CHAPTER 2

Literature Review

2.1 History and Morphology of Sweet Pepper

Sweet pepper (*Capsicum annuum* var. annuum L.) is a cultivated species of the plant in genus *Capsicum*, belonging to the family Solanaceae which also includes tomato, eggplant, potato and tobacco. It has been cultivated for more than 9,000 years with the earliest cultivation having taken place in South and Central America while the name "pepper" was given to this food plant by European colonizers of North America who first came across it in the 1500-1600's, and then transported it back to Europe. The original name for this food plant in Spanish was pimient. Because sweet peppers can be grown in a variety of climates and is popular in cuisines throughout the world, it can frequently be found on small farms in North America, Central America, South America, Europe, Africa, the Middle East, and parts of Asia (Heiser and Pickersgill., 1969).

Botanically, it is a perennial sub shrub that is grown as annual in temperate climates (Tindall, 1983). However, it is actually a herbaceous perennial when cultivated in tropical areas such as its native Latin America. Sweet pepper is considered “sweet” since it lacks the pungent chemical (capsaicin) present in hot peppers. Most sweet peppers are bell-shaped; therefore, the name bell pepper is common. However, sweet peppers come in a range of shapes from round to oblong, to taper. The skin is smooth and shiny and can be of a range of colors. Most peppers are green when immature and red if allowed to ripen. However, new cultivars offer mature and immature peppers in red, yellow, orange, purple, or brown (Agriculture, Forestry and Fisheries, 2013).

2.1.1 The Food Values and Uses of Capsicum

The nutritional value of pepper is relatively high (Grubben, 1977) [Table 1]. In this respect, pepper is a good source of vitamins, mainly A and C (Mathews *et al*., 1975; Andrews, 1984) (Table 2.2). According to Simpson (1983), sweet pepper is one of the vegetables that has a high content of provitamin A due to the high concentration of β-carotene and β-cyptoxanthin. Sweet pepper is a good source of thiamine for nerve and muscle functioning, vitamin B6 to break down protein and make disease-fighting agents, beta carotene for healthy eyes and cells and folic acid for healthy red blood cells. Sweet pepper is also rich in phytochemicals, an antioxidant that fights and prevents cancer-causing agents. Because red sweet pepper is simply a ripen green sweet pepper, it is considered a more nutrient-packed pepper, for the longer it ripens, the more fully these vitamins and minerals (and sweetness) develop. Red bell peppers also contain lycopene, a nutrient thought to protect the heart and eyes.

Capsicum such as sweet peppers comes in many different colors, including: green, red, yellow, orange, purple and brown, each varying with sweetness and flavor. The bright red spice, paprika, is made from ground bell peppers. Bell peppers can be enjoyed raw in salads, or stuffed with rice and spices and baked. Sweet pepper strips taste great accompanied by a low - fat dressing or hummus. Some of Capsicum is used in food industry as colouring and flavouring agent in sauces, soups, processed meat, snacks, candies, alcoholic beverages (Nagle *et al*., 1979). In addition to their use as food or condiments, Capsicums are also used as medicine and have ornamental values (Heiser, 1976; Grubben, 1977).

Table 2.1 Average nutritive value of sweet and hot pepper, per 100 grams edible product.

	Sweet pepper	Hot pepper
Dry matter (%)	8.00	34.60
Energy (K Cal)	26.00	116.00
Protein (g)	1.30	6.30
Fiber (g)	1.40	15.00
Calcium (g)	12.0	86.00
Iron (mg)	0.90	3.60
Carotene (mg)	1.80	6.60
Thiamine (mg)	0.07	0.37
Riboflavin (mg)	0.08	0.51
Naiacin (mg)	0.80	2.50
Vitamin C (mg)	103.00	96.00
Average nutritive value (ANV)	6.61	27.92
ANV. $100g^{-1}$ dry matter	82.60	80.70

Source: Grubben (1977)

