CHAPTER 2

LITERATURE REVIEW

2.1 General role of phosphorous in plant function

Phosphorous is an essential macronutrient for plant growth and is generally considered to be second only to nitrogen in limiting crop production (Willett *et al.*, 1996). Phosphorous has two essential roles in plants and animals, as structural components and in the energetics of cells. One of the main structural roles of phosphorous occurs in nucleic, DNA and RNA (Marschner, 1986). Another important structural role is in phospholipids as an essential component of cell membranes in which phosphorous has a bridging role. Although phosphorous is considered to be a macronutrient, the phosphorous concentration in plant tissue seldom exceed 0.5%, and phosphorous toxicity occurs in some tropical legumes at even lower concentration, for example, 0.3 – 0.4% in pigeon pea (Bell *et al.*, 1990).

Symptoms of phosphorous deficiency vary between crop species as well as in severity depending on growth conditions. Phosphorous deficiency retards the growth of plants and often a reddish coloration occurs because of enhanced anthocynamin formation. Under conditions of phosphorous deficiency, all cells and leaf expansion are retarded while chlorophyll formation continues, thus chlorophyll content per unit leaf area therefore increases (Hecht and Buchholz, 1967 cited by Marschner,1986) but the photosynthetic efficiency per unit of chlorophyll is much lower (Tombesi *et al.*, 1969 cited by Marschner, 1986). When phosphorous concentration in plant tissue become low, results in severe growth reduction especially of plant tops usually observed. Often, leaf expansion is reduced with the efficiency of photosynthesis and reproductive growth adversely affected but with little effect on protein synthesis (Willett *et al.*, 1996).

Because of the many functions of phosphorous in the growth and metabolism of plants, deficiency in this element leads to a general reduction of most metabolic processes including cell division and expansion, respiration and photosynthesis and so limits growth, particularly during the reproductive stage (Terry and Ulrich, 1973 cited by Marschner, 1986). Due to the high phosphorous requirement in metabolically active parts of the plant, there is often much translocation of phosphorous to young tissues regions with high phosphorous demand. Thus, symptoms of phosphorous deficiency are often evident in older tissue with lower metabolic activity. It is clear that inputs of phosphorous to agriculture are necessary and phosphorous is also intimately connected to the nitrogen concentration of soils in systems that rely on biological nitrogen fixation (Willett *et al*, 1996).

2.2. The role of phosphorous and lime in improvement of peanut yield

Sahrawat and Islam (1988) showed that the phosphorous requirement of oil – seed crops is higher than cereal crops because phosphorous is involved in the synthesis of energy rich oils and proteins. However, such requirement varies not only from crop to crop but also among cultivars of same crop. Generally, the amount of phosphorous uptakes by different oils seeds to produce 1 ton of seed is much higher than cereals such as rice and sorghum, as well as pulses such as chicken pea and pigeon pea (Tandon, 1987).

Studying on the role of phosphorous in peanut yield, Bell (1985) indicated that there is close relationship between pod or kernel yield and extractable soil phosphorous level before planting in the top 10 cm of soil followed a Mitscherlich – type equation. This relationship could be represented by the following equation:

$$\text{Pod yield (ton ha}^{-1}) = 4.7 - 6.4^{-0.395\ \text{extractable phosphorous}}$$
$$R^2 = 0.85$$
$$\text{Kernel yield (ton ha}^{-1}) = 3.1 - 4.1^{-0.395\ \text{extractable phosphorous}}$$
$$R^2 = 0.83$$

Nelson (1980) and Tandon (1987) cited by Sahrawat and Islam (1988) also pointed out that the response of phosphorous of peanut varies with the soil available phosphorous status, soil phosphate adsorption – desorption characteristic and the supply of other nutrients. Peanut often uptakes phosphorous in the range of 4.7 – 19.3 kg and in an average of 12 kg to produce 1 ton of pod yield (Pandey and Mc Intosh, 1988). There are many results finding that phosphorous application increases peanut yield. Borif (1986) cited by Ismuadji *et al.* (1987) reported that phosphorous fertilizer application is effective in increasing the number of pods per plant and seed weight of peanut. He also reported that yield was more than 6 times greater than the control when 30 kg of P_2O_5 ha^{-1} was applied and 16 times greater when the rate increased to 120 kg of P_2O_5 ha^{-1}. Phosphorous and calcium together gave large yield increases, but phosphorous or calcium applied separately was relatively ineffective. Nelson (1980) cited by Sahrawat and Islam (1988) found that application 1 kg of P_2O_5 increased peanut yield by 20 ± 4.3 kg ha^{-1}. He also indicated that 15.1 kg of P_2O_5 ha^{-1} was uptaken by a peanut to produce 3.1 ton of pod yield. In general, in acid soils with a pH less than 5.0-5.5 with initial lime applications result in large increases in crop growth and yield (Haynes, 1984).

