GROWTH, YIELD AND CONSUMER ACCEPTANCE OF SWEET PEPPER (*Capsicum annuum* L) AS INFLUENCED BY OPEN FIELD AND GREENHOUSE PRODUCTION SYSTEMS

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MPHIL CROP SCIENCE DEGREE.

COLLEGE OF BASIC AND APPLIED SCIENCE

DEPARTMENT OF CROP SCIENCE

SCHOOL OF AGRICULTURE

UNIVERSITY OF GHANA

LEGON

JULY, 2015

DECLARATION

This work is the results of research undertaken by Martey Abraham towards the award of the Master of Philosophy degree in the department of Crop Science, university of Ghana and that this work has neither in the whole nor in part been presented for an award of degree elsewhere.

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ABSTRACT

The rapid population increase and land scarcity calls for an alternative means of production system for sustenance of the human race. This prompted an investigation into the growth, yield and consumer acceptance of sweet pepper (*Capsicum anuum* L) as influenced by open field and greenhouse production systems at the University of Ghana Forest and Horticultural Crops Research Centre, Okumaning – Kade in the Eastern Region of Ghana. The experiment was conducted in the minor season (dry season) from October 2014 to March 2015.

A 2x9 factorial was laid out in Randomized Complete Block Design with three replications. The experiment consisted of two production systems (greenhouse and open field) and nine varieties of sweet pepper (California Wonder- CW, Yolo Wonder -YW, Kulkukan- KK, F1 Nobile- FN, Crusader- CS, Guardian-GD, Embella 733- EM and Caribbean Red- CR, Pepper 1-P1). Growth indices (plant height, girth, leaf number, biomass dry weight and chlorophyll content) and yield components (fruit length, width, seed number, fruit number per plant fruit weight) of sweet pepper plant were ascertained. It was done to elucidate the difference of growth and development among the varieties as well as their consumer acceptance with regard to greenhouse and open field production systems.

The results obtained indicated that, the greenhouse system significantly affected the growth and yield parameters. Crusader-CS, Kulkukan- KK and California Wonder- CW, significantly had a higher, growth, development and fruit yield enhanced in the greenhouse; California- CW and Crusader- CS also responded significantly in the open

field with Yolo Wonder attaining higher net returns. Results also demonstrated that the greenhouse varieties were highly preferred and accepted by consumers than the open field and this may be attributed to its higher quality.

DEDICATION

To the glory of God I consecrate this thesis to my mother Patience Asante for single handedly sustaining my education and my beloved daughter Paula Martey Abrahams.

ACKNOWLEGEMENTS

Glory is to God for His mercy, grace as well as protection throughout the years of my study. Thank you God for your mercies endures forever. I therefore express my sincerest appreciation to my supervisors Prof. G.O Nkansah Research Scientist at Forest and Horticultural Crops Research Centre (FOHCREC) and Prof. J.C. Norman Lecturer in the Department of Crop Science, University of Ghana for their supervision, useful propositions and assistance throughout the research.

I, therefore, express my profound gratitude to my mother Patience Asante for her support financially, emotionally and morally. My siblings: Dennis, Sarah, Eunice and Theresa all of Martey family I also appreciate your financial support and prayers throughout my studies. I say may God bless you all. My profound thankfulness also goes to my Uncles Mr. Gerald Asare Mantey, Assistant Agric officer, PPRSD- Accra and Mr. Emmanuel Larbi, Research Agronomist at OPRI-Kade for their sustenance in diverse ways, not forgetting my bosom friends: Anenya Isaac, Twumasi Dankwa, Asare Evans and Comfort Arthur for their care and love.

I harmoniously thank all the staff and people of Forest and Horticultural Crops Research Centre (FOHCREC), Kade for their pieces of advice and support more exclusively the Research assistants: Kenneth, Ayarna and Musah. To YOU Mr. Asante of University of Ghana crop Science Department, I say Ayekoo for your help.

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LIST OF ABBREVIATIONS

CEC	Cation Exchange Capacity
EC	Electrical Conductivity
DAT	Days after transplanting
FAO	Food and Agriculture Organization
FOHCREC	Forest and Horticultural Research Center
Min	Minimum
Max	Maximum
PS	Production System
WAT	weeks after transplanting

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Sweet pepper (*Capsicum annum* L.) belongs to the family Solanaceae, which is an important group of vegetables grown extensively and also widely cultivated in almost every country of the world (Channabasavanna and Setty, 2000). It thrives best in warm climate, where frost is not a problem during the growing seasons. In general, it requires temperatures ranging from 25-35 °C (Olalla and Valero, 1994). The sweet pepper of commerce also known as Bell pepper (Sinnadurai 1992), is one of the most varied and widely used foods in the world; it originated in Mexico and Central America regions and Christopher Columbus encountered it in 1493 (Kelley and Boyhan 2009). Sweet pepper is the world's second most important vegetable after tomato (Anon, 1989). It is one of the most important vegetable grown in other parts of sub-humid and semi-arid tropics (Aliyu, 2000)

FAO (1992) reported that, 10 million metric tons of fresh peppers were produced on 1.1million hectares of land which ranked pepper in the middle range of vegetables in terms of popularity. In 2007, over 26 million metric tons of pepper was produced globally (U.S. Dept. of Agriculture, 2008a). China ranked first, producing more than 50% of the world's pepper, while the United States (U.S.) ranked sixth with about 855,000 metric tons produce (U.S. Dept. of Agriculture, 2008a).

The fruits of sweet pepper are harvested either at green mature stage or at colouring stage and are a very good source of vitamin A and C and other nutrients having great demand in big cities and other urban areas of the country. One medium green bell pepper can provide up to 8 percent of the recommended daily allowance of Vitamin A, 180 percent of Vitamin C, 2 percent of calcium and 2 percent of iron (Kelley and Boyhan, 2009). Sweet pepper contributes substantially to our diet, it is a good source of vitamins A, C (More than that obtained from tomato), E, B1, B2, and D (Muhamman and Auwalu, 2009). A phenolic compound called capsaicin is responsible for the pungency in peppers. Pepper is grown as an annual crop due to its sensitivity to frost and is actually herbaceous perennial and will survive and yield for several years in tropical climates (Peet, 1995; Kelley and Boyhan, 2009).

According to Norman (1992), the growing of sweet pepper in West Africa is confined to urban centers but recently large scale or commercial productions has been undertaken under irrigation in the rural areas. It is very vulnerable to frost and grows poorly at temperatures between 5 and 15 °C (Bosland & Votava, 1999). The optimum temperature range for sweet pepper growth is 20 to 25 °C. There are several factors that influence the growth and yield of pepper, some of which include temperature, relative humidity, day length, photoperiod etc. Along with other factors which affect the per unit area production like nutrition, cultivar, growing system and soil fertility, plant density has its significance (Agarwal *et al*., 2007). Plant densities and arrangements in the open field strongly decide the utilization of intercepted solar radiation mainly due to leaf area index.

It is therefore imperative to note that green pepper in Ghana is suited for most of the ecological zones with good climatic and edaphic parameters to support it growth in the open-field cultivations whereas greenhouse technologies enable the cultivation of a large number of species in a specific geographic area. In a controlled environment, climatic conditions are optimal for certain species, regardless of the external environment (FAO 2013). Greenhouses increase crop yields by as much as four to ten times as plants grown under open field conditions; the quality of the product is normally higher than open field and the dependency on chemicals is drastically reduced. The main reasons for increased yields lie in the nature of the growing environment as well as the genetics of some greenhouse varieties. Cultivation in the open field also tend to be much easier and less costly hence production of fresh vegetables by numerous people in this system of production. In Israel, for instance, research is usually carried out in fully climate controlled greenhouse (http://www.arc-avrdc.org/pdf_files/Some(17-N).pdf Greenhouses have been utilized in Europe, U.S.A, Canada and several other countries for many decades for improved yields (Wiltshire, 2007) and this can also be incorporated into our environment.

