAPTER 4

RESULTS OF THE STUDY

4.1 Field surveys

4.1.1 Natural conditions of the study site

Geographically, the North-East mountainous region of Vietnam is situated from $21^{o}5'$ to $23^{o}15'$ North latitude, and from $105^{o}35'$ to $108^{o}5'$ East longtitude. It consists of five provinces: Cao bang, Lang son, Bac thai, Quang ninh and a part of Habac, with an area of 33668 km^2, occupying 11,6 % of total land area of the country (Fig. 1). This region is characterized by chains of earth and lime-stone mountain running along the direction from North-West to South-East. The elevation ranges from 36 to 1900 m above mean sea level.

Most of agricultural lands belong to steep land on the hills with slope varying from 15 to 30 %, and flat land in the narrow valleys laying between hills or mountains. In general, agricultural land is degraded seriously due to deforestation and inappropriate cultivation. leading to severe erosion (Dau et al., 1991; Sam, 1994).

Acording to General Statistical Office (1993), the percentage of forest coverage was quite low, and the area of bare hill with serious erosion during rainy season and very low soil fertility occupied a large area in the region (Table 3). These caused big obstacles in development of agroforestry in this region.

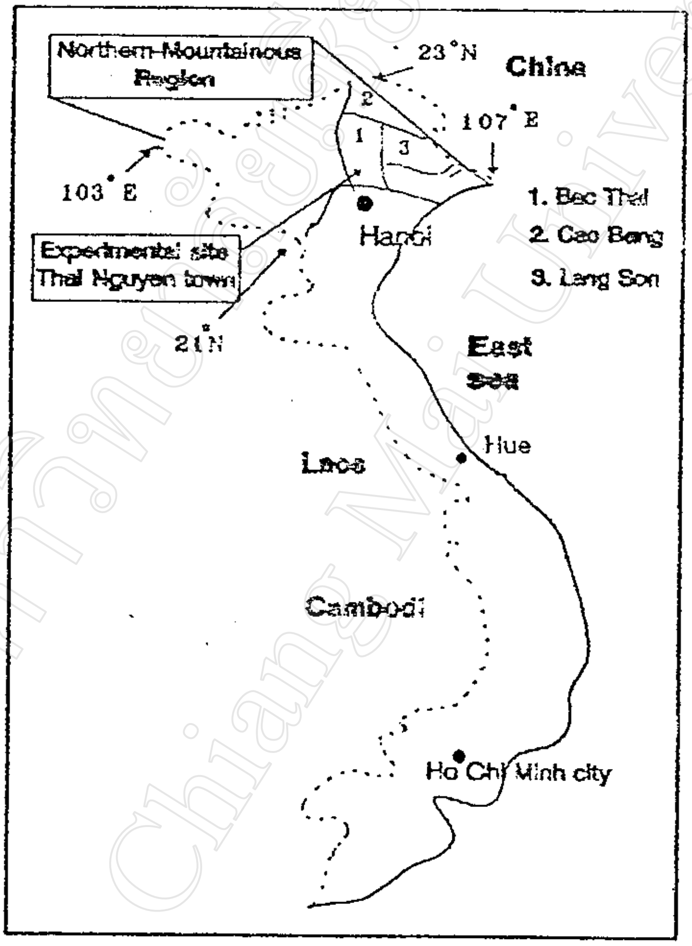

Fig. 2 Vietnam map and the study site

Table 3. The forest area in 1993 of the region

Provinces	Total area (1000 ha)	Forestry area (1000 ha)	level of coverage (%)
Cao bang	844.5	119.5	14.9
Bac thai	650.3	166.6	25.6
Lang son	816.7	140.4	17.2
Quang ninh	593.9	149.7	25.2
Ha bac	461.4	77.6	16.8
Total	3366.8	653.8	19.7

Source: General Statistical Office. Department of Agriculture and Forestry and Fishery, 1993.

Acidity and low soil fertility is main limiting factor to development of agriculture of the region. The results in analyzing soil chemical properties of 3 villages that are representative for 3 provinces in the region are illustrated in Table 4.

Table 4. Some soil chemical properties of 3 surveyed villages

Indicators	Lung rieng (Cao bang, n=9)		Um (Bac thai, n=10)		Pa rang (Lang son, n=9)	
	GM	SD	GM	SD	GM	SD
$pH_{(KCl)}$	5.2	0.58	4.7	0.24	4.6	0.28
N (%)	0.14	0.036	0.12	0.038	0.14	0.037
P(ppm)	5.14	1.13	3.71	0.77	4.76	0.84
K(ppm)	58.3	5.78	54.2	5.22	60.4	6.20

Note: n number of soil samples taken

Climatically, the North-East region is characterized by typical monsoon tropical climate with irregular distribution of rainfall in two seasons. The rainy season from May to October, is characterized by high rainfall and temperature. In this season the rainfall is more than 80 percent of the total annual rainfall, and is concentrated mainly in June, July and August. the maximum rainfall often occurs in July and August. During the rainy season, relative humidity and temperature of atmosphere is so high (>80% and 27^{o}C, respectively). Vegetation develops most strongly in this period of the time. But, as a result of high concentrated rainfall, serious erosion often takes place during this period, leading to decline of the soil fertility, especially on the steep land. In contrast, the dry season (from November to April) is specified by low rainfall and temperature. The rainfall and temperature decrease gradually from October to February, and the minimum rainfall and temperature usually occur in January. After January, when the spring comes, The temperature as well as rainfall increase, and soft rains in the spring increase the relative humidity of atmosphere and moisture content in the soil considerably (Fig. 3). As a result, in agricultural production, the begining of spring is the sowing season for many kinds of crop, especially food legumes.

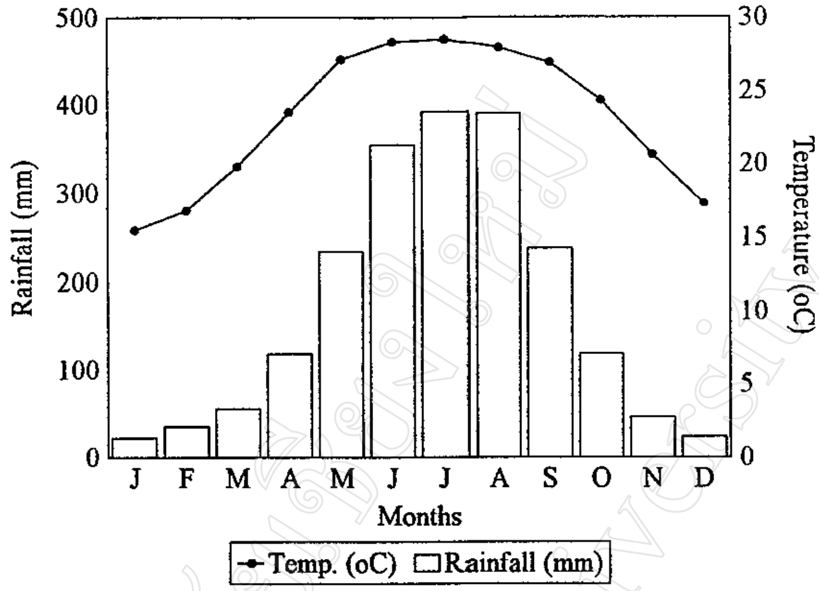

Fig. 3 Climate characteristics in Bac thai province

Source: Meteorological station of Bac thai province

Note: means of 10 years (1983-1992)

4.1.2. Socio-economic conditions

With a population of 5.6 million (General Statistical Office, 1993) over land area of 3366 km^2, the North-East mountainous region has a low population density, ranging from 70 to 190 persons per km^2 (100-1100 persons per km^2 in Red river delta). In regard to the inhabitants, apart from *Kinh* occupying mainly (60 % of population), 43 different ethnic minority groups create a diversity in cultural, socio-economical activities of the region. Each of groups has a certain life style as well as production methods. For example, the *H'Mong* group is known as the largest one practicing shifting cultivation, and they live in the highest altitude (800-1700m). While the *Dao* group lives in the lower altitude, and becomes familiar with water rice cultivation. The *Thai*, *Tay*, Nung and

Muong ethnic groups live in the much lower altitude, and their production activities are very close to *Kinh* people. The *Kinh* lives around narrow valeys or near the roads and towns. Rice and cash crops are grown with more intensive farming in the zones *Kinh* people lives, and their agricultural production relates more to the marketing economy. Among the ethnic minority groups, *Tay*, *Nung*, *Dao* are three main groups.

With a self-sufficient economy, shifting cultivation still remains as a traditional farming practice of some ethnic minority groups such as *Dao*, *H'mong* in Cao bang province, *Thai, Tay, Nung* in Lang son and Bac thai provinces. Among them, *H'mong* is considered as largest group practicing shifting cultivation in the region. In general, standard of living of the mountainous people is still quite low (Table 5). For example, total average income per capita month^{-1} in Cao bang, Bac thai and Lang son provinces are 92,000, 157,000 and 80,000 dong, respectively (average 300,000 dong for whole country). Although the region economy have also undergone great changes in the general changes of the country, but in the mountainous regions, especially where the ethnic minorities live, life still face with many difficulties in the thread of hunger, poverty and illiteracy (Sam, 1994). Food crops are often regarded as the most important crops, and general psychology of the mountainous people is to ensure sufficiently food before thinking to grow other crops. However, average amount of food per capita per year is still very low.

With respect to education and public health, the North-East mountainous region as well as other mountainous regions still meets a lot of difficulties. In the education, the rate of school pupils, especially pupils can go to secondary schools is still very low. The number of pupils who can go to schools decreases gradually from the elementary schools to the secondary schools. .

Table 5. Socio-economic situation of three surveyed provinces in the study site

Indicators	Cao bang	Bac thai	Lang son
A. Land distribution			
Total land (1000 ha)	844.5	650.3	816.7
Agriculture (1000 ha)	88.9	117.4	74.6
Food crops (1000 ha)	74.7	97.2	62.5
Industrial crops (1000 ha)	9.7	8.9	4.4
Vegetable and beans (1000 ha)	4.5	7.1	4.7
B. Population			
Population (1000 persons)	624	1144	671
male (1000)	308	566	326
female (1000)	316	577	345
pop. density (person./km^2)	74	176	82
farm households (1000)	88.2	165.4	92.3
Agricultural population (1000)	525.3	806.9	522.9
Agricultural labors (1000)	225.1	341.2	229.0
C. Education			
Grade school pupils (1000)	94.6	256.8	126.8
In which: Elementary school	90.0	242.6	122.6
Secondary school	4.6	14.2	4.2
Number of grade schools	337	373	360
In which: Elementary schools	316	357	344
Secondary schools	21	16	16
Total teacher	3962	9782	5613
In which: Elementary schools	3647	8988	5264
Secondary schools	315	794	349
D. public health			
Total number of doctor	244	472	228
Number of hospital beds	1458	2952	712
E. Economic conditions			
Food amount/ capita (kg)	277	234	244
Average total income (1000 dong/ person/ month)	92.2	157.4	80.0

Sources: Provincial Statistical Stations of Cao bang, Bac thai and Lang son (1993)

The number of grade teachers is also the same trend. The lack of teachers, schools, transportation facilities as well as economic difficulties of the indigenous people have been main limiting factors for development of education in the region. In the public health, the situation is the same. The indicators such as number of doctor and hospital beds per capita are very low compared with other region in the country (Table 5).

