CHAPTER 6

DISCUSSION

6.1. Soil characteristics

Secondary data from field survey results showed that soil in the hilly zone is acidic, poor soil fertility in humus and other nutrient contents, especially in available phosphorous. This is probably due to deforestation, unreasonable farming measures, shifting cultivation without fertilizer with shortened fallow cycle, the soils have become deteriorated, eroded, a rather large area has completely lost productivity (Phien, 1997). This author also indicated that most of hilly soil pH varies from 4.0 - 4.5 and becomes more acidic because of leaching, replacing basic cation from the cation exchange sites with hydrogen and aluminum ions due to crop removal and oxidation of NH_4^+ from fertilizer and so on. The average soil pH ranged from 4.2 to 5.2 which is unfavorable condition for peanut production (Reid and Cox, 1973). The critical level of soil pH is 5.5 - 6.0 for peanut (Woodroof, 1986 and Adam, 1981 cited by Fageria *et al.*, 1991). Gibbons (1980) and Saxena *et al.* (1983) cited by Fageria *et al.* (1991) also showed that the most suitable soil for peanut production should be well drained, light sandy loam with ample amount of calcium and moderate organic matter.

Available phosphorous in hilly soil zone is poor and gradually decreases in the process of farming due to low pH resulting in phosphorous fixation and crop absorption as well as lack of phosphorous fertilizer application. Planting leguminous crops to return organic matter to the soil apparently improves soil CEC, organic matter and available phosphorous (Phien, 1997). The field survey results of secondary data also pointed out that available phosphorous in the study region is very poor in which it ranges from 3 to 5 ppm. Muetert and Fairhust

(1997) reported that deficiency in available phosphorous and other nutrients is most widespread in many Asian countries. Poor soil fertility in sloping land in Asia is because of high Al^{3+}, Mn^{2+} and Fe^{3+} toxicity, and lack of phosphorous, calcium and potassium. Nitrogen, phosphorous, calcium and magnesium are nutrients that are often deficiency in the hilly zone. Generally, phosphorous and lime application could be essential for both improving soil pH and available phosphorous in the soil (Kha *et al.*, 1993). Liming can also help improving soil acidity and increasing crop yield (Singh, 1989 and Cope *et al.*, 1984).

6.2. Climatic condition

Due to topography, climatic condition in Central of Vietnam has transition characteristics between the North and the South region of Vietnam. In the study area, average air temperature increase from January to July. Rainfall season starts from September and ends at December and January. However, rainfall concentrates from September to November. Rainfall is low at May to July. From January to May also known as the major growing season, there are many crops that were grown in the areas such as cereals, peanut, vegetables and so on. Because at this time the weather is cool and days are short in early period. During this period crops in hilly zone can be grown on rainfed land on stored soil moisture or thanks to small rains.

The survey results showed that average temperature in the time study is suitable for peanut growth and development. According to Saxena *et al.* (1983) cited by Fageria *et al.* (1991), peanut performance is well in the temperature range between 24°C and 33°C but it can also survive up to 45°C if adequate moisture is maintained. However, peanut is often sown in late January to February in order to avoid short period of droughts and low temperature. Average rainfall among studied months of peanut growing is not much difference. It fluctuated from 131 to 282mm. In general, rainfall is also appropriate for peanut. Because peanut requires the total rainfall amount from sowing to harvest is about 400 – 500mm (Kassam *et al.*, 1975 cited by Fageria *et al.*, 1991). However, low amount of rainfall at the end of March and early April (128mm) is partly affected negative on initial flowering stage of peanut. Nevertheless, amount of rainfall is low in May that it is a favorable condition for the final harvesting of peanut in the region. Survey results also indicated that air humidity in January and February is higher than 90%. It is the unfavorable condition for peanut germination and seedling growth. However, air humidity in April (84%) is suitable for process of peg and pod development of peanut (Fageria *et al.*, 1991).

6.3. Land use

Until 1999, agricultural land use in Thua Thien Hue province is in small portion in which total agricultural land is 81,133 ha occupying 16% the total natural land of the province. The annual crop areas are 76,867 ha accounting for 95% of agricultural land area (Hue Statistic Book, 1999).

