UNIVERSITY OF CAPE COAST

EFFECT OF TIME AND AMOUNT OF IRRIGATION ON THE GROWTH, YIELD, PHYSICOCHEMICAL QUALITY AND SHELF LIFE OF SWEET PEPPER (*Capsicum annum* var. Yolo Wonder)

BY

DESMOND PAKU

Thesis submitted to the Department of Agricultural Engineering, School of Agriculture of the College of Agriculture and Natural Science, University of Cape Coast in partial fulfillment of the requirements for the award of Master of Philosophy degree in Irrigation Technology

JULY 2016

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:……………………………. Date: …………...

Name: Desmond Paku

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature: ………………… Date: ……………

Name: Rev. Prof. J.D. Owusu-Sekyere

Co-Supervisor's Signature: ……………………….. Date: ……………

Name: Prof. L. K. Sam-Amoah

ABSTRACT

Knowledge of the required amount of irrigation and the time in the day to irrigate is very important for the efficient use of irrigation water and the maximization of vegetable yield and quality. In this experiment, the effect of time of irrigation (morning and evening) and amount of irrigation (100%ETc, 90%ETc and 80%ETc) on the growth, yield, physicochemical quality, shelf life, WUE and economic value of sweet pepper was investigated using completely randomized design with 3 replications. Plant growth increased as irrigation amount decreased from 100%ETc to 80%ETc for both crops irrigated in the morning and evening but was high in irrigating in the evening than in the morning. Fruit yield was significant and reduced as amount of irrigation decreases (100% > 90%ETc > 80%ETc) in both morning and evening irrigated crops. The yield was high in crops irrigated in the evening than the morning counterparts. Physicochemical qualities were better in less irrigated crops (80%ETc and 90%ETc) than full irrigated crops (100%ETc) for both morning and evening irrigated crops. Fruits from crops irrigated in the morning had better physicochemical qualities (Firmness, TSS, TA and pH) than fruits of crops irrigated in the evening. Shelf life was significant and increases as irrigation amount reduces for both morning and evening irrigated crops. Irrigating in the evening with 90%ETc had the highest WUE of 6.5Kg/m^3 and a cost-benefit ratio of 1:30.81. Irrigating sweet pepper in the evening with 10% reduction in CWR (90%ETc) have no significant effect on fruit yield and it improves fruit quality, extends shelf life as well as increase WUE and maximize profit.

ACKNOWLEDGEMENTS

I am most grateful to God Almighty for the grace and good health that were granted upon me to be able to complete this research work on time. My deepest gratitude is also to my principal supervisor, Rev. Prof. J. D. Owusu-Sekyere, for his immerse contributions and guidance throughout this year long research work. His patience and support helped me overcome many difficult situations and finish this dissertation within time and I am most grateful.

My co-supervisor, Prof. L.K. Sam-Amoah, has been always there to listen and give suggestions and advice when needed. I am deeply grateful to him for the long discussions that helped me sort out the technical details of my work. I take this opportunity again to express my gratitude to all staff of the Department of Agriculture Engineering, University of Cape Coast for their help and support, especially Mr. Joseph Dadzie and Mr. Conduah who are at the School of Agriculture Technology Village.

Last but not the least, I would like to thank my entire family especially my parents; Mr. Otto Paku and Mrs. Mercy Ankrah for their prayers, encouragement and financial support which enable me to complete this work.

DEDICATION

To my entire family, especially my parents, Mr. Otto Paku and Mrs. Mercy Ankrah and my siblings.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Ca	Calcium
CWR	Crop Water Requirement
DI	Deficit Irrigation
DAT	Days after Transplanting
Epan	Evaporation Pan
ETc	Crop Evapotranspiration
ETo	Reference Crop Evapotranspiration
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Statistical Database
FSSA	Fertilizer Society of South Africa
IWUE	Irrigation Water Use Efficiency
Kc	Crop Coefficient
Kpan	Pan Coefficient
NS	Normal Saline
pH	Potential of Hydrogen
TA	Titratable Acid
TSS	Total Soluble Solids
USDA	United State Department of Agriculture
WUE	Water Use Efficiency

CHAPTER ONE

INTRODUCTION

Background to the Study

Sweet pepper (*Capsicum annuum*) belongs to the family *Solanaceae* and it is known to originate from Central and South America. Sweet pepper is an important vegetable crop in many countries of the Tropical and Subtropical regions; especially in Africa where it is an important component of diets (Adetula and Olakojo, 2006). According to Wolff (1999), vegetables account for 96% of the world's total food and 4.9% of total expenditure in Ghana. However, FAOSTAT (2013) revealed that sweet pepper production in Ghana is low and export is only 117 tonnes annually out of a total world production of over 31 million tonnes. Sweet pepper fruit is a large, sweet, crisp, bell-shaped fruit of the pepper family. It is consumed raw as in salads as well as in cooked form as in stew. Sweet pepper is an excellent source of vitamins A and C, two very important antioxidants (Raemaekers, 2001) and also contains a small quantity of Vitamin K which is important in bone health. It is available in different bright colours including red, yellow, green and orange, with green being the commonly grown one in Ghana.

Sweet pepper has been classified as very susceptible to water stress, with blossom stage being the most sensitive period (Bruce et al., 1980) and this affects the yield and quality of the fruit produced. According to Antony and Singandhupe (2004), the total pepper yield was less at lower levels of irrigation. Della Costa and Gianquinto (2002) also reported that continuous water stress significantly reduced total fresh weight of pepper fruits. A similar result was reported by Gencoglan, Akinci, Ucan, Akinci, and Gencoglan

(2006), that, reducing the crop evapotranspiration (ETc) or deficit irrigation significantly affected the fruit numbers, fruit dry weight and dry yield of hot pepper whilst the average fruit numbers increased over 3 times with fully irrigated crops (100%ETc). For high quality yields, an adequate water supply at the right time in the day is required throughout the growing period. Reduction in water supply during the growing period in general has an adverse effect on yield and quality of the fruits. Doorenbos and Kassam (1979) reported that the period at the beginning of the flowering stage is most sensitive to water shortage and soil water deficit in the root zone during this period should not exceed 25%. According to them, water shortage just prior and during early flowering reduces the number of fruits and is greater under conditions of high temperature and low humidity. The concluded that controlled irrigation is essential for high yields because the crop is sensitive to both over and under irrigation.

In Ghana, supply of water for irrigation is limited, and thus cannot meet the continuously increasing demand of water for irrigation in most cases (Kirda et al., 2004; Wakrim, Wahbi, Tahi, Aganchich, & Serraj, 2005). Due to this, irrigation water supply for vegetable crop production especially during the off season is a major constraint for commercial production. The efficient use of irrigation water is therefore becoming increasingly important, and alternative efficient water application methods such as deficit irrigation, partial root zone drying may contribute substantially to making the best use of water for agriculture and improving irrigation efficiency Nagaz, Masmoudi, & Mechlia, 2012). Competition for water resources among Ghana's industrial, domestic and agricultural sector has increased in recent times. This has led to the reduction in the amount of water supplied for agricultural purposes (Kirda, 2002). According to Kere, Nyanjage, Liu and Nyalala (2003), the growth, yield and quality of sweet pepper and most vegetables, are highly dependent on the amount of water supplied. There is therefore the need to adopt irrigation management strategies, which may allow saving irrigation water and still maintaining satisfactory yield of production (Costa, Ortuño, & Chaves, 2007) in such countries which is welcomed.

Reducing the amount of CWR or ETc (deficit irrigation) has been identified as one of the strategies to improving water use efficiency, WUE. Deficit irrigation is a water saving strategy under which crops are deliberately allowed to sustain some degree of water deficit and yield reduction (Pereira, Oweis, & Zairi, 2002). Zegbe-Doninguez, Behboudian, Lang; Clothier (2003), defines it as irrigating the root zone with less than the required water for evapotranspiration of the crop. Reducing the CWR is an efficient way of saving irrigation water without losing significantly from crop yield and quality. This irrigation strategy according to Dorji, Behboudian and Zegbe-Dominguez (2005), could be feasible for pepper production where the benefit from saving water outweighs the decrease in the total fresh fruit yield. Irrigation amount and time of irrigation affect the yield and quality of fruits and vegetables. Vegetable quality mainly firmness, total soluble solids and acid contents are affected by water stress (Vijitha and Mahendran, 2010). The aim of reducing the required irrigation of a crop is to increase the WUE, to generate water stress at a level without excessive yield loss in the production period of the plant and to obtain the highest yield corresponding to each unit of water at a desirable quality (Kirda, 2002).

Water is limited and therefore important to know, how to timely irrigate with the least amount of water that will optimize yields, water use efficiency and ultimately profits (Payero, Tarkalson, Irmak, Davison, & Petersen, 2009). Due to this water management practices that will help conserve water for the sustainability of agriculture production are very important (Nurudin, 2001). Irrigation water management strategy such as irrigating crops at the right time with the exactly needed irrigation amount seeks to maximize yield. However, under local practices, irrigation is typically applied on a routine basis either in the morning or the evening, depending on the time that suits the farmer, without considering the water requirement (ET) of the crop and the right time to supply to meet that requirement, therefore usually supply water to exceed the crop water requirements (Nagaz et al., 2012). This may result in high water losses and low irrigation efficiency. Therefore, the study was undertaken to assess the effect of time and amount of irrigation on the growth, yield and quality and shelf life of sweet pepper to determine the best time of irrigating and what amount of irrigation will maximize crop yield and WUE, improve on fruit quality and profit of sweet pepper production in Ghana.

Problem Statement

Insufficient water supply for agricultural purpose all year round especially for vegetable production is really affecting vegetable production in Ghana. Sezen, Yazar, Tekin, Eker and Kapur (2011), noticed that there is continuous increase in the competition for water between agricultural, industrial, and urban consumers. This creates the need for continuous improvement in the timely application of the right amount of water to meet crop water requirement. This situation is not far from the situation in Ghana's crop production industry, especially in commercial vegetable production.

In Ghana, most sweet pepper producers' use irrigation for all year round production, but getting the needed amount of water and at the right time to irrigate all year is difficult especially in the urban and peri-urban towns. Due to this, sweet pepper production in Ghana is low and export is 116.690 tonnes annually (USDA, 2011). Also storing of the few tonnes of what is produced for a long time without losing it quality or marketability is also a major problem, which increases post-harvest losses and reduces farmer's income.

One of the major setbacks in vegetable production in Ghana is the inability of farmers to determine the correct amount of water required by the crop and adoption of the necessary irrigation practices during the growing season so as to maximize profit. This usually results in over irrigation or water stress which either way, directly affects crop growth, yield (Owusu-Sekyere and Dadzie, 2009) and even quality.

Recently, results from an experiment conducted by Ofori and Owusu-Sekyere (2015) indicated that time of irrigation affects the growth and yield of some vegetables, though another school of thought believes that time of irrigation, whether morning or evening, does not have any effect on vegetable production. There is therefore the need for, an in-depth research into the effect of deficit irrigation and time of irrigation on sweet pepper production to ascertain the findings of (Ofori & Owusu-Sekyere, 2015).

Justification

Efficient use of water by irrigation is becoming an increasingly important issue in irrigating crop (Nagaz et al., 2012) especially vegetable crops in Ghana. It has been observed that pepper production is confined to the warm and semi-arid countries where water is often a limiting factor for production, necessitating the need to optimize water management (Dorji et al., 2005). Improving irrigation efficiency of sweet pepper, by optimizing the time of irrigation and amount of irrigation, could improve fruit yield and quality, reduce production cost, reduce post-harvest losses and increase productivity, making the sweet pepper production industry more profitable and sustainable to vegetable farmers in Ghana.

Water for irrigation is limited in Ghana, therefore knowledge about the link between time of irrigation, amount of irrigation and vegetable growth, yield, quality and WUE is very important to maximize the benefit from the water supplied to the vegetable crop. Results from the study can help maintain the quality of sweet pepper fruits during storage and in turn extend its shelf life.

Objectives

General Objective

The general objective of this research is to assess the effect of time and amount of irrigation on the growth, yield, quality, shelf life, water use efficiency (WUE) and economic value of sweet pepper production in Ghana.

Specific Objectives

1. To determine the effect of time and amount of irrigation on some growth and yield parameters.

2. To determine the effect of time and amount of irrigation on the physicochemical qualities of freshly harvested sweet pepper.
3. To assess the effect of time and amount of irrigation on the physicochemical qualities and shelf life of sweet pepper fruits during storage.
4. To evaluate the effect of time and amount of irrigation on the water savings and yield reduction, WUE and economic value of sweet pepper production.

Significance of the Study

A lot of work has been done on the effect of deficit irrigation on the yield, quality and shelf life of sweet pepper, but little work has been carried out on the effect of time of irrigation and amount of irrigation water applied on the yield, quality and shelf life of sweet pepper in Ghana. Hence this study will help vegetable growers in identifying and adopting an effective and efficient irrigation water management strategy, which will optimize WUE, maximize yield and improve quality and subsequently increase profitability of sweet pepper production.

Delimitation

The study was conducted on the University of Cape Coast Teaching and Research Farms, Cape Coast in the Coastal Savanah ecological zone of Ghana. The area lies on latitude 5.13^{o}N and longitude 1.28^{o}W. The annual temperature of the project site is in the range of 23.2- 33.2 ^{o}C with an annual mean of 27.6 ^{o}C and a relative humidity in the range of 81.3-84.4%.

Limitation

The research work encountered two limitations; budget and time constraints. Due to these two constraints, the research work could not use more plant for the experimental work and therefore used 72 plants for the experiment. These constraints also, did not allow the research work to be performed on other ecological zone instead of only the coastal savannah ecological zone.

Definition of Terms

Time of irrigation; is the specific time in the day (early morning before sunrise or at sunset in the evening) that a crops is irrigated in the scheduled day for irrigating that crop.

Irrigation amount; is the quantity of water supplied to the soil for plant use depending on the plants water requirement based on the crop's evapotranspiration.

Physicochemical quality; is the combination of physical and chemical characteristics like firmness, total soluble solids, treatable acids and pH of a vegetable or fruit.

Water use efficiency; is the ratio of the total fruit yield (kg/ha) to the total irrigation water applied (m^3/ha).

Organisation of the Study

The research work consists of five chapters.

Chapter One is the introduction and is made up of the background of the study, problem statement, justification, objectives of the study, significance of the study, delimitation, limitation, definition of terms and organization of the study.

Chapter Two, literature review, reviews relevant literature works related to the research objectives. It starts with the overview of sweet pepper cultivation, crop evapotranspiration (ETc) of sweet pepper plants, the effect of water stress on the performance, post-harvest qualities, storage, shelf life, WUE and economic evaluation of sweet pepper production.

Chapter Three is the methodology, it explains in details the materials and methods used to conduct the study. It covers the study area of the experiment, the experimental design used, treatment combinations, nursing and transplanting of seedlings, irrigation supply, data collection, determination of physicochemical qualities of sweet pepper, determination of water saving and yield reduction, WUE and economic evaluation, data analysis and summary of the methodology.

Chapter Four is the results and discussion of the research work. It includes results and discussion on the effect of time and amount of irrigation on the growth and yield parameters, physicochemical qualities, shelf life, WUE and economic evaluation of sweet pepper.

Chapter Five is the last chapter of the thesis. It consists of summary of the findings from the research work, conclusion drawn and recommendations for future research works and policy making.

CHAPTER TWO

LITERATURE REVIEW

The Sweet Pepper Plant (*Capsicum annum*)

Origin and Distribution

Sweet peppers (*Capsicum annum* L.) originate from Central and South America where numerous species were used centuries before Columbus landed on the continent (Manrique, 1993). Pepper seeds were later carried to Spain and from there spread to other European and Asian countries (Rehm & Espig, 1991) as well as Africa and Mexico remains one of the major pepper producers in the world. Capsicum contains approximately 20-27 species (Walsh and Hoot, 2001), five of which are domesticated: C. annuum, C. baccatum, C. chinense, C. frutescens, and C. pubescens (Heiser and Pickersgill, 1969). Although perennials, they grow as annuals in temperate climates. They are sensitive to low temperatures and are relatively slow to establish. According to Raemaekers (2001), cultivars of sweet pepper include Big Bertha, California Wonder, Yolo Wonder, North Star, Lady Bell, Jupiter and Bell Boy. The Yolo Wonder is a 4–square, 3-4 lobed pepper. The highly glossy fruits are an improved California Wonder.

General Characteristics

Sweet pepper is a cultivar group of the species Capsicum annum. Cultivars of the plant produce peppercorns which develop into fruits of different colours, including red, yellow, orange and green the most common colour of sweet pepper produced in Ghana. Sweet peppers or bell pepper or green pepper as called by Ghanaians, are sometimes grouped with less pungent pepper varieties as "sweet peppers" hence its name. Capsicum peppers are the most widespread in the countries of the tropics and subtropics (Pickersgill, 1988). The plant is a herbaceous annual with a densely branched stem. The plant reaches 0.5–1.5 m tall. Single white flowers bear the fruit which is green when unripe; changing principally to red while some varieties may ripen to brown or purple colours.

Climatic Requirements

Sweet pepper seeds germinate under temperatures conditions of 15-34 °C, but the optimum germination temperature is 18-24 °C. Lower night temperatures result in greater branching and more flowers; warmer night temperatures induce earlier flowering and this effect is becoming more pronounced as light intensity increases (FAO, 2002). It is grown extensively under rainfed or irrigation conditions and high yields are obtained when the rainfall or irrigation water is well-distributed over the growing season. According to Doorenbos & Kassam, (1979) a water supply of 600-900 mm and an average daily temperature of 18-23 °C is favorable for sweet pepper production. Heavy rainfall during the flowering stage causes flower shedding and poor fruit setting, and rotting of fruits during the ripening stage (Doorenbos & Kassam, 1979).

Berke, Black, Morris, Talekar and Wang (2003), also reported that sweet peppers grow best between 21 and 24°C. When temperatures fall below 18°C or exceed 27°C for extended periods, growth and yield are usually decreased. Sweet peppers can tolerate daytime temperatures over 30°C, as long as night temperatures are within 21–24°C. Sweet peppers are photoperiod and humidity-insensitive (day length and relative humidity do not affect flowering or fruit set). Pepper is a warm-season crop, which performs well under an extended frost-free season, with the potential of producing high yields with outstanding quality. It is very vulnerable to frost and grows poorly at temperatures between 5 and 15 °C (Bosland & Votava, 1999).

Soil Requirements

According to Raemaekers (2001), light deep to deep and well-drained sandy loam soils with adequate water holding capacity are preferred. The maximum crop rooting depth is 1 m. Water logging, even for short periods, causes leaf shedding. Optimum soil pH is 5.5 to 7.0 and acid soils require liming. Raemaekers (2001) also stated that sweet peppers prefer deep, fertile, well-drained soils. Hence planting in low-lying fields next to streams and rivers should be avoided because these sites are subject to high humidity and moisture conditions and, therefore, especially prone to bacterial spot epidemics. Berke et al. (2003) also reported that sweet pepper grows best in a loam or silty-loam soil with good water-holding capacity, but can grow on many soil types, as long as the soil is well drained and the soil pH should be between 5.5 and 6.8.

Water Requirement and Irrigation Water Needs

Sweet pepper plants have a tap root that is broken during transplanting and a profusely branched lateral root system subsequently develops. Root depth can extend up to 1 m but under irrigation and in pots, the roots are concentrated mainly in the upper 0.3 m soil depth. Normally 100% of the water uptake occurs in the first 0.5 to 1.0 m soil depth (FAO, 2008). Many growers of fresh-market peppers, plant under black plastic mulch with trickle irrigation lying under the plastic. This provides uniform moisture and fertilization during the growing season. Dry conditions result in premature small-sized fruit set, which leads to reduced yields (Bosland & Votava, 1999). Excessive rainfall or water supply also negatively affect flower and fruit formation and eventually lead to fruit rot (Coertze & Kistner, 1994). Root rot diseases can be caused by waterlogged conditions that last for more than 12 hours; therefore, drainage of the field is very important. If plant growth is slowed by water stress during flowering, blossoms and immature fruit are likely to drop off (Bosland & Votava, 1999).

Irrigation is essential in arid and semi-arid regions to provide enough water for pepper production (Bosland & Votava, 1999). Furrow irrigation is well known as a major factor favouring conditions leading to the development of diseases like bacterial wilt (Pernezny et al., 2003). According to Bosland and Votava (1990) the control over the root environment with drip irrigation is a major advantage over other irrigation systems. Sprinkler irrigation requires very good quality water. However, the type of irrigation is likely to make bacterial diseases more of a problem through splashing (Grattidge, 1993).

Nitrogen, Phosphorus and Potassium (N-P-K) Requirement and Fertilizer Application in Sweet Pepper

The uptake of nutrients such as nitrogen, phosphorus and potassium by plants are influenced by the amount of water available in the soil. An adequate amount of water in the soil tends to enhance aeration and this according to Cline and Erickson (1956), would improve potassium and nitrogen uptake. Shapiro, Taylor and Volk (1956) indicated that translocation of phosphorus increases when there is an improvement in aeration. The plant requires high nitrogen application early in the growing season with supplemental applications after the fruit initiation stage. Improved nitrogen use efficiency and greater yields are achieved when the nitrogen is applied under polyethylene mulches and with 12 weekly N applications in a drip irrigation system (Nutrigation). At least 50-90% of the total nitrogen should be applied in nitrate form.

The use of supplemental organic matter, fertilizer, lime and manure should be based on a soil test and a soil nutrient management plan. Soil nutrient management plan is the balance of the crop nutrient requirements and nutrient availability, with the aim to optimize crop yield and minimize ground-water contamination, while improving soil productivity. Fertilizer requirements for sweet pepper are 100 to 170 kg/ha N, 25 to 50 kg/ha P and 550 to 100 kg/ha K (Rehm & Espig, 1991; Sys, Van Ranst, Debaveye, & Beernaert, 1993; FAO, 2002). The fertilizer programme for sweet pepper production depends on the type of soil, the nutrient status and the pH of the soil. It is, therefore, important to analyze the soil before planting to determine any nutrient deficiency or imbalances (Coertze & Kistner, 1994).