In agriculture, quality determination of produce is based on a multitude of features (Dull, 1986): flavour (sweetness, acidity); appearance (colour, size, shape, blemishes, glossiness); and texture (firmness, mouth feel). These features may be influenced by the system of production since crops are exposed to varied external environmental conditions.

There are many vegetable crops including pepper that are adapted in all parts of West Africa of which Ghana is no exception. Pepper in Ghana, for instance, is grown in all the ecological zones of the country; coastal savanna, rain forest up to the guinea savanna zones in the open field and green house technology is only applicable in the research stations and the few well established farms have adopted for production of various vegetables. For each of these systems of production there are little or no records to ascertain the growth, yield and preference or the choice acceptable by the consumer.

There are climatic conditions such as prevailing high and low temperatures, energy, high or low rainfall, waterlogging, higher relative humidity and strong winds that are limiting factors for growing sweet pepper under open field. In the green house when the growth parameters are not properly regulated and these may affect the quality of fruit produced which intends to affect consumer demands and acceptance. The fruit set of pepper is greatly influenced by humidity and temperature. Low humidity and high temperatures results in poor fruit set due to dropping of flower buds, flowers and small fruits caused by their abscission because of their excessive transpiration, also night temperatures below 15.6 °C and above 32.2° C prevent fruit set (Norman (1992). According to Sinnadurai (1992), sweet pepper requires milder climate for good production unlike hot pepper that requires high temperatures and very hot weather decreases flower initiation and this affects the fruit yield. Flower production is significantly increased when the night temperatures during the growing season is between 12-21°C and fruits also develops sun scalds when grown in the dry season in the open field.

Adopting ways of increasing production of green pepper has brought to the light the use of controlled environment (green houses, poly houses etc). The greenhouse systems are important since they can be used all year round to increased yield even in the lean seasons. Nevertheless, export and local market both demand high quality sorted fruits and vegetables, which preserve their fresh condition on the market. Additionally, there is an increased demand for fruits and vegetables that are beneficial for healthy life style as well as rich in ingredients that positively influence the prevention of any health malfunction. Since most of the agricultural products changes of inner content and outer properties after harvesting, therefore, it is crucial to determine the optimal production system that may enhance quality and acceptability of fruit by consumers or end users.

To make pepper cultivation successful and accepted by consumer's different systems of production must be tested. Chandra *et al*. (2000) and Singh *et al.*2004 and (2010) indicated that polyhouses, poly-tunnels and plastic-mulching are most suitable solutions for yield increase of sweet pepper. Protected structures act as physical barrier and play a key role in integrated pest management by preventing spreading of insects, pests and viruses causing severe damage to the crop (Singh *et al*. 2003).

It is therefore imperative to note that about 95% of plants, either food crops or cash crops are grown in open field. Since time immemorial, man has learnt how to grow plants under natural environmental conditions. In some of the regions where the climatic conditions are extremely adverse and no crops can be grown, greenhouse technology is the technique of providing favourable environment condition to the plants; it is rather used to protect the plants from the adverse climatic conditions such as wind, cold, precipitation, excessive radiation, extreme temperature, insects and diseases. According to Wiltshire, (2007) greenhouses increase crop yields by as much as 4 to 10 times compared with plants grown under open field conditions. The quality of the produce from greenhouse is normally higher than open field and the dependency on chemicals is drastically reduced and this is brought about by the nature of the growing environment as well as the genetics or the type of varieties cultivated. Yield of crops may differ from the cultivar or variety used.

Therefore, it is imperative to note that, very limited information is available for growing sweet pepper through protected technology or green house and on the open field in Ghana; hence the study was conducted to make information available on the former and latter production systems as well as their acceptance by consumers.

1.2 Objectives of the study

- The study was conducted with **Main objective**;

Determining consumer acceptance of sweet pepper grown under greenhouse and open field production systems.

- **Specific objectives**

I. To determine optimum growth and yield of pepper as influenced by open field production system

II. To determine optimum growth and yield of pepper as influenced greenhouse production system

III. To determine the varieties that perform well under greenhouse and open field conditions

IV. To determine the interaction between the production systems and varieties on growth, yield and consumer acceptance of sweet pepper

CHAPTER TWO

LITERATURE REVIEW

2.0 Production of sweet pepper in Ghana and world

Bell peppers (*Capsicum* annum L.), belongs to the family Solanaceae and is one of the most varied and widely used vegetables in the world; it originated in the Mexico and Central America regions and Christopher Columbus encountered it in 1493 (Kelley and Boyhan, 2009). According to Bosland and Votava (2000), pepper production has increased in recent years worldwide and this could be attributed partly to its high nutritional significance. A greenhouse production system of peppers varies greatly from the traditional open field pepper cultivation system where plants are grown on beds and with drip irrigation, and where fruits are harvested at the mature green stage for utilization. To satisfy consumers demand, Mexico, Netherlands, Canada, Israel, and Spain have been using greenhouse technology for peppers production (http://www.hos.ufl.edu/ProtectedAg).

In 2007, over 26 million metric tons of peppers were produced globally (U.S. Dept. of Agriculture, 2008a). China ranked first, producing more than 50% of the world's peppers, while the United States (U.S.) ranked sixth with about 855,000 metric tons produced (U.S. Dept. of Agriculture, 2008a) but in West Africa peppers are cultivated in the open field which is rain dependent. A greenhouse production system of peppers differs greatly from the traditional field pepper cultivation system where plants are grown on a protected closure such as polyethylene-mulched beds and with drip irrigation, and where fruits are typically harvested at the mature green stage of development (http://www.hos.ufl.edu/ProtectedAg). In Ghana sweet pepper is produced in the open field where crops are exposed to diverse adverse environmental conditions.

2.1 Economic importance of sweet pepper

Sweet pepper and is one of the most popular and highly priced annual herbaceous vegetable crops in Ghana. The crop has helped in poverty alleviation by those engage in the business through the sale of the fruit on the local market and export, which has therefore increased the farmer's income. Sweet pepper consumption in Ghana is growing recently because of increasing demand by urban consumers. There is a good demand for export more especially to the European market that earns the country with foreign exchange. West African countries such as Mali, Burkina Faso, Chad, Guinea, Niger and Senegal etc., majority of pepper and other vegetable fields are located in rural communities and exploited mainly a by male smallholder farmer which provides employment for the producers (AVRDC, 2008) and on the other hand, women are the main marketers, processers, buyers, and users of these products (Yaméogo *et al*., 2002).it is observed that over 25 percent of the world's population consumes and utilizes peppers every day (Namiki, 1990). Production systems have been developed for growing colored peppers with minimal use of pesticides in soil-less culture, (http://www.hos.ufl.edu/ProtectedAg).

2.2 Nutritional Benefit of sweet pepper

Bell peppers, among vegetables, have become exceptionally popular for the abundance and the kind of antioxidants they contain. These compounds levels vary strongly during growth and maturation and are also imperative because of their contribution to pungency, bitterness, colour and flavour of fruits (Estrada *et al*., 2000). According to Howard *et al*, (1994), pepper fruits are being a major source of natural colours and antioxidant compounds for food preservations. The compounds found in pepper is an important health defensive factor; they have been recognized as being useful for inhibition of widespread human diseases, such as, cancer and cardiovascular diseases when taken in adequate amounts (Brainley, 2000).