Field survey results shown that most of agricultural land in the region is rice production concentrated with spring rice and summer rice. Rice is the most important food crop in the region. It is the main source of nutrition for people and constitutes the basic of daily diet. The goal at both the district and household levels is to be self - sufficient in rice. In the paddy fields, people prefer to concentrate their labor in preference to work as compared with other crops. Cultivation is very intensive and employs advanced technology including pesticides, improved seed varieties and fertilizer (Cuc, 1990). However, rice productivity is still low and fluctuating. Rice farmers are facing huge obstacles i.e. declining rice yields and increasing production costs as a result of high cost of inputs while rice price is low (Xuan, 1998). Moreover, there is labor shortage between spring rice harvesting and summer rice transplanting which often occurs at the same time. Besides, the gross margin of rice - rice cropping pattern is lower as compared to other cropping patterns. Therefore, it seems imperative to change the current cropping system (rice - rice) to other suitable alternative cropping patterns. Peanut - rice and peanut - other crops seems to be the alternative cropping patterns to replace rice - rice system in the hilly zone. Peanut, mungbean and sugarcane can also be widely grown on land that is less suitable to rice, particularly in hilly zone. Because labor use became more efficiency, utilizing maximize land source, improving soil fertility, pest status in subsequent crops was decreasing and finally enhancing gross margin when peanut appear in cropping patterns (Survey, 1999 and Na Lampang, 1985). According to Anh (1994), peanut is the necessary crop in agricultural development of the province. It always occupies high portion in exporting. Moreover, farmer in the region has long tradition in peanut cultivation and peanut is a comparative advantage of the province. Hoang (1994) also pointed out that there is necessary to change cropping pattern from rice - rice to peanut - rice together with multiple cropping in line with the agricultural development strategies of Thua Thien Hue province. Study results of Thanh (1998) in Thua Thien Hue province also indicated that to manage crops for the highest economic returns, farmers in Thua Thien Hue province should apply intercropping patterns. Especially, peanut/corn intercropping pattern which performed the best in terms of economic returns. In addition, peanut is considered as a high diversity crop in its response to water deficits and it often utilizes in cropping systems in rainfed areas. So they are cultivated over a wide range of environments as rainfed crop on a small scale by smallholder farmers (Wood and Myers, 1987; Mc William and Dillon, 1987)

In general, crop production is still the mainstay of rural inhabitants in the hilly zone of Thua Thien Hue province where more than 70 percent of its agriculture areas are under rainfed condition. As mentioned in earlier chapter, hilly zone is characterized by two basic land forms including upland and lowland. Survey results indicated that arable agricultural land is extremely limited, soils are generally low in fertility. As the rural population increases, agricultural land is correspondingly expanded to the upland area. Much of the additional land, with soils unsuitable for agriculture and being low in water holding capacity, is where only rainfed single cropping is possible. The present land use situations combined with the scarcity of arable land reflect the low potential for agriculture (Worachai *et al.*, 1989 and Phien, 1997). The traditional techniques of cultivation with no crop rotation or no soil conversation practices is leading to the declining in both soil fertility and crop productivity. Xuan (1998) reported that the diversification of many types of crop in cropping systems on each type of land use is aimed at increasing farm household income by sustainable resource management while maintaining national food security. On land for which supplementary water like lowland irrigation area is available, improved land productivity is feasible by replacing some indigenous rice varieties with high yielding strains and more intensive cultural practice to improve rice productivity can be done. In upland with gentle slope usually is planted to field crops. To increase the capacity of the land for providing sustenance, some areas should be used for legume cultivation. Bruce *et al.* (1987) indicated that leguminous crops are significant for protecting the soil from erosion, especially on the sloping land because they increase organic matter in the surface soil as well as water infiltration and soil aggregation. Besides, shorter growth cycle of legume crop and their lower water requirements permit double cropping such as peanut followed by mungbean or other crops. This can generate greater return to the land in comparison with single cropping of rice. In addition, it can be used fully labor, water and land resource (Na Lampang, 1995). Beside this, there are some crops to plant in this upland area such as cassava, sugarcane, sweet potato and mungbean. Within these basic forms of rural landscape that is common to the hilly zone, there are distinct differences in the specific patterns of land use characteristic. These different patterns may be inferred to represent the outcome of the operation of the difference resource constraints i.e. water, land, nutrient and labor (Cuc, 1990).