In Vietnam, the phosphorous deficiency and acid soil condition are considered a factor limiting crop yields countrywide (Anh, 1992 and Thuy, 1997). It has been reported that each kilogram of phosphorous fertilizer applied to fields could increase 5-8 kg of rice, 8-10 kg of corn and 8.5-15 kg of peanut (Anh and Dinh, 1992).

Beside this, there is also some research results regarding lime application in yield improvement of peanut. Tinh (1991) reported that lime application increased pod yield of peanut especially when applied as a dressing by dusting lime onto the soil at the early flowering stage. She also pointed out that applying 500 kg of CaO ha^{-1} increased 160 - 490 kg ha^{-1} of peanut pod yield as compared with the control.

In terms of soil properties and pod yield of peanut, Tinh (1997) also indicated that applying phosphorous fertilizer not only increased pod yield but also improved soil pH as well as content of total nitrogen and available phosphorous in the soil.

2.3. The role of phosphorous and lime in nitrogen fixation

The source of nitrogen in crop plant may come from the soil, fertilizer and fixation of atmospheric nitrogen through biological nitrogen fixation. However, there are strong interactions among these three sources of nitrogen additions.

In general, food legumes require a large amount of nitrogen for their growth. However, the nitrogen required for plant growth can be obtained either from symbiotic fixation of atmospheric nitrogen or from the direct uptake of soil inorganic nitrogen. Phosphorous plays a key role in the build-up and maintenance of soil productivity through its effects on legume growth which in turn promote the growth, survival and nodulation capability of rhizobia. The rhizobia can take nitrogen in N_2 form from the atmosphere and convert it to the form that available to plants as nitrate (NO_3^-) and ammonium (NH_4^+) forms. This process is commonly called nitrogen fixation (Mc Laughin *et al.*, 1989).

Phosphorous fertilizer and lime application plays a significant role in nitrogen fixation process of peanut. They may reduce their fertilizer nitrogen requirement in some cropping systems. An adequate phosphorous supply is important for balanced fertilization for grain legume production (Pandey and Mc Instosh, 1988). The authors also reported that applying phosphorous to deficient soils has been shown to increase number and weight of nodules in several legume species.

Regarding the role of phosphorous fertilizer and lime in nitrogen fixation of legumes, Loneragan (1972) cited by Mc Laughlin *et al.* (1989) reported the role of phosphorous in nitrogen fixation through interrelated main phases namely host plant growth, rhizobial growth and survival as well as infection and nodule function. Both lime and phosphorous are liable to stimulate nodulation and nitrogen fixation by most legumes although inhibition of nodulation at pH > 6 might be a problem with some legumes (Haynes, 1984).

2.4. The role of peanut in cropping systems

Cropping systems are commonly described simply by the dominant cropping patterns they include, and all components required for the production of the crops in these cropping pattern and their relationships with the environment (Zandstra *et al.*, 1981).

Mc William and Dillion (1987) indicated that food legumes play a particular role in Asia both in the nutrition of humans as animal feeds and as an ecologically sound component of farming systems of the region. Legumes have the capacity to fix nitrogen from atmospheric nitrogen in symbiosis with rhizobia. The amount of nitrogen fixed by a legume crop varies depending on cultivars and environmental conditions. Under good conditions, food legumes in the tropics can fix up to 300 kg of N ha^{-1} (Myers and Wood, 1987). Rerkasem (1989) cited by Mc Laughin *et al.* (1989) found that nitrogen fixed by grain legumes ranged from 10 to 450 kg of N ha^{-1} and legumes can enrich the soil for an associated cereal crop depending on nitrogen balance. The nitrogen fixed by peanut was equivalent to a supply of 60 kg of N ha^{-1} as fertilizer (Fageria *et al.*, 1991).

In terms of economic return, the results of field experiment in Thua Thien Hue province had been shown that corn intercroped with peanut improved income for the farmers as compared with the sole peanut and sole corn (Thanh, 1998).