Table 2.2 Comparison of sources of vitamin A and C in mg

	Vitamin A	Vitamin C
Pepper	94.0	310
Orange	37.0	146
Grape fruit	13.5	166
Lemon	39.0	10
Avocado	10.0	216

Source: Andrews (1984)

2.2.2 Commercial Production of Sweet Peppers

In terms of commercial production, however, China has become by far the largest producer of sweet peppers and produced 14 million metric tons in 2007. At about 2 million metric tons, Mexico is the second largest commercial producer, followed by the United States at approximately 1 million metric tons. Within the U.S., California and Florida are the largest sweet pepper-producing states. (In terms of chili pepper production, however, New Mexico currently stands in first place). The average U.S. adult consumes about 16 pounds of peppers per year, including almost 9.5 pounds of sweet peppers (Agricultural Marketing Resource Center, 2011). In 2007, the state of Florida ranked number one nationally for bell pepper production with 39.1% of the nation's overall bell pepper production. During the 2007–2008 production season, 18,800 acres were harvested in Florida, resulting in 18,277,800 cartons (28 lb/carton) of bell peppers valued at $267,411,000. The largest volume of Florida pepper production came from the Palm Beach County area that has been responsible for 88 and 89% of the state's bell pepper production for the surveyed years of 2002 and 2007, respectively.

2.2.3 Morphology of Sweet Pepper

2.2.31 Roots: Sweet peppers are held upright with a strong central stem that is quite sturdy compared to their roots. A central, tapering tap root is present in the root system of all varieties of pepper. The tap root grows straight down and creates secondary branching roots that are fibrous. Roots may reach between 20 to 30centimeters deep and at least as wide, but they remain fairly fine. Pepper's roots are deeper than those of lettuce, broccoli or spinach; however, they remain fairly close to the surface.

2.2.3.2 Stem: Dorland and Went (1947) demonstrated that the pepper plant grows with a single stem until 9 – 11 leaves have been formed and this main stem terminates with flower. With the development of the first flower bud, the plant branches off at the apex into 2 or 3 shoots and each shoot develops two leaves before it terminates in flower and again branches at apex. Accordingly, the growth of the pepper plant assumes a dichotomous branching habit (Nielsen and Veierskov, 1988). However, there are many different varieties of peppers ranging from 30 to 90 centimeters tall.

2.2.3.3 Leaves: Sweet pepper leaves consist of pinnately-vined leaves attached to a major axial system (Morrison *et al.*, 1986), oval and taper to a point. They are usually bright to dark green, but can also be mottled. The size of the leaf corresponds somewhat to the size of the fruit; plants that produce very small peppers also tend to have small leaves, while the larger sweet pepper cultivars have large, broad leaves.

2.2.3.4 Flowers: Morrison *et al.* (1986) reported that the perfect flowers of pepper appear rather early in development and are composed of a short, thick calyx that covers a corolla consisting of 5 – 7 stamens. The flowers are white and followed by juiceless berries or pods, which vary in shape and size.

2.2.3.5 Fruit: The fruits of sweet peppers are bell-shaped or somewhat oblong fruits. When ripe, the fruit turns to red, yellow or brown but immature fruits of the large mild types are often picked while still green. These species generally bear large fruits.

2.2 Factors Affecting the Growth of Sweet Pepper

There are several factors which influence the growth and development of plant, i.e., internal factor, the genotype of a plant such as cultivars, varieties, and species and external factors which are as follows:

2.2.1 Light: The optimal temperature for sweet pepper preconditions other ideal environment factors. Such factors are very infrequent in the forcing periods. Light is the most important environment factor, but we cannot influence it economically. Therefore, we have to adjust other factors to the all-time light conditions.