6.4. The role of peanut in cropping systems

Peanut in improving soil fertility:

Peanut played an important role in enhancing soil fertility. Survey results indicated that almost all farmers informed that peanut residues contributed to improve soil fertility in terms of increasing soil moisture, organic matter as well as increase soil nutrients ability for subsequent crops, especially in terms of soil nitrogen. Because each species of plant requires various mineral nutrients for its growth, the continuous cropping of cereals or other non-legume crops often leads to depletion of some specific mineral nutrients which consequently decreases yield. This situation could be improved if food legumes are introduced in the rotation with cereal crops (Whyte *et al.*, 1969). This author also reported that apart from direct contribution to economic return of farmer, legumes have benefit affects on soil fertility by improving the nitrogen and organic matter status of the soil and by bringing up minerals through their root systems from the lower soil horizons. Whenever, a legume and non-legume are grown together in a cropping systems, the legume is expected to provide most of its nitrogen through symbiotic Nitrogen fixation, and also to supply some of nitrogen requirements of the non legume crops. Thus, it may substantially reduce the input of fertilizer nitrogen required to growth of the non-legume crops (Myers and Wood, 1987). A considerable amount of nitrogen in crop residues (83 to 141 kg N ha^{-1}) of food legumes can supply for next crop if the residues are returned to the soil.

Field survey results also indicated that all interviewed farmers considered peanut as green manure. Bouldin (1984) cited by Marchners (1986) reported that green manure affected positively to available nitrogen, soil organic matters and soils productivity. Many green manure crops furnish a succeeding rice crop with nitrogen equivalent of 50 to more than 100 kg nitrogen fertilizer per ha. The amount of peanut residual of 5 – 8 ton dry matter yield ha^{-1} applied is equivalent to more than 120 kg of N, 70 kg of P_2O_5 and 150 kg of K_2O ha^{-1} (Phuong, 1991). In addition most of interviewed farmers indicated that peanut residues are applied as mulching. Because crop residue mulch is an important ingredient of improving farming and cropping systems. Frequent application of 4 to 6 tons per ha of residue mulch applied to the soil surface are beneficial for soil and water conservation, regulating soil moisture and temperature regimes improving soil structure, enhancing biological activity of soil fauna, and protecting soils from high intensity rains and from ultra-desiccation. Mulching also suppresses weed growth. The use of crop residues as fertilizer is especially important to resource poor farmers (Lal, 1995). This author also pointed out that, a cover crop usually a legume is grown specially to break the cropping cycle, to produce mulch material, to improve soil structure and to enhance soil organic matter content. Mulching farming as reduction in run off and soil erosion. Peanut, soybean and mungbean are often grown intercropping with corn or cassava will bring high economic return and protect soil from erosion and soil fertility maintenance (Dau *et al*., 1991; Thanh, 1998).

Peanut and pest status in subsequent crops:

According to the field survey results which was presented in Chapter 4, more than 65% interviewed farmers responded that peanut and other crops rotation decreased damages caused by pest for subsequent crops. Because changing to a different crop by rotation helps to break the cycle, changing the selection pressure for a given pest species. Crop rotation against pests which are relatively host specific and have poor powers of dispersal and destruction of alternative host (Dent, 1995). This author also pointed out that rotation to use crops with sharp contrast in biological characteristics, life cycle, planting time and agronomic requirements to maximize the change in conditions and thereby make the cropping environment unfavorable for the pest species. Rotation will ensure maximum impact on pest population levels. Davis (1993) reported that the peanut – rice rotation are good system to limit development of diseases and insects in the field. Hence component of intercrops is less damage by pests than in sole crops. In addition, diversification of agricultural habitats through intercroping or rotation has frequently lower pest populations. Growing the same crops continuously in the same field often encourages accumulation of diseases and insects and should be avoided (Na Lampang, 1985). Mc William and Dillon (1987) also pointed out that advantages of growing legumes are to break the cycle of the cereal cropping and reduce the incidence of soil borne diseases.