4.1.3 The role of food legumes in farming systems of the region

Table 6. The results of the surveys in three villages on the role of food legumes in farming systems

Indicators	Lung rieng (Cao bang) (n=30)		Um (Bac thai) (n=30)		Pa rang (Lang son) (n=27)	
	GM	SD	GM	SD	GM	SD
A. Human nutrition						
% of meals having food legumes	42.8	12.5	41.3	15.2	39.5	13.3
Amount of consumption (kg/year)	95.5	18.2	87.0	18.9	110.2	27.5
In which: Soybeans (kg/year)	33.2	7.1	34.0	8.8	46.5	18.5
Peanuts (kg/year)	32.7	11.9	27.0	8.3	32.6	12.3
Pulses (kg/year)	29.6	11.3	26.3	13.6	31.1	11.4
B. Animal feeds						
% of HH using f.l. for animals	70		65		50	
C. Cropping systems						
% of HH growing food legumes	100		100		100	
D. Economic						
Net return (M. dong/ha): Soybean	1.1	0.3	0.6	0.2	0.8	0.4
Peanuts	1.2	0.4	1.4	0.4	-	-

Source: Survey 1995

Note: **f.l.** Food legumes, **GM** Grand mean, **SD** Standard deviation, **M.** Million

n Number of household interviewed

Table 7. Percentage of farmer's opinion on the role of food legumes in farming systems

Indicators	Lung rieng (Cao bang, n=30)	Um (Bac thai, n=30)	Pa rang (Lang son, n=30)
A. Human nutrition			
- very important	30	20	60
- important	60	50	40
- No important	10	30	0
B. Animal feeds			
- Very important	0	20	0
- Important	70	60	50
- No important	30	20	50
C. Cropping systems			
1. Soil erosion			
- Increase	0	0	0
- Decrease	80	70	90
- No change	20	30	10
2. Soil fertility			
- Increase	85	70	80
- Decrease	0	0	0
- No change	15	30	20
3. Pest situation for sequentcrops in the rotation			
- Increase	0	0	10
- Decrease	60	50	60
- No change	40	50	30
D. Household's income			
- Increase	90	100	60
- Decrease	0	0	0
- No change	10	0	40
E. Household's labor use			
- Efficient	70	60	60
- Inefficient	0	0	0
- No change	30	40	40

Source: Survey, 1995

Note: **n** : Number of households interviewed

4.1.3.1 food legumes as an important source of human nutrition

The results of the survey showed that although there is not any information about percentage of protein amount derived from food legumes in the human diets, about 40 % of daily meals of the indigenous people have food legumes (Table 6). Every year, a considerable amount of food legumes is consumed by the people (Lung rieng: 95.5 kg; Um: 87 kg; Pa rang: 110 kg). Food legumes consist two groups: pulses and oilseeds. Pulse is legumes that bear edible dry seeds that are directly consumed by man. In contrast, oilseeds are traditional used as sources of edible oil rather than for direct consumption. A lot of traditional food preparations of the mountainous people are made from various species of food legumes. The foods may be prepared directly from seeds or edible vegetable parts of food legumes or through processing. The following traditional foods prepared from food legumes are very popular in the mountainous people's diets.

Soybean curd

Soybean curd is very familiar with the indigenous people. It is prepared by precipitation of protein from soymilk, followed by pressing out of whey. There are some households in each village with specialization for producing soybean curd for sale in the local markets, and the others can buy from them. Soybean curd becomes popular traditional food of the people because of both high nutritional value and reasonable price that is suitable for farmers. At the time of the survey (from April to May, 1995), the price of soybean curd was 4000 dong kg^{-1}, while the price of pork and beef was 15000 dong and 22000 dong kg^{-1}, respectively. Soybean curd may be eaten directly or fried in animal fat in order to supplement the fat to it.

Soy sauce

This is also one of the traditional foods in the diets of the indigenous people. Among the food legumes, soybean is the most important raw material used for making soy sauce. Along with soybean, rice or corn are also used for preparing this food. Almost all farmers can make soy sauce by themselves. First soybean is roasted carefully until it has good smell. After that it is unhusked and ground before it is put into the water in order to make a soy-solution. A certain amount of salt is also added soy-solution. Rice is cooked and fermented by specific fungus (*Aspergillus oryzae*). After fermentation for a certain period of time, this material is mixed with the soy-solution and left to age for one week before it can be used as soy sauce. The farmers can use this year-round as a valuable nutritional sauce. Because according to Wijeratne and Nelson (1987), the fungus is the organism which produces proteases and amylases which breakdown the protein and carbohydrate substrates during fermentation. Fermentation also produces the rich flavored peptides in soy sauce.

Sprouted beans

Germinated legumes (mungbean or soybean) are also considered as popular food for daily meals of the indigenous people. The production of bean sprouts is done usually at the home of some specific households in the village who are in specialization of sprouted bean production for sale. The sprouted beans are often regarded as year-round high quality vegetables of the people. Sprouting brings about certain desirable chemical changes of nutritional substances in the legume seeds. For example, Ascorbic acid which is absent in dry beans, appeared in the first 24 hours during germination and reaches a value of about 290 mgr/100 gr at the end of three days (Wijeratne and Nelson, 1987).

Roasted beans

In some locals of Cao bang and Lang son provinces, the people use roasted beans (mainly soybeans and mungbeans) for their daily meals. For example, in Cao bang province, roasted mungbeans and soybeans are year-round traditional food of some ethnic minority groups such as Tay, Nung and H'Mong. Soybeans and mungbeans(separately or mixture) are roasted carefully. Then they are preserved in the large earthenware jars and considered as a food in farmer's daily meals.

4.1.3.2 Food legumes as a source of animal feeds

Along with crop production, animal production also plays an important role in the self-sufficient economy of the mountainous people. And the food legumes are regarded as a high quality source of feed for animals. As interviewed on the role of food legumes for animal feeds, majority of farmers said that food legumes are important. Throughout the surveyed areas, the farmers use food legumes for feeds, either plant residues (after harvesting or processing) or whole seeds (Table 6). For example, after harvesting, plant residues of peanuts are used for cattle; residues of processing soybean curd are used for pig; mungbean and soybean seeds are used for chicken and cattle at the productive period. The farmers said that chickens eaten soybeans or mungbeans give more eggs than the others that are not eaten by these beans. In Cao bang province, the farmers have an experience to feed productive cattle by supplementing some soybeans in their fodder.

Especially, in the locations close to the provincial towns where have large consumption of food and foodstuff, large chicken farms that chickens are reared by industrial type require a large amount of soybeans for chicken feed, and they actually become one of the significant consumption markets of soybeans.

4.1.3.3 Food legumes in cropping systems

Food legumes in cropping patterns

The results of survey in three provinces of the region on the position of food legumes in the cropping patterns are showed in Fig. 4.

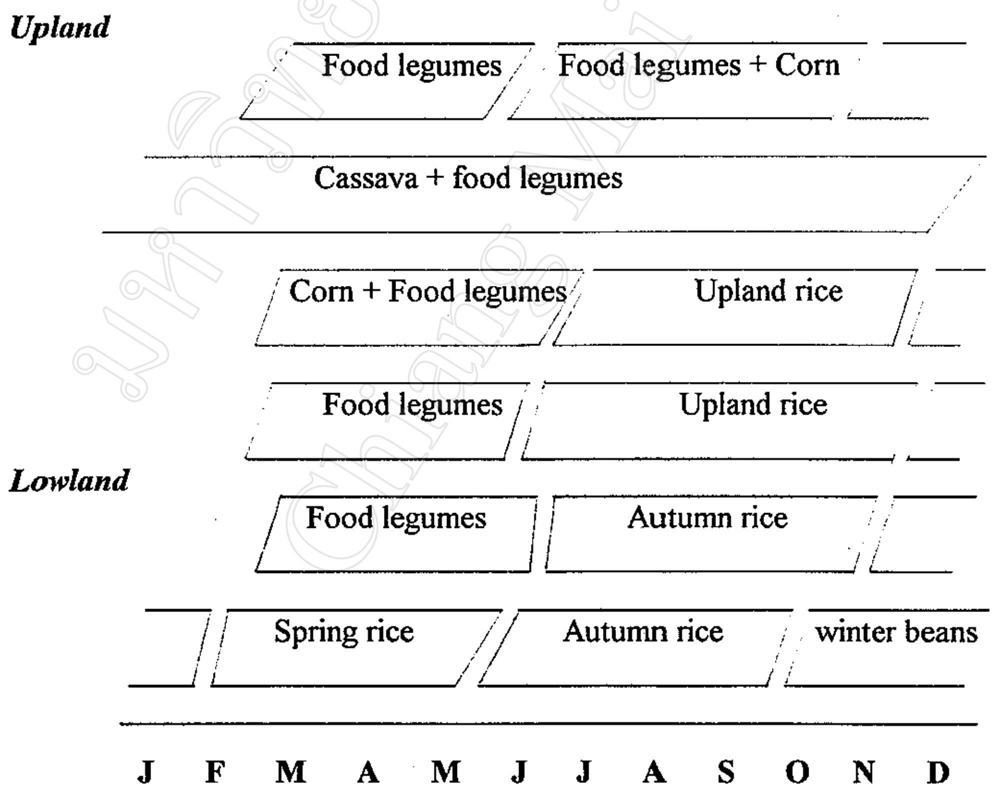

Fig. 4 Food legumes in cropping patterns

In general, food legumes are often grown from March to June in almost cropping patterns. Because at this period, the rainfall is low, and the lack of water is the most limiting factor to growth of other crops, and farmers say that food legumes are likely to be best tolerant to deficiency of water. Thus, in rainfed areas, food legumes can considered as the most efficient crops in terms of soil improvement as well as economics.

Food legumes in protecting the soil from erosion

When asked on this role of food legumes, majority of farmers answered that food legumes are significant crops in decreasing the water erosion on the sloping land, because they have short stems and a lot of leaves (Table 7). The food legumes grown in sole or in intercrop with other crops such as cassava or corn will create a large coverage protecting the soil from erosion in rainy season.

Food legumes in improving the soil fertility

More than 80% of farmers asked supposed that food legumes can improve soil fertility in terms of soil moisture, soil physical properties and mineral nutrients, especially nitrogen (Table 7). Almost all farmers said that rice or corn develop better when they are grown after harvesting food legumes.

Food legumes and pest status in sequence crops

As mentioned above, the food legumes grown mainly from March to June create biodiversity on the fields, break the cycle of cereal cropping (rice, corn) and reduce the incidence of weeds, insects and soil born diseases. Almost all farmers said that the food legumes-rice rotation are the best way to limit development of diseases and insects on the fields (Table 7). In the fact, the farmers often burn straw after harvesting rice, then food legumes are grown. This fact is likely to limit partly development of pests.

In short, the role of food legumes in farming systems may be illustrated in Fig. 5.

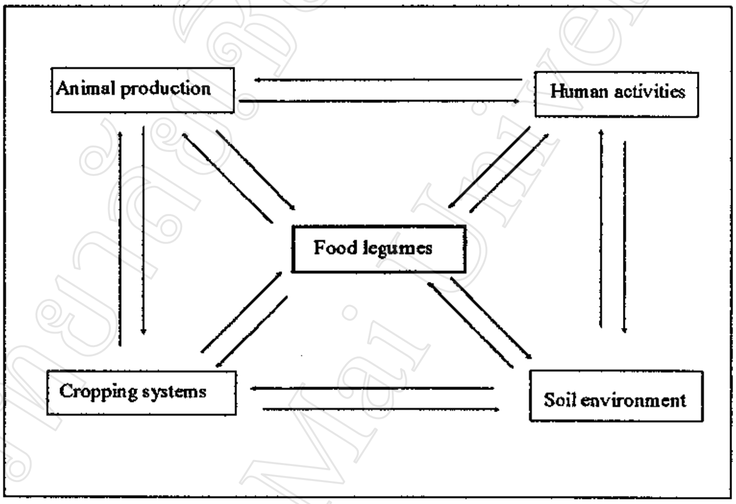

Fig. 5 The food legumes in farming systems

4.1.4 Food legume production and constraints

4.1.4.1 Food legume production

The results of surveys on food legume production in the study site are presented in Table 8 and Table 9.