The growth of plants is determined by several environment factors. Heat, light, water and nutriments are the most influential ones. Light and temperature are crucial factors. If one of the environment factors changes, others should be changed accordingly in order to avoid worse crop quality. To achieve the best growth and yield, it is important to adjust other environment factors to all-time light conditions. Sweet pepper is sensitive to the lack of light, the crop is poorly set, the vegetation is longer, bloom and harvest are getting later. If light is stronger than it should be, set is fewer and berries are less developed, nodes are short and the crop is low and distorted. Sweet pepper is a C3 plant and the intensity of photosynthesis is increased only upto a certain intensity of light. The maximum berry growth (impregnation) occurs at 300-400 W/m^2 light intensity (Taskovics *et al*., 2010)

2.2.2 Temperature: Pepper is a warm-season crop which performs well under an extended frost-free season, with the potential of producing high yields of outstanding quality. It is very vulnerable to frost and grows poorly at temperatures between 5 and 15 °C. The optimum temperature range for sweet pepper growth is 20 to 25 °C. The germination of pepper seed is slow if sown too early when soil temperatures are still too low, but seedling emergence accelerates as temperatures increase to between 24 and 30 °C. The optimum soil temperature for germination is 29 °C. Low temperatures also slow down seedling growth which leads to prolonged seedling exposure to insects, diseases, salt or soil crusting, any of which can severely damage or kill off the seedlings (Bosland and Votava, 1999).

High temperatures adversely affect the productivity of many plant species including green pepper. Sweet pepper requires optimum day/night temperatures of 25/21 °C during flowering. The exposure of flowers to temperatures as high as 33 °C for longer than 120 hours leads to flower abscission and reduced yields. Pollen exposed to high temperatures (>33 °C) normally becomes non-viable and appears to be deformed, empty and clumped (Erickson and Markhart, 2002). Temperatures lower than 16 °C can lead to fruitless plants. Higher yields are obtained when daily air temperature ranges between 18 and 32 °C during fruit set. Persistent high relative humidity and temperatures above 35 °C reduce fruit set. Fruit that is formed during high-temperature conditions is normally deformed. Sweet peppers are also very sensitive to sunscald. Fruit color development is hastened by temperatures above 21°C (Bosland and Votava, 1999).

2.2.3 Humidity: Humidity should be moderate to high, 90-95% relative humidity maintains sweet pepper quality satisfactorily for a period of up to12-18 days (Sealand, 1991), low humidity especially combined with high temperatures may reduce fruit set.

2.2.4 Pruning: Pepper plants are indeterminate plants, that is, they continually grow new stems and leaves. For this reason, the plants have to be pruned to ensure a balanced growth for maximum fruit production. Pepper plants are managed with two main stems per plant. Pruning also improves air circulation around the plant which helps reduce disease (Horbowicz and Stepowska, 1995). The pepper flowers also develop at the nodes. A node is defined as a point on the stem from which leaves arise and the length of stem between nodes is called an internode. The term "axil" refers to the upper angle formed by the junction of a leaf (or lateral) with the stem. After about 1 week in the greenhouse, all the plants will have developed 2 to 3 stem shoots at the fork. At this point, the plants should be pruned to leave two strongest stems (Portree, 1996).

2.2.5 Pests and Diseases of Sweet pepper:

2.2.5.1 Thrips: feeding damage includes distortion and upward curling of leaves, developing a boat-shaped appearance. The leaves become crinkled and the lamina may be reduced, resulting in narrow new leaves. The lower surface of the leaves develops a silvery sheen that later turns bronze, especially near the veins. Damaged fruit is distorted with a network of russeted streaks . The control measures include the use of resistant cultivars and mulching with plastic (Pernezny *et al*., 2003).

2.2.5.2 Powdery mildew: caused by *Leveillulataurica.* (Coertze *et al*., 1994). The symptoms are chlorotic spots on the upper leaf surface. Numerous lesions may coalesce, causing chlorosis of the leaves. Lower leaf surface lesions develop a necrotic flecking and generally, but not always, are covered with a white to grey powdery growth. It progresses from older to younger leaves, and leaf shedding is a prominent symptom. The disease is promoted by warm weather (dry and humid). Fungicides are used to manage the disease during periods of heavy disease pressure.