Nadeem *et al* 2011 reported that, red peppers comprise of moderate to high levels of neutral phenolics or flavonoids, namely quercetin, luteolin and capsaicinoids and which include β-carotene with pro-vitamin A activity and oxygenated carotenoids such as capsanthin, capsorubin and cryptocapsin, (Estrada *et al*., 2000). Table 1 below depicts the nutritional composition of sweet pepper.

2.3 Influence of temperature and Relative humidity on the growth of sweet pepper

Bosland & Votava, (1999), indicated that Pepper seed emergence is slow if sown too early when soil temperatures are still too low, but seedling germination accelerates as temperatures increase to between 24 and 30 °C Low temperatures also minimizes seedling growth, which leads to prolonged seedling exposure to insects, diseases, salt or soil crusting, any of which can rigorously harm off the seedlings. On the other hand, the optimum temperature range for sweet pepper growth is 20 to 25 °C (Anon, 2000). Persistent high relative humidity and temperatures above 35 °C moderate fruit set. Fruit that is formed during high-temperature conditions is normally malformed. Sweet peppers are likewise very sensitive to sunscald especially under higher temperatures (Coertze & Kistner, 1994a) but Erickson & Markhart, (2002), found that when flowers are exposed to extreme temperatures as 33 °C for lengthier than 120 hours leads to flower abscission and reduced yields. Pollen exposed to high temperatures greater than 33 °C normally becomes non-viable and appears to be deformed, empty and clumped. Ashilenje, 2013, also stated temperature also affects fruit quality; best fruit colour is realized at temperatures from 18°C to 24°C. At temperatures below 13°C colour ceases to form. Night temperatures above 22°C lead to poor fruit set.

2.4 The significance of greenhouse for sweet pepper cultivation

There is increasing demand for yearlong stock of fresh vegetables and the necessity of plant protection techniques; therefore, the use of protective housing (insect-proof net houses and greenhouses) for cropping systems has gained global importance. As a result of this, Gruda (2005) revealed that protected cultivation is particularly important for the production and sustainability of fresh vegetables for its demand.

Depending on the climatology of an area and the season of crop production, greenhouses can be a means to economically maintain a warm environment during the adverse conditions such as cool seasons, to protect pepper plants from rain, wind, and high solar radiation, and to retain pollinators and beneficial insects while excluding unwanted insect pests.

Sweet peppers are grown in green houses for high quality fruits during an extended period (Jovicich *et al.*, 2003). Sweet peppers are grown in most countries of the world, with the Netherlands being the world leader in intensive greenhouse sweet pepper production (Bosland and Votava, 1999). Vegetables are important source of food and nutrition and thus provision of income as well to the producer moreover, a prolonged wet season and high rainfall intensities have negative effects on yield and quality of fruits (Arya and Pulver 1993). Research has shown that chemicals are easily washed off where rainfall amounts and frequencies are high which enhances frequent application of insecticide which is additional cost to the farmer (Smith *et al*, 1993).

Hall and Pulver, (1994) found that soil and groundwater pollution is high when crops are exposed to external growth conditions. To increase productivity and make its cultivation successful, green houses (polyhouses, poly-tunnels and plastic-mulching) are most suitable solutions (Chandra *et al*. 2000 and Singh *et al.*, 2004 and 2010). Another research by Singh *et al*. (2003) revealed that protected structures act as physical barrier and play a key role in integrated pest management by preventing the spreading of insects, pests and viruses and other disease causing pathogens that causes severe damage to the crop.

2.5 Effects of temperature on sweet pepper production

The effects of mean daily air temperature on the growth rate of horticultural plants are well acknowledged in literature (Ellis *et al*., 1990; Seginer *et al*., 1994). Peppers are mostly a warm season crop and require a long season for maximum production. Temperature has a great influence on the rate of growth of the plants; temperature also affects the growth, development and quality of the pigments of the fruits. (http://www.ipm.ucdavis.edu/PMG) Different day and night temperatures do not certainly have exactly the same effect on plant growth (Seginer *et al*., 1994). In general it requires temperature, ranging 25-35 ºC. For instance, Bakker and Uffelen, (1988), stated that plant growth, expressed as dry weight, leaf area or stem elongation, reaches a maximum in the range of 21 to 23°C in vegetative sweet pepper but according to Wien, (1997) and Rubatzky and Yamaguchi, (1999) the optimal temperature range for pepper is between 20 to 25 °C for sweet pepper.

The optimum temperature favourable for growth of sweet pepper ranges between 20 and 25°C. When temperature falls below 15°C or exceeds 32°C, growth is usually retarded and yield decreases. Shaked *et al*.,(2004) and Saha *et al* (2010), found that at temperatures below 10 °C fruit size decreases due to inefficient pollination and fertilization which causes a reduction in fruit length.

It has been noted that, Peppers are a warm-season crop that grow best between temperatures of 21.1°C to 23.9°C (Aloni *et al*., 1999). The crop is sensitive to extreme temperatures. Reduced fruit set and blossom drop can be probable when night temperatures drop below 15.6 or day temperatures rise above 29.4°C and these reduces yield, (Virginia Agricultural Statistics Bulletin 2001). The growth and size of sweet pepper fruits are normally affected by air temperature, daylight and relative humidity (RH) during anthesis, fruit set, development and maturation, as well as by plant growth (Jovicich *et al*., 2004).

2.6 Green house pepper production

A green house or glass house is a building or complex in which plants are grown. A miniature green house is known as cold frame. Greenhouses are permanent structures that have metal or wood structural supports, roof and sides made of glass, plastic and/or mesh netting and a structural design that allows for either active or passive ventilation. There are three main plant-house types currently in use. In modern agricultural technologies introduced constructions that can be divided into 3 main groups: Net-houses (screen-house), Tunnels (traditional Egyptian house) and fully controlled greenhouses (Critten and Bailey, 2002).

They are built to create a protective shell around a crop in which: i. Environmental extremes can be avoided leading to growing season extension and uninterrupted labour; ii. Yield per unit area of land and produce quality can be increased by creating a protected, intensive, high-density and high-efficiency crop growing environment, which is advantageous as our rising population and urbanization limits suitable agricultural land; iii Inputs such as water, fertilizer and pest control products can be precisely applied, controlled, contained, recycled and adjusted according to plant demands, resulting in reduction of waste and conservation of resources and money; and iv. there is an opportunity and flexibility to produce specialty crops, on a small or large scale, during non-peak production times, using a variety of different systems and materials and thus earn premium prices in the absence of market competition (Beyer, 2012).

Greenhouse pepper season length is 10-11 months from seeding and weekly harvests sweet pepper continue for a period of up to 6-7 months. All peppers start out green and gradually mature to typically a red, orange or yellow color. Consumer demand for colored sweet peppers has increased their market price by almost two times that of green pepper (Cantliffe *et al*., 2008; Jovicich *et al*., 2005).

2.7 Open field Sweet pepper production

Mostly sweet peppers cultivated in the tropics are grown in the open field with only few greenhouses found in the Agricultural Research Centers and few farmers who can afford. Peppers are traditionally grown in the field, and in the Southeast, they are typically grown on plastic mulched beds and irrigated through sub surface or drip irrigation systems (Olson and Santos, 2013). Beyer (2012), reported that, field-grown peppers are typically determinate cultivars, where the plants grow to a certain size, produce fruit and senesce, with a season length of about 5-6 months from seeding and one to three harvests of mature green peppers for a period of approximately one month. According to Smither-Kopperl and Cantliffe, (2004), field production in Florida is heavily dependant upon the use of the soil fumigant methyl bromide to control soil-borne pathogens, plant parasitic nematodes and weeds.