Nitrogen is important for sweet pepper plant growth and reproduction. Nitrogen is mobile in the soil and leaches out easily and therefore requires split application to minimize leaching (FSSA, 2007). Under high rainfall and humidity conditions, too much nitrogen delays maturity, resulting in succulent late-maturing fruit (Bosland & Votava, 1999). Potassium is associated with resistance to drought and cold, and fruit quality. It promotes the formation of proteins, carbohydrates and oils (FSSA, 2007). Phosphorus is important for photosynthesis, respiration, energy storage, cell division and other processes. It is applied before planting while potassium fertilisers are usually applied at planting time (Ngeze, 1998). Sweet pepper is sensitive to calcium deficiency, which normally results in blossom- end rot (Pernezny, Roberts, Murphy, & Goldberg, 2003). The crop is also sensitive to deficiency of micronutrients such as zinc, manganese, iron, boron and molybdenum (Portree, 1996).

According to Berke et al. (2003), the amount of fertilizer to apply depends on soil fertility, fertilizer recovery rate, soil organic matter, soil mineralization of N and the leaching of soil nutrients. A soil test is therefore recommended to determine the available N, P, and K. They further explained even with example that, the amount to be applied can then be calculated based on your target yield and residual nutrients.

Pests and Diseases

Many pest and diseases affect sweet pepper during their growth period from seedlings till harvest. When sweet pepper plant is irrigated with excessive water leading to water logging, root rot diseases may occur and under water stress conditions nutrient uptake will be impaired and nutrient deficiency diseases like blossom end-rot may occur.

Several insecticides and miticides provide effective control of broad mites (Pernezny et al., 2003). Thrips damage to sweet pepper 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 (Black, Green, Hartman, & Poulos, 1991).

Diseases that affect sweet peeper include, powdery mildew which is caused by Leveillula taurica (Coertze & Kistner, 1994) is one of the main diseases that affect sweet pepper. The symptoms are chlorotic spots on the upper leaf surface. Numerous lesions may coalesce, causing chlorosis of the leaves. The disease is promoted by warm weather (dry and humid). Fungicides are used to manage the disease during periods of heavy disease pressure (Black et al., 1991). Another disease that affects sweet pepper is Damping-off caused by Rhizoctonia solani and certain Pythium species. This mainly affects young seedlings (Coertze & Kistner, 1994). Symptoms include failure of seedlings to emerge, small seedlings suddenly collapse or are stunted. The development of the disease is enhanced by undecomposed organic matter in the soil and high soil moisture. Seed should be treated with a suitable registered fungicide, nursery beds should be placed on well-drained sites and covered beds should be adequately ventilated to prevent high humidity (Black et al., 1991).

Harvesting and Yield

Harvesting begins approximately 60 to 80 days after transplanting and may extend over a period of 30 to 70 days. Depending on the cultivar, the fruits may be gathered before they mature (green) or when they are fully ripped (red or yellow). The cultivars ‘‘Yolo and California wonders’’ are usually harvested when the fruits are 10 – 12cm in length and have a diameter of 8 – 10cm (Amati, Dekker, Vanlingen, Pinners, & Tam, 1995). Sweet pepper is harvested when the fruit is firm and well coloured. In some areas, sweet peppers are generally hand harvested as green mature fruit. For the fresh market, or when the fruit is to be stored, peppers should be cut cleanly from the plant, using a hand clipper or sharp knife, leaving about a 2 cm section of the pedicel (stem) attached to the fruit. A clean cut is important as such cut surfaces heal more quickly. This reduces the incidence of decay in storage and during transport to the market.

In terms of yields, 6 to 10 t/ha of sweet peppers may be obtained for processing. Fresh market yields may range from 500-1 000 12 kg cartons per hectare. When using appropriate plasticulture techniques, yields of 1 428 12 kg cartons per hectare have been reported. Pimiento and dried chilli pepper yields range from 1 to 2 t/ha. Pepper yields are greatly influenced by the number of harvests and season. As peppers mature, their walls thicken. Yields also vary greatly with climate and length of growing period. Under rainfed conditions, commercial yields are in the range of 10 to 15 t/ha. 20 to 25 t/ha are obtained under favourable climatic and irrigated conditions. However, the marketable yield percentage may vary (Sys et al., 1993; FAO, 2002).

Nutritional Value and Health Benefits of Sweet Pepper

Sweet pepper is a vital commercial crop, cultivated for vegetable, spice, and value-added processed products (Kumar and Rai, 2005). Besides vitamins A and C, the fruits contain mixtures of antioxidants notably carotenoids, ascorbic acid, flavanoids and polyphenols (Nadeem, Muhammad, Anjum, Khan, Saed, & Riaz, 2011). This makes it a very important constituent of many foods, adding flavour, colour and pungency and, hence, an important source of nutrition for humans. In most advanced countries, the fresh fruits can be processed into a paste and bottled for sale in supermarkets. Sweet pepper can also be used medically for the treatment of fevers and colds (Norman, 1992). Sweet pepper, being a very rich source of vitamins A, C, B6, folic acid and beta-carotene, provides excellent nutrition and health benefits humans (Nadeem et al., 2011).

Economic Benefit of Sweet Pepper

As a commercial crop in Ghana, pepper was ranked as the second valuable vegetable crop ahead of popular vegetables like okra and eggplant with an estimated total production of 88,000 metric tonnes in 2011 which was valued at $96,397 (FAOSTAT, 2011). Agronomically, different pepper genotypes have been found to show differential responses to Egyptian broomrape, a chlorophyll-lacking root-parasite in Egypt. Hence, the crop is used as a catch/trap crop to reduce field infestation of the parasite (Hershenhorn et al., 1996).

Irrigation Scheduling

Martin, Stegman, and Fereres (1990), defined DI scheduling as the science of specifying future irrigation timing and amount in the implementation of water management strategy. With the application of water at the right time and amount, water will be conserved. Three parameters have to be considered in preparing an irrigation schedule: the daily crop water requirements, the soil with respect to its total available moisture or water-holding capacity and the effective root zone depth. Soil water dynamic should be well-defined so as to regulate the water supply to crops (Hillel, 1990).

Phene et al. (1990) reported that irrigation scheduling involves two main factors; how much to apply and when to apply the water (frequency). And that irrigation quantity (amount) is usually based on the type of irrigation system, plants response to water deficit, growth stage, soil infiltration characteristics, and soil water deficit. Irrigation timing is usually based on soil water measurement and other crop water requirement factors.

Irrigation Water Quality

Irrigation waters whether derived from springs, diverted from streams, or pumped from wells, contain appreciable quantities of chemical substances that could reduce crop yield and deteriorate soil fertility. In addition to the dissolved salt, which has been the major problem for centuries, irrigation water always carries substances derived from its natural environment or from the waste products such as domestic and industrial effluents by man's activities. (Phocaides, 2000). These substances may vary in a wide range, but mainly consist of dirt and suspended solids.

The quality of water for irrigation can be classified in terms of the following considerations:

- Chemical, (salinity/toxicity hazards for the soil, the plants and the irrigation system such as pipe corrosion and clogging of the emitter by chemical).
- Physical (emitters blockages problems from suspended solid particles and other impurities content).
- Biological (problems from bacteria and other contents harmful for human and animal health as well as for the soil the plants and the irrigation systems).

Phocaides (2000) further explains that the classification seems convenient for a broad evaluation to cover a whole spectrum of irrigation waters quality for crop production. With the inclusion of reuse of treated municipal wastewater for irrigation, the water quality considerations are broadened to cover all the physicochemical, biological and microbiological properties of water that may cause any impact on soil, plants, environment and the consumers, human or livestock. The classification adopted by FAO in 1985 and proposed as an initial guide has proved most practical and useful in assessing water quality for on-farm water use (Phocaides, 2000).

Irrigation Requirements

Irrigation requirements (IR) according to Doorenbos & Pruitt (1984) refer to the water that must be supplied through the irrigation system to ensure that the crop receives its full crop water requirements. If irrigation is the sole source of water supply for the plant, the irrigation requirement will always be greater than the crop water requirement to allow for inefficiencies in the irrigation system. If the crop receives some of its water from other sources (rainfall, water stored in the ground, underground seepage, etc.), then the irrigation requirement can be considerably less than the crop water requirement.

Crop Water Requirement and its Measurement

Crop water requirements (CWR) encompass the total amount of water used by evapotranspiration. Doorenbos & Pruitt (1984) defined crop water requirements as ‘the depth of water needed to meet the water loss through evapotranspiration of a crop, which is disease-free and growing in large fields under non restricting soil conditions, including soil water and fertility, and achieving full production potential under the given growing environment. CWR is therefore similar crop evapotranspirtion, ETc.

Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface

(Allen, Pereira, Raes, & Smith, 1998). This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process.

Reference Crop Evapotranspiration (ETo)

Allen et al. (1998) reported that the evapotranspiration from a reference surface not short of water is called the reference crop evapotranspiration and is denoted by ETo. The concept of ETo was introduced to study the evaporative demand of the atmosphere independently of crop type, crop development stage and management practices. Relating evapotranspiration to a specific surface provides a reference to which evapotranspiration from other surfaces can be related. It removes the need to define a separate evapotranspiration level for each crop and stage of growth. The only factors affecting ETo are climatic parameters. As a result, ETo is a climatic parameter and can be computed from weather data. ETo expresses the evaporative demand of the atmosphere at a specific location and time of the year and does not consider crop and soil factors.

Crop Evapotranspiration (ETc)

The crop evapotranspiration under standard conditions, denoted as ETc, is the evapotranspiration from disease-free, well-fertilized crops, grown in large fields under optimum soil water conditions and achieving full production under the given climatic conditions (Allen et al., 1998). The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. The values of ETc and

CWR (Crop Water Requirements) are identical, whereby Etc refers to the amount of water lost through evapotranspiration and CWR refers to the amount of water that is needed to compensate for the loss.

ETc is calculated from climatic data by directly integrating the effect of crop characteristics into ETo. Using recognized methods, an estimation of ETo is done, and the relation between ETc and ETo is given by the following equation (Allen et al. 1998)

ETc = ETo x Kc ……………………………………………… (1)

Where:

ETc = Crop evapotranspiration (mm)

ETo = Reference crop evapotranspiration (mm)

Kc = Crop coefficient (Allen et al., 1998)

Differences in leaf anatomy, stomata characteristics, aerodynamic properties and even albedo (solar radiation reflected by the surface) cause ETc to differ from ETo under the same climatic conditions. Due to variations in crop characteristics throughout its growing season, Kc for a given crop changes from sowing till harvest.

Sezen et al. (2011) observed that, seasonal crop evapotranspiration of pepper plants varied from 327 mm in pepper plants under the least irrigation frequency and highest water deficit regime to 517mm in pepper plants under the highest irrigation frequency and the least water deficit. Water use values increased with increasing irrigation level in each irrigation frequency. Üstün (1993) reported that drip-irrigated pepper seasonal water used varied from 575 to 663 mm in the recommended treatment (6-day irrigation interval and plant pan coefficient of Kp=0.50. Celik (1991) evaluated the effect of various irrigation regimes on surface-irrigated pepper yields, and reported water use of 825 mm and seasonal irrigation water of 654 mm, and recommended irrigating at 40% of available water in the 90 cm profile depth.

Crop Coefficient (Kc)

A crop coefficient is a factor for estimating crop water requirements based on reference crop evapotranspiration. According to Doorenbos & Kassam (1979) and Allen et al (1998), crop coefficients vary between crops and growth stages, which reflects the changing characteristics of a plant over the growing season. As the crop grows, the ground cover, crop height and leaf area change. Differences in the crop's evapotranspiration rate over the various growth stages change the crop coefficient. Norman (1992) stated that there are four stages in the life cycle of every crop and these are; initial, developmental (vegetative), mid-season (reproductive and late season. Each stage has its own crop characteristics and period of time and this determines the amount of water that will be needed by the crop. The values of Kc in the initial and development stages are subject to effects of large variations in wetting frequencies as observed in Table 1 and therefore, refinements to Kc ini should always be made.

Table 1: Basal Crop Coefficients, K_c, for Non-Stressed, Well-Managed Vegetables in Sub Humid Climates

Crop	Kc.ini	Kc.mid	Kc.end
a. Small Vegetables	0.15	0.95	0.85
Broccoli		0.95	0.85
Cabbage		0.95	0.85
Carrots		0.95	0.85
Cauliflower		0.95	0.85
Garlic		0.90	0.60
b. Vegetables - Solanum Family *(Solanaceae)*	0.15	1.10	0.70
Egg Plant		1.00	0.80
Sweet Peppers (bell)		1.00	0.80
Tomato		1.10	0.60-0.80

Source: (Allen et al., 1998)

Kc at the Various Growth Stages of the Crop

During the various growth stages, changes in evapotranspiration occur as the crop develops, this is due to changes ground cover, crop height and the leaf area hence the Kc for a given crop will vary over the growing period as observed in Table 2.

Initial Stage

As reported by Allen et al. (1998), the initial stage runs from planting date to approximately 10% ground cover. Kc at this stage is low as observed in Table 2. During the initial period, the leaf area is small, and evapotranspiration is predominantly in the form of soil evaporation. Therefore, the Kc during the initial period (Kc ini) is large when the soil is wet from irrigation and rainfall and is low when the soil surface is dry (Allen et. al., 1998).

Crop Development Stage

According to the Allen et al. (1998), the crop development stage runs from 10% ground cover to effective full cover. During the crop development stage, the Kc value corresponds to amounts of ground cover and plant development. Typically, if the soil surface is dry, Kc = 0.5 corresponds to about 25-40% of the ground surface covered by vegetation due to the effects of shading and due to microscale transport of sensible heat from the soil into the vegetation. A Kc = 0.7 often corresponds to about 40-60% ground cover (Allen et. al., 1998).

Mid-season Stage

According to Allen et al. at the mid-season stage the Kc reaches its maximum value as seen in Table 2. The value for Kc (Kc mid) is relatively constant for most growing and cultural conditions. Deviation of the Kc mid from the reference value '1' is primarily due to differences in crop height and resistance between the grass reference surface and the agricultural crop and weather conditions.

Late Season Stage

The Kc value at the end of the late season stage (Kc end) reflects crop and water management practices. Allen et al. (1998) reported that, the Kc end value is high if the crop is frequently irrigated until harvested fresh. If the crop is allowed to senesce and to dry out in the field before harvest, the Kc end value will be small. Senescence is usually associated with a less efficient stomatal conductance of leaf surfaces due to the effects of ageing, thereby causing a reduction in Kc.

Table 2: Crop Coefficient (Kc) for Various Growth Stages of Selected Vegetable Crops

Crop	Initial	Development	Mid-season	Late	At harvest
Cabbage	0.4[1] - 0.5[2]	0.7 - 0.8	0.95 - 1.1	0.9 - 1.0	0.8 - 0.95
Carrots	0.4 - 0.6	0.6 - 0.75	1.0 - 1.15	0.8 - 0.9	0.7 - 0.80
Cucumber	0.4 - 0.5	0.7 - 0.8	0.95 - 1.05	0.8 - 0.9	0.65 - 0.75
Lettuce	0.3 - 0.5	0.6 - 0.7	0.95 - 1.1	0.9 - 1.0	0.8 - 0.95
Pepper	0.3 - 0.4	0.6 - 0.75	0.95 - 1.1	0.85 - 1.0	0.8 - 0.9
Tomato	0.4 - 0.5	0.7 - 0.8	1.05 - 1.25	0.8 - 0.95	0.6 - 0.65

[1]The first crop reading is for high humidity and low wind conditions.

[2]The second reading is for low humidity and strong wind conditions.

Source: Doorenbos and Kassam (1979).

Length of the various Growth Stages of Sweet Pepper

As reported by Allen et al. (1998), the initial stage runs from planting date to approximately 10% ground cover. The length of the initial period is highly dependent on the crop, the crop variety, the planting date and the climate and ma last for about 25 to 30 days as shown in Table 3.

The developmental stage according to the Allen et al. (1998), runs from 10% ground cover to effective full cover. Effective full cover for many crops occurs at the initiation of flowering. For some crops, especially those taller than 0.5 m, the average fraction of the ground surface covered by vegetation (fc) at the start of effective full cover is about 0.7-0.8 (Allen et. al., 1998). Table 3 shows that, this growth stage last for 35 day though climatic conditions may increase or reduce the length. From the work of Allen et al. (1998), they reported that the mid-season stage runs from effective full cover to the start of maturity.

The mid-season stage is the longest stage for perennials and for many annuals as observed from the vegetables in Table 3, but it may be relatively short for vegetable crops that are harvested fresh for their green vegetation. According to Allen et al. (1998), the late season stage runs from the start of maturity to harvest or full senescence. For some perennial vegetation in frost free climates, crops may grow year round so that the date of termination may be taken as the same as the date of planting. The length of this stage may take 20 days or more.

Table 3: Lengths of Crop Development Stages (Days), Period of Planting and Climatic Region of Selected Solanum Family Vegetables

Crop	Init. (L_{ini})	Dev. (L_{dev})	Mid (L_{mid})	Late (L_{late})	Total	Month of planting	Region
Broccoli	35	45	40	15	135	Sept	Calif. Desert
	40	60	50	15	165	Sept	Calif. Desert
Carrots	20	30	50/30	20	100	Oct/Jan	Arid climate
	30	40	60	20	150	Feb/Mar	Mediterranean
Lettuce	20	30	15	10	75	April	Mediterranean
	30	40	25	10	105	Nov/Jan	Mediterranean
Egg plant	30	40	40	20	130\1	October	Arid Region
	30	45	40	25	40	May/June	Mediterranean
Sweet peppers (bell)	25/30	35	40	20	125	April/June	Europe and Medit.
	30	40	110	30	210	October	Arid Region
Tomato	30	40	40	25	135	January	Arid Region
	35	45	70	30	180	Oct/Nov	Arid Region
	30	40	45	30	145	April/May	Mediterranean

Source: (Allen et al., 1998)

Methods of Measuring Crop Evapotranspiration

FAO Penman-Monteith Method

The FAO Penman-Monteith method is the recommended method for determining reference crop evapotranspiration (ETo). This method overcomes the shortcomings of all other previous empirical and semi-empirical methods and provides ETo values that are more consistent with actual crop water use data in all regions and climates (Allen et al., 1998).

The method has been developed by unambiguously defining the reference surface as 'a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s/m and an albedo of 0.23' (Allen et al., 1998). The surface resistance describes the resistance of vapour flow through the transpiring crop and evaporating soil surface. The reference surface closely resembles an extensive surface of green grass that is of uniform height, actively growing, completely shading the ground and adequately watered. The requirement that the grass surface should be both extensive and uniform results from the assumption that all fluxes are one-dimensional upwards. The reference crop evapotranspiration (ETo) provides a standard to which evapotranspiration at different periods of the year or in other regions can be compared and evapotranspiration of other crops can be related through the use of crop coefficients.

The Penman-Monteith equation was given by (Allen et al., 1998).

$$ETo = \frac{0.408\Delta(R_N - G) + \gamma\frac{900}{T+273}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:

ETo = Reference evapotranspiration (mm)

Rn = Net radiation at the crop surface (MJ/m^2 /day)

G = Soil heat flux density (MJ/m^2)

T = Mean daily air temperature at 2 m height (°C)

u2 = Wind speed at 2 m height (m/s)

es = Saturation vapour pressure (kPa)

ea = Actual vapour pressure (kPa)

es - ea = Saturation vapour pressure deficit (kPa)

Δ = Slope of saturation vapour pressure curve at temperature T (kPa/°C)

γ = Psychrometric constant (kPa/°C).

Pan Evaporation Method

Despite the FAO Penman-Monteith being the recommended method for calculating ETo, the Pan Evaporation method is also widely used specially in some parts of East and Southern Africa. This is mainly because the method is very practical and simple, which appeals to many farmers and practitioners. A description of the method is given below. The evaporation rate from pans filled with water can be easily determined. In the absence of rainfall, the amount of water evaporated during a given period corresponds to the decrease in water depth in the pan during the given period. Pans provide a measurement of the combined effect of radiation, wind, temperature and humidity on an open water surface (Allen et al., 1998). The pan responds in a similar manner to the same climatic factors affecting crop transpiration.

Various types of evaporation pans exist and the most common type is the Class A pan. According to Allen et al. (1998). The Class A evaporation pan is circular, 120.7 cm in diameter and 25 cm deep. It is made of galvanized iron (22 gauge) or Monel metal (0.8 mm). The pan is mounted on a wooden open frame platform, which is 15 cm above ground level. The soil is built up to within 5 cm of the bottom of the pan. The pan must be level. It is filled with water to 5 cm below the rim, and the water level should not be allowed to drop to more than 7.5 cm below the rim. The water should be regularly renewed, at least weekly, to eliminate extreme turbidity. The measured evaporation from a pan (Epan) is related to the reference crop evapotranspiration (ETo) through an empirically derived pan coefficient (Kp) as given in the following equation by Allen et al. (1998).

$$ETo = Epan \times Kp \quad \ldots\ldots (3)$$

Where;

ETo = Reference crop evapotranspiration (mm)

Kp = Pan coefficient

Epan = Pan evaporation (mm).

Effect of Irrigation Time on Vegetable Production

Irrigation scheduling based on crop water requirements and soil characteristics allows for applying irrigation water when needed during the growing season. However, its application is only possible when water supply and irrigation amounts can be managed independently by farmers (Smith, 1985). Ofori & Owusu-Sekyere (2015) experiment on the effect of time of irrigation on tomato reported that irrigating in the evening recorded a higher fruit yield than irrigating in the morning.