Table 8. Food legume production in three surveyed provinces from 1991 to 1994

Crops	Sown area (1000 ha)				Yield (kg/ha)				Total production (1000t)			
	91	92	93	94	91	92	93	94	91	92	93	94
					Cao bang province							
Soybean	6.8	5.9	7.3	7.8	530	360	636	573	3.6	2.0	4.6	4.5
Peanut	0.6	0.4	0.6	1.0	633	511	679	547	0.4	0.2	0.4	0.5
Pulses	3.0	2.4	2.7	3.1	410	330	426	417	1.2	0.8	1.2	1.3
					Bac thai province							
Soybean	2.2	1.8	2.2	2.8	647	648	798	823	1.4	1.2	1.7	2.3
Peanut	5.1	5.2	5.5	5.9	671	646	837	788	3.8	3.3	4.6	4.6
Pulses	2.7	2.8	2.9	2.9	374	336	486	467	1.0	0.9	1.4	1.4
					Lang son province							
Soybean	1.6	1.8	2.2	1.3	630	836	1013	840	1.0	1.5	2.2	1.1
Peanut	1.2	1.6	1.7	1.2	590	858	1040	989	0.7	1.4	1.8	1.2
Pulses	1.7	1.9	1.6	1.2	400	430	456	549	0.7	0.8	0.7	0.7

Source: Provincial Statistical Station of Cao bang, Bac thai and Lang son, 1991-1994

Table 9. Food legume production in three surveyed villages

Indicators	Lung rieng village (Cao bang, n=30)		Um village (Bac thai, n=30)		Pa rang village (Lang son, n=27)	
	GM	SD	GM	SD	GM	SD
No. persons/household	4.8	1.33	2.2	0.77	5.5	1.69
In which: Male	2.2	1.01	1.0	0.36	2.6	0.87
Female	2.6	0.73	1.2	0.69	2.9	1.36
Agricultural land (ha)	0.55	0.39	0.33	0.16	0.79	0.49
Food legume area (ha)	0.14	0.08	0.10	0.04	0.17	0.13
In which: Soybean (ha)	0.07	0.04	0.05	0.02	0.11	0.08
Peanut (ha)	0.05	0.03	0.04	0.02	0.01	0.07
Pulses (ha)	0.02	0.02	0.01	0.02	0.05	0.05
Yield: Soybean (kg/ha)	580	99.2	759.7	82.5	618	114.3
Peanut (kg/ha)	710	91.8	1052	143.1	550 *	-
Pulses (kg/ha)	421	59.0	438	46.2	445	53.7
Cereal yields (kg/ha) **	1908	259.5	2013	221.3	1835	287.5
Inputs for food legumes						
Organic fertilizer (t/ha)	4.8	1.5	5.1	1.4	5.1	1.8
N. fertilizer (kg/ha)[a]	0	0	0	0	5.9	22.9
P. fertilizer (kg/ha)[b]	92.6	94.4	247.6	56.6	260	142.7
K. fertilizer (kg/ha)[c]	60.7	61.6	71.0	63.8	8.1	29.5
Lime (kg/ha)[d]	188	328	1375	466.9	250	403.6
Weeding (times)	1.43	0.85	1.7	0.44	1.5	0.64

Source: Survey, 1995

Note: **a-** Urea (46% N); **b-** Super phosphate(16.5 % P_2O_5); **c-** KCl (60% K_2O) **d-** Burn limestone; **GM** Grand mean; **SD** Standard deviation; * only 1 household grows ** Mean of rice and corn; **n** number of households interviewed

The results of survey in three villages show that, in general, the yields of food legumes are low. The yields range from 580 (Lung rieng) to 759 kg/ha (Um) for soybean, from 550 (Pa rang) to 1052 kg/ha (Um) for peanut, and from 421 (Lung rieng) to 445 kg/ha (Pa rang) for pulses (Table 9). Among three surveyed villages, Um village has the highest yields of soybean and peanut. This may result from higher inputs of fertilizers and weeding.

4.1.4.2 The constraints for food legume production

As mentioned above, although food legumes have an important role in farming systems, they are still considered as minor crops in terms of sown area as well as inputs for the production. The results of survey showed that food legume productivity was quite low (Table 9), and farmers said that low productivity was one of the bigest factors limiting their production in the region. The farmers want to invest for cereal crops, because, on one hand, their preference is to have enough food before growing other crops, and on the other hand, the yields of cereals are often as much twice or more than those of food legumes, and the farmers get more profit from cereal production. They do not pay more attention to other aspects in the role of food legumes in farming systems as discussed above. It is certain that the farmers would like to grow food legume if their yields were higher. The farmer's opinions on factors limiting productivity of food legumes were summarized in Table 10.

As showed above in Table 4, in general, the soils in the mountainous regions of North-East are acid and very poor fertility. And among the physical factors limiting food legume productivity, acid soil and poor soil fertility are the most important ones. The results of interviewing farmers in three villages proved this. In the fact, the farmers in Bac thai and Lang son provinces had experience to apply lime for soybean and peanuts, and they obtained high yields, especially when lime was combined with phosphorus fertilizer. The farmers also said that as a result of poor soil fertility, application of mineral nitrogen fertilizer or organic manures for soybeans, peanuts and mungbeans gives high grain yields.

Table 10. Farmer's opinions on the constraints to food legume production

Limiting factors	Lung rieng (Cao bang)	Um (Bac thai)	Pa rang (Lang son)
A. Physical factors	n=30	n=30	n=27
Acid soil	20(70)	30(100)	27(100)
Poor soil fertility	30(100)	28(93)	27(100)
drought	21(70)	24(80)	19(70)
Pests	23(76)	20(66)	27(100)
Low temperature	19(63)	21(70)	19(70)n
B. biological factors			
Lack of high yielding variety	30(100)	30(100)	27(100)
C. Socio-economic factors			
Low price	19(70)	26(86)	24(90)
Lack of capital	30(100)	30(100)	27(100)
Poor consumption markets	24(80)	26(86)	17(65)

Source: Survey, 1995

Note: **n** Number of households interviewed

Numbers in bracket are percent of farmer's opinion

The low temperature and drought at the early stage of spring crop are obstacles for growth of almost food legumes as well. Almost food legume varieties farmers use now are local varieties, with low yields and quality, but they can be suitable in the conditions of low inputs and climate of the region. However, the farmers expect to have the varieties that can be tolerant to cold and drought in the spring crop and give higher yields.

On the aspects of socio-economics, low price, lack of capital of farmers, and poor consumption markets are also constraints for food legume production in the region. With the self-sufficient economy, the consumption market is just narrow in the certain local cope along with low price and lack of capital for production, so the farmers only grow legumes just enough for their domestic demands. At the time of the survey in 1995, the price of soybeans was about 4000 dong/kg and peanuts about 5000 dong/kg, while the price of rice was 2800 dong/kg. Thus, price ratio between legumes and rice ranges from 1.5 to 1.7, whereas the yield of rice is often as much twice or more than that of food legumes. As a result, the farmers have to concentrate the capital for food crop production before growing food legumes, and food legumes are often considered as minor crops. These are considerable restrains for spreading sown area of food legumes in most of mountainous provinces at present.

4.2 The field experiment

4.2.1 Effect of N, P, lime (L) on plant height of soybean and peanut

In general, plant height increased gradually from V4.5 (30 days after sowing) to R6.5 (72 days after sowing) , but the growth rate reached maximum between V4.5 and R4.5 (50 days after sowing). The growth rate decreased considerably after R4.5. After R6.5 the increase of plant height was negligible (Fig. 6).

Nitrogen had significant effect on plant height both of soybean and peanuts at all stages when it was applied with P and L ($P<0.01$). Nitrogen applied alone did not increase significantly the plant height of both soybean and peanuts. Both soybean and peanuts responded strongly to P application. Applying P alone increased the plant height about 20 % in both species. Lime did not significantly affect plant height of both soybean and peanuts ($P>0.05$). With combined applications of N and P; N and L; or P and L, plant heights were increased more rapidly at just early stage (V4.5-R4. 5) than alone application.

Significant interaction between N and P was detected for plant height of both species ($P<0.01$). Applying P increased plant height (at harvesting, 90 DAS) with significant difference that depends on N application, ranging from 22 % (without N) to 33 % (with N) in soybean; and from 26 % (without N) to 43 % (with N) in peanuts. As the result, the response of plants to P was increased in presence of N.

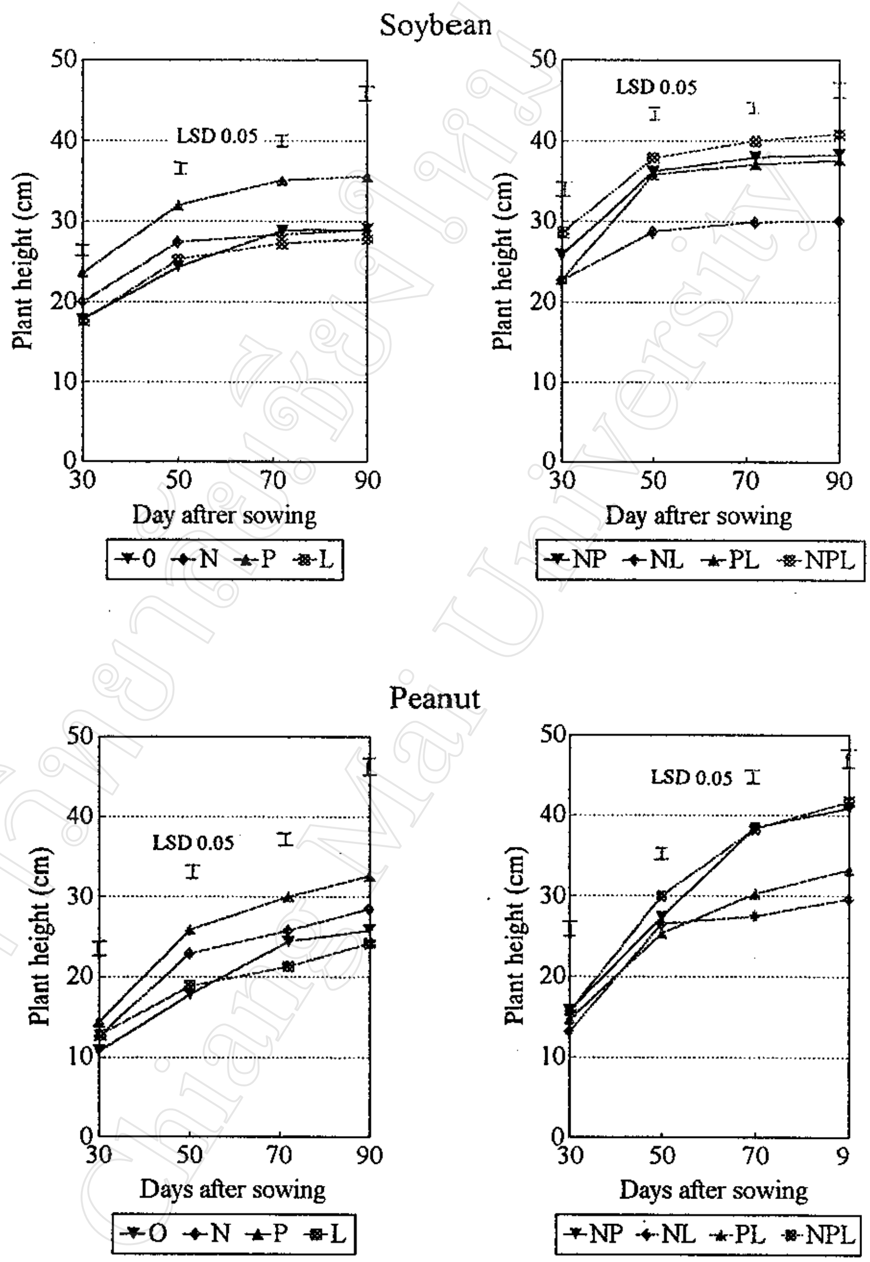

Fig. 6 Effect of N, P, L on plant height of soybean and peanuts (cm) at different growth stages