2.8 Comparism of green pepper grown under greenhouse and open field

Pepper is grown as an annual crop and is actually an herbaceous perennial that's survives and yield for several years in the hot and humid tropical climates (Peet, 1995; Kelley and Boyhan, 2009). Jovicich, (2005) found that greenhouse production system of peppers varies greatly from the open field pepper production system. These crops are grown under polyethylene-mulched beds green house with drip irrigation, and where fruits are typically harvested at the mature green stage of development. On the other hand, crops grown in the open are subjected to heavy rain, strong wind, and high solar radiation, high temperature and unstable humidity and insect pest attack since they are not protected. Pepper fruits grown in green house are harvested with full maturation colour with high yields and even high fruit quality. Crop can be cultivated in the green house all year round as compared to the open field as a result of weather variations.

According to Wiltshire, (2007), greenhouses doubles yields of crops by as much as 4 to 10 times than crops grown under open field conditions, their quality product makes it unique than open field and the dependency on chemicals is considerably reduced. Eversole (1999) and Johnson, (1999a), found that improved plant densities and longer growing seasons have enhanced greenhouse vegetable production and hence, increased yields than open field-grown crops.

Moreover, controlled environment or greenhouses provide favourable or appropriate environmental conditions to produce reliable, higher quality fruits that bring higher returns at the market than the open field-grown produce (Johnson, 1999b). Compared to the field, sweet peppers grown in the greenhouse are typically indeterminate cultivars, where the plants continually develop and grow from new meristems that produce new stems, leaves, flowers and fruit (Beyer 2012).

2.9 Consumer acceptability of greenhouse produce

Production of vegetables to meet the increasing demand of fresh vegetables for both local and export market is limited and these have been boosted by the introduction of greenhouse that has enhanced productivity. All over the world fruits produced from greenhouses are of high quality and accepted by consumers. For instance, peppers grown in most countries of the world, shows that, Netherlands is world leader in intensive greenhouse sweet pepper cultivation. This implies that consumer acceptability of greenhouse grown sweet pepper is high (Bosland and Votava, 1999).

Jovicich *et al*, (2004), revealed that in the US, the consumption of high quality green pepper types (red, yellow, and orange bell peppers) has improved intensely in the past decade. To satisfy consumers demand, countries such as Mexico, The Netherlands, Canada, Israel, and Spain have been exporting high-quality greenhouse-grown peppers into the U.S.

Jovicich *et al*, 2004 also stated that in Florida an averaged year-round wholesale fruit prices went up three 3 times greater than coloured field-grown fruits and 5 times greater than field-grown green fruits. Florida's greenhouse industry profits from growing plants and producing fruits under a relatively optimal plant environment during much of the year.

Green houses are noted for their numerous advantages; yields per acre up to ten times greater than field grown, quality of fruit is increased, Incidence of most fungal diseases is reduced, Incidence of bacterial diseases is reduced, Insect vectored viruses are not a problem in screened greenhouses, Fruit can be produced and marketed as pesticide-free which makes it more attractive to the consumer. (http://www.hos.ufl.edu/ProtectedAg). Smither-Kopperl and Cantliffe (2004), found that, consumers are prepared to pay more for greenhouse-grown sweet peppers, due to their high quality and seasonal availability. Moreso, USDA, (2005c), revealed that from 1998 to (2005), coloured greenhouse-grown bell peppers from Israel received double the average price ($2.08/lb) of Mexico's ($1.04/lb) colored field peppers. Greenhouse-grown colored bell peppers in Mexico receive a 60% premium ($1.66/lb) over field bell peppers ($1.04/lb) from Mexico which implies that consumers accept greenhouse grown peppers.

Abbott (1999) stated that the quality of the product is determined by the following attributes: colour, shape, size, and being without fault, damage or signs of sickness moreover, taste, texture, firmness, weight, internal chemical composition. Furthermore the product quality depends on the preferences and requirements of the consumers.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted during the minor cropping season of 2015 on the University of Ghana Forest and Horticultural Crops Research Centre (FOHCREC) at Kade in the Eastern Region of Ghana. The Centre lies on latitude 6º 09 and 6º 06 N and longitude 0º 55 and 0º 49 W and 135.9 m above sea level. It is located in the semi-deciduous forest agro-ecological zone of Ghana in the Kwaebibrim District. Brammer, (1962) and Owusu-Benoah *et al*., (2000) revealed that the soils of the experimental site have good drainage and they are classified as the forest Ochrosol Great Soil by the Ghanaian soil classification system.

3.1.1 Soil characteristics of the experimental site

Soil samples were collected from the trial field before layout of the experiment for the determination of the soil properties. These were to determine the initial soil chemical and physical properties from the experimental field. Table 3.1 below depicts the characteristics of the soil

Table 3.1 Initial soil chemical and physical properties from the production sites

S/N	Property	Value - Open field	Value -Greenhouse
1	Texture	Sandy clay loam	Sandy clay loam
2	Sand 9%)	52.1	41.45
3	Silt (%)	25.9	29.92
4	Clay (%)	22.0	27.10
5	pH	6.3	5.10
6	Total nitrogen (%)	0.6	0.13
7	Available phosphorus (mg/kg)	7.74	10.18
8	Available potassium (cm/kg)	0.6	0.54
9	Organic carbon	2.26	1.53
10	Electrical conductivity (ds/m)	0.73	0.61

3.1.2 Climatic Conditions

Kwaebibirim is noted for bimodal rainfall pattern with two peaks that is major and minor rainfall. Below are the average relative humidity and temperature recorded during the growth period. Table 3.2 below shows the temperature and relative humidity recorded during the growing period of the crop. The maximum and minimum temperatures were recorded as well as the relative humidity. The maximum temperature recorded in the open field was 34.80 °C with a minimum of 22.54 °C and it was also noted that maximum temperature of 33.61 °C and minimum temperature of 32.99 was recorded in the greenhouse. The maximum Relative humidity recorded in the greenhouse was 81% and January recorded the minimum Relative Humidity 49 .82 but in the open field maximum relative humidity of 99.43 was found and a minimum relative humidity of 39. 52 were recorded in the month of January.

Table 3.2 The mean temperature and relative humidity values on growth parameters of sweet pepper

Open Field					Green house			
Month	Mean Temp. Max °C	Mean Temp Min °C	Mean RH Max %	Mean RH Min %	Mean Temp. Max °C	Mean Temp. Min °C	Mean RH Min %	Mean RH Max %
January	34.40	23.51	94.98	39.52	39.1	20.81	49.82	90.00
February	34.57	22.79	99.11	45.15	33.61	16.8	51.08	81.00
March	34.57	22.54	98.64	46.19	33.04	20.64	52.70	81.00
April	34.80	22.60	99.43	47.75	32.99	21.01	52.91	81.00

SOURCE: FOHCREC, OKUMNING VIA KADE (2014) *RH- Relative Humidity

3.2 Experimental Design

The trial was conducted in the greenhouse and open field simultaneously; therefore, this experiment was conducted in the minor season, from October, 2014 to March, 2015. A 2×9 factorial experiment was laid out in Randomized Complete Block Design with 18 treatments in three (3) replications. The two factors involved in the trial included, two (2) production systems; open field and green house production systems and nine (9) varieties of sweet pepper (California Wonder- CW, Yolo wonder-YW, Guardian pepper – GD, Embella 733-EM, F1 Nobili- FN, Pepper 1- P1, Caribbean red - CR, Kulkukan – KK and Crusader- CS).

