Chapter 5

General Discussion and Conclusion

5.1 General Discussion

According to information obtained by farmers' interview from this study greening and root rot were the important diseases for mandarin cultivation in Mae Soon sub-district which confirmed the report of Nam Ruork Sai *et al.* (2007) who also found that 28.5, 18.4 and 18.1 percent of the total interviewed mandarin farmers in Fang, Chai Prakarn and Mae Ai districts had deteriorated orchards due to root rot, greening and canker diseases respectively. According to Sittigul *et al.* (2008), the important diseases for citrus in 10 northern provinces in Thailand were greening, triteza, canker, melanose and scab and the first two diseases were the most widely spreading ones. Though greening disease was one of the major diseases involved with declination of mandarin production in the studied areas but the disease spreading was not related directly to topographical and soil condition. Furthermore, the tissues of air layering, the commonly used plant material in most mandarin orchards might be already infected by *Liberobacter*, greening disease bacterial pathogen and triteza virus as reported by Sri Thong Chai (2010). Thus, only root rot disease was taken into consideration as one of the cause of productivity declination of mandarin orchards in Mae Soon sub-district because the prevalence of root rot disease for citrus was influenced by many factors such as water level in the soil, age of tree, root stock, pH of soil, type of soil, lightning injury and hurricane damage (Suit and Knorr, 1949).

From risk evaluation of root rot damage in the studied areas, it was found that there were the orchards on the lowland and the foot hill which were risky to root rot damage at high and very high levels about 70 and 72% respectively. According to land use history, the orchards on the lowland were previously used for paddy rice cultivation while those on the foot hill were formerly litchi orchards. Under paddy rice cultivation, hard pan formation in soil profile at the depth below the plow layer is common due to seasonal cycle of pudding (wet tillage) and drying over the long term (Pingali *et al.* (1997). Hand pan is the soil layer that restricts root growth and water movement. The hard pan formation in soil profile creates some problems as follows, reduced root penetration, poor infiltration of water, poor water storage and distribution, restricted drainage and poor leaching (Eck and Unger, 1985). When the paddy fields were used for mandarin cultivation, the farmers did not operate any tillage to break hard pan. They dug the soil to prepare the drainage ditch and the dug subsoil were placed on top of the original surface soil and became the new surface soil with undesirable soil physical properties. Furthermore, from field survey, it was observed that during rainy season, the orchards on the lowland had shallow water table. Under such condition the soil in the mandarin root zone with the depth about 30 cm. in the orchards on the lowland had very high moisture content in the rainy season. With insufficient oxygen for effective respiration of the roots, less ATP (2 ATP) was obtained from anaerobic respiration of the roots instead of 38 ATP from aerobic respiration (Boonyakiat, 2001).

According to Whiteside (1972), Duniway (1983) and Feld *et al.* (1990) which were cited by Naqvi (2004) heavy soil with poor drainage, excessive irrigation and prolonged contact of water with tree trunk increase *Phytophthora* disease in nurseries and orchards and cause foot rot collar rot and gummosis. Injuries to the trunk and prolong wetness make it more susceptible to infections soil moisture, aeration and temperature significantly influence the fibrous root infection, multiplication of the pathogen and its further spread. Stressed conditions due to dry or saturated soil, root damage due to water logging and depletion of oxygen propose the roots for infection and increase their susceptibility. Damaged roots or under stress condition increase the root exudates and restrict the root regeneration. Furthermore from the report of Stolzy *et al.* (1965) which cited by Naqvi (2004), root exudates released in such condition also attract zoospores of *Phytophthora*. According to Naqvi (2004) *Phytophthora*, the fungal disease pathogen of root rot disease in citrus is a water loving fungus. It survives in soil through small thick walled spores (chlamydospores) and oospores which can tolerate dry summer conditions with limited soil moisture but in poorly aerated soil and in high CO_2 concentration in the soil, chlamydospore development also occurs. Oospores development only occurs when both mating types are present in the soils. With onset of monsoon and in optimum temperature (25-32 °C), flooding or excessive irrigation and soil aeration, chlamydospores germinate indirectly to produce sporangium and zoospores or directly to produce mycelium. Chlamydospores also require nutrients in form of root exudates for germination. These zoospores swim in water for short distance by flagellas movement or may be carried away by rain or irrigation water and are attracted to root tips and wounds to cause infection. A new generation of sporangia is formed within 24 hours of their entrance in tissue and again liberates the zoospores to initiate new infection. This cycle repeats so far soil remains saturated and other favorable conditions persist. From the above information about *Phytopthora*, root fungal disease, it was expected that the soil conditions of mandarin orchards on the lowland with hard pan in the soil profile, poor drainage and shallow water table were favorable for root rot development. In the case of the orchards on the foot hill which were formally litchi orchard, the soils were Don Yang En, Li and Ban Chong soils. The first two soils are poorly drained soil while Ban Chong has moderately drainage. However the orchards with Ban Chong soil were extremely acidic with pH less than 5.0. It was therefore expected that not only drainage but also low pH were the factors influencing root rot damage in mandarin orchards on the foot hill.