Labor used:

Labor distribution and utilization are cardinal aspects of human activities in agricultural production. Survey results shown that with the development of peanut production, labor use became more efficient in terms of the working time and using laborers (Table 3). Peanut management practices such as sowing, weeding, harvesting and processing can be done by all sources of labor from children to old - age people in the households. On the other hand, the labor forces were also used year - round if peanut is introduced in the production. Because, peanut growing areas were not far from growers' home, then they can work whenever needed.

In addition, there is labor shortage between spring rice crop harvesting and summer rice crop transplanting due to high labors required which occurred at the same time. Therefore, pressure of labor requirement will be eased if there is changed from rice - rice cropping pattern into peanut - rice cropping pattern. Because, crop calendar of rice and peanut was different leading to distribution of labor resources is not similar between these two crops. It means that spring rice often finishes transplanting on January, farmers can start to sow peanut on February. Similarly, after harvesting rice on May, farmer can continue to harvest peanut. Therefore, pressure of labor will be decreased for growing areas of peanut - rice.

6.5. Responses of peanut to lime and phosphorous fertilizer

The effect of phosphorous fertilizer and lime on growth, development and yield of peanut had been investigated in the field experiment. Generally, phosphorous fertilizer and lime were the most important mineral nutrient for increasing peanut yield because they effected on leaf areas, dry matter yield yield, nodule dry weight and yield components of peanut. Results of the study were presented in Chapter 5. Details of such effect were discussed as follows:

Nodulation:

General speaking, field experiment result shown that number of nodule per plant and nodule dry weight per plant increased with the increasing rates of phosphorous and lime application (Figure 9 and 10). The average maximum value was obtained at treatment where 120 kg of P_2O_5 ha^{-1} combining with 900 kg of lime ha^{-1} were applied. This probably applying lime and phosphorous enhances root development, especially liming will increase Mo which affected to nodulation and development of peanut clearly (Ljones, 1972). This result is similar to the study of Turkhede and Giri (1982) cited by Fageria *et al.* (1991). These authors found that increased phosphorous supply has been showed to increases nodule number and nodule weight, and increased rate of N_2 fixation in a number of leguminous crops. Phosphorous is an essential ingredient for rhizobium bacteria to convert atmospheric nitrogen (N_2) into an amonium (NH_4^+) form which is useable by plants. John and William (1999) reported that nodule number, volume and dry weight can be increased by treating phosphorous deficient soils with fertilizer phosphorous. The nodules became pink earlier, developed more quickly, and became active sooner in response to phosphorous fertilizer.

Lime and phosphorous also increased soil pH in the field experiment. The highest soil pH value was obtained at treatment which was applied 120 kg of P_2O_5 ha^{-1} in combination with 900 kg of lime ha^{-1} was 5.9. In addition, the experimental results indicated that there was significant lower number of nodule per plant and nodule dry weight per plant at treatment where there was no phosphorous fertilizer and lime application. Number of nodule per plant and nodule dry weight per plant was shown the greater value as phosphorous and lime were applied together. Because soil pH before conducting field experiment was very low (4.1) while critical level soil pH for peanut is 5.5 to 6.0 (Fageria *et al.*, 1991). Munns (1980) pointed out that soil acidity affected nodulation of peanut. It has been considered as inhibitors for peanut nodulation. Low soil pH often relates to high exchangeable aluminum and manganese which cause toxicity to plant, and especially to activities of rhizobium bacteria. The symbiosis is particularly sensitive to Al^{3+} and Mn^{2+} toxicities (Munns, 1980; Borkert and Sfredo, 1994). Munns (1980) reported that in acid soil, surface root structure of peanut damages, therefore, rhizobium bacteria are not able to penetrate to root. In case of inadequate phosphorous, it restricts root growth, the process of photosynthesis, translocation of sugars and other functions which directly or indirectly influence nitrogen fixation by legume plants. Therefore, the fundamental practice of liming acid soils to the pH range of 6.5 to 7.0 is significant to the relationship between phosphorous and the symbiotic nitrogen fixation process (John and William, 1999).