3.3 Source of seed and planting.

The seeds for the trial were obtained from East-West Seeds Company. Others varieties were also purchased from Agriseed shop located in Accra. Percentage seed germination was above 85%.

3.4. Agronomic practices

3.4.1 Land preparation

In the open field, it was sprayed with sunphosate (Glyphosate herbicide) at a rate a.i of 150ml/15L Knapsack sprayer. At two weeks after spraying, the field was demarcated into blocks and plots.

3.4.2 Raising of nursery

The seedlings were raised at the green house. The seeds were sown in seed trays of 120 cells per seed tray. The seed trays were filled with carbonated rice husk (Biochar). A 19-19-19 N-P-K foliar fertilizer was applied 2 weeks after germination at the rate of 10g per 1litre of water to seedlings to boost growth.

3.4.3 Transplanting of seedlings

Seedlings were transplanted at 6 weeks after sowing, at 5-6 true leaf stage; transplants were dipped into starter solution to facilitate root formation and early establishment. Seedlings were transplanted out simultaneously on the open field and the green house on 26th December, 2015 at planting distance of 30cm within rows and 40 cm between rows per bed. Distance between beds was 1 m.

3.4.4 Irrigation

Plants were irrigated in the greenhouse using the loop system which is part of the environdome greenhouse setup. In the open field system, supplementary hand watering (1 liter per plant) was applied fortnightly to maintain moisture throughout the growth period.

3.4.5 Fertilizer application

Application of 19-19-19 N-P-K fertilizer at the rate of 100g per knapsack sprayer was applied at the initial phase of the crop (1 WAT) to enhance growth of the crops. At the reproductive growth phase, multi K (potassium containing fertilizer) was applied at two weeks interval at the rate of 100g per knapsack with EC of 2.0 and pH of 6.8 respectively.

3.4.6 Crop protection

Various pests including, white flies, grasshoppers, ants, etc. that attacked the crops were controlled as and when needed using an insecticide (Cydim Super- trade name) at the rate of 35 ml /15L knapsack sprayed fortnightly to reduce the pest damage at both locations.

3.4.7 Weed management operations

Integrated Weed Management (IWM) approach was used to check weeds on the various plots to keep crops free from weeds competition for growth resources. This comprised Chemical usage; pre emergence herbicides, cultural methods; hand picking and hoeing and biological method; canopy spread to smoother weeds in both location

3.5 Data collection

Data were collected on the following parameters: growth parameters, yield parameters and acceptability test.

3.5.1 Temperature and relative humidity

Daily minimum and maximum temperature and relative humidity were recorded using a thermo hydro meter throughout the experiment period. Throughout the growing period, the greenhouse polyethylene side curtains were manually lowered when air temperatures were low (less than 20°C) and covered when air temperatures were high (above 28°C).

3.5.2 Growth parameters

For all parameters measured 5 plants per hill were randomly tagged and selected in each treatment plot for recording growth parameters and the averages of the observations on these 5 plants were recorded.

3.5.2.1 Plant Height

The height of the plants was measured using meter rule from the base of the plant to the tip of the apical leaf.

3.5.2.2 Stem Diameter

The stem diameter or girth was measured at the base of the plant using a pair of Vernier caliper at 1 cm above the ground

3.5.2.3 Number of Leaves per plants

The total numbers of leaves per plant was determined by counting all fully opened leaves on the plants leaving the bud primordial at the shoot apex.

3.5.2.4 Number of branches per plant

The total number of branches per each plant was pruned to two each on each branching point which gave a uniform branching on each plant.

3.5.2.5 Chlorophyll Content

Chlorophyll content of leaves was determined and expressed as Chlorophyll Concentration Index – CCI (Bajracharya, 1999), using the chlorophyll meter. These readings were done both at the vegetative and reproductive growth phases of the plant.

3.5.2.6 Days to 50% flowering

The time taken for half of the plant per plots to flower was recorded. This was done by visual observation on all the plots.

3.5.2.7 Biomass dry weight

The average weight were considered for the freshly harvested plants per replicate and plot and then dried in an oven at 70ºC for 72 hours. This was done both at the vegetative and reproductive growth stage of the plant. For the determination of % biomass dry weight was given:

$$Dry\ weight\ (\%) = \frac{Fresh\ weight - Dry\ weight}{Dry\ weight} \times 100$$

3.6. Yield and yield components

Five plants per hill were randomly tagged and selected in each treatment plot for data collection

3.6.1. Number of fruits per plants

A fruit per each plant was counted and recorded to ascertain the total number of fruit per plants.

3.6.2 Fruit Yield (t/ha)

This was calculated by multiplying the weight of the fruits (kg) by the plant population per hectare and dividing it by 1000 to covert to tonnes (t/ha).

3.6.3 Fruit Length

Ten fruits were selected at the second harvest and the lengths of the fruits were measured using a digital caliper. The mean lengths were then recorded, (IPGRI, 1995)

3.6.4 Fruit Width

Ten fruits were selected at the second harvest and the widths of the fruits were measured using a digital caliper. The mean width were then recorded (IPGRI, 1995)

3.6.5 Pericarp thickness

Ten fruits were selected and cut cross sectionally and the pericarp thickness recorded in millimeters (mm) using digital calipers. The mean thickness of pericarp recorded.

3.6.6 Number of Locules

Ten (10) fruits were selected and a cross sectional cut was made and the locules were counted and the mean number recorded.

3.6.7 Seed number

Ten (10) fruits were selected at the second harvest and the total number of seeds counted and the average seed number recorded.

3.6.8 Consumer Acceptability test

A five member untrained panel assessed the acceptance level of the fruits of the sweet pepper based on the following rankings from 1-9 on Texture, Absence of defects, brightness, size and glossiness as stated by Aoun *et al*, 2013.

- **Acceptability Chart**

1 = very poor quality

2 = Poor quality

3 = Moderate quality

4 = Moderate to strong quality

5 = Strong quality

6 = Strong to very strong quality

7 = Very strong quality

8 = Very strong to extremely strong quality

9 = Extreme excellent quality

Also, fruits were sold in an open market in the Kwaebibirim district of Eastern Region and Accra municipality in the Greater Accra Region of Ghana to ascertain consumer preference of the sweet pepper fruits from the different growing environment (greenhouse and open field).

3.7 Statistical Analysis

The data obtained were subjected to analysis of variance i.e. ANOVA by using Genstat Discovery. Means were separated using Least Significant Difference (LSD) at 5%. Further analysis was done using correlation analysis and simple linear regression analysis.

CHAPTER FOUR

RESULTS

4.1 General observations

There was significant difference among all the treatment used under this study. However, it was observed that the seedlings were well established two weeks after transplanting and vigorous vegetative growth took place in both locations. The plants heights in the green house were taller compared to the open field. Disease and pest such as grasshopper, mosaic and white flies etc. were prevalent in the open field, thus, resulting to control mechanisms which therefore increased the cost of production and reduced market value of fruits. The greenhouse however influenced the plant height of all the varieties compared to the same varieties in the open field. There was flower and fruit drop occurrence in the open field because of the prevailing environmental conditions.

4.1.1 Sweet pepper plant growth indices (plant height Initial, 2, 4 and 6 WAT)

Table 2 shows effects of production systems on plant height of sweet pepper at initial stage (i.e. 2 DAT), 2, 4, and 6 WAT.