According to Suit and Knorr (1949), in Florida, root rot disease has tendency to be more important when the soil show a pH of 7 or above. The other reports related with soil pH and root rot disease of citrus are not available. In this study, significant negative correlation between risky scores on root rot damage and the following soil parameters, soil pH, soil organic matter and microbial biomass were observed. According to Suksawang (1991) (cited by Kitjaideaw, 1998) the following bacteria, *Pseudomonas cepacia, Pseudomonas* and *Bacillus* are antagonistic to *Phytopthora parasitica*, fungal disease of root rot of citrus due to their antibiotic compound products while *Streptomyces* is paracitic actinomycetes of oospores of *P. parasitica*. In general, the population of bacteria and actinomycetes in acid soil is low thus, soil pH improvement by liming results in increasing of population of these two types of soil microorganism too. In this study, it was observed that the mandarin trees in one farmer orchard (Mr. R. Dowee) on the foot hill with good drainage soil but soil pH was below 4.5 were severely damaged by root rot. It was therefore expected that under acidic soil, the populations soil born microorganisms having antagonistic properties against fungal root rot disease might be very small. Without competition, antibiosis or parasitism, there would be more chance for root rot disease to be active as suggested by Broadbent and Baker (1974).

According to Broadbent and Baker (1974) by maintaining the high levels of active microorganism, avocado root rot can be reduced. Many soil-born microorganisms such as *Mycrothecium roridum*, *Tricoderma harzianum*, *Epiccocum purpurascens*, *Catenaria anguillae*, *Humicola fuscoatra*, *Anguillospora pseudolongissma*, *Hypochytrium catenoides*, *Myrothecium venucaria*, *Streptomyces griseoalbus*, *Micromonospora cabonacea*, *Streptomyces violascens*, and *Ceraceomyces tessulatus* have been shown to be inhibitory to *P. cinna moni* via competition, antibiosis or parasitism (Downer, 1998; Erwin and Ribeiro, 1996 cited by Menge and Marais, 2000). Some of these microorganisms such as *Streptomyces grieseoalbus*, *Micromonospora cabonacea* and *Streptomyces violascens* are actinomycetes thus they may prefer non acidic soil condition for increasing of population density in the soil. Soil pH improvement by liming may be beneficial for increasing of the population of those antagonistic bacteria and actinomycetes in the soil and subsequently reduce population density of *Phytopthora* fungal disease. For avocado root rot disease caused by *P. cinnamoni*, the application of Ca as calcium carbonate, calcium nitrate and calcium sulfate was effective to reduce avocado root rot (Broadbent and Baker , 1974; Messenger-Routh, 1996; Pegg *et al*., 1982 cited by Menge and Marais, 2000) According to Menge and Marais (2000) Ca may reduce avocado root rot by: 1) stimulating avocado root growth; 2) increasing disease resistance in avocado roots; 3) impairing activity of P. cinnamon by reducing sporangia formation; 4) interfering with zoospore motility or inducing premature encystment; 5) improving soil drainage; and 6) stimulating antagonistic microorganisms. In California soil, these mechanisms were studied (Messenger-Routh, 1996 cited by Menge and Marais, 2000) and it was found that Ca primarily acted as a weak fungicide by reducing the size and number of sporangia produced by P. cinnamon. Though no information about the effect of liming on occurrence of root rot disease of citrus is available in Thailand but in this study it was observed that in Mr. O. Punya's orchard in which lime was applied and incorporated into the Li soil on the terrace with poor drainage before rainy season, none of the mandarin trees in his orchard was infected by root rot disease while 50% of the trees in Mr. B. Dowee grown on Ban Chong soil with the better drainage but soil pH was 4.44 were damaged by this disease. Liming is one of the proposed methods for reduction of risk on root rot damage in this study which is expected to reduce such risk about 77%. However, it is worth for validate this hypothesis in the future.