Leaf area:

The results of field experiment indicated that leaf areas increased significantly as phosphorous and lime application rates increased (Figure 14). This proved that leaf areas of peanut responded with lime and phosphorous application. The lowest leaf areas value also obtained at the treatment where there was no phosphorous and lime application. Because low soil pH and available phosphorous had adverse effects on leaf area. Borkert and Sfredo (1994) pointed out that low soil pH can affect directly or indirectly plant growth, and among indirect effects, the relationship between soil pH and availability of mineral nutritional elements in the soil such as nitrogen, phosphorous, Ca, Mg and Mo must be concerned. In general, low soil pH leads to reducing availability of these elements to plants. In the case of phosphorous deficiency, the small size and dark green color of the leaf blades are observed which is the result of insufficient cell expansion (Hetch - Buchholz, 1967 cited by Marschner, 1986). When phosphorous is limited, the most striking effects are a reduction in leaf expansion and leaf surface area as well as number of leaf (Armstrong, 1999). Experimental results shown that leaf areas was observed the maximum value at R_6 stage at all rates of lime and phosphorous application after that it decreased at R_8 stage. William *et al.* (1975), Kasam *et al.* (1975), Enyi (1977) and Saxena *et al.* (1983) cited by Fageria *et al.* (1991) reported that leaf areas reach a maximum around 75 days after sowing for cultivars with a 115 to 125 days growth cycle. The decline in leaf areas at all treatments at the harvest stage was due to the occurrence of leaf senescence and leaf drop at this stage. This result is similar to the study of Thin (1996) and Tinh (1997) in northern and central region of Vietnam.

Dry matter yield:

Research results indicated that there were significant differences in dry matter yield among treatments in peanut at all four observed growth stages. General speaking, there was greater response of dry matter yield to phosphorous fertilizer at treatments with liming (Figure 13). The highest dry matter yield was found at application rates of 120 kg of P_2O_5 ha^{-1} and 900 kg of lime ha^{-1} at the harvest stage. Total dry matter yield was increased due to increase of leaf area, and increase interception of energy of sunlight during growth season of crops. Because dry matter yield accumulation in plants are derived from solar radiation through the photosynthesis process, and temperature and soil fertility governs the speed of development (Mc Cloud *et al*., 1990). Tinh (1997) also shown that dry matter yield of peanut was significantly increased (84 - 145%) as phosphorous fertilizer application rates increased. This result also agreed by Thin and Cu (1996). Syers and Crashwell (1995) reported that phosphorous addition increase plant growth and nitrogen fixation by legumes, thus enhancing the quantity and quality of crop residues. Other studies reveal that phosphorous applied to low phosphorous soil can increase the percent nitrogen in legumes and result in greater dry matter yield yields (John and William, 1999).

Results also shown that dry matter yield accumulation at R_4 stage (60DAS) was nearly double as compared with R_2 stage (40DAS). This result is similar with conclusion of Fageria *et al*. (1991). The author reported that dry matter yield accumulation pattern in peanut is slow in the beginning, increases sharply in the late vegetative and early pod filling stages and reaches a plateau during late pod filling.

Pod yield and yield components:

Crop yield is a function of its components and related to physiological features. Economic and biological yields of crop depend on growth and development of crop. Practice management has significant roles in improving pod yield of peanut as well as other crops. The effects of phosphorous fertilizer and lime on growth and development of peanut were presented most clearly in the effect of them on pod yield. Pod yield of peanut increased significantly when phosphorous and lime application rates increased. The maximum pod yield of 2,189 kg ha^{-1} was obtained at 120 kg of P_2O_5 ha^{-1} applied together with 900 kg of lime ha^{-1}, an increase of 101% as compared with control (Figure 21 and 22). This is because application of lime and phosphorous fertilizer affected positive on growth indicators i.e. number of nodule, nodule dry weight, dry matter yield and leaf areas and yield components of peanut (Figure 15-20). This result is similar with the study of An (1996), Tinh (1991) and Tinh (1997). Yield was increased resulting from increases of number of pods, filled pods and seed weight as well as pod weight.