Whyte *et al.* (1969) showed that apart from direct contributions to the economic return of farmers, legumes have beneficial effects on soil fertility through improvement of the nitrogen and organic matter status of the soil and by bringing up minerals through their root systems from the lower soil horizons. Along with this, another very important attribute of legumes in tropical countries is the provision of protection for the soil against the sun and the rain.

On the aspect of the rotation systems of peanut and other crops with pearl millet, Giri and De (1980) cited by Myers and Wood (1987) indicated that pearl millet produced more grain in pearl millet – peanut, pearl millet – cow pea or pearlmillet – pigeon pea as compared with pearl millet – pearl millet system. The use of food legumes in crop rotation is one of the most important means in maintaining organic matter in the soil (Thompson, 1957). In addition, rotation of cereals and food legumes is likely to break the cycle of cereal cropping resulting in reduction of the incidence of soil born diseases and the use of the plant residues after harvest as a valuable source of animal feed (Mc William and Dillon, 1987). Bruce and Swaify (1987) studied legume effects on soil erosion and productivity and concluded that selected legumes alone or in combination with non-legumes provided protection from soil erosion, increased organic matter in the surface soil, increased water infiltration and aggregate stability, and improved nutrient status.

2.5. Effect of liming and phosphorous fertilizer on soil and nutrient properties.

Borkert and Sfredo (1994) indicated that the predominant soils in tropics are Oxisols and Ultisols which together comprises 63.9% of the area. They also pointed out that high acidity is common in many tropical soils and can cause stress to peanut plants. According to Cuc *et al.* (1990) and Chieu (1992), the basic process of soil formation in the hilly and mountainous soil zones of Vietnam is ferralitic, through weathering of the parent material leading to accumulation of iron and aluminum with leaching out of most base cations. This leads to soils with red-yellow coloring, high in oxides of aluminum and iron and high kaolinite clay and low in base saturation. The soils are characterized as high acidity (pH 4-5) and very low in available phosphorous (1-3 ppm).

Soil acidity factors including low pH, low calcium, low phosphorous and high aluminum and manganese are also regarded as inhibitors of legumes nodulation (Munns, 1979). In acid soils, Al^{3+} and Fe^{3+} are most abundant and react with phosphorous to form relatively insoluble aluminum and iron phosphates. Since high acidity is common in many tropical soils and can affect peanut growth, the control of soil acidity is one important method for increasing productivity of many legume crops. The purpose of liming is primarily to neutralize the exchangeable aluminum and this is normally accomplished by raising the pH to 5.5 or 6.0 (Sanchez, 1976). The author also suggests that liming acid soils (pH 5.5) generally reduces formation of insoluble Al^{3+} and Fe^{3+} phosphates and increases phosphorous availability to plants. However, applying lime to soil with a pH level beyond 6 could decrease phosphorous uptake (Fox *et al.*, 1964).

Liming often influences microbiological activity and this can considerably modify solution phosphorous concentrations. Improved phosphorous nutrition which sometimes accompanies the liming of highly weathers soils seems to be more a result of decreased uptake of manganese (Mn^{2+}) and aluminum (Al^{3+}) than of increased phosphorous solubility (Fox *et al.*, 1974).

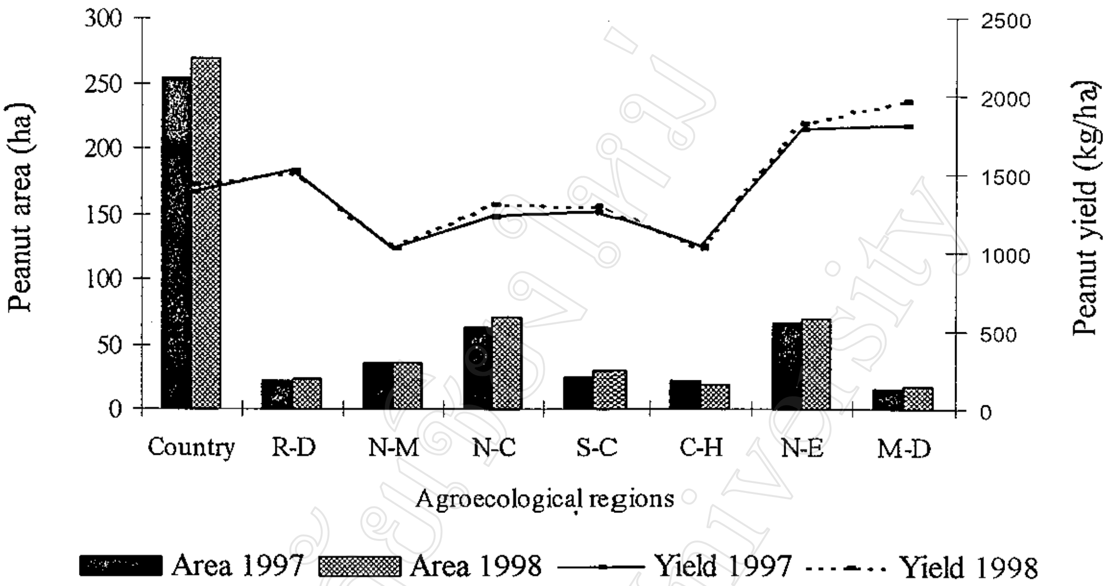
Lime application can improve the effectiveness of phosphorous fertilizer in soils with high Al^{3+} saturation. Liming of acid mineral soils has improved phosphorous uptake and plant growth on acid soils with 50-70% Al^{3+} saturation (Partohardjono and Sri Adiningsih, 1991).