From this study, air layering is the commonly used plant material for mandarin cultivation in Mae Soon sub-district. However, Sai Nam Pueng mandarin cultivar is not tolerant to root rot. The use of tolerant rootstock with desirable horticultural characteristics is the best management strategy of *Phytopthora* diseases in order to reduce the costly application of fungicides (Nuqvi, 2004). According to Naqvi (2004) among the mandarins and hybrids, sweet oranges, citranges, citrumelos, sour orange types and lemon types were susceptible to *Phytopthora* root rot. Among the mandarins and hybrids, Cleopatra, Sun Chu Sha, Cala mandarin and Changsha are least tolerant to root rot except 639 (Cleopatra x trifoliate). Among trifoliate and its hybrids, Swingle citrumelo, C-32, C-35, Benton and Yuma citrange and African Shaddock x Rudidoux have shown resistance to bark infection and tolerant to root rot. The use of grafted or budded plant materials from the root rot tolerant root stocks is recommended for mandarin farmers who want to replant the new mandarin tree in the previous cultivated area in order to reduce root rot damage.

Nevertheless, since the lowland areas which used to be paddy fields are not suitable for mandarin cultivation due to hard pan formation in the soil profile and shallow water table which create problem on poor drainage and poor aeration of soil for the soil in the root zone during rainy season thus if it is possible, the farmers should not use such topographical area for mandarin cultivation. However if the farmers have to use such area for mandarin cultivation, they must have to use special tillage to modify the soil profile by using equipment to destroy hard pan. According to Eck and Unger (1985) the following equipment, moldboard and disk plows, slip plows, chisel type machines, trenching machines, and machines for installing barriers including modification of equipment can be used for soil profile modification. Furthermore, the farmers should not placed the dug subsoil on top the original surface soil during preparation of the drainage ditches and soil bed. Additions of organic material and Ca into the soil are also essential to improve soil physical properties of the soils on lowland and toot hill areas.

In this study, soil nutrient imbalance and plant nutrient lost due to leaching and run off were considered another two causes of productivity declination of mandarin orchards in Mae Soon sub-district. Fifty percent of the orchards on the foot hill and the loping area were risky to soil nutrient imbalance at high and very high level. Furthermore 73% of the total numbers of the orchards on the sloping area had risk to nutrient lost by leaching and run off. Among the influencing factors affecting soil nutrient imbalance and the lost of plant nutrients were soil pH and soil organic matter content. The contents of available P and exchangeable K which were the soil properties affected by fertilizer management were another two factors contributing to the problem on soil nutrient imbalance. The information obtained from farmers' interviews indicated that the popular fertilizer grades were 46-0-0, 13-13-21 and 15-15-15 and 52% of the interviewed farmers applied chemical fertilizer at the rate of 0.4-0.6 kg/tree/month. They also sprayed foliar fertilizer every 7-10 days all year round. The results of soil analysis of the selected orchards showed that 76% of the studied soil had soil pH below the optimal levels while almost all orchards had available P content of the soils above the optimum range and about 48% were rich in exchangeable K.