Experimental results also shown that yield of peanut was maximized at pH around 5.5 to 5.9 corresponding to fertilizing at rates in which 700kg lime ha^{-1} was applied together with 90 kg of P_2O_5 ha^{-1} as well as 120 kg of P_2O_5 ha^{-1} and 900 kg of lime ha^{-1} was also applied together with 90 kg of P_2O_5 ha^{-1} as well as 120 kg of P_2O_5 ha^{-1}. Hinson and Hartwing (1982) cited by Raymond and Donahue (1990) reported that the best pH for certain crop is the one that provides a favorable balance of available nutrients. They also suggested that when phosphorous is adequate and micronutrients (except Mo) are relatively low, a pH between 5.5 and 6.0 usually is the best.

Yield components of peanut i.e. pod number, filled pod number, seed weight and pod weight which was also increased significantly when lime and phosphorous rates application together increased. Fageria *et al.* (1991) stated that yield components variation is related to cultivar, spacing, fertilizer and climate. Bouldin (1978) cited by Marschner (1986) reported that there is close relationship between phosphorous deficiency and a decrease in the number of flowers and delay in flower initiation that effect on pod number and filled pod number. Actually, there is close relationship between yield components and pod yield and the biological data including number of nodule, nodule dry weight, leaf area and dry matter yield in the experiment. Increase of number of pod per plant, 100-pod weight and 100-seed weight occurred correspondingly in relation to pod yield of peanut. Similarly, increase of number of nodule, nodule dry weight, leaf area and dry matter yield resulted in enhancing yield components of peanut.

In general, peanut responded to phosphorous and lime in terms of growth indicators i.e. nodulation, leaf areas, dry matter yield and yield components such as number of pods, filled pods, seed weight and pod weight. The responses of peanut to phosphorous and lime in the experiment was similar to some previous research results that phosphorous deficiency and acidity limited productivity of peanut in the hilly zone (Cu, 1996, Tinh, 1997 and Tin, 1999). However, results also shown that application phosphorous and lime separately, even at high rates did not give maximum yields of peanut. Application together of phosphorous and lime played a very important role in improving peanut yield in the study region. This conclusion is similar with results of Cu (1996). The combination of 120 kg of P_2O_5 ha^{-1} and 900 kg of lime ha^{-1} showed the highest pod yield in this soil in aspect of growth and yield of peanut. Field survey results shown that the highest yield in farmers' field were 1,660 kg ha^{-1}. Most of farmers in three surveyed villages had yield variation from 1,300 kg to 1,500 kg ha^{-1}. It means that peanut yield in field experiment was higher than in farmers' field. This is probably due to effect of proper phosphorous and lime application rates.

6.6. Effects of phosphorous fertilizer and lime on soil characteristics

Phosphorous fertilizer and lime applications play an important role in improving soil fertility. Field experiment results shown that there were positive changes of soil chemical properties at all treatments as compared with soil before conducting experiment. Levels of available phosphorous and pH were increase corresponding with phosphorous and lime application from 5.12 ppm and pH 4.1 in an unamended soil to 10.06 ppm and pH 5.9 when 900 kg lime and 120 kg of P_2O_5 ha^{-1} was applied together (Figure 29 and 30). According to Sanchez (1976), liming soil to pH 6 increased the available phosphorous by precipitation of Al^{3+} and some aluminum hydroxides which can fix phosphorous. The purpose of liming is primarily to neutralize the exchangeable aluminum, and that is normally accomplished by raising the soil pH. Lime application can improve the effectiveness of phosphorous fertilizers in soils with high aluminum saturation. Liming acid mineral soils improved phosphorous uptake by plants grown on acid soils with 50 - 70% aluminum saturation (Partohardjono and Sri Adiningsih, 1991). In addition, when application of phosphorous alone also increased pH from 4.2 to 4.7. Because there are about of 28 - 30% CaO in the composition of super-phosphate (Kha, 1996). In this field experiment, liming soil to pH 5.5 -6 corresponding to 700 - 900 kg lime ha^{-1} increase available phosphorous. At these liming rates, available phosphorous is highest (10.06mg/100g soil). This also agreed with result reported by Fox *et al.* (1964) that in a highly weathered soil phosphorous solubility was greatest in the range pH 5.6 -6.0. In acid soils, phosphorous is usually precipitated as Al^{3+} and Fe^{3+} phosphates or absorbed onto clay surfaces. Soil pH control is a basic consideration in soil improvement programs and a major incentive for that is also gives the possibility of increased phosphorous availability. Liming of some Ultisols and Oxisols increased the availability of soil phosphorous for several crops (Ruaysoongnern and Keerati-kasikorn, 1996). Application of lime and phosphorous in the experiment have also effects on organic matter content. This is probably due to lime and phosphorous application enhanced biomass of peanut crop and the increase of pH resulted in increasing organic matter decomposition in the soil (Kha, 1996). Besides, application of lime and phosphorous also affected positively to other total nutrients, particularly nitrogen (Figure 31, 32, 33 and 34). Haynes (1984) pointed out that both lime and phosphorous fertilizer applications can alter the availability of other macro and micronutrients in the soil and change biological activity in the soil. Phosphorous application tends to increase the soil CEC and therefore the Mg, K and Na buffering capacities. Positive interactions of phosphorous with other essential nutrients have been documented in research studies on many crops. The effects of phosphorous on other nutrients or practices or the effects of other nutrients or practices on phosphorous are interactions significant to profitable crop production (John and William, 1999).