Because of the high phosphorous fixation capacity of acid soils, the amount of phosphorous fertilizer applied is usually greater than the requirement of plants. An annual crops usually takes up about 5 to 25% of the phosphorous supplied by a single application (Wild, 1988).

2.6. Peanut production in Vietnam and in Thua Thien Hue province

2.6.1. Peanut production in Vietnam

Peanut is well adapted to a tropical climate and at present it is cultivated in many parts of Vietnam (Figure 2). The major growing regions are in the mountainous region of Northern Vietnam, the northern region of Central Vietnam and the eastern region of South Vietnam (General Statistical Office, 1999).



N-M: North mountain and Midland; R-D: Red River Delta; N-C: North Central Coast; S-C: South Central Coast; C-H: Central Highlands; N-E: North East South; M-D: Mekong Delta River.

Figure 2: Area and yield of peanut by agroecological regions

Source: General Statistical Yearbook, 1999.

Figure 2 indicated that the highest yield of peanut is obtained in the Mekong Delta River and the Southeast part of the country. The lowest yield is found in central Vietnam including the North Central and South Central coasts. Thua Thien Hue province belongs to the North region of Central Vietnam where both area under cultivation and yield of peanut are low in comparison with other regions in Vietnam.

2.6.2. Peanut production in Thua Thien Hue province

Total area and average yield of peanut in the whole province and in hilly zone of Thua Thien Hue province are presented in Figure 3.

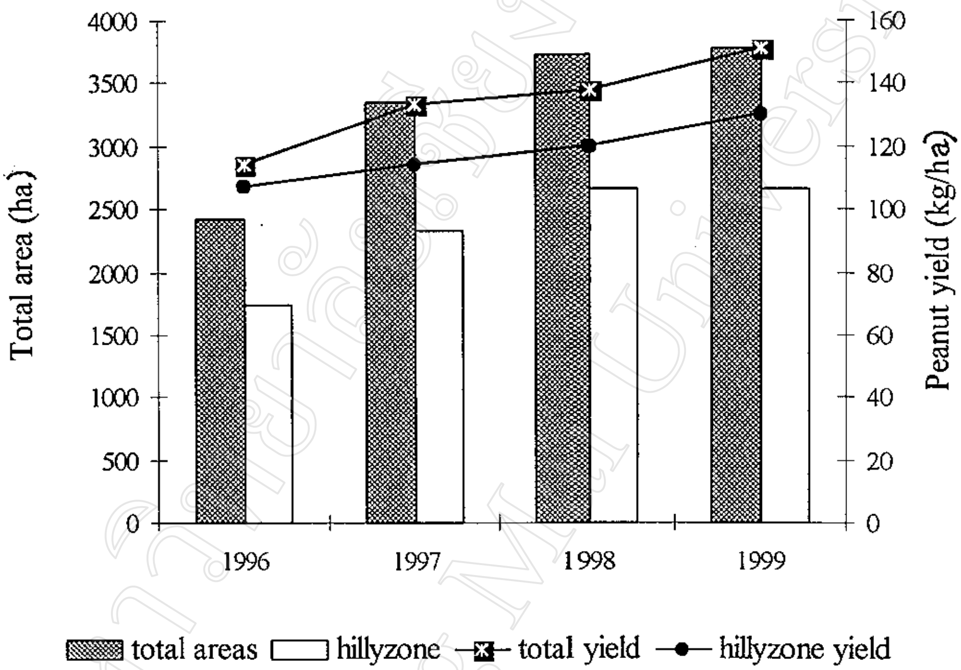


Figure 3: Area and yield of peanut in hilly zone and in Thua Thien Hue province
Source: Hue Statistical Book, 1999.