Weight or Water Loss in Vegetables during Post-Harvest Storage

According to Mpelasoka, Behboudian, and Mills (2001) at postharvest conditions, fruits exposed to water restrictions had lower weight loss during cold storage than those originated from fully irrigated treatments. According to the authors, the reduced weight loss can be explained by the structure and/or composition of the skin or the epicuticular waxes covering the skin. This reduction in weight loss could prolong the cold storage life.

The quality of fruits after harvest rapidly decreases due to water loss (Ryall and Lipton, 1972; Showalter, 1973; Watada, Kim, Kim, & Harris, 1987). According to Kays (1991), initial fruit water content may affect the water-loss rate. Fruit with lower water content would have a smaller vapour pressure deficit (VPD) and may, therefore, lose moisture at a lower rate than fruit with higher moisture content. Lownds, Banaras, and Bosland (1993), also reported that postharvest weight loss increased linearly with storage time. New Mexican-type peppers as reported by Lownds & Bosland (1988) become flaccid in 3 to 5 days at 20^{o}C (7% to 10% weight loss) and lose water twice as fast as bell or jalapeño types.

Lownds & Bosland (1988) reported that studies on pepper varieties, such as bell, jalapeño and New Mexican, differ in water-loss rate during storage. The following fruit physical properties, including initial water content, surface area, surface area: volume (SA:V) ratio, and surface morphology, may all affect water loss in horticultural crops (Albrigo, 1972; Ben-Yehoshua, 1987; Robinson, Browne, & Burton, 1975; Wills, Lee, Graham, McGlasson, & Hall, 1981) including peppers (Albrigo, 1972). Lownds et al. (1993) stated that fruits, as with other aerial plant parts, are covered with a cuticle composed of biopolymer cutin and embedded wax, with epicuticular waxes on the outer surface. The cuticle serves as the major barrier to moisture loss (Schonherr, 1976). Therefore, differences in pepper fruit surface morphology and/or epicuticular waxes may affect water-loss rates and postharvest longevity (Lownds et. al., 1993).

Effect of Water Stress on the Growth of Vegetables

Sezen et al. (2011) from his experiment on yield and quality response pepper to different water regimes observed that, plant growth was negatively affected by water stress during the growing period. The total length of the growing season of pepper was 122 days. Water plays an important role in plant life. In many localities, it is the limiting factor for agricultural crops and hence increasing yield. According to Sezen et al. (2011), under conditions of drought the free energy of water available to the plant is reduced well below that of pure free water. The osmotic adjustment as the accumulation of solutes within the cell helps in maintaining turgor at decreasing water potentials. During water stress conditions tomato plants cannot get enough water for physiological processes resulting in low yield of fruits (Nahar & Gretzmacher, 2002).

Level of water in plant controls the physiological processes and conditions which determine the quality and quantity of growth (Kramer, 1969). Since water is essential for plant growth, it is obvious that water stress, depending on its severity and duration, affect plant growth, yield and quality of yield. Coincidentally, a decrease in nutrient uptake was observed by decreasing the concentration of nutrient in the irrigation solution. According to Doorenbos & Kassam (1979) fruiting vegetables like sweet pepper, tomato and eggplant, the critical water requirement period is during flowering, fruit set and development of the fruit and seeds. Sweet pepper, is very sensitive to water deficit during and immediately after transplanting, at flowering and during fruit development.

Effect of Water Stress on the Nutrients Uptake in Sweet Pepper

Abdallar and El-koshiban (2007), in an experiment on the influence of water stress on photosynthetic pigments, some metabolic and hormonal contents of two *Triticium aestivum* cultivars, reported that increasing water resulted in the reduction of, phosphorus, potassium and calcium uptake by the two cultivars. According to Hegde & Srinivas (1990), work on tomato grown in different levels of soil matrix potential and Nitrogen applied, they observed that nutrient uptake from the soil by plants decreased as the amount of irrigation reduces. Brown, Pezeshki, and DeLaune (2006), also made a similar observation of a reduction in the uptake of calcium, nitrogen, phosphorus and potassium spartina alterniflora plants under water stress. Similar observation was reported by Owusu-Sekrere, Sam –Amoah, Teye, and Osai (2012) for tomato grown under deficit irrigation that, N-P-K uptake declined as the plants water stress increases.

Effect of Water Stress on Calcium Deficiency and Blossom End Rot (BER) in Sweet Pepper

BER occurs mainly during hot weather and under water stress conditions. Fruits are affected in their early stages of development (10-15 days after fruit set); the cause is related to lower supply of calcium to the sweet pepper plant for growth and development. Blossom-end rot is a common physiopathy affecting sweet pepper and increasing the loss of it marketability. It starts with a calcium deficiency during the initial stage of fruit devlopment (Ho & White, 2005; Rubio, Garcia-Sanchez, Rubio, & Martinez, 2009). According to Tadesse, Nichols and Fisher (1999), low nutrient conductivity increase BER incidence since they contribute to reducing water uptake by roots and then calcium allocation to the fruit. Salas, Urrestarazu and Castillo (2006); Lee and Liao (2007) also reported that, tinning the plants with two or three stems helps to optimize greenhouse cropping conditions, solar radiation interception and marketable quality. This seriously affects the leaf area index and influences the plant ability to uptake water and nutrients from the soil. Environmental conditions including high temperature and light intensity, water deficit, and high salinity are also known to cause blossom-end rot (Rubio et al., 2009; Saure, 2001). The factors that lead to high incidence and severity of BER are directly related to calcium uptake deficiency and it transport to the fruit, like high temperatures and water shortage.

Marschner (1986) found that calcium is essential for the stability of biomembranes, and calcium-polygalacturonates are required in the middle lamella for cell wall stability. When a rapidly growing fruit is deprived of the necessary Ca, necrotic lesions are initially developed at the outer surface of the flowering end of the fruit. Plants become susceptible to such localized calcium deficiencies in low or non-transpiring tissues.

The Ca deficiency in plants that causes BER is commonly caused by one of the following; lack of Ca in the soil, periods of drought followed by large amounts of water, over-watering, excess nitrogen, and excess competitive cations. Under these conditions, a lack of Ca uptake from the soil, a rapid plant growth and fruit development, and a low transpiration of the whole plant may restrict the transfer of Ca to the low transpiring fruits (Bradfield and Guttridge, 1984; Marcelis & Ho, 1999). Ho et al. (1993) noted that BER develops most frequently when vegetative growth is rapid and fruit setting starts, just as fruits need Ca the most. According to Ho et al. (1993), under high temperature in the greenhouse, competition for water between leaves and fruits can restricts Ca translocation to the low transpiring fruits.

Effect of Water Stress on Vegetables and Fruits Quality

According to Mpelasoka et al. (2001) the irrigation water treatments did not affect the crop load. Irrespective of fruit thinning treatment, deficit irrigated stress resulted in lower fruit weight, total yield and fresh-market yield at harvest than control. In a related study by Velez, Intrigliolo, and Castel, (2007) using the "maximum daily trunk shrinkage" method, which is used as an indicator of water stress, the experiment produced a water saving reaching 18% without significant decreases in average fruit yield, weight and number. Perez-Pastor et al. (2007), evaluated postharvest fruit quality of apricot harvested from trees exposed to three different irrigation treatments: control treatment (100% of evapotranspiration); regulated deficit irrigation, which consists in full irrigation during critical periods; and 50% water regime. Comparing the two treatments noticed that at harvest there was no observed differences in weight and equatorial diameter for the various treatments.

Bordonaba & Terry (2010), noticed that there were no significant differences in the sugar contents of the various irrigation treatments. But, fructose and glucose were in higher concentrations for water stressed plants, thus, berries were sweeter. The acidity in all cultivars increased as water stress condition increases except for Elsanta and Sonata cultivars.

Mpelasoka et al. (2001) also observed that deficit irrigation (DI) has effects on fruit maturation and ripening depending on timing of application. It was noticed that all DI treatments increased fruit total soluble solids (TSS) and firmness regardless of maturity but had little or no effect on titratable acidity (TA). They further noted that, the DI fruit may be harvested over a longer period due to their earlier increased TSS and their higher firmness prior to harvest and for most of the storage period. Regarding quality parameters, deficit irrigated plants exhibite higher contents of TSS than fully irrigated plants. Similar increase was observed in fruit firmness. In a related experiment, with apple, the fruit firmness was higher under water restriction treatments compared to fully irrigated treatments despite fruit size (Mpelasoka et al., 2000).

Perez-Pastor et al. (2007), they assessed postharvest fruit quality of apricot harvested from trees exposed to three different treatments: control treatment (100% of evapotranspiration); regulated deficit irrigation, which consistsed of full irrigation during critical periods; and 50% water regime compared to control. The results showed that during harvest differences was observed in the firmness of the fruits among the different treatments. Again, fruit from water stressed apricots had higher values of total soluble solids and titratable acidity. Velez et al. (2007), using the “maximum daily trunk shrinkage” method, which is used as an indicator of water stress, fruit submitted to deficit irrigation, had significantly higher TSS and similar TA. He further explained that the higher accumulation of sugars is a result of an active response to water deficit.

In a similar work, García-Tejero (2010) determined the postharvest fruit quality of oranges exposed to DI in commercial orchards in the semi-arid region of Andalusia- Spain. The experiment was made up of four different treatments: Control (irrigation replacing 100% of Evapotranspiration, ETc), low deficit irrigation (75% of ETc), moderate deficit irrigation (65% of ETc) and severe deficit irrigation (50% of ETc). The results showed that fruit quality parameters such as TSS and TA increased in all stressed treatments resulting in better organoleptic parameters.

Effect of Water Stress on the Fruit Quality of Sweet Pepper after Harvest and During Storage

Dorji et al. (2005) in an experiment to determine the effect of DI and partial root zone drying (PRD) on the quality of pepper reported that, quality improved in DI fruit in terms of higher TSS compared to PRD and continuously irrigated (CI) fruit at final harvest. Reduced fruit water content and greater hydrolysis of starch into sugars (Kramer, 1983,) may have contributed towards increased TSS in DI fruit. As internal ethylene concentration and respiration rate were small and similar among the treatments, differences in TSS due to respiratory loss of sugars as speculated for tomato by Zegbe-Dominguez et al. (2003), would have been negligible in our study. Ascorbic acid, an important source of Vitamin C, has been shown to have a strong positive correlation with changes in dry mass and TSSC in sweet pepper fruit (Niklis, Siomos, & Sfakiotakis, 2002).

DI advanced fruit maturity in terms of colour development at harvest. DI fruit had the lowest hue angle and hence was redder than the other treatments. ‘Chooraehong’, a Korean hot pepper cultivar, has been reported to exhibit significant increases in respiration rate and ethylene production corresponding with colour development (Gross, Watada, Kang, Kim, & Lee, 1986). It is well known that sugars and simple acids are respiration substrates, and the longer the time of fruit respiration, the higher will be the rates of consumption of sugars and acids (Atta-Aly & Brecht, 1995). Gorny & Kader, (1998) reported that an increase in the amount of soluble solids as fruits ripen decrease once senescence was reached. Change in TA and pH are founded on changes in citric, malic and ascorbic acid. Concentrations of these acids are known to diminish during ripening (Medlicott, Reynolds, & Thompson, 1986). Wills et al. (1989); Antoniali, Leal, Magalhães, Fuziki, & Sanches (2007) reported that, high ambient temperature could raise respiration rate which could also raise the use of organic acids in the respiration process with the variations among cultivars in a given storage could be due to their genetic make-up.

Acids make up the energetic reserves and the metabolic reactions that involve the synthesis of pigments, enzymes and other materials and degradation of pectin and celluloses, which are essential for the ripening process (Lurie & Klein, 1990; Antoniali et al., 2007) which could be the cause for gradual reduction of the TA. According to Mohammed et al. (1999), higher fruit acidity is an advantage, which causes a lower incidence of spoilage. Early stages after harvest, overall acidity increased and then decreased in storage (Castro, Avila, Rocha, Ochoa, & Gallegos, 2002). Getenit, Seyoum, and Woldetsdik (2008) also presented an acidity decrease and a pH increase along with maturity evolution.

According to Antoniali et al. (2007) the polysaccharides of the cell wall are broken up with a consequent increase in sugar levels during ripening. The higher TSS contents of pepper stored at ambient condition could be related to the higher temperature that resulted in a faster conversion of starch into water-soluble sugars (Getenit et al., 2008).

In Cochran (1964) experiment on the changes in pH of pepper during maturation verified a drop in the pH of pepper during its transformation from unripe green to red stage. However, Antoniali et al. (2007) and Vicentini, Castro, and Cereda (1999) showed that, such difference was not significant. Increasing pH values and reduced acidity with prolonged storage time since the fruit with the proceeding of the ripening process is going to diminish its predominant malic acid (Medlicott & Thompson, 1985). Mizrach, Filtsanov and Fuchs (1997) experiment on the quality of pepper during storage reported that, carbohydrate and acid metabolism are closely connected during postharvest ripening period which would thus raise pH of the produce.

Effect of Water Stress on WUE of Sweet Pepper

In an experiment conducted by Sezen et al. (2011), the WUE on fresh yield basis increased with more frequent irrigation application and WUE decreased with increasing irrigation levels. IWUE values decreased with increasing irrigation interval at the same irrigation level. Dukes, Simonne, Davis, Studstill and Hochmuth (2003) reported a higher IWUE values for drip-irrigated pepper ranging from 16.0 to 52.6 kg/m^3 for marketable yields in Florida, USA. Karam, Masaad, Bachour, Rhayem and Rouphael (2009) reported that, WUE values for fresh pepper yield ranging from 5.9 to 7.8 kg/m^3 for full irrigated pepper.

According to Ismail (2010), WUE had a highly significant difference among irrigation treatments and increasing the irrigation deficit was met by a high increase in WUE. The total dry mass of fruit may be slightly affected by deficit irrigation (Dorji, et al., 2005). This indicates that water movement into fruit may have decreased with the progressive development of water deficit without affecting the translocation of dry matter into the fruit and resulted in an increase in mass production per unit of water, which led to high water use efficiency (Ismail, 2010).

Effect of Water Stress on Economic Analysis of Irrigated Sweet Pepper

In a study of deficit irrigation on sweet pepper, Sezen et al. (2011) evaluated the economic benefit of the yield from their experiment. They found out that, income values increased from DI of 50% ETc treatment to full irrigation or 100%ETc treatment. In each irrigation frequency, 20mm accumulated Epan with full irrigation was found to be the most profitable. According to this economic evaluation, the maximum net income obtained was US$ 12514/ha which is for the treatment with full irrigation level. Low irrigation levels resulted in the lowest net income. It was noted that there was a significant difference in terms of net income between the irrigation treatments. As water supply increased, net income was also raised in all irrigation frequencies. Zhang & Oweis (1999) performed an economic analysis of wheat grown in northern Syria in consideration of rainfall and found out that; maximum irrigation water gave the maximum economic benefit.

Factors affecting Vegetables during Storage

Fruit water loss occurs through the stomata, lenticels, cuticle, and epicuticular wax platelets, as well as through the calyx, pedicel or floral ends (Ben-Yehoshua, 1987). Ben-Yehoshua, Shapiro, Chen, and Lurie (1987) and Lownds et al. (1994) reported that bell pepper fruit quality and postharvest life are highly determined by fruit water loss or transpiration. D´ıaz-P´erez (1998) and Lownds et al. (1994) also found that excessive fruit water loss results in softening and reduced shelf-life in bell pepper, and eggplant fruit. According to Burton (1982) fruit water loss accounts for most of the weight loss in the majority of horticultural produce. In tomatoes, transpiration represents 92–97% of fruit weight loss (Shirazi & Cameron, 1993). Lurie et al. (1996) also reported that water stress hastens and triggers the onset of senescence in bell pepper fruit.

Burton (1982) reported that temperature and humidity also have the strongest influence on fruit quality. This was further investigated and reported by

Lurie, Shapiro, and Ben-Yehoshua (1986) and Lownds et al. (1994) that in non-climacteric fruit, such as bell pepper, storage in high humidity conditions which results in reduced fruit transpiration has a stronger effect in delaying senescence than storage at low temperatures. The shelf life of vegetables can also depend on the level of some inherent biochemical activities after harvest. Respiration of fruits results in an increased temperature hence accelerates metabolic activities and decay phenomena (Sanchez-mata, Cámara, & Díez-Marqués, 2003). Perez, Mercado and Soto-Valdez (2003) also reported that most fruits and vegetables are affected by water loss during storage, which depends on the temperature and relative humidity conditions at storage.

Factors affecting the Shelf Life of Sweet Pepper

Meir, Rosenberger, Aharon, Grienber and Fallik (1995) reported that, using plastic materials such as polyethylene bag packaging was useful in maintaining the postharvest quality of pepper fruits as it prevents water loss and fruit softening. According to Bayoumi (2008), sweet pepper is a very perishable vegetable with a short shelf-life. He attributed the inherent postharvest problems of the fruits after harvesting to metabolic and physiological activities, quality degradation and shriveling, as well as fast physical decay and rapid senescence. Ceponis et al. (1987) reported that the storage life of the pepper fruit was limited by pathological deterioration. Diaz-Perez, Muy-Rangel and Mascorro (2007) also in their shelf life studies, concluded that rapid water loss was a major determinant of fruit shelf life. Kader (2002) recommended rapid cooling of fruits after harvest and storage at an optimum temperature of 7–10^{o}C with a high relative humidity of 95–98% to help extend the shelf life of most fruits.

CHAPTER THREE

MATERIALS AND METHODS

Study Area

The study was conducted on the University of Cape Coast Teaching and Research Farms in the Coastal Savanah ecological zone. The study area enjoys two growing seasons namely the major season which starts from May and ends in July and the minor season that starts around September and ends around mid-November. Owusu-Sekyere et al. (2012) stated that, the study area experiences a rainfall of between 650 to 1100mm annually.

Experimental Design

A Completely Randomized Design (CRD) was used for the experimental work. The experiment was carried out in pots (plastic buckets) under rain sheltered plots at the University of Cape Coast Teaching and Research Farm. It is a 2 factor experiment consisting of 2 levels of time of irrigation (morning and evening) and 3 levels of the amount of irrigation water applied, making 6 irrigation treatment combinations with each of the treatment combination having three replications (R1-R3). This gives a total of 18 plots, with each plot containing 4 pots of plants making 72 plants in all. The treatment applications comprised of water replacements of accumulated evapotranspiration of the crop (ETc) at the given time of the day of irrigation.

Treatment Combinations

The treatment combinations were:

Full irrigation or 100% ETc (crop evapotranspiration) in the morning (100% ETcM), Full irrigation or 100%ETc (crop evapotranspiration) in the evening (100%ETcE),

90%ETc (crop evapotranspiration) in the morning (90%ETcM),

90%ETc (crop evapotranspiration) in the evening (90%ETcE),

80%ETc (crop evapotranspiration) in the morning (80%ETcM),

80%ETc (crop evapotranspiration) in the evening (80%ETcE),

Nursing and Transplanting of Seedlings

Seeds of the Yolo wonder variety of sweet pepper were purchased from a certified Seed Seller in Cape Coast. The seeds were nursed on the 2nd of July, 2015, on a sandy loam seed bed with dimension 1.5m x 1m, mulched with dry grasses and watered at 2days' intervals. After germination, the seedlings were transplanted into the buckets of sandy loam soil under a rain shelter. The transplanted seedlings were supplied with equal amounts of water for 7days for the seedling to get established in its new environment before the treatments were applied.

Irrigation Supply

A 2-day irrigation interval was adopted; irrigation days amounted to 45 days out of 90 days of the growing period of the sweet pepper grown. This excluded days the seedlings spent on the nursery bed before transplanting and days allowed for plant establishment after transplanting. Tap water from the University of Cape Coast Teaching and Research Farm was used to irrigate the plants.

Data Collection

Crop Water Requirement/ Crop Evapotranspiration (Etc)

The volume of water to be applied after each 2 days was obtained by computing the difference in weight loss of each bucket of plant after the two days of irrigation and its equivalent in volume was applied to each plant as its corresponding treatment demanded. The ETc for a growth stage is the summation of the ETc in the number of irrigation days in that growth stage.

Reference Evapotranspiration (ETo)

The ETo calculator version 3.2 was used to calculate the daily ETo based on Penman-Monteith equation from daily climatic data. Each growth stages accumulated ETo was then calculated.

Climatic Data

Climatic data was collected on daily basis for the entire growing period of the experimental work from the U.C.C weather station, which is close to the project field. The following data was collected: Maximum and minimum temperature (^oC), maximum and minimum relative humidity (%), sunshine hours, and wind speed (m/s).

Calculation of Crop Co-Efficient (kc)

$$Kc = \frac{ETc}{ETo} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

(FAO, 1998)

Where: ETo = Refernce evapotranspiration.

ETc = Crop evapotranspiration.

Growth and Yield Data

Growth Parameters

In terms of growth, data was collected on the plant height (PH) and leaf area (LA) at 21, 44, 72 and 92 days after transplanting (DAT) representing the initial, developmental, mid-season and late season stages respectively. The PH of each plant was measured from the surface of the soil close to the plant's stem to the apex of the plant with a metre rule. For LA, the longest part along the petiole line of the leaf was taken as its length with its breadth being the widest measurement across the leaf, using a 30cm rule. Van der Varst and Postel (1972) formula for calculating the leaf area of the plants was used to determine the LA.

$$LA = \frac{0.25\,(L \times W)}{1 - 1.48\,L \times W} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where;

LA is the Leaf Area

L is the length (cm) and W is the width (cm) of the leaf

Yield

Three healthy plants from each treatment were selected for the measurement in terms of yield. Data was collected on the number of fruits per plant, fruit size and fruit weight.

The number of fruits per treatment was determined by counting the number of harvested fruits on each plant of each treatment and dividing by the number of plants to get the mean.

The fruit size per plant was determined from the number of fruits harvested per treatment and a vernier caliper used to measure the length of the fruit biggest side transversely.

The weight of fruits produced by each plant of each treatment was weighed using an electronic balance; the weights was summed up and divided by the number of plants to get the mean. Accumulated weight of each irrigation treatment at the end of the harvest period was taken as the total yield for that treatment and converted to yield on hectare basis. The fruit were weighted using an electronic balance (A&D Corp. Ltd Electronic scale, FX-3000i WP model).

