Chapter 2

LITERATURE REVIEW

2.1 Fruit Quality of Apple

The word quality for apple is used in reference to characteristics of fresh fruit such as marketing quality, edible quality, dessert quality, shipping quality, table quality and appearance quality (Adel, 1990). Producers prefer that their commodities have good appearance, few visual defects, and shipping quality. For a trader, appearance is the most important quality; they are also keenly interested in firmness and long storage life. Moreover, consumers choose to purchase on the basis of good appearance and flavor.

The criteria used for grading Golden Delicious apples as high quality include fruit size (diameter >75 mm), firmness > 11 kg cm^{-2}, soluble solids > 12%, sugar:acid ratio range from 40 to 29, which is the deciding factor for determine price in the exporting market in China (Wang, 1992). In the Japanese market, a larger apple fruit tends to be sold at a higher price. Therefore, the growers make every effort to raise apples larger than 300 g in size (Fukuda, 1994). In 1990, Huguet and Borioli developed the quality index (QI) to quantify Golden Delicious fruit quality, where QI=Total sugars (g l^{-1}) +10x Malic acidity (g l^{-1}). QI has been widely used subsequently as a fruit quality indicator, and it has been found that high quality is associated with QI =13.8 in France.

2.2 Boron Uptake by Plant

Long-distance transport of B from the root to shoot was confined to the xylem and uptake and translocation were closely related (Marschner, 1986).

Many factors affect plant B uptake (Gupta, 1993). Boron deficiency often occurred of due to high Ca and high soil pH (6.3-7.0) (Bergmann, 1983). The absorption of B by solution grown barley roots decreased with the increase of solution pH, this corresponded with the decreased in fraction of undissociated $B(OH)_3$, demonstration that $B(OH)_3$ is the form of B available to plant (Oertli and Grgurevic, 1975). Soil moisture affected B availability. Boron deficiency is often accentuated when the soil becomes dry. Soil water depressed B uptake in barley (Gupta, 1979) and black gram (Noppakoonwang, 1997). Boron adsorption decreased in the range of 10-40 ^{0}C on soils dominant in crystalline minerals (Goldberg *et al.*, 1993).

2.3 Redistribution of Boron in Plant

Symptoms of B deficiency always firstly occur in active growing tissues (Eaton, 1944). This pattern has led to the general conclusion that there is little movement of B from older to younger plant parts and implies that B is not highly mobile within the phloem relative to many nutrient elements (Mengel and Kirkby, 1987). Epstein (1973) suggested that the exclusion of B from the phloem maintains phloem function, because B injections into petioles caused heavy plugs of callose to form in sieve tubes (Eschrich et al., 1965). Oertil and Richardson (1970) proposed a theory that explained the limited movement of B out of leaves based on the loss of B from phloem to xylem.

Although the phloem mobility of B is generally limited, transport may occur under some conditions (Raven, 1980). Boron concentration in mature leaves of broccoli, grapes cotton and turnip plants declined when B was withheld from the root environment (Benson *et al.*, 1961; McIlrath, 1965) suggesting remobilization of B from leaves. Similarly, B concentration in plum leaves decrease soon after B was applied to leaves in the fall (Hanson *et al.*, 1985). Van Goor and Van Lune (1980) reported that B was highly mobile in the apple phloem. Brown and Hu (1996) showed that B applied to leaves was mobile in some species such as the Pyrus, Malus and Prunus genera. In these genera, sorbitol is a major sugar and commonly transported in the phloem. Boron forms stable complexes with sorbitol in species that utilize sorbitol as a primary translocated photosynthate.

Boron is commonly thought to be immobile in the phloem, Brown and Hu (1996) have found that species in which orbital is a major sugar, B is mobile. Sorbitol (D-glucitol) is known to form six stable 1:2 (B:sorbitol) complexes because of the favorable zigzag arrangement of the 2-, 3-, and 4-hydroxyls. High sugar:B ratios was found in the high sorbitol genera (Pyrus, Mulus and Prunus), more than 99% of the B will be tired up as 1:2 complex.

2.4 Role of Boron in Plant

Boron is an essential micronutrient required for the normal growth of plants (Gupta, 1993).