6.8. Effect of phosphorous fertilizer and lime on N, P and K concentration in the plant.

Results from field experiment indicated that phosphorous fertilizer and lime application effected on the content of nitrogen, phosphorous and potassium in peanut plant. However there was no significant interaction between phosphorous and lime application together. It was observed that nitrogen concentration in peanut is less than 4% when phosphorous was applied. This value was also showed nitrogen deficiency in peanut because the critical level for nitrogen was 4.2 (Robinson, 1986). Phosphorous and lime application enhanced plant growth and its in turn enhance the uptake of nitrogen from the soil and the nitrogen concentration in plant. The highest concentration of plant nitrogen was obtained at 120 kg of P_2O_5 ha^{-1} and 900 kg of lime ha^{-1} application separately which was 3.51% and 3.40% respectively (Figure 23 and 24). Mc. Laughlin *et al.* (1989) found that phosphorous application increases both dry matter yield and nitrogen percentage in the plant. They also found that a positive relationship between phosphorous percentage and nitrogen percentage in the top of grain legumes with phosphorous application. In acid soil with high aluminum concentration have been considered as inhibitors for nodulation (Munns, 1979). Thus liming acid soil encouraged activities of rhizobium bacteria and resulting in increasing plant nitrogen concentration (Abruna, 1979; Borkert and Sfredo, 1994).

Robinson (1986) also pointed out that the critical level for phosphorous in plant was 0.35%. The highest phosphorous concentration was also obtained at 900 kg of lime ha^{-1} and 120 kg of P_2O_5 ha^{-1} application alone which was 0.35% and 0.36%, respectively. The concentration of phosphorous in plant was also observed at the level less than 0.35% when phosphorous and lime were not applied. It was also observed that the highest soil available phosphorous of 10.06 mg/100g soil at 120 kg of P_2O_5 ha^{-1} applied together with 900 kg of lime ha^{-1}. The availability of phosphorous in soil was increased by liming as the result interaction effects between phosphorous and lime and this also resulted in increasing concentration of phosphorous in plant. Furthermore, liming reduced

Al^{3+} in soil, and enhanced root growth, increased nutrient uptake and translocation in the plants (Mengel *et al.*, 1987). Haynes and Naidu (1991) also reported that in acid soils, Al^{3+} toxicity prevents the plants from using available phosphorous. Liming make effective use of available soil phosphates and increase phosphate absorption by plants.

Research results shown that there was no significant interaction between phosphorous fertilizer and lime application on K concentration in the plant. However, it was found that liming and phosphorous application alone increased K concentration in the plant (Figure 27 and 28). This probably due to lime and phosphorous application make potassium more efficient in plant nutrition. When potassium is plentiful, all plants absorb more of it than they need (Raymond and Donahue, 1990). This conclusion is also similar to the study results on peanut of Tinh (1997).

6.9. Economic consideration

Analysis of economic efficiency is final necessary stage for the assessment of production output and investment efficiency in the cropping systems. Economic consideration of application phosphorous and lime as presented on Table 18 and Figure 35.