2.2.5.3 Virus diseases: *Cucumber mosaic virus* (CMV) is one of the most important virus diseases of pepper worldwide**.** The age of a plant at the time of infection strongly influences what types of symptoms will be manifested. CMV symptoms can be transitory and often appear on lower, mature leaves as ring-spot or oak-leaf necrotic patterns. Ring-spot symptoms are more prominent on determinate-type peppers. The necrotic symptoms, whether they occur on the foliage or on the fruit, are basically a shock reaction attributed to early virus infection. Sometimes plants adjacent to ring-spotted plants display only a mild to moderate mosaic pattern and have a general dull appearance (Zitter and Florini, 1984)

2.2.5.4 Plant nutrients: Sweet pepper plants require nutrients to survive, grow and develop and finally for producing economic yields. Plants take nutrients from the air, the soil, and the water. Nutrients are taken up by the fine root hairs which absorb the nutrients and water they need. The only way to know if one nutrient is missing is to analyse the leaves, stems or roots in the laboratory and compare this to published values for that species. If values are not known, fertilizer trials might show what is lacking. This would involve adding different types of nutrients at different levels during the growing season.

2.3 The Importance of Plant Nutrients

Improved fertilizer management for vegetables is important in view of today's need to reduce production costs, conserve natural resources and minimize possible negative environmental impacts. These goals can be achieved through optimum management of the fertilizer applied. Understanding the crops' nutrient requirements and using soil testing to predict fertilizer needs are keys to fertilizer management efficiency.

Plant tissue testing is another tool for use in achieving a high degree of precision in fertilizer management. Timely tissue testing can help diagnose suspected nutrient problems or can simply assist in learning more about fertilizer management efficiency and the process of identifying nutrient deficiencies.

2.3.1 The Role of Macronutrient Nutrition

The N, P, K, Ca and Mg are those macronutrients (Brinkman, 1998; Campbell, 2000) found in comparatively high concentrations in plants and are measured in percent (%). Each of the elements has at least one specifically-defined role in plant growth so that plants fail to grow and reproduce normally in the absence of that element. However, most of the elements have several functions in the plant. A basic summary of some of these functions is as follows:

2.3.1.1 Nitrogen: is found in many compounds including chlorophyll (the green pigment in plants), amino acids, proteins and nucleic acids (DNA and RNA) (Hochmuth *et al.*, 2004; McCauley, 2009). A large part of the plant body is composed of N-containing compounds. Nitrogen is a mobile nutrient which means that when nitrogen is deficient, plants move it from the older foliage to the younger, the older leaves become yellow first while the new leaves remain green (chlorosis of lower leaves and necrosis of older leaves) stunted and slow growth. N deficient plants will mature early and crop quality and yield are often reduced (Jones, 1997) while increasing N decreases marketable yields and blossom-end rot is increased with increased N. (Hochmuth and Hanlon, 2013).

2.3.1.2 Phosphorus: is used in several energy-transfer compounds in plants. A very important function for P is its role in nucleic acids, the building blocks for the genetic code material in plant cells. P is very mobile in the plant (Hochmuth *et al.*, 2004; McCauley, 2009). P deficient plants generally turn dark green (both leaves and stems) and appear stunted. Older leaves are affected first and may acquire a purplish discoloration due to the accumulation of sugars in P deficient plants which favor anthocyanin synthesis; in some cases, leaf tips will turn brown and die. Plants suffering from P deficiency appear weak and maturity is delayed. Leaf expansion and leaf surface area may also be inhibited, causing leaves to curl and be small. Deficient leaves will have only about 0.1% P in the dry matter. Normal, most-recently matured leaves of most vegetables will contain 0.25 to 0.6% P on a dry weight basis. Excess P in the root zone can result in reduced plant growth, probably as a result of P retarding the uptake of Zn, Fe and Cu.