Determination of Physicochemical Qualities after Harvest and During Storage

Weight Loss

Sweet pepper fruits stored at room temperature were weighed every 4days using an electronic balance ((A&D Corp. Ltd Electronic scale, FX-3000i WP model). The loss in weight (%) of the fruits was determined using the formula.

$$\text{Weight Loss (\%)} = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \text{ x } 100 \quad \dots\dots\dots\dots\dots(5)$$

Firmness

The firmness of the sweet pepper fruits was determined with a penetrometer fitted with an 8-mm diameter probe (mod FT327 (3-27 kg). Fruit pulp firmness was determined on three sides of each fruit, in the equatorial area.

Total Soluble Solids (TSS)

Fruit samples (3-4) from each treatment was washed, dried and blended. As described by Antoniali et al. *(*2007), a 10 g fruit juice was extracted from the bulk blended sample. The 10g sample was filtered using a funnel with filter paper in a beaker. The filtrate was then used to determine the TSS by a hand held refractometer (RHB-32/ATC model) with a range of 0 to 32 °Bx, and a resolution of 0.2 °Bx by placing 1 to 2 drops of clear juice on the prism. Between every new treatment sample, the prism of the refractometer was cleaned with tissue paper soaked in methanol, washed with distilled water and dried before use. The refractometer was standardized against distilled water (0 °Bx TSS).

Titratable Acidity (TA)

Sweet pepper pod juice was extracted as described by (Antoniali et al. 2007). An aliquot of pepper juice was extracted by weighing 10 g fruit blended samples and adding 90 ml of distilled water and then mixed in a blender. The mixed sample was then filtered using funnel with filter paper in a beaker. As described by Antoniali et al. (2007), the titratable acidity (TA) was determined by titrating 10g of the mixed sweet pepper juice with 0.1 N NaOH (sodium hydroxide) to an end point as indicated by phenolphthalein indicator and the value expressed in percentage (%).

$$\text{TA}(\%) = \frac{\text{Titre x 0.1N NaOH x 0.67}}{1000} \text{ x } 100\% \quad \ldots\ldots\ldots\ldots\ldots \quad (6)$$

pH Value

As described by Antoniali et al. (2007), sweet pepper juice was extracted from 10 g fruit sample to which 90 ml distilled water was added and homogenized in a blender was used to determine the pH. The homogenized sample was filtered using funnel with filter paper in a beaker and the pH value of the filtrate was measured by a pH meter (Jenway International 3510 pH meter). The pH meter was calibrated using buffer solution of pH 7- 7.5.

During Storage

During storage, all the four physicochemical qualities (firmness, TSS, TA and pH) of each treatment sample were tested at 4days' intervals using the same described methods of Antoniali et al. (2007) for each quality parameter. The room temperature and relative humidity during the storage period ranged from 27.2 - 28.5^{o}C and 74 - 79% respectively.

Determination of Shelf Life

Fruits were stored at room temperature (25-32^{o}C and 85-90%RH) in one of the store rooms of the School of Agriculture Teaching and Research Farm after the fruits had been weighed for their fresh weights. At storage, the fruit weight was taken every 4 days till the fruit losses were 50% of their fresh weight just after harvest. Thus the number of days taken for the fruits kept in storage to lose 50% of their initial weight were taken as the shelf life of the fruit. The differential weight loss was calculated for each interval and converted into percentage by dividing the change in weight at storage with the initial weight recorded on each treatment sample (Waskar, Khedlar, & Garande, 1999).

Determination of Water Saving and Yield Reduction, WUE and Economic Evaluation

WUE

Water use efficiency (WUE) (kgm^{-3}) is the ratio of the total fruit yield (kgha^{-1}) to the total irrigation water applied (m^{3}ha^{-1}) (Kirda, Cetin, Dasgan, Topcu, Kaman, Ekici, Derici, & Ozguven, 2004) and this was calculated for each irrigation treatment.

Water Saving and Yield Reduction

$$\text{Water saving (\%)} = \frac{100 - (\text{water use for } 80\%\text{ETcM or } 80\%\text{ETcE} + 90\%\text{ETcM or } 90\%\text{ETcE})}{100\%\text{ETcM or } 100\%\text{ETcE}} \text{ x } 10$$

………………………… (6)

Where;

100%ETcE or 100%ETcM is the full crop water requirement or the control in the evening or morning respectively (Ismail, 2010).

90%E or 90%M is 90% crop water requirement in the evening or morning respectively.

80%E or 80%M is 80% crop water requirement in the evening or morning respectively.

$$\text{Fruit yield reduction (\%)} = \frac{100 - (\text{fruit yield of 80\%ETcM or 80\%ETcE or 90\%ETcM or 90\%ETcE})}{\text{100\%ETcM or 100\%ETcE}} \times 100 \ldots$$

………………………….. (7)

Where;

100%ETcE or 100%ETcM is the full crop water requirement or the control in the evening or morning respectively (Ismail, 2010).

Economic Valuation (cost-benefit ratio)

Economic evaluation or cost-benefit analysis is the ratio of the cost of the volume of water used for irrigation in the growing period of the sweet pepper to the total income obtained from the total yield of the fruits. This excludes, irrigation water used when the seedlings were on the nursery bird before transplanting and days allowed for the seedlings to establish after transplanting. The only input cost factor considered in this valuation was the cost of total volume of irrigation water supplied to each treatment. This was because all the other input factors were all equally applied, except the amount of irrigation water supplied to the plants.

The economic value of the sweet pepper production was determined by the formula:

$$\text{Cost} - \text{Benefit ratio} = \frac{\text{Cost (cost of total volume of irrigation water applied)}}{\text{Benefit (income from the sale of total fruit yied)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Data Analysis

Data collected on the sweet pepper plant and fruit was analyzed using the Analysis of Variance (ANOVA), by GenStat version 10.1 to determine any significant difference between treatments. Treatment means that show significant difference were further subjected to Duncan Multiple Range Test for the comparison at significant level of $p < 0.05$.

Summary of Methodology

Data was collected on the various parameters using standard instruments and approved process and procedures as stated by literature. Statistical analysis was performed on the data collected using the appropriate statistical analyzing tools.

CHAPTER FOUR

RESULTS AND DISCUSSION

Growth Stages of Sweet Pepper after the Cultivation Period

Based on the crop water requirement or ETc of sweet pepper during the growing period, four growth stages were observed: The initial stage: this is the period from transplanting until the crop covered about 10% of the ground. It lasted for a period of 14 days (21DAT) from the 1st of August to 14th of August, 2015. The crop development stage: this period started at the end of the initial stage and lasted until the full ground cover had been reached (ground cover 70-80%); it does not necessarily mean that the crop is at its maximum height. This stage lasted for 23 days (44DAT) from the 15th of August to 7th September, 2015.

The mid - season stage: this period starts at the end of the crop development stage and lasts until maturity; it includes flowering and fruit - setting. This period lasted for 28 days (72DAT) from the 8th of September to 6th of October, 2015. The late season stage: this period starts at the end of the mid-season stage and lasts until the last day of the harvest. The late growth stage lasted for a period of 20 days (92DAT) from 7th October to 27th October, 2015.

ETo, ETc and Kc of the Various Irrigation Treatments at the Different Growth Stages of Sweet Pepper

From Table 4, it can be observed that the CWR or ETc and Kc of sweet pepper were highest during the mid-season growth stage for both irrigating in the morning and irrigating in the evening with the various irrigation amounts. This might be due to the fact that this growth stage which starts at the end of the crop development stage and lasts until maturity is characterized by flowering and fruit-setting and therefore requiring a lot of irrigation water. A similar result was obtained by Sam-Amoah et al. (2013) on hot pepper.

From all the 6 treatment levels, it is seen that, 100%ETc in the morning and evening recorded the highest ETc, followed by 90%ETc in the morning and evening and finally 80%ETc in the morning and evening. Furthermore, 100%, 90%, 80%ETc in the morning used the higher amounts of water compared to their evening counterparts. This may be due to the increased temperatures that come in the day time just after irrigating in the morning resulting in high evaportranspiration. Full irrigation or 100%ETc in the morning recorded the highest CWR, 165.80 mm, and Kc, 1.05, during the mid-season growth stage followed by 100%ETc in the evening with a CWR of 151.30 mm and a Kc of 0.95, because in the morning the ETo is high and the full irrigation amount was applied at this level.

Irrigating with the various irrigation levels shows that in the morning, 100%ETc recorded the highest seasonal ETc of 435.01-mm followed by 90%ETc, 313.80 mm, while 80%ETc recorded the lowest, 260.30 mm. The same trend was observed with irrigating in the evening with the various amounts of irrigation water, suggesting that whether crops are irrigated in the morning or evening, ETc reduces as the amount of irrigation reduces. The total ETc for the growing season from this experiment except for 80%ETc, corresponds with the total ETc for the growing season of pepper reported by Agodzo et al. (2003), 300 - 700 mm depending on the climatic condition and the season of the crop. Grimes & Williams (1990), also reported an ETc of 400 - 500 mm depending on the season of planting and the climatic condition in the area and the season of the crop. This, result, however is not within the range of total water requirement for pepper as reported by Doorenbos & Kassam (1979) that, the total water requirements (ETc) of pepper ranges from 600 - 900 mm.

Kc for all the growth stages for crops irrigated in the morning and evening was also higher for the 100%ETc or full irrigation compared to the others. At full irrigation, the Kc for the initial, developmental, mid-season and late stages were 0.60, 0.81, 1.0 and 0.86 respectively. This is not much different from the Kc, initial; 0.60, mid-season; 1.05 and late stage; 0.90 stated by Allen et al. (1998). This also compares well with the findings of Doorenbos & Kassam (1979) on the Kc of pepper which are initial stage: 0.40; developmental stage: 0.75; mid-season: 1.1 and late stage: 0.90. However, the ETc for this experiment is less than what was recorded by FAO (1999) where the water requirement was 600 mm for a 120-days growing period, maybe because of the longer growing period.

Table 4: ETo, ETc and Kc of the Various Irrigation Treatments at the Different Growth Stages of Sweet Pepper

amount of irrigation	Growth Stage & periods (Days)	ETo (mm)	ETc (mm)		Kc	
			Evening	morning	evening	morning
100%	Initial (14)	97.50	61.90	55.01	0.56	0.63
	Dev’tal (23)	131.30	106.08	106.10	0.81	0.81
	Mid-season (28)	158.60	151.30	165.80	1.05	0.95
	Late Season (20)	119.60	98.20	108.10	0.90	0.82
	Seasonal ETc (mm)		417.48	435.01		
90%	Initial (14)	87.75	41.26	41.50	0.47	0.47
	Dev’tal (23)	118.17	82.30	83.70	0.70	0.71
	Mid-season (28)	142.74	110.00	110.00	0.77	0.77
	Late Season (20)	107.64	68.80	78.60	0.64	0.73
	Seasonal ETc (mm)		302.36	313.80		
80%	Initial (14)	78	27.50	34.40	0.35	0.44
	Dev’tal (23)	105.04	58.90	70.70	0.56	0.67
	Mid-season (28)	126.88	82.50	96.30	0.65	0.76
	Late Season (20)	95.68	58.90	58.90	0.62	0.62
	Seasonal ETc (mm)		227.80	260.30		

Growth and Yield Performance of Sweet Pepper

Leaf Area

Table 5 shows the effect of time of irrigation and amount of irrigation on the leaf area of sweet pepper. Irrigating in the evening with full CWR or 100%ETc had the largest leaf area across all the four growth stages of the crop except the initial stage of 100%ETc in the morning. This was followed by morning irrigation with 100%ETc and irrigating in the morning with 80%ETc or CWR of sweet pepper had the smallest leaf area across the four growth stages of the crop.

There was a significant difference within the treatment levels of the amount of irrigation in both irrigating in the morning and evening treatments across the growth stages of the sweet pepper growing period. Irrigating in the evening with the various amount of irrigation showed that in the developmental stage, full irrigation or 100%ETc treatment level was significantly ($p<0.05$) different from 90%ETc and 80%ETc was also significantly different from 90%ETc. The same trend was observed for sweet pepper plants irrigated in the morning with the various irrigation amounts. There was significant difference in leaf area at the mid-season as well for both plants irrigated in the morning and those irrigated in the evening. For the two time of irrigation; morning and evening, 100%ETc treatment level was not significantly different from 90%ETc, but both were significantly different from 80%ETc treatment level. The same trend was observed during the late growth stage of the crop for both morning and evening irrigation times. This may be attributed to the fact that at these two stages (development and mid stage) the plant are vigorously growing producing vegetative and in some cases floral parts hence required more irrigation water as reported by Sam-Amoah et al. (2013) compared to the initial stage. Hence, a crop at this stage becomes sensitive to water stress. From the results, it can be observed that the leaf area of sweet pepper decreases as ETc decrease. A similar observation was made by Owusu-Sekyere et al. (2012) in an experiment on hot pepper. Allen et al. (1998) also reported that plants grow vigorously, in this case the leaves, with increase in crop water use as observed in this experiment as well.

When it comes to the time of irrigation, there was a significant difference among the treatment levels at the various growth stages. Crops irrigated in the evening had a larger leaf area than those irrigated in the morning across the growth stages, which may be due to the supply of water to the crops in the evening where evaporation is low, making extra water available for those crops, except in the initial stages where the leaf area of the crops irrigated in the morning were not significantly different from the ones irrigated in the evening.

Plant Height

Results from Table 6 show that, plant height at all the growth stages was high in crops with full irrigation or 100%ETc for both sweet pepper irrigated both in the evening and morning. Plant height was low in crops with least irrigation or 80%ETc for both morning and evening time of irrigation throughout the growth stages. However, there was no interaction effect between the two treatments, time of irrigation and the amount of irrigation. This may be because full irrigation makes more water available for plant use and increase plant metabolic activities (Kramer, 1983). Hence, the tallest plants were from plots irrigated with full irrigation for both morning and evening time of irrigation than those irrigated with less irrigation amount.

Interestingly, for all irrigation levels, there was no significant difference among the treatment levels. However, full irrigation or 100%ETc treatment had the highest plant height at all the growth stages of the sweet pepper crop, followed by 90%ETc and then 80%ETc. This result shows that plant height decreases with decreasing crop water use or ETc, whether irrigated in the morning or evening. This, according to Kramer (1983) and Craft (1999), is because when crops are supplied with less water, it reduces metabolic activities such as photosynthesis, transpiration and translocation, which are the metabolic activities that ensure plant growth and increase in plant height.

Considering the time of irrigation alone irrespective of the amount of irrigation water applied, though there was no significant difference between the two treatment levels; morning and evening, crops irrigated in the evening were a little taller than their morning counterpart at all four growth stages. This may be because plants irrigated in the evening had more water available for plant use due to less evaporation than those in the morning where evaporation was higher.

Table 5: Mean Leaf Area (Cm2) of Sweet Pepper Plant at the Various Growth Stages for the Different Irrigation Treatments

	Initial (21DAT)		Developmental (44DAT)		Mid-Season (72DAT)		Late Season (92DAT)	
amount of	time of irrigation		time of irrigation		time of irrigation		time of irrigation	
irrigation	Evening	Morning	Evening	Morning	Evening	Morning	Evening	Morning
100%	15.87a	16.19a	54.19a	50.98a	67.00a	66.90a	68.53a	68.67a
90%	15.46a	15.57a	48.87b	46.57b	65.47a	64.57a	66.57a	67.2a
80%	14.55a	14.29b	46.14c	42.93c	60.24b	59.65b	63.19b	60.24b
Lsd(0.05)	1.57	0.99	1.85	2.01	3.21	2.24	3.81	4.03

Mean values followed by the same letters are not significantly different (P<0.05)

Table 6: Mean Plant Height (cm) of Sweet Pepper Plant at the Various Growth Stages for the Different Irrigation Treatments

	Initial (21DAT)		Developmental (44DAT)		Mid-Season (72DAT)		Late Season (92DAT)	
amount of	time of irrigation		time of irrigation		time of irrigation		time of irrigation	
irrigation	Evening	Morning	Evening	Morning	Evening	Morning	Evening	Morning
100%	17.7a	17.3aa	31.5a	31.5a	42.4a	42.4a	43.9a	43.8a
90%	16.7a	16.6a	30.9a	29.7a	41.4a	41.5a	43.1a	42.9a
80%	16.1a	16.1a	29.3a	30.4a	41.7a	40.2a	42.3aa	42.8a
Lsd(0.05)	1.82	1.97	2.42	2.32	1.76	2.11	1.73	1.93

Mean values followed by the same letters are not significantly different (P<0.05)

Fruit Diameter and Number

In Table 7, there was no combined effect of the two factors on the fruit diameter and fruit number of sweet pepper, though the fruit diameters and fruit numbers were all higher in crops irrigated in the evening with 100%ETc, 90%ETc, 80%ETc than their counterparts irrigated in the morning with 100%ETc, 90%ETc, 80%ETc irrigation amount. The reason may be that the combined treatments of irrigating in the morning experienced more water stress than their evening counterparts, hence having less water for flowering and eventually fruiting which affected the fruit number and size. A similar reason was reported in tomato studies by Nahar and Gretzmander (2002).

Irrigation in the morning with the various amounts of irrigation had a significant ($p<0.05$) effect on the fruit diameter of sweet pepper. Among the treatment levels, full irrigation or 100%ETc, 48.92 mm was not significantly different from the treatment, 90%ETc, 48.29 mm, but both treatment levels were significantly different from the least amount of irrigation treatment, 80%ETc, (41.94 mm). Similar results were obtained for the plants irrigated in the evening with the various irrigation water levels as well, with 100%ETc and 90%ETc not significant from each other but significant from 80%ETc. For both morning and evening irrigation times with their various irrigation amounts, it was observed that fruit number of sweet pepper was high with 100%ETc, closely followed by 90%ETc and then 80%ETc. The same significant difference existed for fruit number among the treatment levels of sweet pepper plants irrigated with the various amounts of irrigation in the morning and in the evening as well. Irrigating with 100%ETc was not significantly different from 90%ETc, but both were significantly different from 80%ETc. It was observed from this result that, fruit number and diameter decrease as the amount of irrigation decreases for crops irrigated both in the morning and those irrigated in the evening. This could be linked to factors like blossom drop, which occurs when cells and tissues at the distal and blossom end of the plant stems fail to receive enough moisture to maintain their body growth and development, and so leads to cell breakdown, flower abortion (Berrie et al., 1990) and consequently fruit drop. This observation also conforms to a report by Fernandez et al. (2005) that reduction in fruit size and numbers might be due to the water deficit, but mainly from fruit size because water deficit may slightly affect fruit number. Similar results were obtained by Dorji et al. (2005) that water deficit reduces fruit number and weight.

Table 7: Effect of Time and Amount of Irrigation on the Fruit Diameter and Fruit Number for the Various Irrigation Treatments

amount of irrigation	mean fruit diameter (mm)		mean fruit number	
	Evening	Morning	Evening	Morning
100%	49.68a	48.92a	8.67a	8.67a
90%	49.00a	48.29a	8.33a	8.00a
80%	42.70b	41.94b	6.00b	5.67b
Lsd(0.05)	1.22	1.59	1.49	1.48

Mean values followed by the same letters are not significantly different ($P<0.05$)

Fruit Weight and Yield

From Table 8, the amount of irrigation and the time of irrigation had a combined effect on the fruit weight of sweet pepper. Full irrigation or 100%ETc in the evening, 26.29g and 90%ETc in the morning, 25.83g, were not significantly different from each other but both were significantly different from, full irrigation in the morning, 90%ETc in the morning, 80%ETc in the evening and 80%ETc in the morning. This may be due to the unfavourable moisture stress that the sweet pepper plants irrigated with less irrigation amount (90% and 80 %ETc) had to experience throughout its growing period, hence the least crop yield. This is similar to what Smittle et al. (1994) reported in their experiment on bell pepper grown under water stress, that fruit weight is closely associated with a lack of soil water in the root zone; an increase in water stress in the root zone results in a reduction in growth and fruit weight. There was no combined effect of the two treatments on the fruit yield, though sweet pepper irrigated in the evening with 100%ETc, 90%ETc and 80%ETc irrigation amounts were more yielding than its counterpart irrigated in the morning with 100%ETc, 90%ETc, 80%ETc irrigation amounts.

Results from Table 8 also show that fruit weight from irrigating in the morning and in the evening with 100%ETc, 90%ETc, 80%ETc were all significantly ($p<0.05$) different from each other and it decreased with decreasing irrigation amount, 100%ETc>90%ETc>80%ETc for both morning and evening irrigation times. Similar observation was made by Smittle et al. (1994) from their experiment on bell pepper grown under water stress. Significant effect was observed for treatment levels of both crops irrigated in the morning and evening on the fruit yield (t/ha) of sweet pepper, with 100%ETc and 90%ETc not being significantly different from each other but both were significantly different from 80%ETc for crops irrigated in the evening. However, significant difference existed for yield produce at all irrigation levels in the morning. The highest yield was obtained from highest irrigated crops and lowest yield obtained from the least irrigated crops (Fisher et al., 1985). According to Alvino et al. (1994) and Dimitrov & Ovtcharrow (1995), pepper is among the most susceptible horticultural plants to drought stress. Therefore, water deficit during the period from flowering to fruit development reduces final fruit production (Jaimez et al., 2000; Dorji et al., 2005 and Fernandez et al., 2005).

Yield from crops irrigated in the morning was significantly different from those irrigated in the evening, with sweet pepper plants irrigated in the evening recording a higher yield than sweet pepper plants irrigated in the morning. This may be because plants irrigated in the morning experience more water stress due to higher evaporation than those irrigated in the evening as reported by Fernandez et al. (2005); Dorji et al. (2005) that water stress from flowering to fruit development results in low crop production hence the higher yield in the evening.