Experiment results pointed out that all treatments with fertilizer application have higher gross margin as compared with non fertilizered treatment. Gross margin from peanut production found range from 2.4 million – 7.1 million VND. This result is similar with report of Anh (1994). Table 18 also indicated that phosphorous fertilizer and lime application at the rates of 120 kg of P_2O_5 ha^{-1} together with 900 kg of lime ha^{-1} did not give significant increase in gross margin as compared with gross margin at 90 kg of P_2O_5 ha^{-1} combining with 700 kg of lime ha^{-1}. This indicates that gross margin varied with different treatments and depended on increasing yield and variable costs. Additional cost, which is mainly from additional phosphorous fertilizer and lime costs, is not relevant to additional pod yield and total revenue. This proved that application phosphorous fertilizer and lime at 120 kg of P_2O_5 ha^{-1} and 900 kg of lime ha^{-1} are not economically sound. In terms of efficiency of phosphorous and lime investment in peanut production, results from field experiment shown that value cost ratio (VCR) for phosphorous and lime at most of treatments where there were phosphorous and lime application was higher than 2. According to Kha (1996), VCR is greater than 2 proved that investment of fertilizer for crops have profit. It indicated that phosphorous and lime application in this field experiment can bring higher profit for peanut growers. When phosphorous fertilizer applied together with lime, the highest VCR value was obtained at 90 kg of P_2O_5 ha^{-1} combining with 700 kg of lime ha^{-1} which was 4.0. Results from Table 18 also pointed out that the optimum yield for this experiment is 2,154 kg ha^{-1} corresponding with treatment that applied 90 kg of P_2O_5 ha^{-1} together with 700 kg of lime ha^{-1}. Because at this treatment farmers can obtain highest gross margin and VCR value. However, the maximum VCR value of 4.2 was obtained at 700 kg of lime ha^{-1} application alone because of low costs of lime application. But due to the investment for liming was low that resulted gross margin per ha was also low at nearly 3,7 million VND while the maximum gross margin the experiment was 7.1 million VND. Phosphorous application alone increased the gross margin up to 4.7 million VND when 120 kg of P_2O_5 ha^{-1} was applied. But the VCR value was low at only 2.1 because the increase yield was much lower proportion than that to the costs. In general, phosphorous application alone could not give high VCR because of the high cost of phosphorous fertilizer. But VCR value is highest at

2.3 with application of 60 kg of P_2O_5 ha^{-1}. Thus application at 60 kg of P_2O_5 ha^{-1} was considered as the economic rate when phosphorous applied alone.

Higher yields and greater profits are major reasons why farmers apply phosphorous and lime to crops. All crops need phosphorous for profitable yields (John and William, 1999). The results obtained in this study allow farmers to examine the cost of fertilizer application at various rates against a range of potential yield increase. They may then choose appropriate fertilizer application rates with their particular situation. With farmers who have capital for investment, the rate of 700 kg of lime ha^{-1} and 90 kg of P_2O_5 ha^{-1} should be applied to maximize gross margin from peanut per a unit area. Because there was highest gross margin together with high VCR value of 4.0 at this rate of application. With moderate farmers, it is recommended to apply phosphorous fertilizer at 60 kg of P_2O_5 ha^{-1} and 700 kg of lime ha^{-1} because of the high VCR value at 3.1. With very poor farmers, liming alone at rate of 700 kg of lime ha^{-1} could give them with very high VCR value from peanut production but it could not give high gross margin per a unit of area. Lime and phosphorous fertilizers were economically feasible only at the proper rates to compensate for the cost of application. In developing sustainable nutrient management strategies it is important to consider the interactions of phosphorous with lime and nitrogen in particular. Addition of lime, where feasible, is frequently a less expensive way of increasing soil phosphorous availability than adding phosphorous fertilizer, except where phosphorous is deficient (Syers and Myers, 1996). It is essential that the rate of phosphorous and lime recommendation made to farmers be improved considerably beyond the common practice in the region. There were two reasons for the low rates of fertilizer used by farmers: (1) lack of understanding of the need for fertilizer application to peanut and (2) lack of capital for investment (Anh and Lai, 1994, Cu, 1996). Thus, it is necessary to introduce advanced fertilizer management and supplying farmers with fund to improve peanut production in the region.