2.3.1.3 Potassium: is utilized by plants in the activation of enzymes and co-enzymes (specialized proteins serving as catalysts and co-factors), many enzymes responsible for cellular reactions require K as a co-factor, Another role for K in plants occurs in special leaf cells called guard cells found around the stomata

(Hochmuth *et al.*, 2004; McCauley, 2009). By regulating the turgor pressure in the guard cells, the degree of opening of the stomata is controlled and thus the level of gas and water vapor exchange through the stomata is regulated. Turgor is largely controlled by K movement in and out of guard cells, photosynthesis, and sugar transport. K is absorbed in large quantities by an active uptake process. Once in the plant, K is very mobile and is transported to young tissues rapidly, K deficient symptoms appear in older leaves first. These start to yellow at the edges, and have some green at the base. Later, leaf edges turn brown and may crinkle or curl and small necrotic (dead) spots may appear. Plants may wilt, even though sufficient water is available in the substrate. When deficiencies are severe, leaves will die. Deficient plant leaves usually contain less than 1.5% K. Deficiencies of K lead to blotchy ripening of tomatoes where fruits fail to produce normal red color in some areas on the fruit.

2.3.1.4 Calcium: a role of calcium is cell membrane structure and function controlling, such as membrane permeability and that is a potential signal transducer. Calcium is immobile in the plant (Hochmuth *et al.*, 2004; McCauley, 2009), therefore, deficiency symptoms show up first on the new growth. Deficiencies of Ca cause necrosis of new leaves or lead to curled, contorted growth. Examples of this are tipburn of lettuce and cole crops. Blossom-end rot of tomato also is a calcium-deficiency related disorder. Ca, unlike most elements, is absorbed and transported by a passive mechanism. The transpiration process of plants is important in the transport of Ca. Once in the plant, Ca moves toward areas of high transpiration rate, such as rapidly expanding. The research showed that the influence of calcium levels on fruit yield and quality of sweet pepper (*Capsicum annuum* L. cv. Orlando) plants showed that high calcium increased yield, in addition, it improved fruit quality such as fruit shape index (Rubio *et al*., 2010).

2.3.1.5 Magnesium: Magnesium is the central molecule in chlorophyll and is an important co-factor for the production of ATP. Mg is highly mobile in the plant (Hochmuth *et al.*, 2004; McCauley, 2009). Deficiency symptom first appears on the lower leaves, symptoms consist of an interveinal chlorosis which can lead to necrosis of the affected areas. On tomato leaves, advanced Mg deficiency leads to a mild purpling of the affected areas. Mg is commonly deficient in coarse-structured soils and in acidic soils. Uptake may be blocked if there is too much potassium in the soil. Magnesium is usually found in concentrations of 0.2 to 0.8% in normal leaves. Conditions that lead to deficiency are usually related to poorly-designed fertilizer programs that supply too little Mg, or when Ca and/or K compete with Mg for uptake.

2.4 Plant Tissue Analysis

Plant analysis is a chemical evaluation of nutritional status of the plant. To improve crop nutrition and yield of a plant forms the basis of most schemes for using plant analysis to assess plant nutrient status (Reuter *et a.l*, 1997). The critical range refers to the nutrient level below which significant yield reduction is expected. Although "significant" yield reduction is open to interpretation, typically 10% is used for many crops. On the other hand, if a nutrient is either at the sufficient or high range, minimal or no yield response is expected due to fertilization (Figure 2.1) (Silveira *et al*., 2007).

2.4.1 The factors that affect plant nutrient concentrations include (1) physiological maturity of the stand, (2) sampling procedure and parts of the plant that are sampled, (3) sample preparation and handling, and (4) environmental conditions, such as soil moisture and temperature. Thus, it is essential that samples are properly collected and handled prior to analysis. The interpretation of a plant analysis report requires a thorough understanding of the factors that may influence the test results.