Initial plant height significantly ($p<0.05$) affected the height of the plant and significant difference was also observed in plant height at 2WAT, 4WAT and 6WAT respectively. The initial plant height of the various varieties revealed that, in the greenhouse the highest plant height variety was Crusader (13.6) and Guardian pepper (12.9). However, in the open field it was noted that plant height differed significantly ($p<0.05$) and Guardian pepper had the highest initial plant height (12.7) followed by the Caribbean Red (12.5) and Embella 733 as well recorded the shortest plant height (10.3). At 2 WAT the Crusader had the highest height (26.9) followed by the Guardian pepper (22.1) with CR recording shortest height while in the open field the highest height of the plant at 2 WAT was Kukulkan (19.2) followed by Crusader (18.5). At 4 WAT the highest height was Kukulkan and crusader (46.4) and 42.4 respectively whereas P1 recorded the shortest height, however, compared at 4 WAT in the open field Kukulkan recorded the highest height (32.6) followed by Crusader (28.2) with Yolo wonder which had the shortest height (20.2).

Also at the greenhouse at 6 WAT, Kukulkan had the highest height (93.7) followed by CR (65.7) with Embella 733 recording the shortest height and in the open field at 6 WAT KK recorded the highest height (43.9) and Crusader also followed with 38.9 whereas Pepper 1 (26.7) had shortest height. There was significant interaction among treatments at 6 WAT. The production systems showed that the height of plants was higher at the greenhouse compared to the height in the open field. There was no significant interaction between production systems and varieties at initial, 2 and 4 WAT but significant interactions was observed at 6 WAT

Table 4.1: Effects of production systems on plant height of sweet pepper varieties

Variety	**Initial plant height (cm)**		**Plant height 2 WAT(cm)**		**PH 4 WAT (cm)**		**PH 6 WAT (cm)**	
	Open Field	Green house	Open Field	Green house	Open Field	Green house	Open Field	Green house
Caribbean	12.5	8.6	16.7	15.2	24.5	34.7	33.5	65.7
Crusader	12.0	13.6	18.5	26.9	28.2	42.4	38.9	59.8
California	10.1	7.2	14.1	16.3	20.8	32.2	29.7	53.5
Embella	10.3	9.6	14.2	18.0	20.5	28.4	27.0	42.1
F1 Nobili	11.7	8.7	17.0	17.9	25.6	28.8	33.6	43.3
Guardian	12.7	12.9	16.1	22.1	23.4	29.7	32.0	45.6
Kukulkan	11.9	10.9	19.2	21.5	32.6	46.4	43.9	93.7
Pepper 1	11.5	10.6	14.0	18.7	20.5	28.9	26.7	44.5
Yolo	10.5	9.9	13.4	17.4	20.2	29.9	28.5	43.4
LSD(0.05)								
Var	**2.2**		**2.9**		**5.7**		**7.2**	
PS	**1.0**		**1.3**		**2.7**		**3.3**	
Var×PS	**3.1NS**		**4.1NS**		**8.1NS**		**9.9**	

4.1.2 Sweet pepper plant growth indices (Stem girth Initial, 2, 4 and 6 WAT)

Table 3 shows effects of production systems and varieties on stem girth of sweet pepper at initial stage (2 DAT), 2, 4, and 6 WAT

Significance differences were also observed in terms of stem diameter in both greenhouse and open field between at initial and at 6 WAT among varieties. In the greenhouse, the initial plant girth was significantly influenced. P1 had the thickest girth (0.38) followed by Embella 733 (0.36) but Caribbean Red and California Wonder both had the smallest plant girth (0.31). No significance differences were observed in stem girth at 2 and 4 WAT. There were no interaction among varieties and locations.

Table 4.2: Effects of production systems on stem girth of sweet pepper varieties

Variety	**Initial plant girth (cm)**		**Plant girth 2 WAT (cm)**		**Plant girth 4 WAT (cm)**		**Plant girth 6 WAT (cm)**	
	Open Field	Green house	Open Field	Green house	Open Field	Green house	Open Field	Green house
Caribbean	0.32	0.31	0.42	0.42	0.59	0.64	0.81	0.78
Crusader	0.37	0.37	0.49	0.51	0.66	0.72	0.85	0.94
California	0.32	0.31	0.45	0.46	0.67	0.65	0.88	0.79
Embella	0.34	0.36	0.50	0.51	0.69	0.66	0.85	0.79
F1 Nobili	0.34	0.32	0.46	0.43	0.66	0.66	0.84	0.79
Guardian	0.36	0.36	0.53	0.46	0.68	0.68	0.86	0.89
Kukulkan	0.32	0.34	0.46	0.44	0.62	0.72	0.89	1.00
Pepper I	0.38	0.38	0.47	0.49	0.63	0.65	0.79	0.83
Yolo W	0.34	0.35	0.47	0.47	0.62	0.70	0.80	0.76
LSD.05								
Var	**0.04**		**0.06NS**		**0.07NS**		**0.10**	
PS	**0.3NS**		**0.02 NS**		**0.03 NS**		**0.04 NS**	
Var× PS	**0.05 NS**		**0.09 NS**		**0.09 NS**		**0.14 NS**	

Var- Variety, PS- production system × Interaction

4.1.3 Sweet pepper plant growth indices (Number of leaves per plant)

High significant difference were observed among the treatments in terms of number of leaves both in the greenhouse and the open field at the 6 WAT where Kukulkan had the highest number of leaves (94.0) per plant followed by Caribbean Red (62.0). Embella 733 and FN had the lowest number of leaves (33.0 and 30.0) respectively in the greenhouse. In terms of open field, at 6 WAT highly significant difference was observed among treatment with both Kukulkan and Crusader recording the highest number of leaves (39.0) followed by Embella 733 (34.0) and Caribbean Red (33.0). California Wonder had the lowest leaves number (29.0) but no significant difference were observed at initial, 2 WAT and 4 WAT both in the greenhouse and the open field. Table 4.3 shows that there was interaction between production system and variety both at 4 and 6 WAT.

Table 4.3 Effects of production systems on number of leaves of sweet pepper varieties

Variety	**Initial number of leaves**		**Number of leaves 2 WAT**		**Number of leaves 4 WAT**		**Number of leaves 6 WAT**	
	Open Field	Green house	Open Field	Green house	Open Field	Green house	Open Field	Green house
Caribbean	7.0	8.0	11.0	11.0	20.0	21.0	33.0	52.0
Crusader	8.0	7.0	12.0	14.0	19.0	22.0	39.0	43.0
California	7.0	7.0	11.0	10.0	20.0	18.0	29.0	41.0
Embella	70	7.0	12.0	12.0	20.0	18.0	34.0	33.0
F1 Nobili	7.0	7.0	11.0	12.0	22.0	17.0	28.0	30.0
Guardian	8.0	7.0	12.0	12.0	18.0	21.0	33.0	41.0
Kulkukan	8.0	10.0	14.0	15.0	24.0	36.0	39.0	94.0
Pepper I	8.0	7.0	12.0	11.0	21.0	19.0	30.0	41.0
Yolo W	7.0	7.0	12.0	11.0	19.0	20.0	29.0	37.0
LSD (0.05)								
Var	**1.0**		**1.8**		**4.6**		**9.5**	
PS	**0.4 NS**		**0.8 NS**		**2.2 NS**		**4.5**	
Var×PS	**1.4 NS**		**2.6 NS**		**6.6**		**13.5**	

Var- Variety, PS production system × Interaction

4.1.4 Chlorophyll content

Chlorophyll content differed significantly among treatments in both greenhouse and the open field both at vegetative and reproductive growth stages (i.e. 4WAT). Greenhouse varieties significantly had the highest chlorophyll content as compared to varieties grown in the greenhouse (**Table 4.4**). In the greenhouse, the highest chlorophyll content was observed in F1 Nobili (43.2), Crusader (42.1), Guardian pepper (41.4) and Embella 733 (40.1). The lowest chlorophyll content was Kukulkan and Yolo Wonder (27.0 and 35.4) respectively compared to the open field, at the vegetative growth phase (i.e. 6 WAT), highest chlorophyll content was found in F1 Nobili (69.1), Crusader (61.7), and California Wonder (61.3). The lowest chlorophyll content was also found in Caribbean Red (49.8) and KK (51.7).