Table 11. Analysis of variance for plant height

F Test	Source of variance								
	N	P	L	N*P	N*L	P*L	N*P*L	N*P*L*S	S
F Test V4.5	**	**	ns	ns	ns	ns	ns	ns	**
F Test R4.5	**	**	**	*	ns	ns	ns	ns	**
F Test R6.5	**	**	ns	**	ns	ns	**	ns	**
F Test Har.	**	**	ns	**	ns	ns	ns	ns	ns

	V4.5	R4.5	R6.5	Harvest
CV (%) (N*P*L)	9.0	4.7	4.2	5.7
CV (%)(N*P*L*S)	13. 0	9.7	8.9	7.9
LSD 0.05 (N*P*L)	2.0	1.6	1.6	2.3
LSD 0.05 (N*P*L*S)	4.1	4.7	4.1	4.5

Note: **- significant at 1 % level **S**- species **Har**.- harvesting (90 DAS)

*- significant at 5 % level **ns**- nonsignificant (N*P*L)- main plot (N*P*L*S) Sub plot

Interactions between N, P and L were (also evident $P<0.01$) in their influence on plant height of soybean and peanuts at R6.5. The effect of N on plant height was influenced considerably by P and L application. With P, applying N increased plant height about 8 % in soybean and 28 % in peanuts. With L, applying N increased plant height by 10 % in soybean and 29 % in peanut, whereas without P and L, applying N increased negligibly the plant height of both species (at R6.5). However, the interactions between N, P and L were not found at harvesting stage. Soybean and peanuts responded to combined application of N, P, and L in the same way (Table 11).

4.2.2. Effect of N, P, and L on leaf area index (LAI) of soybean and peanut

It was clear that LAI of both soybean and peanuts was affected considerably by N, P, and L at all three observed stages, except effect of L at early stage (V4.5).

Among three factors N, P, and L, P had the strongest effect on LAI of both soybean and peanuts (Fig. 7).

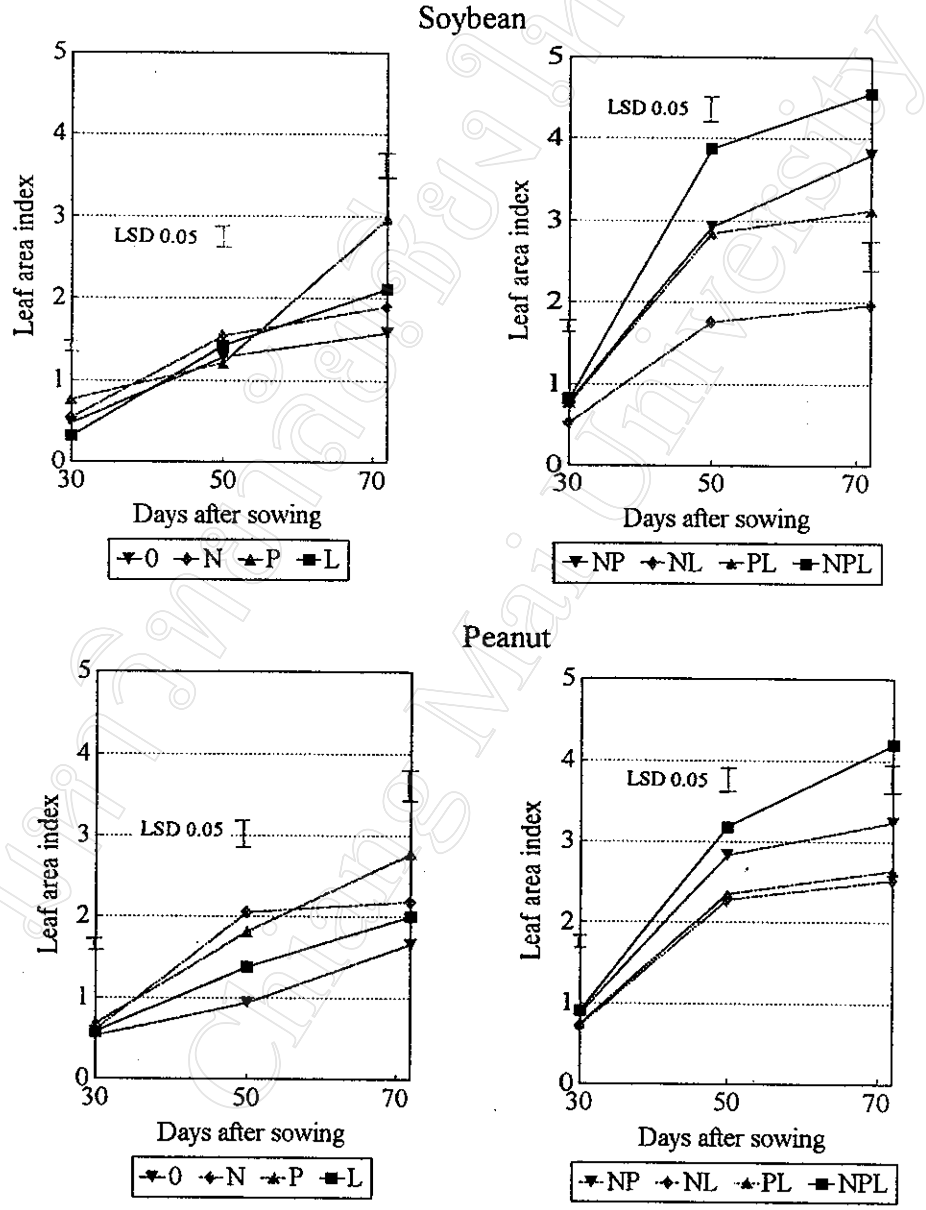

Fig. 7 Effect of N, P, and L on LAI of soybean and peanut at different growth stages

Table 12. Analysis of variance for LAI

	Source of variation								
	N	P	L	N*P	N*L	P*L	N*P*L	N*P*L*S	S
F Test V4.5	**	**	ns	ns	ns	ns	ns	ns	**
F Test R4.5	**	**	**	ns	ns	*	ns	ns	ns
F Test R6.5	**	**	**	**	ns	ns	**	ns	ns

	V4.5	R4.5	R6.5
CV (%)$_{(N*P*L)}$	14.5	13.4	11.5
CV (%)$_{(N*P*L*S)}$	14.6	14.3	10.9
LSD 0.05 $_{(N*P*L)}$	0.11	0.36	0.38
LSD 0.05 $_{(N*P*L*S)}$	0.16	0.54	0.50

Applying P alone increased LAI by 88 % in soybean and 67 % in peanuts at R6.5, while N or L increased only about 20-30 %. The rate of early LAI expansion (between V4.5-R4.5) in both soybean and peanuts was highest when N, P, L were applied together. The combined applications of N and P; N and L; P and L had slightly smaller effect but still larger than when N, P, or L was applied separately.

P and N had significant interaction effect on LAI of both species (P<0.01). The increase of LAI due to P application depended strongly on N application. In presence of N, applying P increased LAI at R6.5 by 100 % in soybean and 50 % in peanuts, whereas in absence of N, these increases were about 85 % in soybean and 70 % in peanuts.

A strong interaction between N, P, and L was also apparent at R6.5 (P<0.01), showing their mutual effects on LAI in both species. For example, effect of P on LAI depended considerably on N and L. With N and L together, applying P increased LAI about 130 % in soybean and 65 % in peanuts; but with N only, theses increases were 28 % and 17 %; and with L only, they were 47 % and 32 %, respectively.

Soybean and peanuts responded to the combined effects of N, P, and L in the same way. With N, P, and L together, LAI at R6.5 was largest, and it was more than 1.5 times greater than unamended soil in both species.

4.2.3. Effect of N, P, L on nodulation of soybean and peanut

4.2.3.1. Nodule number

Nodule number $plant^{-1}$ increased from V4.5 to R6.5 stage. But the growth rate was maximum between V4.5 and R4.5 (Fig. 8). By R6.5, the number of nodules in both soybean and peanuts was about halved by N application. In contrast, nodule formation was strongly stimulated by the application of L and even more strongly by P ($P<0.01$).

P application increased nodule number in both soybean and peanuts. However, this increase depended strongly on L application. At R6.5, with L, applying P increased nodule number by 88 % in soybean and 95 % in peanuts, whereas without L, these increases were much greater (180 % in soybean and 110 % in peanuts). The application of P and L together gave the highest nodule number, and increased the nodules more than three times in soybean and twice in peanuts (At R6.5). In terms of nodule number, the response of soybean and peanuts to combined application of N, P, and L was not significant different at R6.5 ($P>0.05$, Table 13).

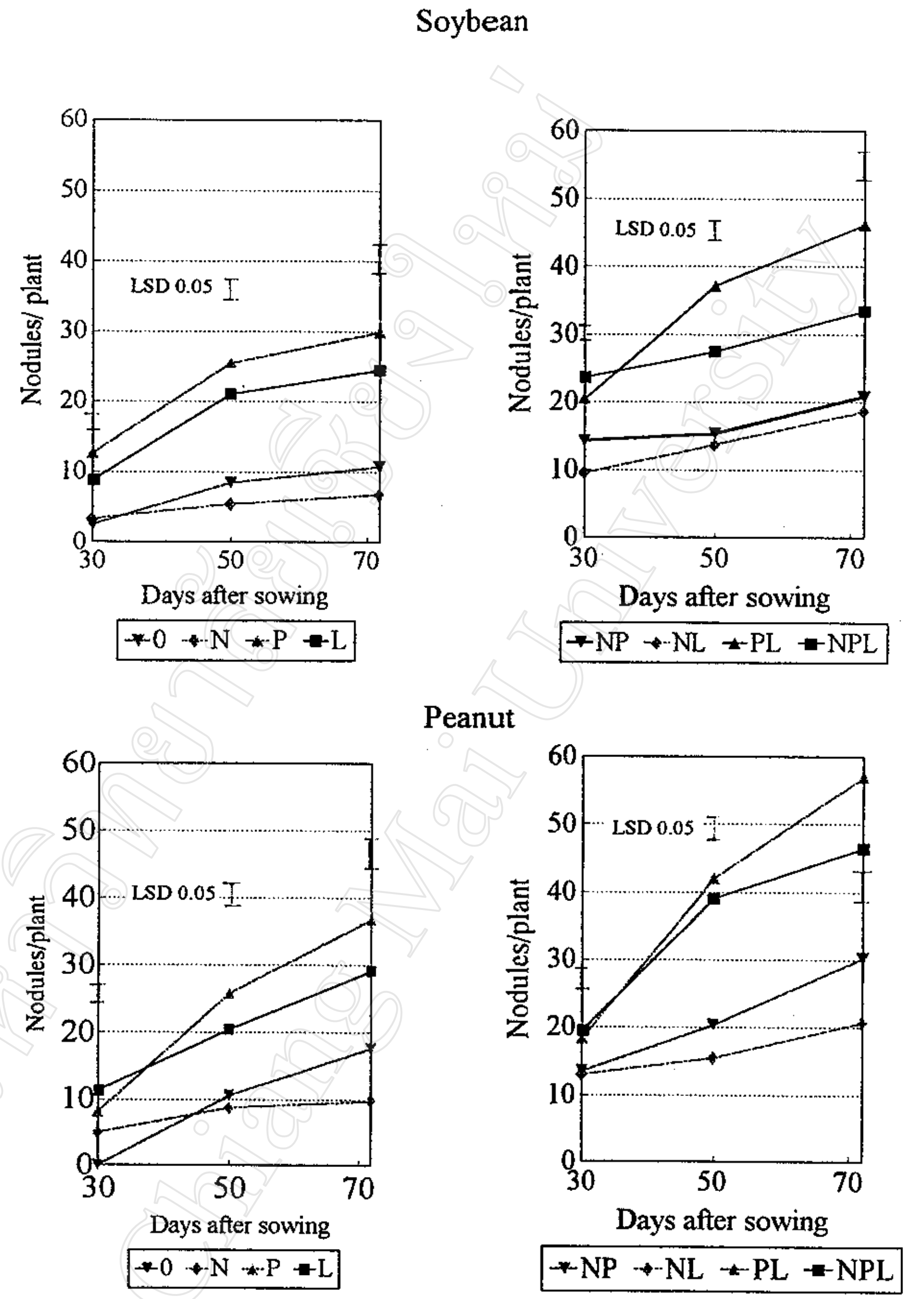

Fig. 8 Effect of N, P, and L on nodule number plant^{-1} of soybean and peanut at different growth stages

