Chapter 5

Discussion

1. Nutrient concentration in different soil types, according to parent material

Nutrient concentrations in different soil types, granite; sandstone and limestone, were analysed. Soil pH of granite and sandstone were acidic, 4.7-5.8, whereas in limestone soil, pH was slightly alkaline, 7.5-7.7. According to Menzel and Symptom (1987), in subtropical Queensland, the soil pH of lychee orchard usually fluctuated in the range of 4.5-5.0. In China, the soil pH was about 5.5 (Groff, 1921 cited by Menzel and Simpson, 1987). Base on the soil information in Queensland and China, the soil pH of granite and sandstone supposed to be suitable for growing lychee. In the case of limestone, pH at 7.5-7.7 might be too high for the optimum growth. From observation, lychee plants grown on limestone showed light yellowish green leaf, N deficiency symptom, although the extractable N from the soil was the greatest (Table 5.1). According to Marschner (1999), too high soil pH usually affected the plant efficiency to uptake N from the soil, so that, the leaves of lychee trees growing on limestone showed deficiency symptom although the concentration of N in the soil was abundant.

Soil parent material also affected the extractable nutrient in the soil. Similar to N concentration, limestone soil was very rich in Ca, whereas sandstone soil was very rich in Mn and Fe. Both soil types were very low in K. It indicated that it would be necessary to apply K to plants grown in these types of soil. However, precaution must be taken for Mn and Fe toxicity in sandstone soil because of too high concentration of extractable Mn and Fe.

According to Marschner (1999), Mn and Fe also affected the efficiency of plant to absorb other cation nutrients such as Ca, Mg, Zn and B due to the competitiveness among cation nutrients. These elements and side effects must therefore be taken into account for the fertilizer application.

General information for lychee normal growing condition, the most susceptible nutrients for deficiency in all kind of soils were P, Mg, Zn and B. Fertilizer application should therefore be emphasized. In the case of limestone soil, applications of N and K were also necessary whereas Ca concentration might have been too high to affect availability of other elements. In sandstone soil, applications of P, K, Mg, Zn and B were necessary however, Mn and Fe toxicity might occur in sandstone soil. Whereas in granite soil, availability of P, K, Mg, Zn and B were very sensitive, deficiency might occur easily.

Table 5.1 Nutritional status of soil at three different soil types.

Orchards	Soil depth (cm)	pH	Extractable nutrients (mg/kg)								
			N	P	K	Ca	Mg	Mn	Fe	Zn	B
Granite	0-15	5.8	140	8.8	357	1,200	130	59	27	1.1	0.1
	15-30	6.0	110	4.0	133	700	100	40	20	0.8	0.1
	30-45	5.1	90	1.3	100	700	79	24	8	0.2	0.1
	45-60	4.7	70	2.6	66	500	62	20	3	<0.1	0.1
Sandstone	0-15	4.8	150	13.2	60	1,300	77	354	160	2.6	0.2
	15-30	4.9	100	11.0	34	900	52	244	96	0.3	0.1
	30-45	4.8	80	14.0	33	800	53	264	86	0.4	0.1
	45-60	4.7	60	9.7	30	600	45	149	56	0.2	0.1
Limestone	0-15	7.5	170	18.5	67	5,500	130	16	16	1.7	0.1
	15-30	7.6	160	7.9	75	5,200	130	14	11	0.8	0.2
	30-45	7.7	140	5.3	60	5,100	110	12	6	0.5	0.1
	45-60	7.7	50	5.7	33	4,600	100	11	4	0.3	0.1
Soil Standard for tree, nut and fruit crop suitable											
Anon(1984) cited by Menzel and Simpson, 1987		5.0 to 5.5		20 to 60	78 to 195	1,200 to 1,200	192 to 384	2 to 50	2 to 50	2 to 15	1 to 5

Nutritional status: high, low

From the information showed in table 5.1, soil with granite parent material supposed to be the most suitable soil type for lychee cultivation due to its pH value and nutrient content. Among all the studied nutrients, concentrations of P, Mg, Zn and B were very low in all soil types, especially when compared with soil standard. They indicated that plants grown in these soils might easily show deficiency symptom of these 4 elements. Zn and B have been mentioned that these two important micronutrients were closely related to tryptophan and auxin accumulations, in addition, B was also closely correspondent to sugar balance in plants (Marschner, 1999 and Foth, 1987). These two elements therefore very important for reproductive stage especially for fruit setting and fruit development.