The biochemical role of B is not yet well understood. The role based on the formation of stable cis-diol borate complexes (Thellier *et al.*, 1979). The effect of B in plant growth were considered as lignin biosynthesis, xylem differentiation (Lewis, 1980), membrane stabilization (Pilbeam and Kirkby, 1983), structure of plant cell walls (Loomis and Durst, 1991; Goldbach et al., 1991) and altered enzyme reactions (Dugger, 1979). Some of the role reflected enhancement in translocation of sugars (Gupta, 1979), proper pollination and fruit set (Gupta, 1993). Boron is also required for cell division (Cohen and Lepper, 1977; Kouchi, 1977) and cell elongation (Lovatt *et al.*, 1981). Leaf metabolism and composition might be affected by B deficiency indirectly via its effect on cytokinin synthesis in the root tip (Dugger, 1983). When the supplying of B was withheld, both the production and export of cytokinins decreased (Wagner and Micheal, 1971 cited in Marschner, 1986

It has been reported that B deficiency not only impairs yield but also reduces quality of fruit or seed. Apple is sensitive to B deficiency (Shorrocks, 1985). Boron deficiency in apple causes blossom blast, reduction or even failure of fruit set. Boron deficiency also reduced fruit growth rate and its quality, through symptoms such as internal and external cork formation and development of small, deformed and cracked fruit (Shorrocks, 1980).

Boron is required for pollination and fertilization success, and fruitlet retention (Crassweller *et al.*, 1981). Boron applications increase retained fruit has been observed apples (Davison, 1971), pears and plum (Callan, *et al.*, 1978, Hanson *et al.*, 1985).

Influence of B status on ion and carbohydrate absorption and translocation processes may indirectly affect pollination, fertilization and fruit development by affecting the supply of nutrients during critical development stages (Parr and Loughman 1983). Marschner (1986) speculated that B deficiency alters the transportation of sugars to the developing flower thereby reducing the sugar content of the nectar. This would implicate B in the promotion of pollinator activity during flowering. Related to this function, it is speculate that B increases flavanoid content of the pollen (Taylor *et al.*, 1994). Boron deficiency decreases pollen viability, pollen germination and pollen tube growth (Cheng and Rerkasem, 1991; Dickinson, 1978; Nyomora, 1995).

Boron deficiency has been reported to alter sugar, starch and other carbohydrate levels (Atalay *et al.*, 1988). This could be due to changes in their translocation and/or metabolism. Gauch and Dugger (1954) attributed the principal role of B to the facilitation of sugar translocation suggesting that $B(OH)_3$ formed complexes with sugar, which were more easily able to traverse membranes than highly polar molecules. However, this idea became unacceptable because $B(OH)_3$ weakly reacts with sucrose, the major sugar translocated route for sucrose. Boron was necessary for sugar synthesis in sugar beet (Shkolnik, 1984 cited by Loomis and Durst, 1992).

2.5 Plant Analysis

Plant analysis is the more significant testing procedure for perennial horticultural crop because of the difficulty of determining with sufficient accuracy for soil analysis the root zones in which deep-rooting plants take up most of their nutrients (Jones, 1985).

The use of plant analysis to assess plant nutrient status is based on the relationship between crop response and nutrient concentrations in plant tissues (Smith, 1986). The calibration curve showing this relationship is shown in figure 2.1. On the basis of this curve, nutrient concentrations can be classified as deficient, marginal, adequate and toxic zones. When nutrients are in the deficiency zone, plant growth is significantly reduced. In this zone, application of the nutrient results in a sharp increase in growth with very little change in nutrient concentration in the plant. In the marginal zone, growth is reduced but plant do not show deficiency symptoms and both nutrient concentrations and growth increase as more nutrient is absorbed. Within the marginal zone lies the critical concentration (Ulrich, 1952). The third zone is the adequate zone, in which there is no increase in growth but nutrient concentration increases. This zone is also known as satisfactory, normal or sufficiency concentration. The toxic zone in the range of nutrient concentration in which there is reduction in growth but concentration of nutrients continues to increase (Ulrich, and Hill, 1973). This type of curve can be used to establish critical nutrient concentration for prognosis and diagnosis. Prognosis tests define the nutrient status of crops between sampling time and harvesting time (Smith, 1986). Diagnosis tests define nutrient status of crops at the time of sampling (Craswell *et al.*, 1986).