Table 8: Mean of Fruit Weight and Yield of Sweet Pepper for the Various Irrigation Treatments

amount of irrigation	mean fruit weight (g)		mean fruit yield (t/ha)	
	Evening	Morning	Evening	Morning
100%	26.29a	23.76a	56.98a	51.45a
90%	25.83a	22.59b	53.84a	45.12b
80%	21.19b	19.98c	31.81b	28.31c
Lsd(0.05)	0.86	0.90	9.28	5.63

Mean values followed by the same letters are not significantly different ($P<0.05$)

Effect of Time and Amount of Irrigation on some Physicochemical Properties of Sweet Pepper Fruit after Harvest

Firmness

From Figure 1, it could be seen that, irrigating both in the morning and evening with 80%ETc had the highest firmness, followed by 90%ETc then 100%ETc. In other words, the firmness of sweet pepper fruit increases as the amount of irrigation levels decrease both in the morning and in the evening. This result is in conformity with the results of Mpelasoka et al. (2001), which stated that deficit irrigation treatments increased fruit flesh firmness. A similar finding was observed by Abdel-Razik (2012) on mango fruit that decreasing irrigation water results in increased fruit firmness. According to Billy et al. (2008), the difference in firmness may also be due to differences in their pectin content. However, analysis of variance showed that there was no significant effect of irrigating in the morning with 100%ETc, 90%ETc and

80%ETc on the firmness of sweet pepper neither was there any significant difference among 100%ETc, 90%ETc and 80%ETc of crops irrigated in the evening on the firmness of the fruits. Even though there was no combined effect of the two treatments on the firmness of sweet pepper fruits, fruits from crops irrigated in the morning with the various levels of irrigation seemed to be more firm than those from crops irrigated in the evening. This might be due to the less moisture content of fruits from plants irrigated in the morning as a result of the high ET during the day compared with the evening irrigated crops since firmness is believed to increase as irrigation amount decreases.

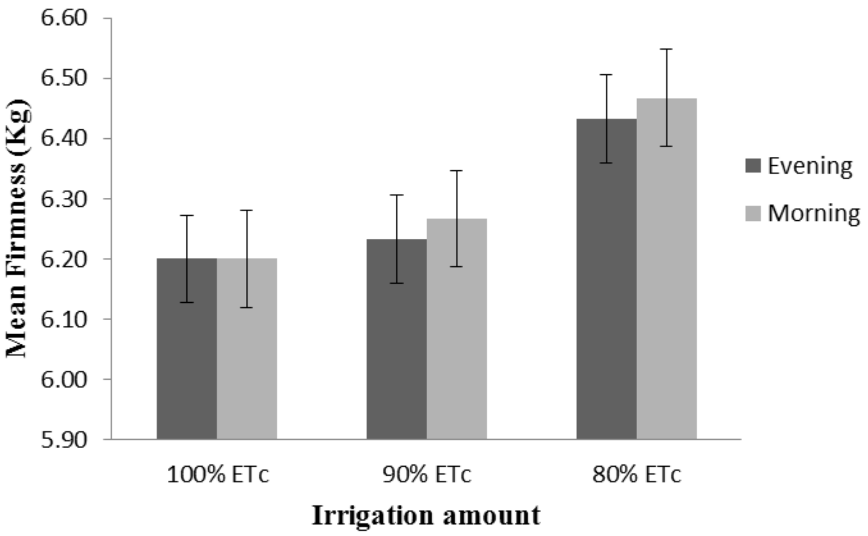

Figure 1: The effect time and amount of irrigation on the firmness of sweet pepper fruits with standard error bars

TSS (Total soluble solids)

In Figure 2, the treatment combinations had no significant ($p<0.05$) effect on the TSS of sweet pepper although TSS increased across the treatment combination levels from full irrigation or 100%ETc in the evening, 4.57 ºBrix to the last treatment combination level, 80%ETc in the morning, 4.63 ºBrix.

TSS of sweet pepper fruits irrigated in the morning increases as the level of the amount of irrigation water applied decreases from100%ETc to 80%ETc. The same trend was observed for sweet pepper crops irrigated in the evening with the various amount of irrigation. This result means increasing the amount of irrigation in sweet pepper results in a reduction of TSS. The same observation is reported by Shahein et al. (2012) and Tuzel et al. (1993). According to Abdel-Razik (2012), the difference in TSS of the various water treatments was due to difference in water content of the fruits. Mpelasoka et al. (2001) and Leib et al. (2006) also reported that reducing the amount of irrigation applications in apple increases the TSS values.

There was no significant difference among the treatment levels of both sweet pepper plants irrigated in the morning as well as in the evening. Fruits from plants irrigated in the morning in general had a higher TSS compared to the ones irrigated in the evening which may be due to the hot weather during the afternoon, providing sweet pepper irrigated in the morning with less water to utilise compared with those irrigated in the evening.

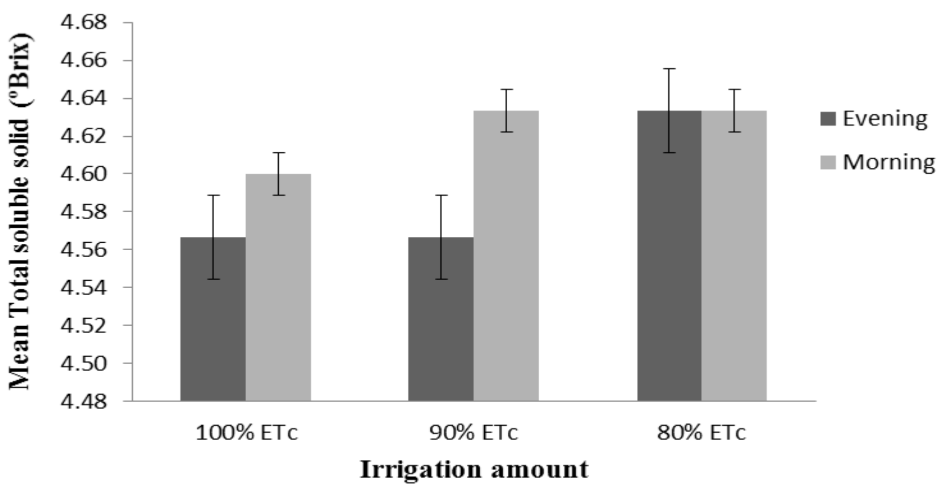

Figure 2: The effect of time and amount of irrigation on the total soluble solids (TSS) of sweet pepper fruits with standard error bars

TA (Titratable acidity)

From Figure 3, the treatment combinations showed that percentage TA slightly decreased from 100%ETc to 90%ETc but increased at 80%ETc for both morning and evening irrigated crops. Irrigating in the morning with 80%ETc had the highest percentage TA, 0.590% and irrigating in the morning or evening with 90%ETc had the lowest percentage TA, 0.577%. However, there was no interactive effect of the two treatment combinations on the TA of sweet pepper fruits. In terms of irrigating in the morning and evening with 100%ETc, 90%ETc and 80%ETc, there was no significant ($p<0.05$) difference among the water levels for both morning irrigated crops and evening irrigated crops, but 90%ETc recorded the marginally lower percentage of TA, 0.577% for both the morning irrigated crops and the evening irrigated crops. The 80%ETc recorded marginally higher percentage TA for both morning and evening irrigated crops followed by 100%ETc with a percentage TA of 0.577 and 0.587 for evening and morning irrigated sweet pepper respectively. This result, to some extent, is in conformity with the findings of Kirnak et al. (2002) in an experiment on the effects of water stress on yield and the quality of eggplant in which they observed that TA increased with decreasing amounts of irrigation. From this study, it was observed that fruits from the highest water stressed crops (80%ETc) resulted in the highest TA, implying that reducing the amount of irrigation increased the TA of sweet pepper fruits. This same observation was made by Pantane et al. (2011) in a study in which they reported that the TA contents were increased as irrigation amount is reduced or under water stress from 90%ETc to 80%ETc.

In the case of time of irrigation, there was no significant difference among the treatment levels but sweet pepper fruits from plants irrigated in the morning with 100%ETc had a higher percentage TA compared to the other irrigation water treatments. This may be that the higher water stress sweet pepper plants irrigated in the morning experienced during the growth period compared to those irrigated in the morning.

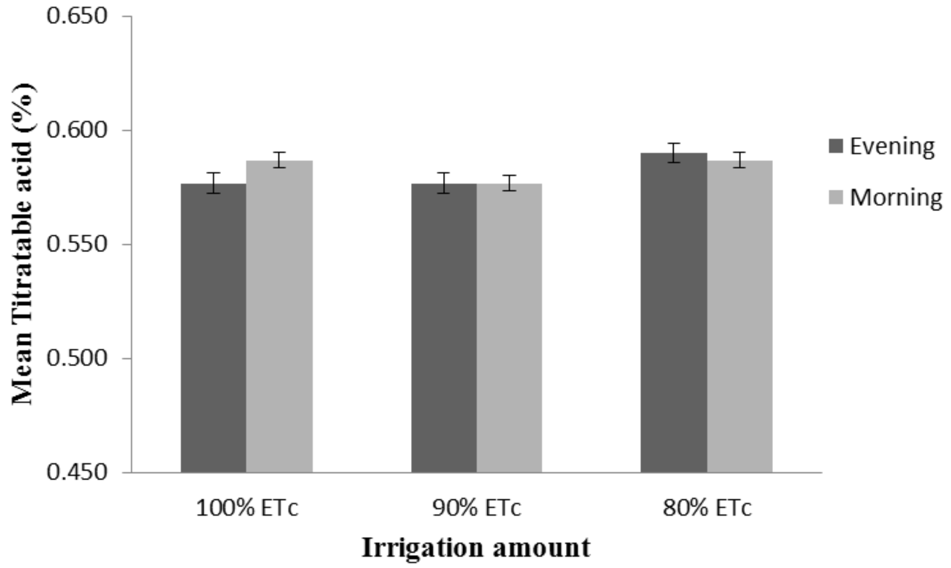

Figure 3: The effect of time and amount of irrigation on the titratable acid (TA) of sweet pepper fruits with standard error bars

pH value

In Figure 4, the treatment combinations resulted in sweet pepper fruit pH decreasing from full irrigation or 100%ETc through to 80%ETc in both morning and evening excerpt 100%ETc in the evening which recorded the lowest pH of 6.03, though there were treatment combination effect on the pH of sweet pepper fruits.

The pH of sweet pepper fruits generally decreases as the irrigation amount levels decreases from 100%ETc to 80%ETc for crops irrigated in the morning though no significant differences were observed among these treatment levels. This suggests that as the amount of irrigation is reduced for sweet pepper plants, the pH of its fruits also decreases and this improves the fruit quality of sweet pepper (Rouphael et al., 2008) and maintain quality at storage. Fruits from sweet pepper plants irrigated in the evening were not in conformity with the observation of Van Zyl (1984) since pH increased from 100%ETc to 90%ETc and then decreased from 90%ETc to 80%ETc. With time of irrigation treatment, there was no significant difference among the treatment level either but fruits from morning irrigated crops tended to have a higher pH compared to fruits from evening irrigated plants.

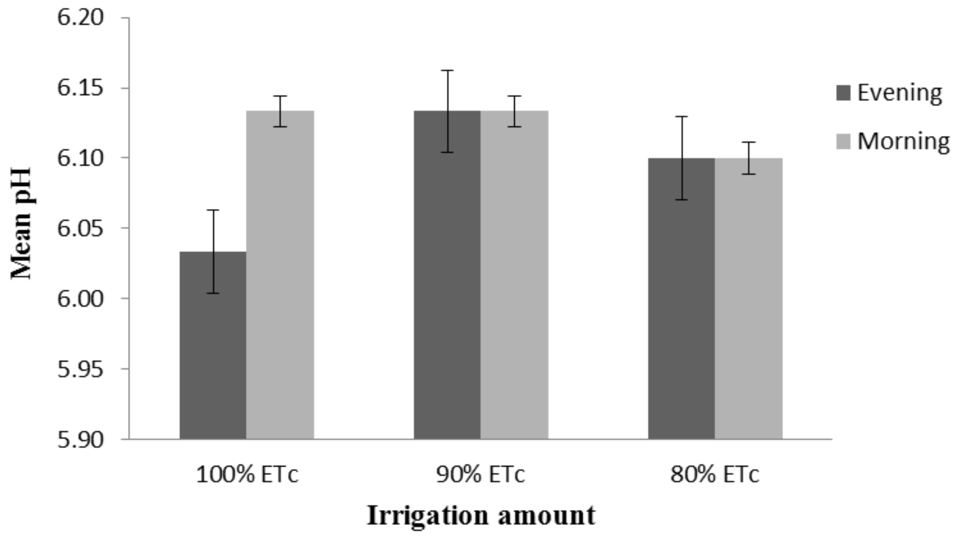

Figure 4: The effect of time and amount of irrigation on the pH of sweet pepper fruits with standard error bars

Effect of Time and Amount of Irrigation on some Physicochemical Properties of Sweet Pepper Fruit during Storage

Weight loss

Figure 5 shows the effect of irrigation amount and time of irrigation on the weight loss of sweet pepper fruits during storage. It can be observed that irrigating in the morning with full irrigation or 100%ETc recorded the highest

% weight loss, 53.36% and irrigating in the morning with 80%ETc had the lowest % weight loss, 45.47%, during the 16-day storage period. This may be as a result of the high fruit moisture content expected for fruits from plants irrigated in the evening with full irrigation or 100%ETc and since initial fruit water content (moisture content after harvest) affects the water-loss rate. Fruits with lower water content would have a smaller vapour pressure deficit (Kays, 1991) and may lose moisture at a slower rate compared to fruits with higher moisture content. The combination effect of storage period and amount of irrigation as well as storage period and time of irrigation all had highly significant effect on the weight loss of sweet pepper.

Fruits from plants irrigated in the morning with 100%ETc, 90%ETc and 80%ETc at storage showed a significant increase in weight loss as the storage days' increased and at the end of the 16-day storage period, sweet pepper fruits from crops irrigated in the morning with 100%ETc recorded the highest weight loss of 51.82% and 80%ETc recorded the least weight loss of 46.43%. The same trend was observed for sweet pepper plants irrigated in the evening with the various irrigation amounts with the ones irrigated in the evening with 100%ETc recording the highest weight loss and 80%ETc recording the least weight loss. This may be due to the higher initial water content, larger surface area volume ratio (SA: V) which according to Albrigo (1972) and Ben-Yehoshua (1987), are some of the factors that affect fruit water loss during post-harvest storage. According to Lownds et al. (1993) postharvest weight (water) loss increased linearly with storage time as observed for all the irrigation treatment levels during the storage period.

Time of irrigation had a significant ($p<0.05$) effect on the weight loss of sweet pepper, with fruits irrigated in the evening having a higher % weight loss than fruits from crops irrigated in the morning, which may be due to the higher moisture content of sweet pepper fruits from crops irrigated in the evening than those irrigated in the morning. This conforms to Kays (1991), who reported that fruits with lower water content have smaller vapour pressure deficit (VPD) hence lower fruit moisture loss during post-harvest storage.

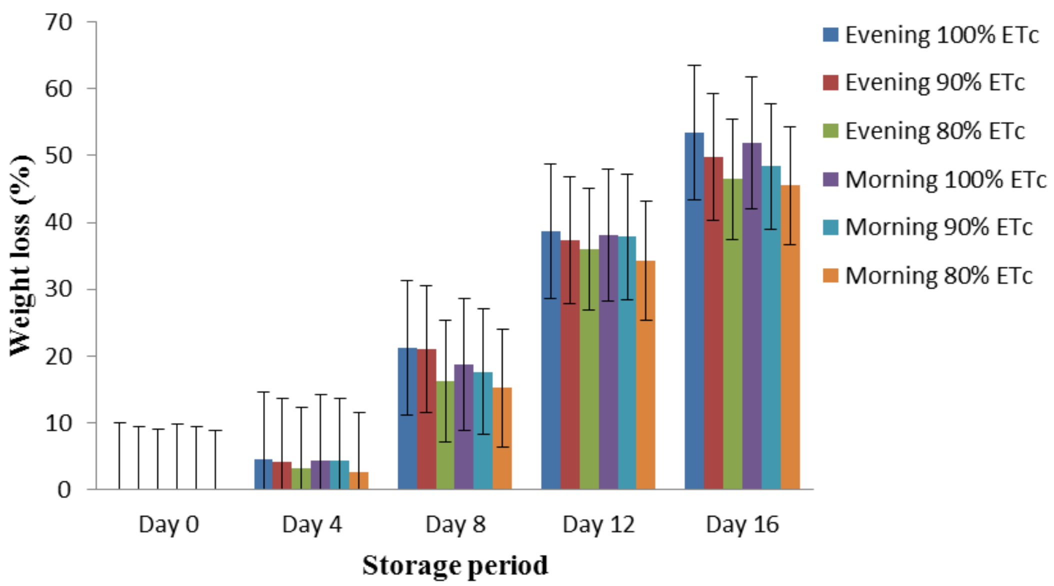

Figure 5: The effect of time and amount of irrigation on the weight loss of sweet pepper fruits during storage ($p < 0.05$). Vertical bars represent standard error of the mean

Firmness

Figure 6 shows that firmness of sweet pepper fruits decreases continuously across the 16-day storage period. Fruits from the various treatment combinations showed a slight or no decrease in firmness from 0-4 days of storage, but the real decrease started from the 8th to 16th day at storage. Over the 16 days of storage, irrigating in the morning with 80%ETc though decreasing, recorded the highest firmness. The continuous reduction in firmness of sweet pepper fruits over the storage period is due to the continuous water loss from the fruits during the storage period. This observation is in line with the work of Lurie et al. (1986) who noticed that there is a strong relationship between fruit firmness and weight loss in bell pepper. This result was also obtained by Mitropoulos and Lambrinos (2005) in apples, stating that changes in firmness in storage are related to fruit water loss. At the end of the storage period, sweet pepper fruits from crops irrigated in the morning with 80%ETc recorded the highest firmness of 4.06 kg and 100%ETc recording the least firmness of 3.93 kg.

A similar trend was observed for sweet pepper plants irrigated in the evening with the various irrigation amounts, with the ones irrigated with 80%ETc recording the highest firmness of 4.03 kg and 100%ETc recording the least firmness of 3.77 kg. This may be due to the less water activity in the fruits of sweet pepper plants irrigated with less amount of irrigation, since firmness of fruits increase with decreasing amount of irrigation as reported by Abdel-Razik (2012) from his experiment on the quality of mango fruits. There were no combined effects of the various treatments on the firmness of sweet pepper fruits during the storage period.

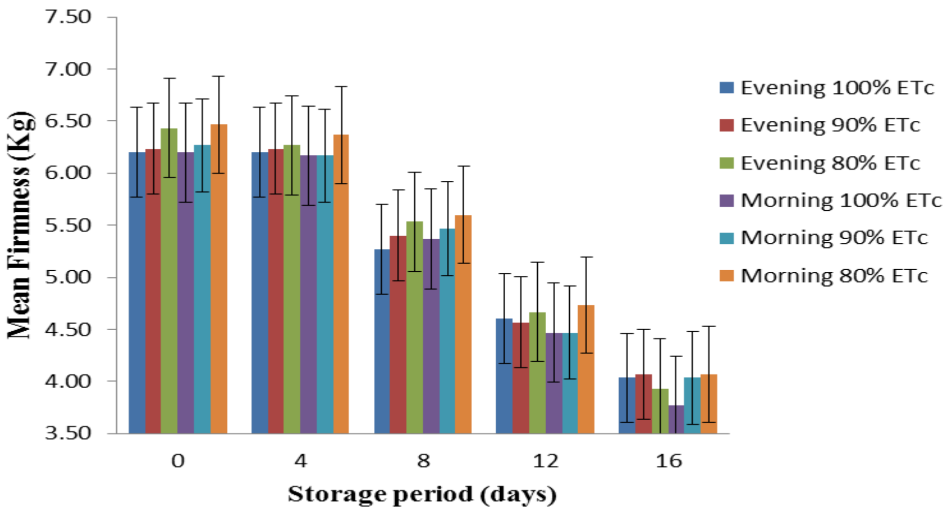

***Figure 6*:** The effect of time and amount of irrigation on the firmness of sweet pepper fruits during storage ($p < 0.05$). Vertical bars represent standard error of the mean

TA

From the results presented in Figure 7, it is observed that, percentage TA generally decrease over the 16 days' period of storage for both fruits from crops irrigated in the morning with 100%ETc, 90%ETc and 80%ETc and those irrigated in the evening with the same irrigation water levels. The decrease over the storage period was gradual from day 0 to day 8 before it starts to decrease a little drastically from day 8 to the last day of storage. Change in TA is related to changes in acids; malic, citric and ascorbic acid. Sweet pepper fruits started to ripe at storage from day 8 and this was the periods TA started to decrease drastically.

This observation is in line with the findings of Medlicott et al. (1986) that concentration of acids like malic, citric and ascorbic acid are known to diminish during ripening thus decreasing the TA content of the fruit. Another factor that might result in the decline in the TA of fruits is the ambient temperature at which they were stored, which is associated with the higher rate of respiration with increasing temperature that might have raised the use of organic acids in the respiration process (Wills et al., 1989; Antoniali et al., 2007). Irrigating in the morning with the various irrigation levels showed a highly significant effect on the TA of the fruits during storage. TA at day 0 was not significantly different from day 4 but were both highly significantly different from TA at the rest of the storage periods and day 4, 8, 12 and 16 were all highly significantly different from each other. The same trend of significance difference was observed for the TA of crops irrigated in the evening with the different amount of irrigation.

Over the storage period, fruits of plants irrigated in the evening with the various irrigation amounts recorded a higher TA than their morning counterparts though the difference was not significant. At the end of the storage period, though TA decreased, 90%ETc had the highest percentage TA for crops irrigated in the morning and 100%ETc had the highest percentage TA for fruits from crops irrigated in the evening. The results obtained are in conformity with the report of Castro et al. (2002) that soon after harvest, overall acidity was high and then decreased as the storage period increased.