Table 13. Analysis of variance for nodule number plant^{-1}

F Test	Source of variation								
	N	P	L	N*P	N*L	P*L	N*P*L	N*P*L*S	S
V4.5	**	**	**	ns	ns	ns	ns	ns	ns
R4.5	**	**	**	ns	ns	**	ns	*	**
R6.5	**	**	**	ns	ns	**	ns	ns	ns

	V4.5	R4.5	R6.5
CV (%)$_{(N*P*L)}$	20.3	11.8	12.5
CV (%)$_{(N*P*L*S)}$	22.7	13.6	12.0
LSD 0.05 $_{(N*P*L)}$	2.9	3.0	4.2
LSD 0.05 $_{(N*P*L*S)}$	4.5	4.9	5.7

4.2.3.2. Nodule dry weight

Like nodule number, nodule dry weight also increased gradually from V4.5 to R6.5 in both species. The increasing rate was most rapid between V4.5 and R4.5 when P or L was applied alone as well as together. At R6.5, P application increased nodule dry weight by more than three times in soybean and five times in peanuts. Liming also increased the nodule dry weight in both species, but to a slightly less extension. Whereas N application decreased considerably nodule dry weight in both species (Fig 9). However, when N was applied with P, nodule dry weight at R6.5 was increased by 125 % in soybean and 150 % in peanuts . With N, applying P increased nodule dry weight three times in soybean and more than four times in peanuts, but without N, these increases were much greater. This indicated that there was interaction effect between N and P on nodule dry weight in both species ($P<0.05$, Table 14).

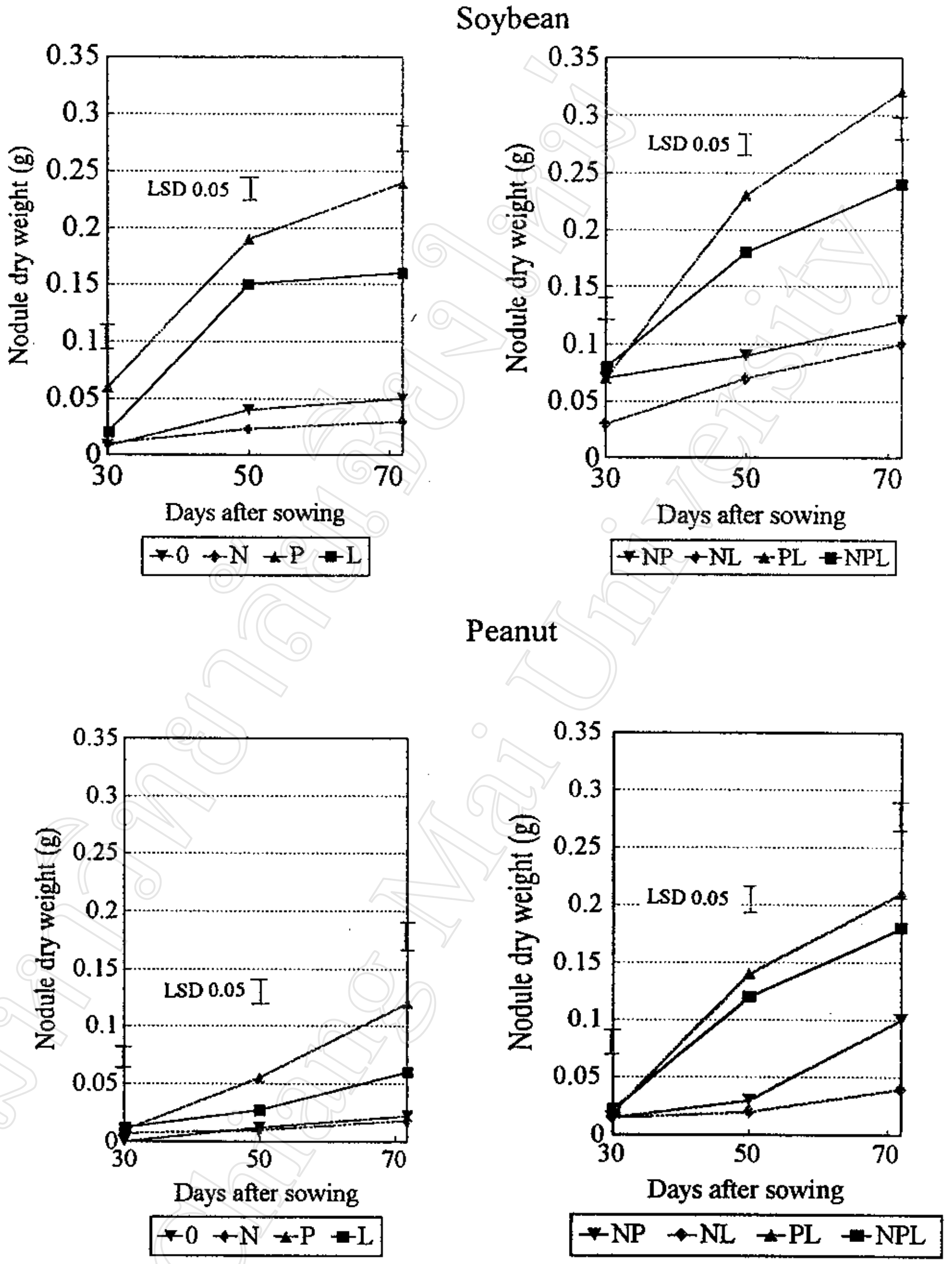

Fig. 9 Effect of N, P, and L on nodule dry weight of soybean and peanut at different growth stages

Effect of P on nodule dry weight also depended markedly on L application (P <0.01). The increase of nodule dry weight as result of P application ranged considerably from 100 % (with L) to 380 % (without L) in soybean, and from 250 % (with L) to 500 % (without L) in peanuts. As the result, liming decreased markedly effect of P on nodule dry weight.

Table 14. Analysis of variance for nodule dry weight

F Test	Source of variation								
	N	P	L	N*P	N*L	P*L	N*P*L	N*P*L*S	S
V4.5	ns	**	**	ns	ns	ns	ns	ns	ns
R4.5	**	**	**	ns	ns	**	ns	ns	**
R6.5	**	**	**	*	ns	**	ns	**	**

	V4.5	R4.5	R6.5
CV (%)(N*P*L)	28.7	32.3	19.2
CV (%)(N*P*L*S)	31.9	38.0	17.2
LSD 0.05 (N*P*L)	0.03	0.03	0.03
LSD 0.05 (N*P*L*S)	0.05	0.05	0.04

Soybean and peanuts also responded differently to combined effects of N, P, and L (P<0.01), i.e. nodule dry weight was increased by near four times in soybean, but up to eight times in peanuts when N, P, and L were applied together.

4.2.4 Effect of N, P, and L on dry matter yield (kg ha^{-1}) of soybean and peanut

The dry matter yield increased gradually from V4.5 to R6.5. But the accumulation of dry matter was most rapid between R4.5 and R6.5 stage. In general, the rate of dry matter accumulation in both soybean and peanuts in this soil was clearly depressed by the deficiencies of N and P as well as soil acidity (Fig. 10). The highest rate of dry matter accumulation in both species was recorded when N, P, and L were applied together.

Combining just two of three factors (N, P, L) also had larger effects on dry matter accumulation than single factor application, but less than when all 3 were applied together. With N, P or L alone, the dry matter yields were increased by 20, 110 , and 30 % in soybean; 50, 80 and 20 % in peanuts, respectively. Whereas the combined application of N and P; N and L; as well as P and L increased correspondingly dry matter yields by 160, 60 and 130 % in soybean; 110, 70 and 90 % in peanuts.

Dry matter yields at R6.5 in both species were affected considerably by significant interaction effects between N and P ($P<0.01$. Table 15). For example, with P, applying N increased dry matter yield at R6.5 about 10 % in soybean and 15 % in peanuts, whereas without P, these increases were about 20 % in soybean and 55 % in peanut. Furthermore, effect of P on dry matter in both species also depended on liming. Without L, applying P increased dry matter yield at R6.5 by 112 % in soybean and 85 % in peanuts, but in the limed soil, these increases were decreased markedly.

A strong interaction effect between N and L on dry matter yield was also recorded at R6.5. Liming increased dry matter yield (at R6.5) about 26 % in soybean and 9 % in peanuts in the soil with N applied, whereas these increases were 30 % and 20 %, respectively, when N was not applied.

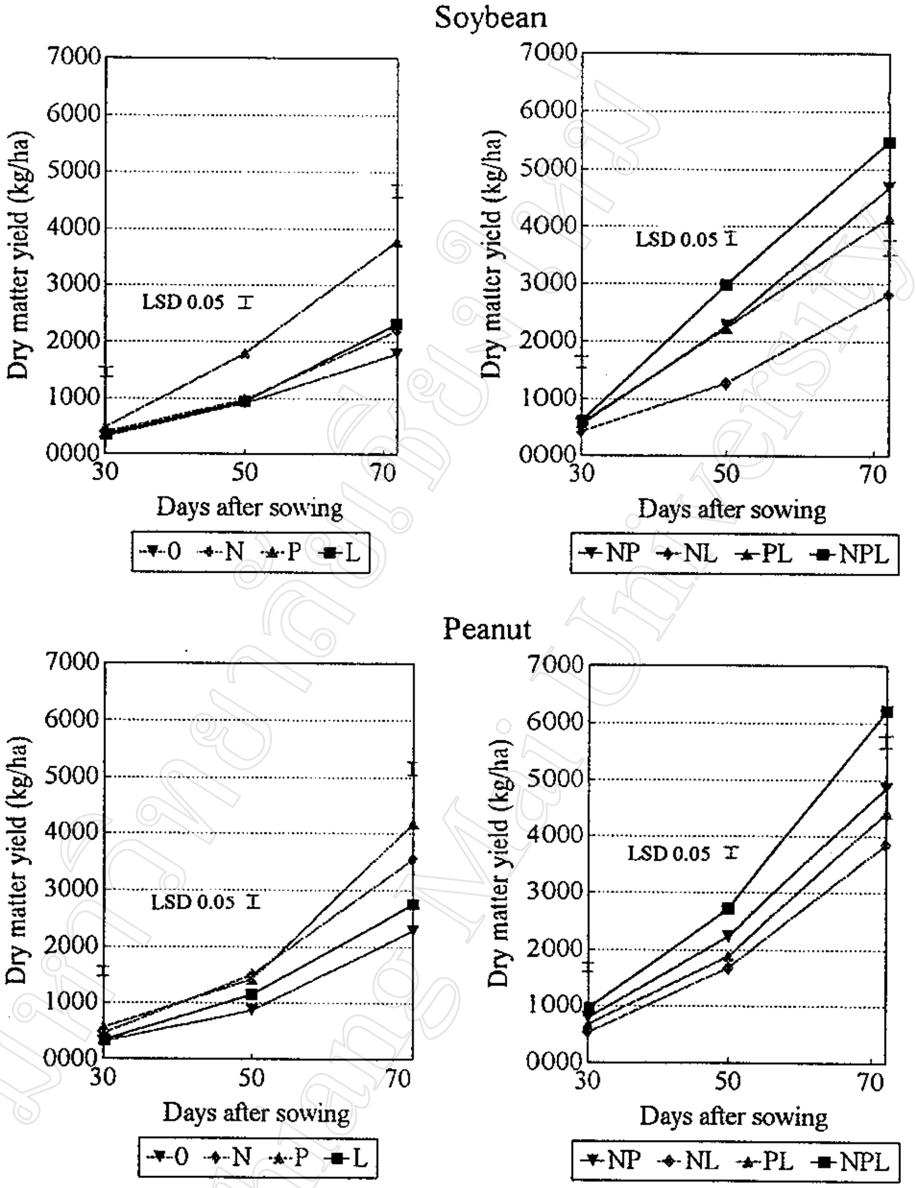

Fig.10 Effect of N, P, and L on dry matter yield of soybean and peanut at different growth stages