2. Nutrient concentration in lychee leaf

Leaves from lychee tree grown in limestone soil contained the lowest concentration of N, Mn and Fe (Table 5.2). This result was similar to the previous explanation by Marschner (1999) and Motavalli (2001) that the high soil pH together with high Ca could affect the efficiency of plant to absorb N and other cation nutrients for examples Mn^{2+} and Fe^{2+}, Fe^{3+}.

Leaves of lychee from tree grown in granite and sandstone soils were very rich in Mn but very low in Ca. According to Hung (2001), Ca was very important element for the normal development of plant. Deficiency in Ca caused malformation of fruit. Lychee fruit from tree grown in granite and sandstone soils always showed fruit cracking and peel browning at the fruit expansion stage. That might be due to lack of Ca. Thus, application of Ca at proper time of fruit development might alleviate cracking and peel browning problem in fruits.

Zn and B were also found to be very low in the leaves from all soil types. Whereas Fe was found in low concentration in granite and limestone soils.

This information suggested the importance to apply fertilizer which contained Zn, and B to lychee grown in all soil types, whereas some additional elements might be needed in particular soil type such as N, Fe and Mn in limestone orchard, Ca and Fe in granite orchard and only Ca in sandstone orchard.

Table 5.2 Leaf nutrient level in the present study compared with standard values developed for lychee in South Africa, Israel, Australia and in Thailand.

Nutrient	South Africa standard (Cull, 1977)	Israel standard (Galan Sanco, 1987)	Tentative Australia standard	Thailand (Supakamnerd, 2001)	current experiment		
					granite	sandstone	limestone
N (%)	1.30-1.40	1.50-1.70	1.50-1.80	1.37	1.4	1.6	1.2
P (%)	0.08-0.10	0.15-0.30	0.14-0.22	0.10	0.1	0.3	0.3
K (%)	1.00	0.70-0.80	0.70-1.10	1.11	1.1	1.3	1.3
Ca (%)	1.50-2.50	2.00-3.00	0.60-1.00	0.86	0.8	0.6	1.6
Mg (%)	0.40-0.70	0.35-0.45	0.30-0.50	0.11	0.2	0.4	0.3
S (%)	-	-	-	-	0.2	0.5	1.7
Mn(mg/kg)	50-200	40-80	100-200	307.65	121.0	96.0	40.0
Fe(mg/kg)	50-200	40-70	50-100	69.65	43.0	71.0	41.0
Zn(mg/kg)	15	12-16	15-30	7.67	11.0[1/]	12.0[1/]	12.0[1/]
B(mg/kg)	27-75	45-75	25-60	15.12	1.3[1/]	2.0[1/]	2.8[1/]

Nutrition status: high, [1/] = low (deficiency)

Figure 5.1 Sunburn symptom of lychee leaf in granite and sandstone orchards

3. Nutrient concentration in fruit of lychee

Amounts of nutrient concentrations in lychee fruit harvested from tree grown in granite soil type were compared with the standard value suggested by Menzel *et al.* (1988) (Table 5.3). Concentration of Ca, Zn and B were very low as was found in leaves. Thus, application of these three elements might increase fruit quality.