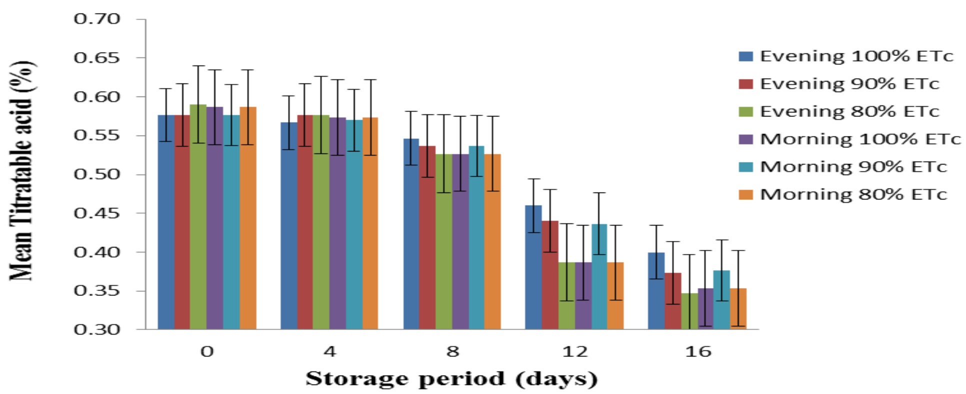

Figure 7: The effect of time and amount of irrigation on the titratable acids (TA) of sweet pepper fruits during storage ($p < 0.05$). Vertical bars represent standard error of the mean

TSS

Figure 8 shows that during the storage period, TSS generally increases continuously for all the six treatment combinations. The increase in TSS content over the storage period could be attributed to moisture loss by the fruits and conversion of organic acids to sugars. According to Atta-Aly & Brecht (1995), sugars and simple acids are respiration substrates, and the longer the time of fruit respiration, the higher will be the rates of consumption of sugars and acids. The storage of the fruit at ambient temperature contributed to the increasing TSS contents of the sweet pepper fruit due to the relatively high temperature in the storage room; this resulted in faster conversion of starch into water-soluble sugars (Getenit et al., 2008). There was no combined effect from the interaction of any of the two treatments; time of irrigation and amount of irrigation during storage period on the TSS of the fruits.

For fruits of sweet pepper irrigated in the morning with the 3 irrigation levels, TSS generally increased across the storage period. It was observed that the increment from day 0 to day 4 was gradual; however, the increment was sharp from day 8 till the end of the storage period on day 16. Irrigating in the morning with 100%ETc had the highest TSS (6.33 ºBrix) at the end of the 16 days' storage period. For fruits of sweet pepper from plant irrigated in the evening with the 3 irrigation levels, TSS generally also increased over the storage period with the increment from day 0 to day 4 being gradual and eventually increasing sharply from day 8 till the end of the storage period on day 16. At the end of the 16 days' storage period, irrigating in the evening with 100%ETc and 90%ETc had the highest TSS, 6.27ºBrix. A continuous increase in TSS over the storage period contradicts the result of Mattoo et al. (1975) and Vicentini et al. (1999). Their experiments on pepper produced an increase in the level of TSS, followed by a fall after 12 days of storage. Antoniali et al. (2007) concluded that this is due to the breaking up of the polysaccharides of the cell wall that result in increase in sugar levels and eventually decrease in TSS during ripening at storage. Over the storage period, fruits of sweet pepper plants irrigated in the morning with the various irrigation amounts recorded a higher TA than fruits from crops irrigated in the morning, though the difference was not significant.

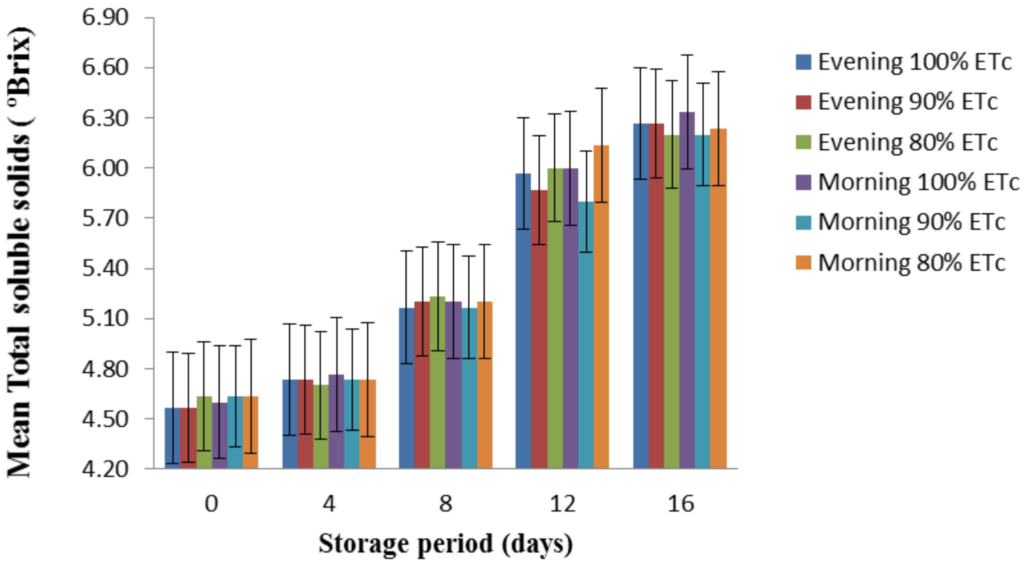

Figure 8: The effect of time and amount of irrigation on the Total soluble solids (TSS) of sweet pepper fruits during storage ($p < 0.05$). Vertical bars represent standard error of the mean

pH Value

It was noticed that storage period had no significant effect on the pH of sweet pepper fruits for crops irrigated either in the morning or evening with the various amount of irrigation, which conforms to the findings of Vicentini et al. (1999), that storage period may have no significant effect on the pH of pepper fruit. Even though there was no significant effect, Figure 9 shows that, pH increases as the storage days' increase for both fruits of crops irrigated in the morning and evening with 100%ETc, 90%ETc and 80%ETc. At the end of the storage period, 100%ETc had the highest pH value for fruits from sweet pepper plants irrigated in the morning, 6.53, and 90%ETc had the highest pH value for fruits from sweet pepper plants irrigated in the evening, 6.56.

This increase in pH during storage according to Gonzalez-Aguilar et al. (1999) is due to the relatively high temperature at storage which increases metabolic activities resulting in the increase in pH during storage. From Cochran (1964) experimental results showed a drop in the pH of the bell pepper during its transformation from unripe green to red stage, which was not observed in the results of this experiment. However, Antoniali et al. (2007) also reported that pH increases over the storage period though there was no significant difference in pH values of pepper during ripening. At storage, carbohydrate and acid metabolism are closely connected during postharvest ripening period which would thus raise pH of the produce (Mizrach et al., 1997) which might be the reason for the higher pH value from day 8 where ripening seems to begin in most of the treatment combinations.

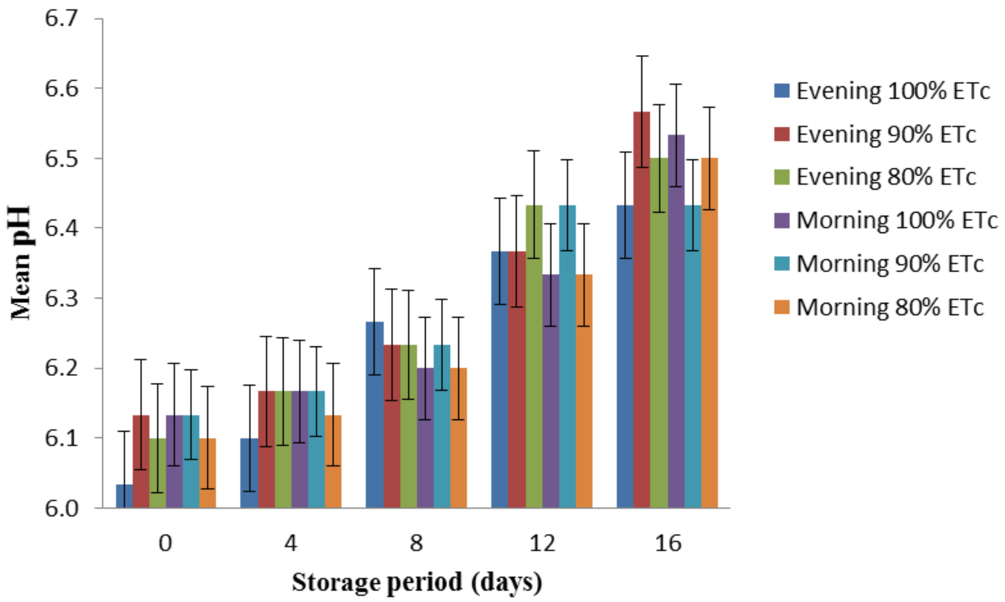

Figure 9: The effect of time and amount of irrigation on the pH of sweet pepper fruits during storage ($p < 0.05$). Vertical bars represent standard error of the mean

Shelf Life

Table 9 shows the effect of time of irrigation and amount of irrigation on the shelf life of sweet pepper. There was no combined effect of the two treatments on the shelf life of sweet pepper comparing all the six treatments but crops irrigated in the morning and evening with the less irrigation amount seem to have a higher shelf life. This shows that the shelf life of sweet pepper increases as the amount of irrigation decreases. Irrigating in the morning with 80%ETc recorded the longest shelf life (13 days) and irrigating in the evening with 100%ETc recorded the shortest shelf life of 8 days. This may be due to less moisture content in the fruit from crops irrigated in the morning with various irrigation amounts compared to their evening counterparts due to the more water stress they experienced on the field. According to Ben-Yehoshua et al. (1987) and Lownds et al. (1994), bell pepper fruit quality and postharvest life are highly determined by fruit water loss or transpiration which will be low in fruits irrigated in the morning with the various irrigation amount since fruit moisture content decreases with water stress.

Irrigating in the morning and evening with the 3 levels of irrigation amount showed a significant effect among its treatment levels. For fruits from morning irrigated plants, each of the treatment levels was significantly ($p<0.05$) different from each other; irrigating with 100%ETcM (8.6 days), 90%ETcM (10.6 days) and 80%ETcM irrigation amount levels (12.7 days). For fruits from sweet pepper plants irrigated in the evening, the shelf life of each of the treatment levels 100%ETcE, 90%ETcE and 80%ETcE was also significantly different from each other. It could be seen that the shelf life of sweet pepper fruit increases with reduction in amount of irrigation water applied. The shorter shelf life of fruit from fully irrigated crops, may be due to the rapid water loss (Diaz-Perez et al., 2007), high post-harvest metabolic and physiological activities, quality degradation and shrivelling, fast decay and rapid senescence (Bayoumi, 2008) since fruit from 100%ETc may have higher moisture content than the rest of the treatment levels. A similar observation was reported by D´ıaz-P´erez (1998) and Lownds et al. (1994) that excessive fruit water loss results in softening and reduced shelf-life in citrus, bell pepper, and eggplant fruit. Mohammed et al. (1999) also reported that higher fruit acidity lower the incidence of fruit spoilage and increases the shelf life of the fruit.

Comparing irrigating in the morning and it levels of irrigation amount with irrigating in the evening’s irrigation amount levels, there was no significant ($p<0.05$) difference but irrigating in the morning treatment levels tend to have a day longer shelf life than the evening irrigated treatment levels, since fruits from evening irrigated crops may have higher moisture content than the morning ones and high moisture content means high water loss or water activity during storage hence reducing the shelf life of the fruit (D´ıaz-P´erez, 1998).

Table 9: Means of Shelf Life (Days) for the Various Irrigation Treatments

amount of irrigation	time of irrigation	
	Evening	Morning
100%	8.3a	8.6a
90%	10b	10.6b
80%	12.3c	12.7c
Lsd(0.5)	0.89	1.26

Mean values followed by the same letters are not significantly different (P<0.05)

Effect of Time and Amount of Irrigation on the Water Saving and Yield Reduction, WUE, and Economic Evaluation

Water saving and Yield Reduction

Table 10 shows the effect of time of irrigation and amount of irrigation on water savings and yield reduction. It was observed that, reducing ETc by 10% and irrigating in the evening resulted in a lower fruit yield reduction 5.51%, and a higher water saving 30.49%, compared to reducing ETc by 10% and irrigating in the morning which resulted in a higher fruit yield reduction percentage, 12.3% and a lower water saving percentage, 24.83%. The same trend was observed when the ETc was reduced by 20% though in this instance the percentage fruit yield reduction percentage was high and the water saving percentage was also high. In terms of the amount of irrigation applied, 10% deficit or 90%ETc recorded a lower fruit yield reduction percentage, 8.91% and a higher water saving percentage, 27.66%, than 20% deficit or 80%ETc which resulted in a drastic fruit yield reduction percentage of 44.57% and a water saving percentage of 42.64%, which is not justifiable.

It can be clearly observed from these results that reduction in the amount of irrigation water saves water that can be used for utilization of extra land but it also results in yield reduction for both crops irrigated in the morning and for crops irrigated in the evening. For both sweet pepper plants irrigated in the morning and evening, a 10% reduction is more beneficial than the 20% reduction in the irrigation water applied. This is because, the water saved in the process can compensate for the yield loss which in all cases, a high water saving percentage resulted in a lower yield reduction. A similar observation was made by Dorji et al. (2005). They reported that reducing the amount of irrigation or the CWR could be a feasible irrigation strategy for pepper production where the benefit from saving water outweighs the decrease in the total fresh mass yield of fruit. This was not the case when CWR or ETc was reduced from 100%ETc to 80%ETc. In this case, a high water saving was obtained which was expected but this resulted in a higher yield reduction as well. Hence, the amount of water saved in the process could not compensate for the yield loss. A similar result was reported by Ismail (2010) that irrigating hot pepper at 85% of field capacity during the complete growing season reduced the total yield by 28.9% and saved about 41% of irrigation water. Increasing the deficit irrigation resulted in a severe yield reduction. Giving 70% of the field capacity reduced the fresh fruit yield by 39.7%, but sharply increased the water saving to be about 85% of irrigation water. It can be observed that a reduction in the CWR for sweet pepper plant to some extent increases water saving but after some level (20% reduction in ETC and above) it eventually reduce the yield drastically, which the amount of water saved cannot compensate for.

Table 10: Fruit Yield Reduction and Water Saving for the Various Irrigation Treatments of Sweet Pepper

amount of irrigation	Mean fruit yield (t/ha)		Mean fruit yield reduction (%)		Amount of water used (mm)		Water saving (%)	
	evening	morning	evening	morning	evening	morning	Evening	morning
100%	56.98	51.45	0	0	435.01	417.48	0	0
90%	53.84	45.12	5.51	12.3	302.36	313.8	30.49	24.83
80%	31.81	28.31	44.17	44.97	227.8	260.3	47.63	37.64

WUE

Table 11 shows the WUE of sweet pepper applied with the various irrigation treatments. It can be observed that, for crops irrigated in the evening with the various amount of irrigation, there was no significant difference among the irrigation treatment levels for WUE of sweet pepper. However, 90%ETc recorded the highest, 6.5 kg/m^3 WUE and 80%ETc recorded the lowest WUE, 5.3 kg/m^3. Significant difference existed for sweet pepper plants irrigated in the morning with the various irrigation amounts, though the same trend of result was obtained as in the evening irrigated crops, where 90%ETc had the highest WUE, and was significantly different from 100%ETc and 80%ETc but both were not significantly different from each other.

It can be observed from all the treatment results that WUE increased as ETc was reduced from 100%ETc to 90%ETc. However, a further reduction in ETc from 90%ETc to 80%ETc resulted in a lesser WUE. These observations do not conform to the trend reported by Ismail (2010) that the highest value of WUE was obtained from 70% field capacity treatment while the lowest one was recorded for 100%FC treatment. Wahb-Allah et al. (2014) also reported that the less irrigated crops gave the highest WUE. Comparing crops irrigated in the morning and evening with 100%ETc, 90%ETc and 80%ETc, WUE of sweet pepper plants irrigated in the evening were higher than the ones irrigated in the morning. This may be because sweet pepper irrigated in the evening produces a higher yield with a smaller seasonal irrigation water or seasonal ETc, than the ones irrigated in the morning, resulting in the higher WUE.

Table 11: Means of WUE (Kg/m3) for the Various Irrigation Treatments

amount of irrigation	time of irrigation	
	Evening	Morning
100%	5.2a	4.5b
90%	6.5a	5.3a
80%	5.3a	4.3b
Lsd (0.05)	1.67	0.86

Mean values followed by the same letters are not significantly different (P<0.05)

Economic Evaluation

The results presented in Table 11 show the effect of time of irrigation and amount of irrigation on the cost-benefit ratio (economic evaluation) of sweet pepper in terms of water input. It can be observed that there was no significant difference among the evening irrigation treatment levels. However, morning irrigation treatments showed a significant difference among the levels. Full irrigation and 80%ETc in the morning were significantly different from each other but both were not significantly different from 90%ETc. The combined effect of the two treatments from Table 11 shows that, irrigating in the morning and evening with 90%ETc gives the highest cost-benefit ratio, 1:30.81 and 1:26.02 respectively. Irrigating in the morning with 80%ETc recorded the lowest cost-benefit ratio of 1:21.29 which might be due to the yield obtained from the amount of irrigation water used since low yield (output) from less irrigation water application (input) produces a lower cost-benefit ratio.

Irrigating in the evening with the various irrigation levels showed that 90%ETc recorded the highest cost benefit ratio, 1:30.81, followed by irrigating with 80%ETc, 1:25.24 and 100%ETc, 1:24.81, respectively. A similar trend of results was obtained for sweet pepper irrigated in the morning, but the cost-benefit ratio of 100%ETc and 90%ETc were not significantly different from each other but both were significantly different from 80%ETc. This may be due to the less mount of water used to obtain a high yield in the case of 90%ETc but in 100%ETc; high irrigation amount was used to obtain a high yield and in 80%ETc; less amount of water was use to obtain a low yield. This result does not conform to the economic evaluation of deficit irrigated pepper conducted by Sezen et al. (2011).

They reported that the highest irrigated crop gave the highest economic benefit and the least irrigated gave the least economic benefit; in other words, economic benefit increased with the amount of irrigation supplied to the crop. A similar observation was reported by Zhang and Oweis (1999), in their experiment on wheat in the Mediterranean region. Comparatively, sweet pepper plants irrigated in the evening with the various irrigation water levels all had a better cost-benefit ratio compared to crops irrigated in the morning with the various irrigation water levels. The reason may be that, irrigating in the evening used less irrigation water but produced a higher yield, whereas irrigating in the morning used more irrigation water during the growing season and produced a lower yield.

Table 12: Means of Cost-Benefit Ratio for the Various Irrigation Treatments

amount of irrigation	time of irrigation	
	Evening	Morning
100%	24.81a	22.17ab
90%	30.81a	26.02a
80%	25.24a	21.29b
Lsd(0.05)	7.56	4.02

Mean values followed by the same letters are not significantly different ($P<0.05$)

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary of Findings

CWR or ETc and Kc for sweet pepper crops irrigated in the morning with 100%ETc, 90%ETc and 80%ETc were relatively higher than sweet pepper plants irrigated in the evening with 100%ETc, 90%ETc and 80%ETc.

Irrigating in the morning or evening with the various irrigation water levels had no significant effect on the plant height of Sweet pepper through the growth stages but it had significant effect on the leaf area of sweet pepper through the growth stages.

Irrigating in the morning and evening with 100%ETc, 90%ETc and 80%ETc all had significant effect on the fruit number, diameter, weight and yield (t/ha) of sweet pepper. Fruit number, diameter, weight and yield (t/ha) decreased with reduction in the amount of irrigation for both morning and evening irrigated sweet pepper fruits.

Irrigating in the evening with the levels of irrigation tends to have a better growth and yield performance than irrigating in the morning with the various levels of irrigation.

Firmness, TSS and TA of sweet pepper fruits generally increased with decreasing amounts of irrigation and pH of sweet pepper decreased with decreasing irrigation amount for fruits from sweet pepper crops irrigated in the morning and from the ones irrigated in the evening as well.

At storage, firmness and TA decreased across the storage period whilst weight loss, TSS and pH increased across the storage period for both fruits from sweet pepper irrigated in the morning and evening with 100%ETc, 90%ETc and 80%ETc.

Irrigating in the morning or evening with 100%ETc, 90%ETc and 80%ETc has significant effect on shelf life of sweet pepper fruits. Fruit shelf life increased with reduction in the amount of irrigation for both sweet pepper crops irrigated in the morning and in the evening. Fruits from sweet pepper plants irrigated in the morning with the various amount of irrigation had a longer shelf life than their counterpart irrigated in the evening.

10% reduction in the amount of irrigation (90%ETc) in both crop irrigated in the morning and evening resulted in a yield reduction that could be compensated for by the amount of water saved in the process, unlike the 20% reduction in the amount of irrigation.

Irrigating in the evening with 90%ETc tend to use water more efficiently and was economically more beneficial (high cost- benefit ratio) than the rest of the treatment combinations.

Conclusions

Irrigating sweet pepper in the evening with 10% reduction in the amount of irrigation (90%ETc) slightly reduce sweet pepper fruit yield but not significantly. It improves fruit quality during post-harvest storage, extends shelf life as well as increases WUE and give the highest economic benefit. All these improvements compensated for the reduction in yield as a result of the 10% reduction in ETc. Though irrigating in the evening with 90%ETc did not resulted in the best quality and longest shelf life, however it is the treatment combination level that maximized yield, quality, shelf, WUE and the Economic value of sweet pepper production.