Interaction effect between N, P, and L on dry matter yield at R6.5 was also apparent ($P<0.01$) in both species. For example, effects of P on dry matter yields depended a lot on N and L. With N and L together, applying P increased dry matter yields by 95 % in soybean and 60 % in peanuts; whereas without N and L, these increases were up to 112 and 85 %, respectively. This indicated that response of plants to P was decreased considerably in presence of N and L.

By comparison with the untreated soil, at R6.5, dry matter yield increased by 200 % in soybean, while only 170 % in peanuts when N, P, and L were applied together. This indicated that soybean and peanuts responded differently to combined effects of N, P, and L (P<0.01).

Table 15. Analysis of variance for dry matter yield

F Test	Source of variation								
	N	P	L	N*P	N*L	P*L	N*P*L	N*P*L*S	S
V4.5	**	**	**	ns	ns	ns	ns	*	**
R4.5	**	**	**	**	*	**	ns	**	ns
R6.5	**	**	**	**	**	**	**	**	**

	V4.5	R4.5	R6.5
CV(%)(N*P*L)	13.6	4.9	2.8
CV (%)(N*P*L*S)	15.4	6.0	2.7
LSD 0.05 (N*P*L)	86.5	100.5	129.5
LSD 0.05 (N*P*L*S)	138.5	174.0	181.0

4.2.5. Effect of N, P, and L on nitrogen concentration (%) in the plant of soybean and peanuts

In general, nitrogen concentration in the plant decreased gradually from V4.5 to R6.5 for both of soybean and peanuts in all treatments (Fig. 11). However, the reduction rate was different from one treatment to others. At early stage (V4.5), applying N increased strongly plant N concentration, but after V4.5, the rate of decrease was faster than with applying P or L. Plant N concentration was influenced considerably by N, P, and L. However, the responses of soybean and peanuts to these factors were different. When N, P, or L was applied separately, plant N concentration at R6.5 increased correspondingly by 4.9, 12.5 and 13.3 % in soybean, 15.3, 14.5 and 7.6 % in peanuts. This pointed out that peanuts was more sensitive to N than soybean.

The combined applications of N and P as well as P and L remained higher plant nitrogen concentration until later stage (R6.5) than N applied alone. Effect of N on plant N concentration was depended on P application. With P, applying N increased plant N content by 8 % in soybean and 12 % in peanuts; but without P, these increases were 5 % in soybean and 15 % in peanuts, respectively.

Table 16. Analysis of variance for plant N content

F Test	Source of variation								
	N	P	L	N*P	N*L	P*L	N*P*L	N*P*L*S	S
V4.5	**	**	**	ns	ns	ns	ns	*	**
R4.5	**	**	**	**	*	**	ns	**	ns
R6.5	**	**	**	**	**	**	**	**	**

	V4.5	R4.5	R6.5
CV (%)(N*P*L)	2.6	2.0	3.2
CV (%)(N*P*L*S)	2.7	2.7	2.1
LSD 0.05 (N*P*L)	0.10	0.07	0.10
LSD 0.05 (N*P*L*S)	0.10	0.15	0.10

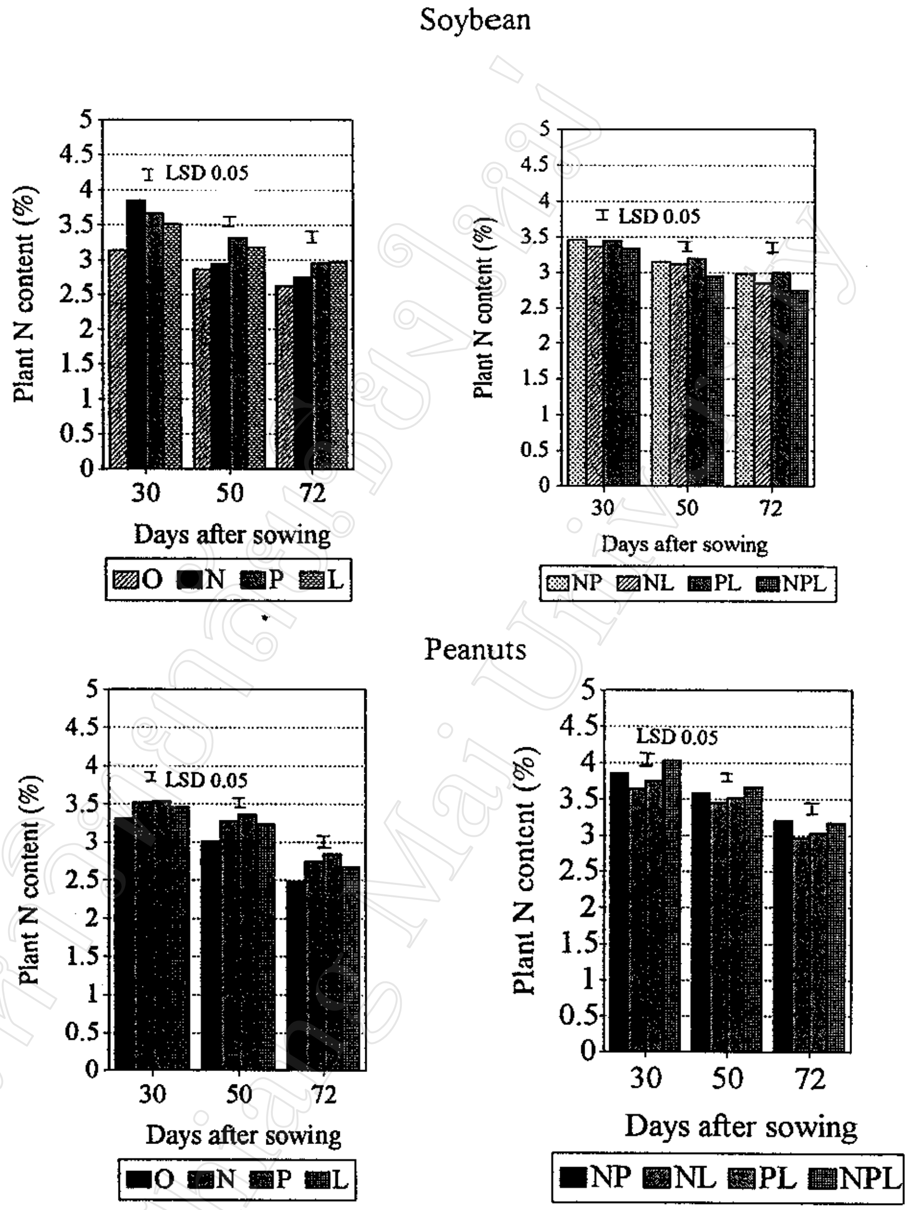

Fig. 11. Effect of N, P and L on plant N concentration of soybean and peanuts at different growth stages

The increase of plant N content due to liming was also depended on N, and varied from 4 % (with N) to 13 % (without N) in soybean, and from 4 % (with N) to 8 % (without N) in peanuts. P and L also affected plant N content of both species in the significant interaction. For example, without P, liming increased plant N content at R6.5 by 13 % in soybean and 8 % in peanuts, but with P, these increases were 1 % in soybean and 12 % in peanuts. On the other hand, effect of P on plant N content also depended on N and L application. For example, without N and L, applying P increased plant N content at R6.5 by 13 % in soybean and 15 % in peanuts, but with N and L, applying P increased only about 3 % in soybean, 7 % in peanuts. As the result, N and L decreased effect of P on N content in plant. Soybean and peanuts responded differently to combined application of N, P, and L ($P<0.01$, Table 16)

4.2.6. Effect of N, P, and L on nitrogen yield (kg ha^{-1}) of soybean and peanut

Nitrogen yields increased from V4.5 to R6.5 due to strong increase of dry matter yields, but this increase reached maximum from R4.5 to R6.5. The applying N, P, or L separately increased considerably the nitrogen yields at all three observed stages both of soybean and peanuts (Fig. 12). However, P application increased most strongly the nitrogen yield, because it increased both nitrogen content in the plant and the dry matter yield. At R6.5, nitrogen yields were increased 140 % in soybean and 100 % in peanuts as the result of P application. While, applying alone N or L increased only 30 % and 45 % in soybean; 80 % and 30 % in peanuts, respectively. The combined application between N and P; P and L gave the higher increase of nitrogen yields. The highest nitrogen yield was obtained with combined application of N, P, and L.

Nitrogen yields at R6.5 were affected markedly by apparent interaction between N and P ($P<0.01$). The increase of nitrogen yield by applying N depended on P, and ranged from 30 % (without P) to 130 % (with P) in soybean, and from 54 % (with P) to 80 % (without P) in peanuts.

Interaction effect between N, P, and L on nitrogen yield in both species at R6.5 was also recorded ($P<0.05$). The role of P in increasing nitrogen yield depended on N and L. With N and L together, applying P increased nitrogen yields around 90 % in soybean and 70 % in peanuts, but these increases were 150 % in soybean and 110 % in peanuts when N and L were not applied. Thus, effect of P on nitrogen yields was decreased in presence of N and L.

Obvious difference in response between soybean and peanuts to N, P, and L combined application was detected at R6.5 ($P<0.01$, Table 17). At R6.5, the combined application of N, P, and L increased N yield about 200 % in soybean and 250 % in peanuts.