Table 5.3 Nutrients concentration in fruit of lychee from tree grown in granite soil type as compared to data studied by Menzel *et al.*(1988)

Nutrients	Nutrient concentration	
	Menzel *et al.* 1988	Current experiment
N (%)	0.85-1.06	1.08
P (%)	0.019-0.023	0.11
K (%)	1.04-1.40	1.09
Ca (%)	0.01-0.02	0.08
Mg (%)	0.016-0.018	0.13
S (%)	-	0.08
Mn (mg/kg)	16-29	21.1
Fe (mg/kg)	25.3-57.2	21.2
Zn (mg/kg)	31.8-44.0	9.9
B (mg/kg)	14.7-31.0	0.003

4. Comparison of the nutrient concentration in leaves at four cardinal points and at different developmental stage

Many observations have been made on leaves of lychee tree at different cardinal point, especially in cool dry season. Leaves from southern and south-western side of the trees usually showed a pale green color, a sign of sunburn effect or phototoxic (Figure 5.1). This phenomena was believed to be result of major stress condition. which lower the flowering possibility due to less concentration in nutrients, e.g. Zn on such a stressed leaves. The study therefore aims to confirm the nutritional status (south, west, east and north sides of the canopy). It might be a cause of low flowering. In addition to that, nutrient concentrations might be in low level and it can cause stress in plant e.g. stress from deficiency of Zn. This study was conducted to observe whether cardinal point had an effect on nutritional status or not.

The level of leaf nutritional concentration varied more or less depend on plant developmental stage. N, P, Mg and B were slightly declined during flowering and fruiting (January – April). Menzel and Simpson (1992) reported that the concentration of the mobile nutrients, such as N and P, generally, the decrease fell slightly during initiation of the new flush, and then increased to reach maximum level in May – July as the flush matured. Values declined again during flowering and early fruit growth to reach minimum levels between fruit set and mature. The nutritional concentration of Mg and B also slightly decreased during flowering to fruit development (Figure 4.17 and 4.22). These information suggested that application of high mobile nutrients at the most active stage of development in plants e.g. flushing, flowering and fruit growing stages, might enhance good fruit quality.

The nutritional status of Mn, Fe and Zn varied with sampling periods. The level of Mn and Fe was significantly increased from flowering to fruit set, and then decreased when fruit mature (fruit harvest) (Figure 4.20). In the case of Zn, the concentration of nutrient firstly increased and then decreased during sampling periods (Figure 4.21). Whereas level of Zn fluctuated throughout the year. Great concentrations were obtained during the emergence of the late summer – early autumn vegetative flush, prior to fruit set and again at harvested (Menzel and Simpson, 1992).

In conclusion, nutritional status of all nutrients in leaves remained in the same level at all four cardinal points. Nutrient level varied depending upon plant developmental stage, and environmental condition. At flushing stage, most of mobile nutrients like N, P, Mg and B was measured in the leaves. At flowering stage and fruit setting, the decrease in nutrients concentration was observed in the leaves. This result was found to be similar to other plant species (Menzel and Simpson, 1990)

5. The Relationship of nutritional concentrations in soil, leaf and fruit of lychee

The correlation of nutrients concentrations in soil and leaf and/or in fruit could be explained by R^2values. The R^2value was the coefficient of determination which could be used for measuring the relative reduction of the sum of square of dependent value Y (nutrient concentration in leaf of fruit) by adjusting the independent variable X (nutrient concentration in soil). In addition, R^2 value could also be described in the percentage. For example, $R^2 = 0.7$ meant the value Y could be changed in following of the value X at 70% confident. In this study, the R^2 value was used to identify the correlation of the analytical value of each element between soil and leaf, soil and fruit as well as leaf and fruit. The correlation of R^2 value that was greater than 0.9, indicated that plants could absorb nutrients in according to the nutrient level in soil. On the other hand, correlation between leaf and fruit could inform that the amount of nutrient found in leaf was correspondent to the similar amount in fruit. With low R^2 value (R^2 >0.8), the proportion of nutrient concentrations among soil, leaf and fruit was very positive for N, P, Mg, Mn and Fe and less positive (R^2 >0.6) for K and B. In the case of P and K (very mobile nutrient), nutrient concentrations in leaf and fruit were always high, despite nutrient concentration in the soil was low. This suggested the lychee root was very efficient in absorbing K from soil even at low availability. In contrast, amount of Mg, Mn Fe and Zn (intermediate mobile nutrient) concentration in leaf and fruit were proportioned to nutrient concentration in soil although plants needed them as trace elements. In the case of B, due to a very low availability in the soil (Table 5.1), lychee leaves and fruits were facing a strong deficiency condition. Proper foliar or soil application of B is needed in all type of soils.