From index leaf analysis, it was found that the mandarin trees in the selected farmers' orchards were not deficient in any plant nutrients except N and Ca. Nevertheless, the soils in the selected orchards had optimum level of Ca content. The Ca deficiency of the index leaves suggested that the mandarin trees could not effectively take up Ca by the roots. There are three processes for plant roots to up take nutrients in the soil (Putijun, 2005; Mengel, 1995). In the passive process, the nutrients such as P, Zn and

K Menge and Marais (2000) will be taken up by the root by diffusion which does not energy depended process. In the active process or mass flow process in which NO_3^-N, Ca, Mg and S Menge and Marais (2000) are taken up by the root is energy depended process. In the third process, nutrients can move into the roots by ionic exchangeable which is not energy depended process also. By ionic exchange, cation absorbed on clay micelle will be exchanged with hydrogen ion from the roots or directly exchanged between the ions from root and soil particles and then move into the plant cells (Putijun, 2005). Since the mandarin trees in the selected orchards were deficient in Ca or low in N content, while the soils contained optimum level of Ca and the farmers applied N fertilizer into the soil. It was possible that the trees had problem with the root system. In the case of Ca, only the young roots are effective to take up Ca from soil (Havlin *et al.*,2005). Furthermore Ca movement in the plant is directly involved with transpiration. When the soil is dry or during the cloudy or rainy days, Ca uptake is reduced (Forth and Ellis, 1997).

According to Noling (2003), citrus root growth is greatly affected by environmental factors, particularly soil temperature and moisture. In Arizona, California and Florida, the mature citrus tree have three district cycles of root growth. In general, root growth is periodic during the month of February to early December with periods of inactively occurring only during periods of shoot flush. Root growth activity declines with the initiation of each new shoot growth flush and then increases immediately after the cessation of shoot elongation. This alternation of growth is thought to occur as a result of competition between roots and shoots for photosynthetic carbohydrates. By locking available carbohydrate, citrus will loss fibrous roots. Significant fibrous root losses can also occur in water saturated soils due to poor aeration and anaerobic conditions. Majority of the owners of the selected orchards did not use fruit pruning and some of them even prolonged fruit harvest. Excessive number of fruits and prolonging of fruit harvest required large amount of photosynthetic carbohydrate. Under such condition, the trees might not be able to supply sufficient carbonsynthates to the roots for development of the new roots and supporting good function of the root system. Furthermore, if the soil has poor drainage, root respiration is not effective resulting in poor assimilation of nutrients by active process. Thus nutrient supplement by foliar spraying seemed to be effective to maintain the good growth of the mandarin trees grown on poor drainage soils. The percentage of the orchards having nutrient deficiency as indicated by leaf analysis reduced in July as compared to that in May might be due to foliar fertilizer application by the farmers. From the above information and the obtained experimental results, the farmers should not produce off season mandarin fruit and prolong fruit harvest. If those practices could be avoid, the mandarin trees in their orchards will be able to remain productivity and healthy in the longer period. These experimental results suggested improper fertilizer management of mandarin farmers which resulting in soil nutrient imbalance of these soils and subsequently affecting the other causes of productivity declination of their mandarin trees. The results of fertilizer trial from this study indicated that in the orchard in which soil was rich in available P and exchangeable K and the mandarin trees were still healthy, omission of P and K fertilizers, reduction of N application rate from the commonly used N rate to the amount of N removal by fruit yield plus additional N to compensate N lost about 40% of total N removal by fruit yield and using foliar spraying according to the need from index leaf analysis did not reduce significantly fruit yield but the cost of input on fertilizer reduced about 98% of that by farmer rate. Those experimental results are useful for mandarin farmers not only in Mae Soon sub-district but also in the major mandarin cultivated areas of Chiang Mai province. The information obtained from this study can be used as the guideline for recommending the suitable methods for soil management for the farmers in order to reduce the risk on productivity declination on root rot, soil nutrient imbalance and lost of plant nutrients by leaching and run off including reduce cost of input on fertilizer. However, further studies in the future are still needed for additional fertilizer trials conducting in the different farmers' orchards and to validate the proposed hypothesis for reduction of risks on root rot damage, soil nutrient imbalance and nutrient lost by leaching and run off.