Recommendations

Recommendations for Future Research

1. This research work collected data from 72 plants for its analysis, hence performing this experiment on a larger field area with more plants to sample data from would give a more representative results.
2. Further studies on the effect of time of irrigation and the amount of irrigation on the nutritional quality (protein, fat, fibre, moisture and mineral content) of sweet pepper should be carried out to determine which levels of the two treatments gives the best nutritional quality to sweet pepper.
3. Further studies should also be carried out on the effect of time of irrigation and the amount of irrigation on the different varieties of sweet pepper to determine which levels of the two treatments and with which variety will maximize the yield and quality performance of sweet pepper.
4. The economic evaluation (cost-benefit ratio) took into consideration only the cost of irrigation water as the input cost hence further work can be done by taking into consideration the cost of other inputs like labour, land, pest and disease control and fertilizer.
5. The research work was carried out in the coastal savannah ecological zone and hence should be carried out in other ecological zones of Ghana since CWR varies from one ecological zone to the other.

Recommendations for Policy Making

Irrigating in the evening with 10% reduction in CWR or ETc (90%ETc) may maximize yield and profit, improve fruit quality and increase the standard of living of farmers whilst conserving water which could be used for other productive activities. Therefore, farmers should be encouraged to adopt this strategy in their water management practices.

REFERENCES

Abdalla, M. M., & El -Khoshiban, N. H. (2007). The influence of water stress on growth, relative water content, photosynthetic pigments, some metabolic and hormonal contents of two Triticium aestivum cultivars. *Journal of Applied Science*, 3, 2062-2074.

Abdel-Razik, A. M. (2012). Effect of different irrigation regimes on quality storability of Mango fruits (*Mangifera indica* L.). *Journal of Horticulture Science & Ornamental Plants, 4*(3), 247-252.

Adetula, A. O., & Olakojo, S. A. (2006). Genetic characterization and evaluation of some pepper accessions (*Capiscum frutescens* L): The Nigerian Shombo collection. American-Eurasian, *Journal of Agriculture & Environ Sicence, 1*(3), 273-281.

Agodzo, S. K., Durán, A., Moscoso, O., Romero, A. M., Huibers, F. P., Chenini, F., & van Lier, J. B. (2003). Use of wastewater in irrigated agriculture. *Country Studies from Bolivia, Ghana and Tunisia*, *1*, 55.

Albrigo, L. G. (1972). Distribution of stomata and epicuticular wax on oranges as related to stem and rind breakdown and water loss. *Journal of American Society of Horticulture Science*, *97*, 220-223.

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop Evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. *FAO, Rome*, *300*(9), 51-59.

Alvino, A., Centritto, M., & De Lorenzi, F. (1994). Phytosynthesis response of sunlit and shade pepper leaves at different positions in the canopy under two water regimes. *Australia. Journal of Plant Physiology*, *21*, 377-391.

Amati, M., Dekker, E., Vanlingen, T., Pinners, E., & Tam, S. C. (1995). *How to grow tomato and pepper*. Wegeningen: Agromisa.

Antony, E., & Singandhupe, R. (2004). Impact of drip and surface irrigation on growth, yield and WUE of capsicum (Capsicum annuum L.). *Agriculture Water Manag*ement, *65*(2), 121-132.

Antoniali, S., Leal, P. A., Magalhães, A. M., Fuziki, R. T., & Sanches, J. (2007). Physico-chemical characterization of'Zarco HS'yellow bell pepper for different ripeness stages. *Scientia Agricola*, *64*(1), 19-22.

Atta-Aly, M. A., & Bercht, J. K. (1995). *Effect of postharvest high temperature on tomato fruit ripening and quality*. In Postharvest Physiology, Pathology and Technologies for Horticultural Commodities: Recent Advances, Agadir (Maroc), 16-21 Jan 1994. IAV Hassan 2.

Bayoumi, Y. A. (2008). Improvement of post- harvest keeping quality of white pepper fruits *(Capsicum annuum L.)* by hydrogen peroxide treatment under storage conditions. *Acta Biologica Szegediensis*, *52*, 7–15.

Ben-Yehoshua, S. (1987). Transpiration, water stress, and gas exchange. *Postharvest Physiology of Vegetables*, *87*, 113-170.

Ben-Yehoshua, S., Shapiro, B., Chen Z., & Lurie, S. (1983). Mode of action of plastic film in extending life of lemon and bell pepperfruits by alleviation of water stress. *Plant Physiology*, *73*, 87-93.

Berke, T. G., Black, L. L., Morris, R. A., Talekar, N. S., & Wang, J. F. (2003). Suggested cultural practices for sweet pepper. *Int. Coop. Guide, AVRDC Publ*, *5*, 99-497.

Berrie, G. K., Berie, A., & Eze J. M. (1990). *Tropical plant science* (2^{nd} ed.) London: Longman Group.

Billy, L., Mehinagic, E., Royer, G., Renard, C. M., Arvisenet, G., Prost, C., & Jourjon, F. (2008). Relationship between texture and pectin composition of two apple cultivars during storage. *Postharvest Biology and Technology, 47*(3), 315-324.

Black, L. L., Green, S. K., Hartman, G. L., & Poulos, J. M. (1991). *Pepper diseases: A field guide*. Taipei: Asian Vegetable Research and Development Center.

Bordonaba, J.G., & Terry, L.A. (2010). Manipulating the taste-related composition of strawberry fruits (Fragaria x ananassa) from different cultivars using deficit irrigation. *Food Chemistry*, *122*(4), 1020-1026.

Bosland, P., & Votava, E. (1999). *Peppers: Vegetable and spice capsicums*. New York: CABI Publishing,

Bradfield, E.G., & Guttridge, C.G. (1984). Effects of night-time humidity and nutrient solution concentration on the calcium content of tomato fruit. *Science Horticulture, 22*, 207-374.

Broeshart, H., Haunold, E., & Fried M. (1965). The effect of water conditions and oxidation status of rice soils on the availability of soil and fertilizer phosphate. *Plant and Soil, 23*(3), 305-313.

Brown, C. E., Pezeshki, S. R. & DeLaune, R. D. (2006). The effects of salinity and soil drying on nutrient uptake and growth of Spartina alterniflora in a simulated tidal system. *Environmental and Experimental Botany, 58*(1), 140-148.

Bruce, R. R., Chesness, J. L., Keisling, T. C., Pallas Jr, J. E., Smittle, D. A., Stansell, J. R., & Thomas, A. W. (1980). *Irrigation of crops in the Southeastern United States: Principles and practice*. New York: Agricultural Reviews and Manuals.

Burton, W. G. (1982). *Post-harvest physiology of food crops*. London: Longman

Castro, J. M., Avila, V. C. M., Rocha, F. M., Ochoa, M. A., & Gallegos, I. A. (2002). *Effect of controlled atmospheres on quality of green pepper poblano (ancho).* In Proceedings of the 16th International Pepper Conference. November (pp. 10-12).

Celik, S. (1991). *Water consumption of pepper in the slap-kazova and the effect of drying plants of different irrigation programs.* Boston: Rural Services Tokat Research Instiitute Publication.

Ceponis, M. J., Cappellini, R. A. and Lightner, R. A. (1987). Disorders in fresh pepper shipments to the New York market. *Plant Disease, 71*, 380–382.

Cline, R. A., & Erickson, A. E. (1956). The effect of oxygen diffusion rate and applied fertilizer on the growth, yield and chemical composition of peas. *Soil Sci. Soc. Amer. Proc. 23*, 331-335.

Cochran, H. L. (1964). Changes in pH of the pimiento during maturation. *Proc Am Soc Hortic Sci. 84*, 409–411.

Coertze, A. F., & Kistner, M. H. (1994). *Cultivation of peppers, paprika and chilli, No. A1*. Pretoria: Institute of Vegetables and Ornamentals.

Costa, J. M., Ortuño, M. F., & Chaves, M. M. (2007). Deficit irrigation as a strategy to save water: Physiology and potential application to horticulture. *Journal of Integrative Plant Biology*, *49*(10), 1421-1434.

Craft, A. S. (1999). Solute transport in palnts. *Plant Science*, *90*, 337-346.

Della Costa, L., & Gianquinto, G. (2002) Water stress and water-table depth influence yield, water use efficiency, and nitrogen recovery in bell pepper: Lysimeter Studies. *Australia Journal of Agriculture Research*, *53*, 201-210.

D´ıaz-P´erez, J. C. (1998). Empaque de berenjena (*Solanum melongena* L.) ‘Clasica’ y ‘Japonesa’ con pel´ıculas de polietileno. *Agrociencia*, *32*, 71–74.

Diaz-Perez, J. C., Muy-Rangel, M. D. & Mascorro, A. G. (2007). Fruit size and stage of ripeness affect postharvest water loss in bell pepper fruit (*Capsicum annuum* L.). *Journal of the Science of Food and Agriculture*, *87*, 68–73.

Dimitrov, Z., & Ovtcharrova, A. (1995). The productivity of peppers and tomatoes in case of insufficient water supply. *Irrigation and Drainage System*, *1*(9), 1-5.

Doorenbos, J., & Kassam, A. H. (1979). Yield response to water. *Irrigation and Drainage Paper*, *33*, 257.

Doorenbos, J. W., & Pruitt, O. (1984). Crop water requirement. Rome: FAO.

Dorji K., Behboudian M. H., & Zegbe-Dominguez J. A., (2005). Water relations, growth, yield, and fruit quality of hot pepper under deficit irrigation and partial rootzone drying. *Science Horticulture*, *104*, 137-149.

Dukes, M. D., Simonne, E. H., Davis, W. E., Studstill, D. W., & Hochmuth, R. (2003). *Effect of sensor-based high frequency irrigation on bell pepper yield and water use*. In Proceedings of 2nd International Conference on Irrigation and Drainage, May (pp. 12-15).

Food and Agriculture Organization (FAO). (1999)**.** *Production yearbook*. Rome: Food and Agriculture Organization.

Food and Agriculture Organization FAO. (2002). *Land and water development division*. Retrieved 12 September, 2008, f rom Food and Agriculture Organization of the United Nations: http://w ww.fao.org/AG/aGL/aglw/cropwater/pepper.stm

Food and Agriculture Organization (FAO) FAO. (2008). Water development and management Unit.Retrieved September 11, 20 15, from Food and Agriculture Organization of the United Nations: htt p://www.fao.org/nr/water/cropinfo_pepper.html

FAOSTAT. (2011). FAO statistics division. Retrieved September 8, 2015, from Food and Agriculture Organization of the United Nations: http://www.faostat.fao.org.

FAOSTAT. (2013). FAO statistics division. Retrieved November 12, 2015, from Food and Agriculture Organization of the United Nations: http://www.faostat.fao.org.

Fernandez, M. D., Gallardo, M., Bonachela, S., Orgaz, F., Thompson, R. B., & Fereres, E. (2005). Water use and production of a greenhouse pepper crop under optimum and limited water supply. *Journal of Horticultural Science and Biotechnology*, *80*(1), 87-96.

Fisher, K. H., Cline, R. A., & Bradt O. A. (1985). The effects of trickle irrigation and training systems on the performance of concord grapes. *Drip/Trickle Irrigation in Action*, *1*, 220-230.

FSSA. (2007). *Fertilizer handbook* (6th edn.). Pretoria: The Fertilizer Society of South Africa,

García-Tejero, I., Jimenez-Bocanegra, J. A., Martinez, G., Romero, R., Duran-Zuazo, V. H., & Muriel-Fernandez, J. (2010). Positive impact of regulated deficit irrigation on yield and fruit quality in a commercial citrus orchard Citrus sinensis (L.) Osbeck, cv. salustiano. *Agricultural Water Management*, *97*(5), 614-622.

Gencoglan, C., Akinci, I. E., Ucan, K., Akinci, S. & Gencoglan, S. (2006) Response of red hot pepper plants (Capsicum annuum L.) to the deficit irrigation, *Akdeniz Üniversitesi Ziraat Fakultesi Dergisi*, *19*(1), 131-138.

Getenit, H., Seyoum, T., & Woldetsdik, K. (2008). The effect of cultivar, maturity stage and storage environment on quality of tomatoes. *Journal of Food Engineering, 87*, 467–498.

Gonzalez-Aguilar, G. A., Cruz, A., & Baez, R. (1999). Storage quality of bell peppers pretreated with hot water and polyethylene packaging. *Journal of Food Quality, 22*, 287–299.

Gorny, J. R., & Kader, A. A. (1998). *Fresh-cut products: maintaining quality and safety*. New York: UC Davis.

Grattidge, R. (1993). *Growing capsicums and chillies in Queensland*. Queensland: Department of Primary Industries.

Grimes D.W., & L.E. Williams. (1990). Irrigation effects on plant. Water relations and Seedless grapevines. *Crop Sci*ence, *30*, 255-260.

Gross, K., Watada, A. E., Kang, M. S., Kim, S. D., & Lee, S. W., (1986). Biochemical changes associated with the ripening of hot pepper fruit. *Physiology, Plant, 66*, 31–36.

Hegde, D. M., & Srinivas, K. (1990). Effect of irrigation and nitrogen fertilization on yield, nutrient uptake, and water use of tomato. *Gartenbauwissenschaft, 55*, 173-177.

Heiser, C. B., & Pickersgill. B., (1969). Names for the cultivated Capsicum species (Solanaceae). Taxon, *18*(3), 277-283.

Hershenhorn, J., Goldwasser, Y., Plakhine, D., Herzlinger, G., Golan, S., Russo, R. & Kleifeld, Y. (1996). Role of pepper (*Capsicum annuum* L) as a trap and catch crop for control of *Orobanche aegyptiaca* and *0. cernual. Weed Science, 44*, 948-951.

Hillel, D. (1990). Role of irrigation in agricultural systems. *Agronomy*, (30), 5-30.

Ho, L. C., R. Belda, M. Brown, J. Andrews, & Adams, P. (1993). Uptake and transport of calcium and the possible causes of blossom-end rot in tomato. *J. Exp. Bot*. *44*, 509-518.

Ho, L. C., & White, P. J. (2005). A cellular hypothesis for the induction of blossom-end rot in tomato fruit. *Annals of Botany, 95*(4), 571-581.

Hooper, L. & Cassidy, A. (2006). A review of the health care potential of bioactive compounds. *Journal of the Science of Food and Agriculture, 86*(12), 1805-1813.

Howell, T. A., Cuenca, R. H., & Solomon, K.H., (1990). *Crop yield response, in management of farm irrigation systems*. Boston: ASAE Monog.

Ismail, S. M. (2010). Influence of deficit irrigation on water use efficiency and bird pepper production (*Capsicum annuum* L.). *Meteorology, Environment and Arid Land Agriculture Sciences Journal*, Jkau, *21*(2), 29-43.

Jaimez, R. E., Vielma, O., Rada, F., & Garcia-Nunez C. (2000). Effects of water deficit on the dynamics of flowering and fruit production in Capsicum Chinense Jacq in a tropical semiarid region of Venezuela. *Journal of Agriculture Crop Science*, *185*, 113-119.

Kader, A. A. (2002). *Postharvest technology of horticultural crops*. Rome: UCANR Publications.

Karam, F., Masaad, R., Bachour, R., Rhayem, C., & Rouphael, Y. (2009). Water and radiation use efficiencies in drip-irrigated pepper (Capsicum annuum L.): response to full and deficit irrigation regimes. *European Journal of Horticultural Science*, *74*(2), 79-85.

Kays, S. J. (1991). *Postharvest physiology of perishable plant products*. Van Nostrand Reinhold, New York, N.Y.

Kere, G. M., Nyanjage, M. O., Liu, G., & Nyalala, S. P. (2003). Influence of drip irrigation schedule and mulching material on yield and quality of greenhouse grown tomatoes to partial root drying and conventional deficit irrigation. *Agriculture Water Management, 69*,191-201.

Kirda, C. (2002). Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Deficit irrigation practise. *Water Rep.*, *22*, 3-10.

Kirda, C., Cetin, M., Dasgan, Y., Topcu, S., Kaman, H., Ekici, B., Derici, M. R., & Ozguven, A. I. (2004). Yield response of greenhouse grown tomato to partial root drying and conventional deficit irrigation. *Agriculture Water Management*, *69*, 191-201.

Kirnak, H., Tas, I., Kaya, C., & Higgs, D. (2002). Effects of deficit irrigation on growth, yield, and fruit quality of eggplant under semi-arid conditions. *Australia Journal of Agriculture. Research*, *53*, 1367-1373.

Klaring, H. P. (2001). Strategies to control water and nutrient supplies to greenhouse crops: A review. *Agronomie*, *21*, 311-321.

Kramer, P. J. (1969). *Plant and soil water relationships: A modern synthesis*. New York: McGraw-Hill.

Kramer, P. J. (1983). *Effect of water stress on status deficit and growth of wheat*. London: Academic Press.

Kumar, S. & Rai, M. (2005). *Chile in India*. Chile: Chile Pepper Institute

Lee, A. C., & Liao, F. S. (2007). Effects of organic substrates, training system and plant density on the yield of sweet pepper (*Capsicum annuum* L.) grown in basket culture under plastic house. *Acta Horticulturae*, *761*, 533-538.

Leib, B. G., Caspari, H. W., Redulla, C. A., Andrews, P. K. & Jabro, J.J. (2006). Partial rootzone drying and deficit irrigation of 'Fuji' apples in a semi-arid climate. *Irrigation Science, 24*(2), 85-99.

Lownds, N. K. and P. W. Boslaud. (1988). Studies on postharvest storage of pepper fruits. *HortScience*, *23*, 71-82.

Lownds, N. K., Banaras, M., & Bosland, P. W. (1993). Relationships between postharvest water loss and physical properties of pepper fruit (Capsicum annuum L.). *HortScience*, *28*(12), 1182-1184.

Lownds, N. K., Banaras, M., & Bosland, P. W. (1994). Postharvest waterloss and storage quality of nine pepper (*Capsicum*) cultivars. *HortScience 29*, 191–193.

Lurie, S., Shapiro, B., & Ben-Yehoshua, S. (1986). Effects of water stress and degreeof ripeness on rate of senescence of harvested bell pepper fruit. *Journal of the American Society for Horticultural Science*, *111*, 880–885.

Lurie, S., & Klein, J. (1990). Heat treatment on ripening apples: Differential effect on physiology and biochemistry. *Plant Physiol*ogy, *78*, 181–186.

Lurie, S., Fallik, E., & Klein, J. D. (1996). The effect of heat-treatment on apple epicuticular wax and calcium-uptake. *Postharvest Biology, Technology*, *8*, 271–277.

Manrique, A. (1993). Greenhouse crops: A review. *Journal of Plant Nutrition, 16*(12), 2411-2477.

Marcelis, L. F., & Ho, L. C. (1999). Blossom-end rot in relation to growth rate and calcium content in fruits of sweet pepper (*Capsicum annuum* L.). *J. Exp. Bot*. 50, 357-363.

Marschner, H. (1986). *Mineral nutrition of higher plants*. London: Academic Press.

Martin, D. L., Stegman, E. C., & Fereres, E. (1990). Irrigation scheduling principles. *American Society of Agricultural Engineers*, *90*, 155-203.

Mattoo, A. K., Murata, T., Pantastico, E. B., Chachin, K., Ogata, K., & Phan, C. T. (1975). Chemical changes during ripening and senescence. *Postharvest Physiol, Handling and Util of Tropical and Subtropical Fruits and Vegetables. EB Pantastico, ed*.

Medlicott, A. P., & Thompson, A. K. (1985). Analysis of sugars and organic acids in ripening fruits by high performance liquid chromatography. *Journal of Science Food Agriculture*, *36*, 561–566.

Medlicott, A. P., Reynolds, J. B., & Thompson, E. K. (1986). Effects of temperature on the ripening of mango fruit (Mangifera indica L. var. Tommy Atkins). *Journal of Science Food Agriculture*, 37, 469–474.

Meir, S., Rosenberger, Y., Aharon, Z., Grienber, S., & Fallik, E. (1995). Improvement of the postharvest keeping quality and colour development of bell pepper by packaging with polyethylene bags at a reduced temperature. *Postharvest Biology and Technology*, *5*, 303–309.

Mitropoulos, D., & Lambrinos, G. (2005). Changes in firmness of apples affected by moisture loss during storage. *Journal of Horticulture Science Biotechnology*, *80*, 421–426.

Mizrach, A., Filtsanov, U., & Fuchs, V. (1997). An ultrasonic nondestructive method for measuring maturity of fruit. *Trans ASAE*, *40*, 1107–1111.

Mohammed, M., Wilson, L. A., & Gomes, P. L. (1999). Postharvest sensory and physicochemical attributes of processing and non-processing tomato cultivar. *Journal of Food Quality*, 22, 167–182.

Morley, P. S., Hardgrave, M., Bradley, M., & Pilbeam, D. J. (1993). Susceptibility of sweet pepper (Capsicum annuum L.) cultivars to the calcium deficiency disorder ‘Blossom end rot’. *Optimization of Plant Nutrition, 45,* 563-567.

Mpelasoka, B. S., Behboudian, M. H., Dixon, J., Neal, S. M., & Caspari, H. W. (2000). Improvement of fruit quality and storage potential of 'Braeburn' apple through deficit irrigation. *Journal of Horticultural Science & Biotechnology*, *75*(5), 615-621.

Mpelasoka, B. S., Behboudian, M. H., & Mills, T. M. (2001). Effects of deficit irrigation on fruit maturity and quality of 'Braeburn' apple. *Scientia Horticulturae*, *90*(3-4), 279-290.

Nadeem, M., Muhammad, F., Anjum, F. M., Khan, A. M. R., Saed, M. & Riaz, A. (2011). Antioxidant Potential of Bell Pepper (*Capsicum annum* L.). *Pakistan Journal of Food Science*, *21*(14), 45-51.

Nagaz, K., Masmoudi, M. M., & Mechlia, N. B. (2012). Effects of deficit drip-irrigation scheduling regimes with saline water on pepper yield, water productivity and soil salinity under arid conditions of Tunisia. *Journal of Agriculture and Environment for International Development*, *106*(2), 85–103.

Nahar, K. & Gretzmacher, R. (2002). Effect of water stress on nutrient uptake, yield and quality of tomato (L.e) under subtropical conditions Die Bodenkultur. *Austrian Journal of Agricultural Research*, *53*, 45-51.