Soybean

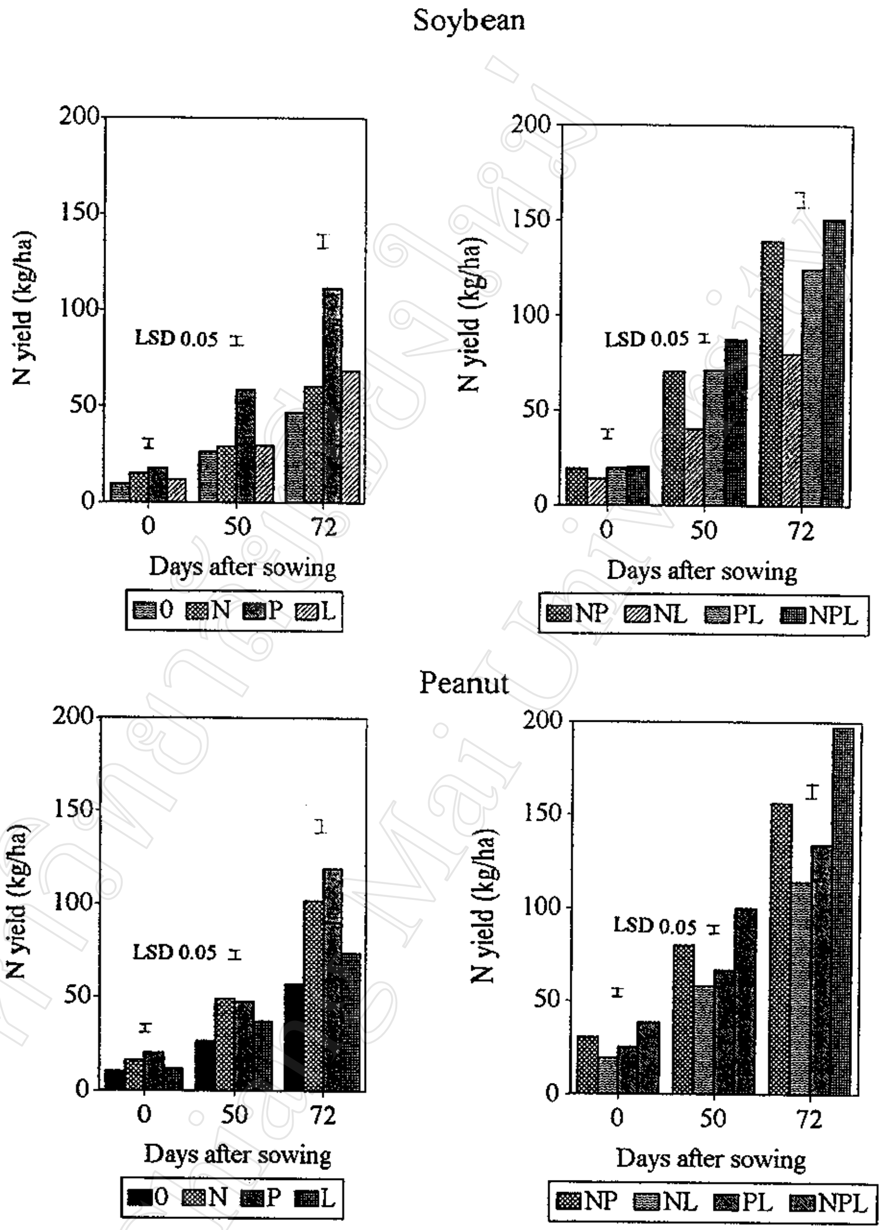

Fig. 12 Effect of N, P, and L on N yields of soybean and peanuts at different stages of growth

Table 17. Analysis of variance for N yield

F Test	Source of variation								
	N	P	L	N*P	N*L	P*L	N*P*L	N*P*L*S	S
V4.5	**	**	**	ns	ns	ns	ns	**	**
R4.5	**	**	**	**	ns	**	ns	**	**
R6.5	**	**	**	**	ns	ns	*	**	**

	V4.5	R4.5	R6.5
CV(%)$_{(N*P*L)}$	13.6	5.5	4.9
CV(%)$_{(N*P*L*S)}$	15.1	5.8	4.2
LSD 0.05 $_{(N*P*L)}$	3.1	3.7	6.6
LSD 0.05 $_{(N*P*L*S)}$	4.9	5.7	7.9

4.2.7. Effect of N, P, and L on economic yield and its components of soybean and peanut

4.2.7.1. Pods plant^{-1}

It was clear that in this soil condition, pods plant^{-1} was limited considerably by deficiency of N, P, and acidity (Fig. 13). By comparison with unamended soil, applying N, P, or L increased pod number by 36, 56, and 30 % in soybean; 68, 67 and 61 % in peanuts, respectively.

A strong positive interaction effect (P<0.01) between N and P on pod number was detected in both species. With N or P alone, pod number was increased by 35 and 55 %, respectively, in soybean; about 65 % for both in peanuts. Whereas with N and P together, pod number was increased up to 120 % in soybean and 180 % in peanuts.

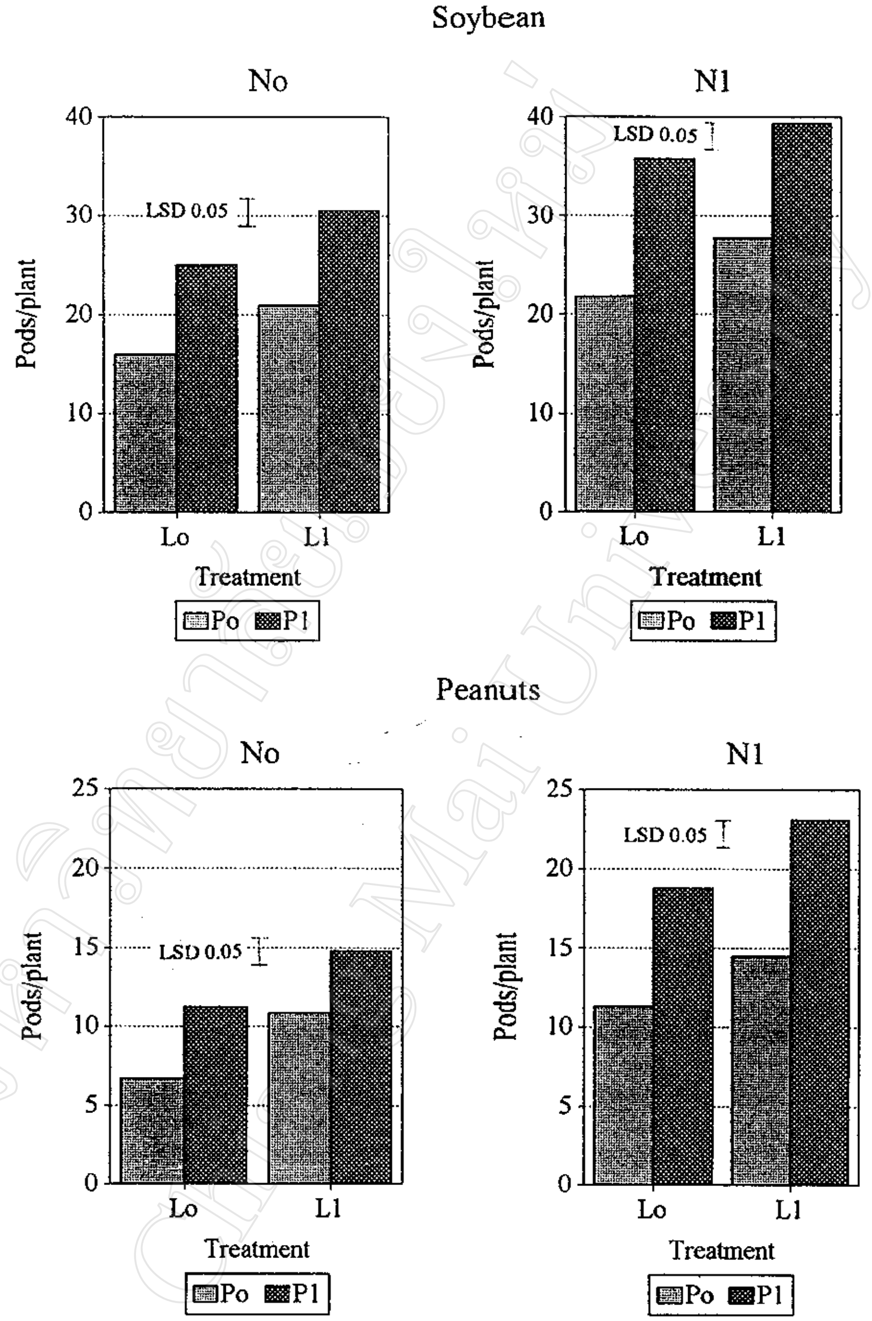

Fig. 13 Effect of N, P, and L on pods plant^{-1} of soybean and peanuts

Table 18. Analysis of variance for pod number

	Source of variation								
	N	P	L	N*P	N*L	P*L	N*P*L	N*P*L*S	S
F Test	**	**	**	**	ns	ns	ns	**	*
CV (%)(N*P*L)	8.7								
CV (%)(N*P*L*S)	7.5								
LSD 0.05 (N*P*L)	2.2								
LSD 0.05 (N*P*L*S)	2.6								

Soybean and peanuts, in terms of pod number, responded differently to combined effect of N , P, and L ($P<0.01$). With N, P, and L together, pod number was highest, and it was increased about 150 % in soybean and 250 % in peanuts.

4.2.7.2. Filled pods plant^{-1}

Filled pod number was increased markedly when N, P or L was applied (Fig. 14). N and P had effect on filled pod number of soybean and peanuts in significant positive interaction ($P<0.05$). With N and P together, filled pod number was increased by 160 % in soybean and 190 % in peanuts. Whereas when N or P were applied separately, filled pod number was increased correspondingly about 35 and 70 % in soybean, 80 and 95 % in peanuts. With N, applying P increased filled pod number by 90 % in soybean, and 60 % in peanuts. Whereas without N, applying P increased filled pods only about 70 % in soybean and 95 % in peanuts. This means that effect of N on response of plants to P was different between two species.

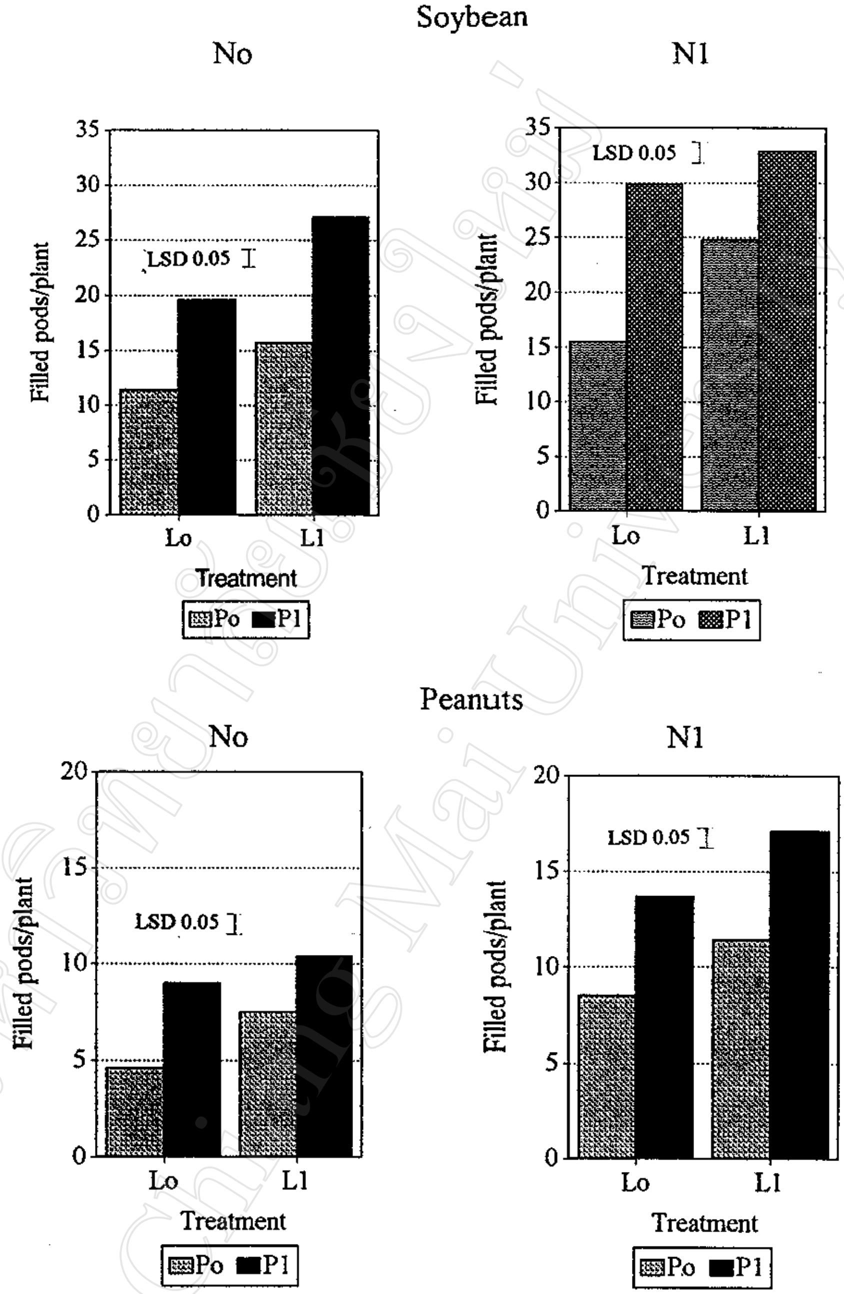

Fig. 14 Effect of N, P, and L on filled pods $plant^{-1}$ of soybean and peanuts

Table 19. Analysis of variance of filled pod number

	Source of variation								
	N	P	L	N*P	N*L	P*L	N*P*L	N*P*L*S	S
F Test	**	**	**	*	ns	ns	*	**	*
CV (%)(N*P*L)		9.0							
CV (%)(N*P*L*S)		9.1							
LSD 0.05 (N*P*L)		1.8							
LSD 0.05 (N*P*L*S)		2.6							