According to the Hue Statistical Office (1999), the sowing area of peanut in the hilly zone has increased during 1995-1999. The area of peanut is concentrated in two districts namely Phong Dien and Huong Tra. Peanut areas in the hilly zone of Thua Thien Hue province occupy about 70% of total peanut area in the whole province.

The average yield of peanut in the hilly zone is still low as compared with peanut yield in the delta zone and of the whole province (Figure 3) because of low soil fertility, high soil acidity and low in available phosphorous in the area (Vi and Khai, 1978, Cuc *et al.*, 1990; Dau *et al.*, 1991). These become limiting factors for peanut growth and yield production.

Dien and Long (1991) reported that peanut production has high economic efficiency in terms of profit and soil fertility improvement. In addition, inputs for peanut are lower than other crops but protein content is higher than rice up to 70% greater. Therefore, the expansion of peanut sowing areas in the region is necessary and fits one of the agricultural development strategies plan of the Ministry of Agriculture and Rural Development (Hoang, 1994).

2.7. Constraints on peanut production in Vietnam

2.7.1. Socio-economic factors

In Thua Thien Hue province, apart from low inputs and poor markets, difficult transportation facilities and price policy are factors that limit peanut production. According to Lai (1994), the survey on peanut production constraints of Vietnam pointed out that lack of cash for input, low price, low productivity, lack of technology for peanut production, poor soil fertility as well as low efficiency of biological nitrogen fixation are limiting factors for peanut production in Vietnam.

2.7.2. Agronomic factors

According to An (1996), apart from climatic factor, farmer production management also affected to peanut yield. It was reported that factors that limit peanut production in Vietnam are water stress, lack of land preparation, poor seed quality, lack of fertilizer input and chemical control of pest and diseases and weeds. The other main reasons for low peanut yield in the farmer's field are deficiencies in nitrogen and phosphorous (Cu, 1996 and Tinh, 1997).

2.7.3. Management practices for yield improvement

The capacity of supplying phosphorous of the soil to plant relates to soil acidity. In general, soil phosphorous availability is depressed at high acidity. In acid soil, increasing the soil pH causes minerallization of phosphorous phytate, thereby increasing phosphorous availability to plant, because in acid soils, the very insoluble Al and Fe phytates are believed to be the most abundant organic phosphorous compounds (Borkert and Sfredo, 1994). The authors also indicated that phosphorous management is critical to the production of soybean and peanut, particularly in acid soils with high phosphorous-fixation. A lack of this element is doubly serious since it may prevent other nutrients from being absorbed by plants. And the low P availability and the high phosphorous – fixation capacity of tropical soils imply a high requirement for phosphorous fertilizers.

Mengel *et al.* (1987) showed that liming acid was important part of any legumes fertilization program in USA. It had a number of potential benefits for crops as follows: (1) the reduction in the concentration of potentially toxic elements such as H, Al and Mn, (2) the increased availability of plant nutrients such as Ca, Mg, and Mo and (3) improved nodulation and N_2 fixation. Alexander (1961) cited by Borkert and Sfredo (1994) supposed that liming acid soils enhances carbon volatilization and organic matter decomposition. Adoye and Singh (1985) carried out field experiments on acid soils of Oxisols and Ultisols in Indonesia and indicated that application of dolomitic limestone are successful in overcoming soil acidity problems, and allow quite high yield to be achieved. However, response to lime by peanut grown in these experiments varies with different cultivars.

In benefit aspect of lime application, Borkert and Sfredo (1994) showed that not all reactions following the liming are beneficial to plants. Under the certain conditions, overliming may be detrimental. In tropical, optimum pH for peanut is 5.5 – 6 with heavy soil, and 5-5.5 with sandy soils. Overliming may reduce availability of some nutrients and increase base leaching. It may also have an adverse effect on soil structure and on the total complex organisms.

In short, peanut is a component in many cropping systems and an important component of the farming systems for both ecologically sound production and for human and animal nutrition. However, peanut productivity in the hilly zone is low as compared with other places and the yield of peanut fluctuates. Low phosphorous and acidity are the main reasons for limiting peanut yield in this zone. Therefore, identifying these factors exist as limiting factors to peanut production and how to overcome them are necessary to enhance peanut production in the region.