Furthermore the long term fertilizer trial is also needed in order to follow up the changes of available P and exchangeable K contents of the soils after omission of P and K fertilizers in P and K rich soils. To be safe, the farmers should check their soils every year after fruit harvest for the need of P and K fertilizer application in their mandarin orchards. Though leaf analysis is very useful and can be used for the requirement of plant nutrients by foliar spraying but the cost of leaf analysis is high compare to the cost of soil testing which the farmers could do by themselves using soil testing kit. Thus foliar spraying seemed to be needed and useful for the farmers particularly when the roots cannot take up the nutrients from soil effectively. By reduction of the rate of N, P and K fertilizers, applied to soils, the farmers may be able to afford the cost of foliar fertilizers in order to ensure that the trees obtain sufficient nutrient requirement for profitable fruit yield.

5.2 Conclusion

The mandarin cultivated areas in Mae Soon sub-district have the total area of 11,156.6 rais. Fifty productive orchards with the total cultivated areas of 154.1 rais were selected for detail study of soil properties, plant nutrient status of mandarin trees and farmer practices of orchard management. Among the selected 50 orchards, 56.5% were on the lowland and 21.7% were on the foothill while that on the sloping land were 21.8%.

At least 64% of the total numbers of 50 tested soils had optimum levels of total soil property, EC, exchangeable Ca, extractable Mn and K:Mg ratio while those which were high in available P, exchangeable K, extractable Fe, extractable Zn and extractable Cu were 94, 48, 90, 88 and 50% respectively. The orchard soils which were poor in bulk density were about 66% and those had the lower leaves of soil pH, exchangeable K and exchangeable Mg than the optimum levels were 60, 76, 44 and 98% respectively.

From index leaf analysis, in April, the trees in 90% of the selected orchards were deficient in Ca and 60% had low B content. In July, the index leaves from 54% of the selected orchard were deficient in N and 38% had low Ca content. The contents of the other plant nutrients were mostly at optimum levels.

The most popular chemical fertilizer grades for the farmers were 46-0-0, 13-13-21 and 15-15-15. Fifty two % of the interviewed farmers applied chemical fertilizer at the rate of 0.4-0.6 kg/tree/month and 24% applied at the rate of 0.8-1.0 kg/tree/month. Regular spraying of foliar fertilizer were practiced by 70% of the interviewed farmers.

The fertilizer trial conducted on farm indicated that in the orchard which the soil had higher levels of available P and exchangeable K than the optimum levels, no P and K fertilizer applications were not needed for healthy mandarin trees. The foliar fertilizer application to mandarin trees could be managed by following the result of leaf analysis. Omission of P and K fertilizer, reduction of rate of fertilizer by foliar spraying and reduction of N rate from that used by the farmer to the amount of N removal by fruit yield plus additional N to compensate of N lost by leaching and runoff about 40% of total N removal by fruit yield did not reduced significantly fruit yield but reduced cost of input on fertilizer about 98% of that by farmer practice.

The declination of productivity of the selected orchards were due to three main causes as follows ; root rot, plant nutrient lost through leaching and runoff and plant nutrient imbalance condition of the orchard soils. The factors contributed to root rot damage were, slope, elevation, drainage, bulk density, porosity, pH and organic matter content of the soils. In the case of plant nutrient lost, the influencing factors were slope, runoff, permeability, soil depth, CEC, pH and soil organic matter. The factors contributed to plant nutrient imbalance of the soils were pH, CEC, soil organic matter, available P and exchangeable K. The map of mandarin orchards showing the orchards with the different risky levels of root rot damage, nutrient lost by leaching and run off and plant nutrient imbalance of soils were developed. In the case of the risk of root rot damage it was found that 70% of the selected orchards on the lowland and 72% of the orchards on the foothill had the risk at high and very high levels while the orchards on the sloping land with such risky levels were only 16%. None of the studied orchards on the lowland and the foothill were risky to nutrient lost by leaching and run off while 73% of the total orchards on the sloping land had risk at high and very high levels. In the case of the risk on plant nutrient imbalance of the soils, 50% of the orchards on the foothill and 50% on the sloping land were risky at the level of high to very high while those in the lowland with such risky levels were only 3.1%.