Filled pod number was also affected considerably by interaction between N, P, and L ($P<0.05$). For example, with N and L, applying P increased filled pods by 30 % in soybean, and 50 % in peanuts. Whereas without N and L, these increases were 70 % in soybean and 95 % in peanuts. As the results, the effect of P on filled pods depended strongly on N and L application. Response of plants to P was decreased strongly in the presence of N and L.

Applying N, P, and L together gave the highest filled pods in both soybean and peanuts. However, the responses of soybean and peanuts to combined effect of N, P, and L were significant difference ($P<0.01$). In soybean, applying N, P, and L together increased filled pods about 190 %, but in peanuts, this increase was up to 270 %.

4.2.7.3. Weight of 100 seeds

In general, the weight of 100 seeds of both soybean and peanuts was also affected considerably by N, P, or L application (Table 20). P had the strongest influence on seed weight, it increased weight of 100 seeds about 15 % in soybean and 7 % in peanuts. However, effect of P on seed weight depended markedly on N. With

N, P application increased seed weight about 12 % in soybean and 9 % in peanuts. Whereas without N, applying P increased seed weight about 15 % in soybean and 6 % in peanuts.

A strong interaction effect of N and L on seed weight of soybean and peanuts was also detected (P<0.01). The effect of L on seed weight was increased by N application. With N, liming increased seed weight about 17 % in soybean and 6 % in peanuts, whereas without N, these increases were negligible.

Table 20. Effect of N, P, and L on 100 seeds weight (g)

		No		N1	
		Po	P1	Po	P1
Soybean	Lo	8.2	9.4	8.6	9.7
	L1	8.3	9.2	9.7	10.2
Peanuts	Lo	45.6	48.5	45.7	49.8
	L1	46.0	49.7	48.6	51.5

Source of variation

	N	P	L	N*P	N*L	P*L	N*P*L	N*P*L*S	S
F Test	**	**	**	*	**	ns	*	**	*

CV (%)$_{(N*P*L)}$ 7.8
CV (%)$_{(N*P*L*S)}$ 7.1
LSD 0.05 $_{(N*P*L)}$ 0.27
LSD 0.05 $_{(N*P*L*S)}$ 0.39

On the other hand, seed weight of soybean and peanuts was also influenced significantly (P<0.05) by interaction between N, P, and L. With L, applying N increased seed weight about 17 % in soybean and 6 % in peanuts, whereas with P and

L, applying N increased seed weight much less. Soybean and peanuts had different responses to combined effect of N, P, and L. With N, P, and L together, seed weight was increased by 24 % in soybean, but in peanuts it was only 13 %.

4.2.7.2 Economic yield

Seed yield of soybean (14 % moisture) and pod yield of peanuts (12 % moisture) in this acid soil were clearly limited by N, P deficiency and acidity (Fig. 15). Without any soil amendment, the yields were only 433 kg ha^{-1} for soybean and 652 kg ha^{-1} for peanuts. Applying N, P, or L separately increased yield by 40, 94, and 55 % in soybean; 74, 70 and 56 % in peanuts, respectively. This indicated that P deficiency was the strongest factor limiting the productivity of both species. However, the responses of soybean and peanuts to N, P, and L was different. Peanuts responded more strongly to N than soybean, but soybean responded more strongly to P than peanuts.

A strong interaction effect ($P<0.01$) between N and P on yield in both species was detected showing mutual dependence of N and P. For example, in soybean, with N or P alone, yield was increased correspondingly by 40 and 90 %, but with N and P together, yield was increased by 170 %.

The yields of soybean and peanuts were also influenced markedly by interaction between N, P, and L ($P<0.01$). The effect of P on the yields of both species was much less in the limed soil, i.e. only 30-35 % of yield increased; whereas, in the unlimed soil, P fertilizer increased the yields by 93 % in soybean and 74 % in peanuts.

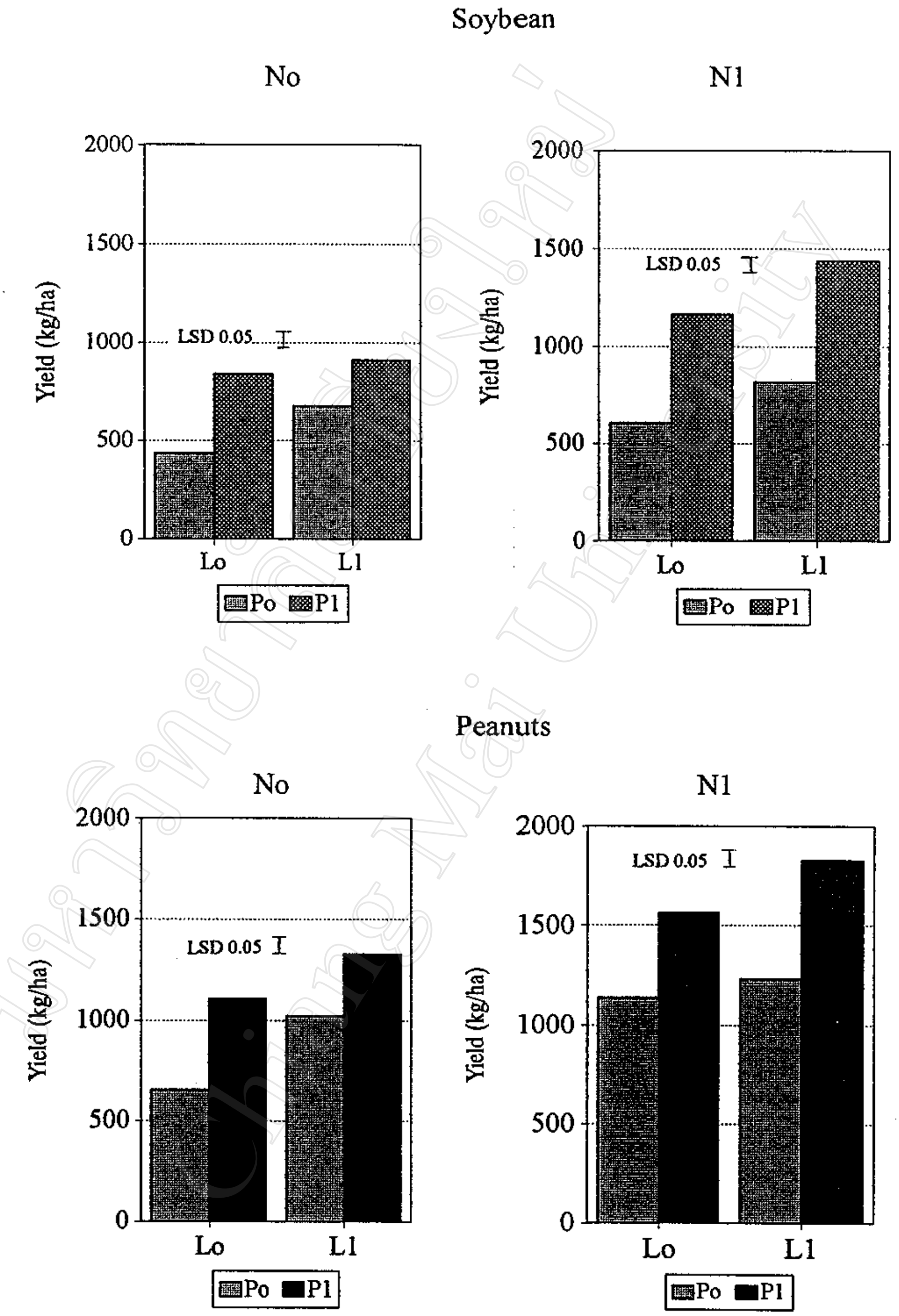

Fig. 15 Effect of N, P, and L on grain yield of soybean (14 % of moisture) and pod yield of peanut (12 % of moisture)

With N and L, applying P increased the yield about 75 % in soybean and 50 % in peanuts, but without N and L, these increases were about 95 % in soybean and 70 % in peanuts. As the results, the increase of yields due to P depended obviously on N and L.

The highest yields in both species were obtained when N, P, and L were applied together, and the yields were increased most strongly, ranging from 180 % in peanuts to 230 % in soybean. Soybean and peanuts responded differently to combined application of N, P, and L ($P<0.01$).

Table 21 Analysis of variance of yield

	Source of variation								
	N	P	L	N*P	N*L	P*L	N*P*L	N*P*L*S	S
F Test	**	**	**	**	ns	ns	**	**	**

CV (%)$_{(N*P*L)}$	5.7
CV (%)$_{(N*P*L*S)}$	5.9
LSD 0.05 $_{(N*P*L)}$	73.9
LSD 0.05 $_{(N*P*L*S)}$	107.2

4.2.8 Evaluation of economic efficiency of the different treatments

In order to assess economic profit of different treatments, total variable costs, gross return and net return were calculated (Table 22)

Table 22 Effect of the different soil improving measures on economic return

Treat.	Total variable costs (1000 dong)	Gross return (1000 dong) S	Gross return (1000 dong) P	Net return (1000 dong) S	Net return (1000 dong) P
PoLoNo	700	1732	2934	1032	2234
P1LoNo	1900	3352	4986	1452	3086
PoL1No	850	2696	4591	1846	3741
P1L1No	2050	3636	5971	1586	3921
PoLoN1	1660	2420	5116	760	3456
P1LoN1	2860	4660	7038	1800	4178
PoL1N1	1810	3260	5548	1450	3738
P1L1N1	3010	5752	8230	2742	5220

In general, growing soybean and peanuts gave the farmers profits (price or costs of soybean and peanuts as well as N, P, L were indicated in Appendix C, Table 9, 10, 11). Peanuts proved to be more profitable than soybean. However, in the fact, the yield of peanuts was often not more stable than soybean by damages of diseases and insects, especially bacterial wilt. The inputs of N, P, and L for improving the soil fertility conditions obtained high benefits. However, the profitability of the treatments was different. In the condition of separate application of N, P or L, liming gave the highest profit. Applying N alone for soybean was not profitable, however a considerable profit was still obtained for peanuts. The combined application between N and P; P and L; N and L gave the high profits in both soybean and peanuts. The highest profits were obtained when N, P, and L were applied together.