Table 4.4 shows that in the greenhouse, chlorophyll content at the reproductive growth stage showed that FN had the highest chlorophyll content followed by Caribbean Red (61.9) and then Yolo Wonder (60.1). Lowest chlorophyll content was found in Caribbean Red and Guardian (39.4 and 39.6) respectively. While at the reproductive growth stage, the highest chlorophyll content was observed in Guardian pepper (101.0), Yolo Wonder (93.3), Kukulkan (99.2) and F1 Nobili (94.2). Lowest chlorophyll content was recorded in Caribbean Red (70.1) and California Wonder (85.7). Significant difference was observed in the production systems where the chlorophyll content of the leaves in the open field was higher than the greenhouse. No interaction was found among treatments **(Table 4.4).**

Table 4.4 Effects of production systems on chlorophyll content of sweet pepper varieties

Variety	Chlorophyll content at vegetative stage (μmol.m²)		Chlorophyll content at reproductive stage (μmol.m²)	
	Open Field	Green house	Open Field	Green house
Caribbean	49.8	33.4	70.1	39.4
Crusader	61.7	42.1	89.9	61.9
California	61.3	31.5	85.7	50.3
Embella	65.3	40.4	89.3	59.3
F1 Nobili	69.1	43.2	94.2	64.1
Guardian	61.0	41.4	101.0	46.8
Kukulkan	51.7	27.0	99.2	39.6
Pepper I	66.6	35.8	88.6	48.8
Yolo W	60.3	35.4	93.3	60.0
LSD(0.05) Var	**9.5**		**12.9**	
PS	**4.4**		**6.0**	
Var× PS	**13.4 NS**		**18.2 NS**	

Var- Variety, PS- production system × Interaction

4.1.5 Sweet pepper biomass dry weight (vegetative and reproductive growth stage)

Significant differences were observed in sweet pepper plant biomass among all the different treatments both in the greenhouse and the open field.

In the greenhouse at the vegetative growth stage (i.e. 4 WAT), the highest dry biomass weight was Kukulkan (5.3), Crusader (3.4) and California Wonder (3.0). Both Caribbean Red and Embella had the same biomass weight (2.8). P1 (2.4), Yolo Wonder (2.5) and

Guardian pepper (2.6) recorded the lowest dry biomass weight. Whereas, in the open field the highest biomass weight was Kukulkan (3.9), Crusader (3.2) Guardian pepper (3.1) with the lowest biomass recorded in Caribbean Red (1.9), Embella 733 (2.1), and Yolo Wonder (2.1) (**Table 4.5**).

Table 4.5 shows that at the reproductive growth stage (i.e. 6 WAT), the California Wonder (8.9) Kukulkan (8.6) and Embella 733 (8.5) recorded the highest biomass weight followed by Caribbean Red (7.5) and F1 Nobili (7.4). The lowest dry biomass weight was found in Crusader (5.5) and Guardian pepper (6.9). While, in the open field, Kukulkan (9.3) and F1 Nobili Nobili (7.1) had the highest dry biomass weight followed by Crusader (5.8), Pepper 1 (5.7) and Caribbean Red (5.6) while Embella 733 (5.3) recorded the lowest biomass weight. Significant difference ware observed among the production systems as the greenhouse had highest biomass weight compared to the open field at both growth stages. There was significant interaction among the system of production and varieties at both vegetative and reproductive stages (**Table 4.5**)

Table 4.5 Effects of production systems biomass weight of sweet pepper varieties

Variety	Biomass dry weight/plant (g) vegetative stage		Biomass dry weight/plant (g) reproductive stage	
	Open Field	Green house	Open Field	Green house
Caribbean	1.9	2.8	5.6	7.9
Crusader	3.2	3.4	5.8	5.5
California	2.7	3.0	7.1	8.9
Embella	2.1	2.8	5.3	8.5
F1 Nobili	2.5	2.9	7.5	7.4
Guardian	3.1	2.6	6.2	6.9
Kukulkan	3.9	5.3	9.3	8.6
Pepper I	2.3	2.4	5.7	7.0
Yolo W	2.1	2.3	5.6	7.9
LSD (.05) Var	**0.4**		**0.9**	
PS	**0.2**		**0.4**	
Var×PS	**0.6**		**1.9**	

Var- Variety, PS- production system × - Interaction

4.1.6 Days to 50% flowering and number of fruits per plant

Table 5 shows effects of production systems on days to 50% flowering and fruit number of fruits per plants of sweet pepper varieties.

Significant differences were observed among treatment both in the greenhouse and open field. In the greenhouse, California Wonder, Pepper 1, F1 Nobili (22) was significantly influenced days to 50% flowering. Caribbean Red and Kukulkan (32 and 35) were found to be late flowering varieties compared to the open field varieties, where significant difference were also observed and Guardian (23) and Yolo Wonder (26) were found to flower early followed by Crusader (27) and Embella 733 (27). Caribbean Red (37) and Kukulkan (34) showed late flowers. Significant interaction existed between production system and the varieties. i.e. the greenhouse showed earlier flowers than the open field.

Number of fruits per plants was significantly affected all the treatments both in greenhouse and the open field. Fruit number per plant differed significantly in the greenhouse among the varieties. Caribbean Red (40) and Kukulkan (33) had the highest number of fruits per plants. California Wonder, Embella 733, and F1 Nobili each had 13 fruits per plant. Yolo Wonder and Guardian had the lowest number of fruits per plants while Fruit number per plant differed significantly in the open field where, Kukulkan (30.0) and Caribbean Red (27.0) had the highest number of fruits per plants followed by Crusader (11.0) and Guardian pepper (10.0). California Wonder, Embella 733 and Yolo Wonder (9.0) each had equal number of fruits per plants. P1 (7.0) and FN (8.0) also had lowest number of fruits per plants. There was significant difference observed between production systems that showed that greenhouse recorded higher fruit number compared to the open field. No interaction existed between growing environment and the varieties. There was no significant interaction between the variety and the location. (**Table 4.6**)

Table 4.6 Effects of production systems on 50% flowering and Number of fruits per plant of sweet pepper varieties

Variety	Days to 50% flowering		Number of fruits per plant	
	Open Field	Green house	Open Field	Green house
Caribbean	37.0	35.0	27.0	40.0
Crusader	27.0	23.0	11.0	12.0
California	28.0	22.0	9.0	13.0
Embella	27.0	23.0	9.0	13.0
F1 Nobili	29.0	22.0	8.0	13.0
Guardian	23.0	24.0	10.0	10.0
Kukulkan	34.0	32.0	30.0	33.0
Pepper 1	29.0	22.0	7.0	12.0
Yolo W	26.0	25.0	9.0	10.0
LSD (.05) Var	**1.6**		**7.6**	
PS	**0.7**		**3.6**	
PS×Var	**2.3**		**10.8NS**	

Var- Variety, PS- production system × Interaction

4.2 Yield and yield components

4.2.1 Fruit yield of sweet pepper varieties (Kg/ha and T/ha)

Table 4.10 shows the effects of production systems on fruit yield of sweet pepper

Significant difference was observed among fruit yield of fruits in all the treatments compared both in the open field and the greenhouse. In the greenhouse Kukulkan (21340), California Wonder (20990), Crusader (17290) recorded the highest fruit yield and Caribbean Red (417) and Guardian pepper (541) fruit weight recorded the lowest yield as far as fruit yield on kg/ha is concerned.