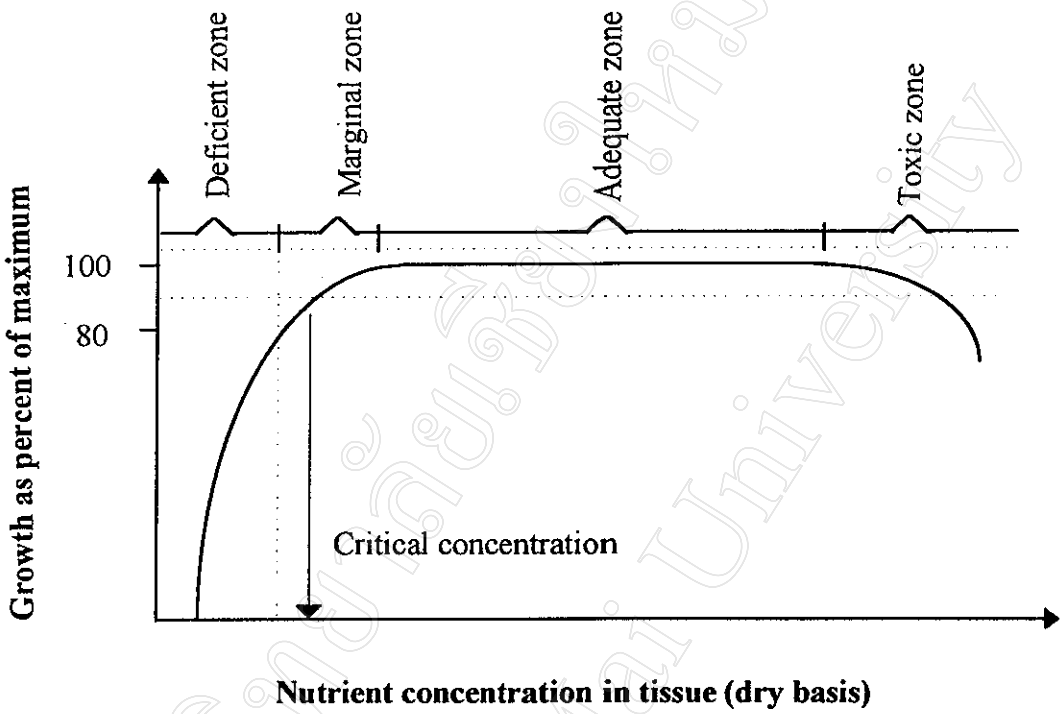

Figure 2.1 The relationship between growth and nutrient concentration in plant (Ulrich, and Hill, 1973)

The critical nutrient concentration of a plant with respect to growth defined in terms of the nutrient concentration that is just deficient or that is just adequate for maximum growth or as the concentration separating the zone of deficiency from the zone of adequate (Ulrich, 1952).

No procedure is completely satisfactory for all experiment data. However, critical values would be expected to be within narrow range of the marginal zone provided (Ulrich, and Hill, 1973). They meet two conditions; firstly, the fitted line should fit the actual values across the range of nutrient concentration. Secondly, the variation of data points from the fitted line should be low (high R^2) (Noppakoonwong, 1991).

The common procedures used for deriving the critical concentration of a given nutrient are the Mitischerlich equation (Mitischerlich, 1915 cited by Ware *et al.*, 1982), Cate and Nelson procedures (Cate and Nelson, 1971), two-phase linear model (Smith and Dolby, 1977) and hand-fitted curve (Smith, 1986). However, critical B concentration as defined by Ulrich (1952) may not be obtained by the Cate and Nelson procedures which partition data into responsive and non-responsive sets, regardless of relative yield.

2. 6 Boron Requirement in Fruit Tree

Bergmann (1983) suggested that for fruit tree, the sufficient levels of B in leaves were within the range of 20-30 mg kg^{-1} dry wt.. Shear and Faust in 1980, suggested that leaf B concentration higher than 15-20 mg kg^{-1} dry wt. were sufficient for most fruit drop. Hanson in 1993 concluded that fruit set was most consistently increased by B foliar sprays in trees containing leaf B levels of 19-25 mg kg^{-1} dry wt.. In mature Golden Delicious apple apple, 2.7 mg kg^{-1} fresh wt. B is associated with high fruit quality (Huguet and Borioli, 1990).