Ngeze, P. (1998). *Artificial fertilizers: and how to use them*. Nairobi: Stantex Publishers.

Niklis, N. D., Siomos, A. S., & Sfakiotakis, E. M. (2002). Ascorbic acid, soluble solids and dry matter content in sweet pepper fruit: change during ripening. *Journal of Vegetable Crop Production, 8,* 41–51.

Norman, J. C. (1992). *Tropical vegetable crops*. London: Arthur H. Stockwell Ltd.

Nuruddin, M. M. (2001). *Effects of water stress on tomato at different growth stages*. New York: McGraw Hill.

Ofori, W., & Owusu-Sekyere, J. D. (2015). *Effect of irrigation time on the growth and yield of tomato.* (Unpublished undergraduate dissertation). University of Cape Coast.

Owusu-Sekyere, J. D., & Dadzie, M. (2009). Effect of deficit irrigation on the growth and development of tomao plant (Lycopessicum esculentum Mill). *Journal of Ghanaian Science Association*, *11*(2), 90-98.

Owusu -Sekyere J. D., Sam -Amoah L. K., Teye E., & Osai B. P. (2012). Crop coefficient (Kc), water requirement and the effect of deficit irrigation on tomato in the Coastal Savannah Zone of Ghana. *International Journal of Science and Nature*, *3*(1), 83-87.

Pantane, C., Tringali, S., & Sortino, O. (2011). Effects of deficit irrigation on biomass, yield, water productivity and fruit quality of processing tomato under semi-arid Mediterranean climate. *Sci. Horticulture*, 125, 590-596.

Payero, J. O., Tarkalson, D. D., Irmak, S., Davison, D., & Petersen, J. L. (2009). Effect of timing of a deficit-irrigation allocation on corn evapotranspiration, yield, water use efficiency and dry mass. *Agricultural Water Management*, *96*(10), 1387-1397.

Pereira, L. S., Oweis, T., & Zairi, A. (2002). Irrigation management under water scarcity. *Agricultural Water Management*, *57*(3), 175-206.

Perez, K., & Mercado, J., Soto-Valdez, H. (2003). Effect of storage temperature on the shelf life of Hass avocado (Persea americana). *Food Science Technology International, 10*, 73–77.

Perez-Pastor, A., Ruiz-Sanchez, M. C., Martinez, J. A., Nortes, P. A., Artes, F., & Domingo, R. (2007). Effect of deficit irrigation on apricot fruit quality at harvest and during storage. *Journal of the Science of Food and Agriculture, 87*(13), 2409- 2415.

Pernezny, K., Roberts, P., Murphy, J., & Goldberg, M. (2003). *Compendium of pepper diseases*. Minnesota: The American Phytopathological Society.

Phene, C. J., Reginato, R. J., Itier, B., & Tanner, B. R. (1990). *Sensing irrigation needs*. Michigan: Amer. Soc. Agr. Eng.,

Phocaides, A. (2000). *Technical handbook on pressurized irrigation techniques*. Rome: FAO.

Pickersgill, B. (1988). The genus *Capsicum*: A multidisciplinary approach to the taxonomy of cultivated and wild plants. *Biologisches Zentralblatt, 107*(4), 381-389.

Portree, J. (1996). *Greenhouse vegetable production guide for commercial growers*. Columbia: .Ministry of Agriculture, Fisheries, and Food.

Raemaekers, R. H. (2001). *Crop production in tropical Africa*. Belgium: GOC Kint Graphics NV.

Rehm, S., & Espig, G. (1991). *The cultivated plants of the tropics and subtropics*. Verlag Josef Margraf, weikersheim.

Robinson, J. E., Browne, K. M., & Burton, W. G. (1975). Storage characteristics of some vegetables and soft fruits. *Ann. Applied Biol*. *81*, 399-408.

Rubio, J.S., Garcia-Sanchez, F. Rubio, F., & Martinez, V. (2009). Yield, blossom end rot incidence, and fruit quality in pepper plants under moderate salinity are affected by K^+ and Ca^{2+}fertilization. *Scientia Horticulturae*, *119*, 79-87.

Ryall, A. L., & Lipton, W. J. (1972). *Handling, transportation and storage of fruits and vegetables*. Boston: AVI, Westport.

Salas, M. C., Urrestarazu, M., & Castillo, E. (2006). Effect of cultural practices on a sweet pepper crop in a mild winter climate. *Acta Horticulturae*, *614*, 301-306.

Sam-Amoah, L. K., Darko, R. O., & Owusu-Sekyere, J. D. (2013). Water requirement, deficit irrigation and crop coefficient of hot pepper (capsicum frutescens var legon18) using irrigation interval of two (2) days. *Journal of Agricultural & Biological Science*, *8*(2), 139-146.

Sánchez-Mata, M. C., Cámara, M., & Díez-Marqués, C. (2003). Extending shelf-life and nutritive value of green beans (*Phaseolus vulgaris* L.), by controlled atmosphere storage: macronutrients. *Food Chemistry*, *80*(3), 309-315.

Saure, M.C. (2001). Blossom-end rot of tomato (*Lycopersicon esculentum* Mill.) - a calcium- or a stress-related disorder? *Science Horticult*ure, *90*, 193-208.

Schönherr, J. (1976). Water permeability of isolated cuticular membranes: The effect of cuticular waxes on diffusion of water. *Planta*, *131*, 159–164.

Sezen, S. M., Yazar, A., Tekin, S., Eker, S., & Kapur, B. (2011). Yield and quality response of drip-irrigated pepper under Mediterranean climatic conditions to various water regimes. *African Journal of Biotechnology*, *10*(8), 1329-1339.

Shahein, M. M., Abuarab, M. E., & Hassan, A. M. (2012). Effects of regulated deficit irrigation and phosphorus fertilizers on water use efficiency, yield and total soluble solids of Tomato. *American Eurasian J. Agric. & Environ. Sci.*, *12*(10), 1295- 1304.

Shapiro, R. E., Taylor, G. S., & Volk, G. W. (1956). Soil oxygen contents and ion uptake by corn. *Soil Sci. Soc. Amer. Proc. 20*, 193-197.

Shirazi, A. & Cameron, A. (1993). Measuring transpiration rates of tomato and other detached fruit. *HortScience, 28*, 1035–1038.

Showalter, R. K. (1973). Factors affecting pepper firmness. *Proc. Fla. State Hort. Soc. 86*, 230-232.

Smith, M. (1985). Irrigation scheduling and water distribution. In: Actes de Conférence Internationale, Besoins en Eau des Cultures.

Smittle, D. A., Dickens, W. L., & Stansell, J.R. (1994). Irrigation regimes affect yield and water use by bell pepper. *J. Am. Soc. Hortic. Sci*., *119* (5), 936-939.

Sys, C., Van Ranst, E., Debaveye, J., & Beernaert, F. (1993). Land evaluation. Part III. Crop requirements. *Agricultural Publications*, *7*, 191-195.

Tadesse, T., Nichols, M. A., & Fisher, K. J. (1999). Nutrient conductivity effects on sweet pepper plants grown using a nutrient film technique 1. Yield Yield and fruit quality. *New Zealand Journal of Crop and Horticultural Science, 27*, 229-237.

Tüzel, I. H., Ul, M. A., & Tüzel, Y. (1993). Effect of different irrigation intervals and rates on spring-season glasshouse tomato production: I. Yield and plant growth. In *II Symposium on Protected Cultivation of Solanacea in Mild Winter Climates 366* (pp. 381-388).

USDA. (2011). *Animal and plant health inspection service, fresh fruit and vegetable import manual*. New York: USDA.

Üstün, H. (1993). *Planning of time watering the bell peppers in Ankara conditions*. Ankara: Ankara Research Institute of Rural Services Publications General Publications.

Van der Varst, P. D. I., & Postel, J. D. G. (1972). Bepaling bladoppervlak van tomatenplanten. *Report ITT, Wageningen*.

Van Zyl, J. L., (1984). Response of Colombar grapevines to irrigation as regards quality aspects and growth. *S. Afr. J. Enol. Vitic. 5*, 19-28.

Velez, J. E., Intrigliolo, D. S., & Castel, J. R. (2007). Scheduling deficit irrigation of citrus trees with maximum daily trunk shrinkage. *Agricultural Water Management*, *90*(3), 197-204.

Vicentini, N. M., Castro, T. M., Cereda, M. P. (1999). Influência de películas de fécula de mandioca na qualidade pós-colheita de frutos de pimentão (Capsicum annum L.). *Ciênc Tecnol Aliment*. *19*, 127–130.

Vijitha, R., & Mahendran, S. (2010). Effects of moisture stress at different growth stages of tomato plant Lycopersicon esculentum Mill.) on yield and quality of fruits. *J. Sci. Univ. Kelaniya, 12*(5), 1-11.

Wahb-Allah, M., Abdel-Razzak, H., Aslsdon, A., & Ibrahim, A. (2014). Growth, yield, fruit quality and water use efficiency of tomato under arbuscular mycorrhizal inoculation and irrigation level treatments. *Life Sci J*, *11*, 109-117.

Wakrim, R., Wahbi, S., Tahi, H., Aganchich, B., & Serraj, R. (2005). Comparative effects of partial root drying and regulated deficit irrigation on water relations and water use efficiency in common bean (Phaseolus vulgaris L.). *Agric. Ecosyst. Environ. 106*, 275-287.

Walsh, B. M., & Hoot, S. B. (2001). Phylogenetic relationships of Capsicum (Solanaceae) using DNA sequences from two noncoding regions: The chloroplast atpB-rbcL spacer region and nuclear waxy introns. *International Journal of Plant Sciences*, *162*(6), 1409-1418.

Waskar, D. P., Khedlar, R. M., & Garande, V. K. (1999) Effects of postharvest treatment on the shelf life and quality of pomegranate in evaporative cooling chamber and ambient conditions. *J Food Sci Technol*. 2, 114–117.

Watada, A. E., Kim, S. D., Kim, K. S., & Harris, T. C. (1987). Quality of green beans, bell peppers and spinach stored in polyethylene bags. *Journal of Food Science*, *52*(6), 1637-1641.

Wills, R. B. H., Lee, T. H., Graham, D., McGlasson, W. B., & Hall. E.G. (198l). *Water loss and humidity. In: Postharvest: An introduction to the physiology and handling of fruit and vegetables*. New York: AVI, Westport, Conn.

Wills, R. B. H., McGlasson, W. B., Graham, D., Tlee, H., & Hall, E. G. (1989). *Postharvest: An introduction to the physiology and handling of fruit and vegetables*. New York: Van Nostrand Reinhold.

Wolff, H. (1999). *Economics of tomato production with special reference to aspects of plant protection: a case study of two tomato production systems in Brong-Ahafo Region, Ghana. Attachment* (Doctoral dissertation).

Zegbe-Domınguez, J. A., Behboudian, M. H., Lang, A., & Clothier, B. E. (2003). Deficit irrigation and partial rootzone drying maintain fruit dry mass and enhance fruit quality in 'Petopride'processing tomato (Lycopersicon esculentum, Mill.). *Scientia Horticulturae*, *98*(4), 505-510.

Zhang, H., & Oweis, T. (1999). Water-yield relations and optimal irrigation scheduling of wheat in the Mediterranean region. *Agric. Water Manage.*, *38*, 195-211.

APPENDICES

APPENDIX A

ANOVA Tables

The Effect of Irrigation Amount and Time of Irrigation on the Plant Height of Sweet Pepper Plant at the Initial (21DAT) Growth Stage ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
%ETc	6.41	2	3.21	3.56	0.06
Daytime	0.14	1	0.14	0.15	0.70
Interaction	0.09	2	0.05	0.05	0.95
Within	10.81	12	0.90		
Total	17.45	17			

The Effect of Irrigation Amount and Time of Irrigation on the Plant Height of Sweet Pepper Plant at the Developmental (21DAT) Growth Stage ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
%ETc	8.18	2	4.09	2.89	0.09
Daytime	0.00	1	0.00	0.00	0.96
Interaction	3.74	2	1.87	1.32	0.30
Within	16.95	12	1.41		
Total	28.87	17			

The Effect of Irrigation Amount and Time of Irrigation on the Plant Height of Sweet Pepper Plant at the Mid-Season (21DAT) Growth Stage ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
%ETc	6.64	2	3.32	3.51	0.06
Daytime	0.89	1	0.89	0.94	0.35
Interaction	2.51	2	1.26	1.33	0.30
Within	11.35	12	0.95		
Total	21.39	17			

The Effect of Irrigation Amount and Time of Irrigation on the Plant Height of Sweet Pepper Plant at the Late (21DAT) Growth Stage ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
%ETc	5.47	2	2.73	3.26	0.07
Daytime	0.01	1	0.01	0.01	0.92
Interaction	0.47	2	0.23	0.28	0.76
Within	10.07	12	0.84		
Total	16.01	17			

The Effect of Irrigation Amount and Time of Irrigation on the Leaf Area of Sweet Pepper Plant at the Initial (21DAT) Growth Stage ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
%ETc	8.12	2	4.06	9.42	0.00
Daytime	0.02	1	0.02	0.03	0.86
Interaction	0.26	2	0.13	0.30	0.75
Within	5.18	12	0.43		
Total	13.57	17			

The Effect of Irrigation Amount and Time of Irrigation on the Leaf Area of Sweet Pepper Plant at the Developmental (44DAT) Growth Stage ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
%ETc	197.16	2	98.58	105.38	0.00
Daytime	37.90	1	37.90	40.52	0.00
Interaction	0.83	2	0.41	0.44	0.65
Within	11.23	12	0.94		
Total	247.11	17			

The Effect of Irrigation Amount and Time of Irrigation on the Leaf Area of Sweet Pepper Plant at the Midseason (72DAT) Growth Stage (p < 0.05)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
%ETc	157.18	2	78.59	40.88	0.00
Daytime	1.26	1	1.26	0.65	0.43
Interaction	0.48	2	0.24	0.13	0.88
Within	23.07	12	1.92		
Total	181.99	17.00			

The Effect of Irrigation Amount and Time of Irrigation on the Leaf Area of Sweet Pepper Plant at the Late Season (92DAT) Growth Stage (p < 0.05)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
%ETc	2.391	1	2.391	0.62	0.45
Daytime	154.03	2	77.02	20.03	<.001
Interaction	11.28	2	5.64	1.47	0.27
Within	2.391	1	2.391	0.62	0.45
Total	213.84	17			

The Effect of Irrigation Amount and Time of Irrigation on the Fruit Number of Sweet Pepper Fruits (p < 0.05)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	0.222	1.00	0.222	0.400	0.539
%ETc	27.444	2.00	13.722	24.700	0.000
Interaction	0.111	2.00	0.056	0.100	0.906
Within	6.667	12.00	0.556		
Total	34.444	17.00			

The Effect of Irrigation Amount and Time of Irrigation on the Fruit Diameter of Sweet Pepper Fruits (p < 0.05)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	2.494	1.00	2.494	4.929	0.046
%ETc	178.424	2.00	89.212	176.31	0.000
Interaction	0.003	2.00	0.002	0.003	0.997
Within	6.072	12.00	0.506		
Total	186.993	17.00			

The Effect of Irrigation Amount and Time of Irrigation on the Weight per Fruit

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	24.453	1.000	24.453	127.737	0.000
%ETc	67.113	2.000	33.557	175.290	0.000
Interaction	3.179	2.000	1.590	8.304	0.005
Within	2.297	12.000	0.191		
Total	97.043	17.000			

The Effect of Irrigation Amount and Time of Irrigation on the Fruit Yield of Sweet Pepper Fruits (p < 0.05)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	157.71	1.00	157.71	8.884	0.011
%ETc	1966.24	2.00	983.12	55.378	0.000
Interaction	20.77	2.00	10.39	0.585	0.572
Within	213.03	12.00	17.75		
Total	2357.75	17.00			

The Effect of Irrigation Amount and Time of Irrigation on the Firmnesum of Squares of Sweet Pepper Fruits (p < 0.05)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	0.005	1.000	0.005	0.346	0.567
%ETc	0.023	2.000	0.012	0.808	0.469
Interaction	0.003	2.000	0.002	0.115	0.892
Within	0.173	12.000	0.014		
Total	0.205	17.000			

The Effect of Irrigation Amount and Time of Irrigation on the Total Soluble Solids of Sweet Pepper Fruits (p < 0.05)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	0.005	1.000	0.005	0.818	0.384
%ETc	0.008	2.000	0.004	0.636	0.546
Interaction	0.003	2.000	0.002	0.273	0.766
Within	0.073	12.000	0.006		
Total	0.089	17.000			

The Effect of Irrigation Amount and Time of Irrigation on the Titratable Acid of Sweet Pepper Fruits ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	0.0000	1.00	0.0000	0.8000	0.3887
%ETc	0.0006	2.00	0.0003	11.400	0.0017
Interaction	0.0000	2.00	0.0000	0.2000	0.8214
Within	0.0003	12.00	0.0000		
Total	0.0010	17.00			

The Effect of Irrigation Amount and Time of Irrigation on the pH of Sweet Pepper Fruits ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	0.005	1.000	0.005	0.900	0.361
%ETc	0.008	2.000	0.004	0.700	0.516
Interaction	0.010	2.000	0.005	0.900	0.432
Within	0.067	12.000	0.006		
Total	0.089	17.000			

The Effect of Irrigation Amount and Time of Irrigation on the Shelf Life of Sweet Pepper Fruits ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	0.50	1.00	0.50	1.69	0.22
%ETc	48.20	2.00	24.10	81.33	0.00
Interaction	0.15	2.00	0.07	0.25	0.78
Within	3.56	12.00	0.30		
Total	52.40	17.00			

The Effect of Irrigation Amount and Time of Irrigation on the WUE of Sweet Pepper Fruits ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	4.16	1	4.16	9.38	0.01
%ETc	4.58	2	2.29	5.16	0.02
Interaction	0.29	2	0.15	0.33	0.72
Within	5.33	12	0.44		
Total	14.37	17			

The Effect of Irrigation Amount and Time of Irrigation on the Cost-Benefit Ratio of Sweet Pepper Fruits (p < 0.05)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	64.90	1	64.90	7.07	0.02
%ETc	101.58	2	50.79	5.53	0.02
Interaction	3.52	2	1.76	0.19	0.83
Within	110.19	12	9.18		
Total	280.20	17			

The Effect of Irrigation Amount and Time of Irrigation on the Firmness of Squares of Sweet Pepper Fruits during Storage (p < 0.05)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	0.000	1	0.000	0.010	0.921
%ETc	0.500	2	0.250	22.070	<.001
Storage_Days	74.472	4	18.618	1642.760	<.001
Daytime. %ETc	0.084	2	0.042	3.720	0.030
Daytime.Storage_Days	0.057	4	0.014	1.260	0.296
%ETc.Storage_Days	0.154	8	0.019	1.700	0.117
Daytime. %ETc.Storage_Days	0.097	8	0.012	1.070	0.397
Residual	0.680	60	0.011		
Total	76.045	89			

The Effect of Irrigation Amount and Time of Irrigation on the Total Soluble Solids of Sweet Pepper Fruits during Storage ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	0.007	1	0.007	0.980	0.325
%ETc	0.048	2	0.024	3.340	0.042
Storage_Days	38.558	4	9.640	1334.710	<.001
Daytime. %ETc	0.016	2	0.008	1.120	0.332
Daytime.Storage_Days	0.006	4	0.002	0.220	0.929
%ETc.Storage_Days	0.158	8	0.020	2.740	0.012
Daytime. %ETc.Storage_Days	0.037	8	0.005	0.640	0.739
Residual	0.433	60	0.007		
Total	39.265	89			

The Effect of Irrigation Amount and Time of Irrigation on the Titratable Acids of Sweet Pepper Fruits during Storage ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	0.000	1	0.000	0.840	0.364
%ETc	0.008	2	0.004	87.350	<.001
Storage_Days	0.603	4	0.151	3157.480	<.001
Daytime. %ETc	0.000	2	0.000	0.280	0.757
Daytime.Storage_Days	0.000	4	0.000	1.130	0.352
%ETc.Storage_Days	0.017	8	0.002	45.690	<.001
Daytime. %ETc.Storage_Days	0.000	8	0.000	0.130	0.997
Residual	0.003	60	0.000		
Total	0.632	89			

The Effect of Irrigation Amount and Time of Irrigation on the pH of Sweet Pepper Fruits during Storage (p < 0.05)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	0.000	1	0.000	0.100	0.756
%ETc	0.014	2	0.007	1.490	0.234
Storage_Days	1.894	4	0.473	103.930	0.001
Daytime. %ETc	0.018	2	0.009	1.930	0.155
Daytime.Storage_Days	0.013	4	0.003	0.710	0.590
%ETc.Storage_Days	0.008	8	0.001	0.210	0.989
Daytime. %ETc.Storage_Days	0.066	8	0.008	1.800	0.094
Residual	0.273	60	0.005		
Total	2.285	89			

The Effect of Irrigation Amount and Time of Irrigation on the Weight Loss of Sweet Pepper Fruits during Storage ($p < 0.05$)

	Sum of Squares	Df	Mean Sum of Squares	F	Sig.
Daytime	1116.14	2.00	558.07	526.26	<.001
%Etc	187.25	3.00	62.42	58.86	<.001
Daytime. %ETc	0.16	1.00	0.16	0.15	0.71
Residual	12.73	12.00	1.06	0.98	
Storage days	21111.00	3.00	7037.00	6512.01	<.001
Storage days. Daytime		635.06	6.00	105.84	97.95
Storage days. % Etc	42.54	9.00	4.73	4.37	0.00
Storage days. Daytime. % Etc	3.42	3.00	1.14	1.05	0.36
Residual	38.90	36.00	1.08		

APPENDIX B

Pictures from The Project Site

Figure 10: Sweet pepper plants at the initial growth stage (14DAT).

Figure 11: Sweet pepper crops at the late growth stage (71DAT)