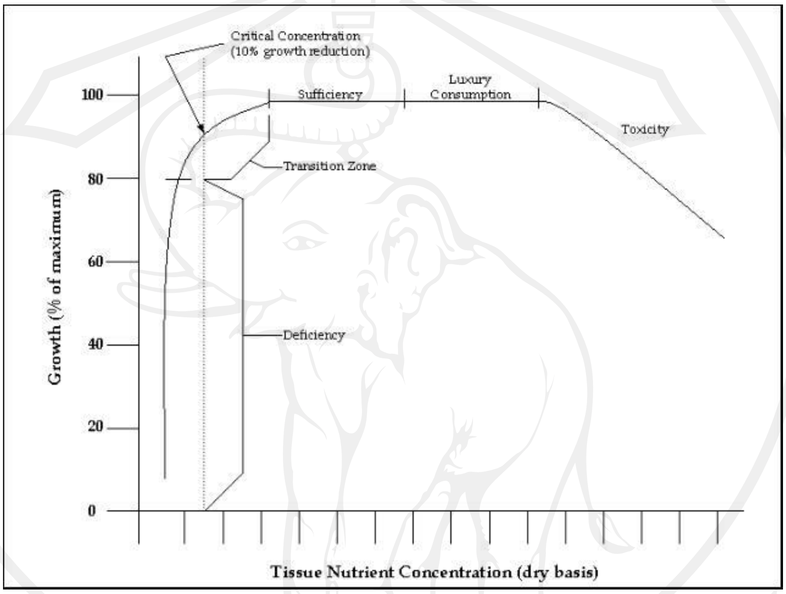

Figure 2.1. Crop growth in relation to concentration of a nutrient in the diagnostic tissue sample. Source : Hochmuth *et al*. (2004)

2.4.2 Sample Collection

Plant analysis is generally associated with evaluation of leaf samples (Campbell and Plank, 2000). It is not practical to harvest and prepare entire plants for chemical analysis. Therefore, a plant part is used for convenience. However, it is essential that the plant part selected for chemical analysis accurately represents the nutritional status of the plant during its entire life cycle. For many vegetable crops, the most-recently-matured leaf (MRML), including the blade and its petiole, provides the most sensitive indicator of the nutritional status of the plant. The MRML is the leaf that has turned from a light-green juvenile color to a darker-green color and has reached full size. Specific plant parts for sampling each vegetable crop are specified in the section on sampling, such as petioles are generally preferred as the tissue to use for predictive purposes because they more accurately reflect the immediate nutritional status of the plants and whether they are currently taking up sufficient nutrients. Nutrients are ultimately transported from the petiole to the leaflets and the whole leaf provides a more integrated nutrient status since nutrients tend to accumulate in the leaflet. Therefore, leaves are better indicators of the cumulative nutritional status of plants and whether nutrient uptake has been adequate up the present point in time (Kelling *et al*., 2013). Samples are collected on the basis of physiological age of the plant (not on calendar date) such as prebloom, tasseling, midgrowth or heading. Plant and soil scientists have spent years performing experiments in order to develop this interpretive guidance for plant tissue analysis (Hochmuth *et al*., 2004).

2.4.3 Application of Plant Analysis

There are two main reasons to test plant tissue for nutrient status. The first reason is to monitor the nutrient within the plants during the growing season. This technique is a good management strategy so long as the grower has a means of regulating nutrition in field conditions, for example, addition of nutrients through the micro irrigation system.

The second reason for tissue testing is to diagnose a suspected nutritional deficiency or toxicity. This diagnostic sampling is usually only done after a problem has been detected. In the case of deficiencies, the sampling should only be undertaken if the grower has enough time to apply extra fertilization and the addition will actually enhance production. Too often, supplemental fertilization at the end of the season does not result in higher production, but only in greener foliage. With toxicities, information obtained on the current stressed crop can only be used to make management decisions that may benefit subsequent crops. For example, diagnosis of copper toxicity can only be treated by liming the field for the next crop.

Guidelines for interpretation of analytical results have been developed over years based on research, surveys and experience. Plant analysis continues to evolve as an important management tool as interpretive databases for various crops, stages of growth and indicator tissue are developed (Campbell, 2000).