Table 5.4 The R^2 value of correlation between soil - leaf nutrients and soil - fruit nutrients

Nutrients	The coefficient of determination (R^2)		
	Soil - Leaf	Soil - Fruit	Leaf – fruit
N	0.9194	0.9355	0.8988
P	0.7338	0.8408	0.8617
K	0.6560	0.6159	0.6323
Ca	0.8628	0.6401	0.8141
Mg	0.9237	0.8433	0.8576
Mn	0.9209	0.9315	0.9094
Fe	0.9368	0.9461	0.8335
Zn	0.8871	0.7048	0.7537
B	0.6789	0.6599	0.6257

6. Field application possibility

Lychee is one of the economic fruit trees widely grown in northern Thailand. Growth and yield performances are however differing according to growing areas and province. Many factors have been described to effect the growth of lychee e.g. climatic conditions, soil fertility, and cultivars. In the case of soil fertility, results from this study could provide some useful informations as follow:

1. Inappropriate conditions of soil with limestone parent material

Among the studied soil types with three different parent materials such as granite, sandstone and limestone, it was found that limestone derived soil was the most inappropiated soil condition for growing lychee. Soil pH value of 7.5 – 7.7 and high concentration of Ca could decrease the availability of many nutrients in the soil, i.e. N and S by forming the insoluble $Ca(NO_3)_2$ and $CaSO_4$ salt. High rate of N and S fertilizer would be therefore required to achieve the normal growth and high fruit yield.

Moreover, the limestone soil usually contains a very low concentration of P, Mn, Fe, B and Zn. Deficiency risk might be more serious, when plenty of Ca is available and amount of these nutrients was low so, the competition for root absorption among Ca^{2+} and the other cation nutrients (Mn^{2+}, Fe^{2+}, Fe^{3+},B^{2+}, Zn^{2+}) may occur. Therefore, the lychee trees grown on limestone soil usually show yellowish in leaf color and stunt in growth performance.

Soil with granite or sandstone as parent material is more favorable for growing lychee. However, the pH value should be increased and maintained at 5.5 – 6.5 (e.g. by liming). Both soil types were poor in P, Mg, B and Zn concentrations.

2. Very low concentration of B and Zn in mountainous soil of northern provinces.

All the three soil types, granite, sandstone and limestone, contain very low concentration of Zn and B. The extractable Zn was only <0.1 – 2.6 (mostly < 1.0) mg/kg, whereas the appropriate range should be 2 – 15 mg/kg (Menzel and Simpson, 1987). B was 0.1 – 0.2 mg/kg, whereas the normal condition should be 1 – 5 mg/kg.

Although plant usually requires B and Zn only in small amount (as trace elements), B is very crucial nutrient for sugar balance and sugar transportation from leaves to active tissues, like young shoot, and to flower to ensure good fruit setting. Zn is very important for enzymatic metabolism and auxin activity. Both nutrients are therefore the most important nutrients to be carefully managed for all soil types in northern Thailand.

3. Fertilizer application

In general, limestone soil is unfavorable for lychee growing. However, some growers could not avoid growing lychee in this soil type. Application of high rate of N, P, K, Mg, Mn, Fe, B and Zn are recommended. In granite and sandstone soil, special application of Ca, B and Zn should be practiced, i.e. at the peak of growth rate stage such as flushing, flowering and fruit setting.

For precision farming system or minimizing the use of fertilizer, soil analysis should be practiced. However, analysis of newly full mature leaves could be an alternative choice in order to obtain similar result as soil analysis for N, Mg, Mn and Fe (R^2 >0.9).

Amount of applied fertilizer should be relied firstly on fruit yield and nutrient concentrations in harvested fruit. The current research found that the amount of nutrients exported through 1,000 kg harvested fruit were 108 kg N, 11 kg P, 109 kg K, 8 kg Ca, 13 kg Mg and 8 kg S. With these amount of exported, amount of fertilizer application after harvesting could be calculated. However, it is not all applied fertilizers are used, some loss might occur from leaching, nutrient competition, environmental condition and plant growth stage. The detail information must be closely followed.