With regard to the open field, significant difference was observed among the all the varieties considered. California Wonder, (12570), Crusader (10560) got the highest fruit yield with the lowest been observed in Pepper 1 (5020) and Caribbean Red (5760) and respectively. There were high significant difference observation among the productions system that is the greenhouse and the open field. The greenhouse recorded the highest fruit weight compared to the open field. There was significant interaction found between production system and the varieties (**Table 4.7**).

4.2.2 Fruit yield (t/ha)

The highest fruit yield (t/ha) per treatments replicate was significantly obtained by Kukulkan (21.34) California Wonder (20.99) and Crusader (17.29) which was superior in its effect in the greenhouse. Caribbean Red (14.79), Embella 733 (13.76) and Guardian (11.4) also differed significantly with Yolo Wonder (8.20) and F1 Nobili (9.23) attained the lowest fruit yield in the greenhouse compared to the open field where significant difference was observed which revealed that California Wonder (12.57), Crusader (10.57) Kukulkan (9.22) and Guardian (9.18) had the highest fruit yields, followed by Yolo Wonder (7.53), Embella 733 (7.05) and F1 Nobili (6.31). Low fruit yield recorded in the open field was observed in Pepper 1 (5.02) and Caribbean Red (5.76) respectively.

Significant difference was observed among the productions system both in the greenhouse and the open field. The greenhouse recorded the highest fruit weight compared to the open field. There was significant interaction found between production system and the varieties (**Table 4.7**).

Table 4.7 Effects of production systems on average fruit weight/plant and fruits yield of sweet pepper

Variety	Yield (Kg/ha)		Yield (t/ ha)	
	Open Field	Green house	Open Field	Green house
Caribbean	5760	14790	5.76	14.79
Crusader	10560	17290	10.56	17.29
California	12570	20990	12.57	20.99
Embella	7050	13760	7.05	13.76
F1 Nobili	6310	9230	6.31	9.23
Guardian	9180	11140	9.18	11.14
Kukulkan	9220	21340	9.22	21.34
Pepper I	5020	14820	5.02	14.82
Yolo W	7530	8200	7.53	8.20
LSD (.05) var	**2291.8**		**2.29**	
PS	**1080.4**		**1.08**	
Var × PS	**3241.1**		**3.24**	

4.2.3 Effects of production systems on yield and yield components of sweet pepper

Table 4.8 shows the effects of production systems on fruit length and width of sweet pepper varieties

4.2.4Fruit length

Highly significant difference was observed among treatments both in the greenhouse and the open field. In the greenhouse, however, California Wonder (8.75) and Crusader (7.11) had the longest fruit length followed by F1 Nobili (6.91), Embella 733 (6.75), Pepper 1 (6.67) and Guardian (6.65). The shortest fruit length therefore was Caribbean Red (3.23) compared to open field significance difference was observed among the treatments. California Wonder (6.51) and Crusader (6.19) as well recorded the longest fruit length followed by P1 (5.63), Embella 733 (5.61), F1 Nobili (5.49) and Yolo Wonder (5.37). But Caribbean Red (3.00) and Kukulkan (3.39) had the shortest fruit length. Significant difference was observed among productions system, that is, both in the greenhouse and the open field. The greenhouse had longest fruits length compared to the open field. No significant interaction found among treatments **(Table 4. 8**).

4.2.5 Fruit width

There was high significant difference observed among the fruit width. In the greenhouse the width significantly increased with Pepper 1 (6.34), Yolo Wonder (6.08) and Crusader (6.05) recording the longest fruit width followed by Guardian (5.66), EM (5.48), FN (5.42) and California Wonder (5.36) while the shortest fruit width was observed in Caribbean Red (2.57) and Kukulkan (2.86) compared to the open field, significant difference were observed on all the varieties with Pepper 1 (5.54), Yolo Wonder (5.26) and California Wonder (5.24) had the longest fruit width followed by Crusader (5.18), F1 Nobili (5.14), Guardian (5.08) and Embella 733 whereas Caribbean Red (2.57) and Kukulkan (2.86) had the lowest width. Significant difference was observed among the productions system, that is, both in the greenhouse and the open field. The greenhouse had longest fruits width compared to the open field. No significant interaction found among treatments **(Table 4. 8**). No significant interaction found among treatments.

Table 4.8 Effects of production systems on Fruit Length and fruits diameter of sweet pepper

Variety	**Fruit length (cm)**		**Fruit diameter (cm)**	
	Open Field	Green house	Open Field	Green house
Caribbean Red	3.00	3.23	2.57	2.80
Crusader	6.19	7.11	5.18	6.05
California	6.51	8.75	5.24	5.36
Embella	5.38	6.75	5.00	5.48
F1 Nobili	5.49	6.91	5.14	5.42
Guardian	5.43	6.65	5.08	5.66
Kukulkan	3.39	3.83	2.86	3.22
Pepper I	5.63	6.67	5.54	6.34
Yolo Wonder	5.37	6.42	5.26	6.08
LSD (.05) Var	**0.98**		**0.34**	
PS	**0.46**		**0.16**	
Var × PS	**1.9NS**		**0.49NS**	

4.2.6. Effects of production systems on pericarp thickness and number of locules per fruits of sweet pepper

Table 4.9 shows the effects of production systems on pericarp thickness and number of locules of sweet pepper

Highly significance difference was observed among the treatments which influenced pericarp thickness both in the greenhouse and the open field. Also the interaction effects highly significantly affected the pericarp of the fruit. In the greenhouse pericarp thickness differed significantly of which Guardian (4.0), Crusader (4.0), California Wonder (4.0), Embella 733 (4.0) had the thickest pericarp thickness followed by P1 (3.5) and the thinnest pericarp thickness was observed in Caribbean Red and Kukulkan both had equal pericarp thickness whereas in the open field, significant difference was observed among treatments. GD (4.2), Yolo Wonder (4.0) recorded the largest pericarp thickness. Significant difference also existed among Embella 733 (3.5), F1 Nobili (3.4), and Crusader (3.3) and California Wonder and Pepper 1 (3.0). Both Kulkukan and Caribbean Red (2.0) respectively had the thinnest pericarp thickness.

Significant difference was observed among the productions system both in the greenhouse and the open field. The greenhouse varieties had thickest pericarp compared to the open field. There was significant interaction found between production system and the varieties (**Table 4.9**).

4.2.7Number of Locules per fruits

There was no significant difference observed among all the treatment compared in both in greenhouse and the open field as far as the number of locules per fruits is concerned (**Table 4.9**).

Table 4.9 Effects of production systems on pericarp thickness and number of Locules per fruits of sweet pepper

Variety	**Pericarp thickness (mm)**		**Number of Locules per fruit**	
	Open Field	Green house	Open Field	Green house
Caribbean	2.0	2.0	3.0	3.0
Crusader	3.3	4.0	3.0	3.0
California	3.0	4.0	2.0	2.0
Embella	3.5	4.0	4.0	4.0
F1 Nobili	3.4	4.0	4.0	4.0
Guardian	4.2	4.0	3.0	3.0
Kukulkan	2.0	2.0	4.0	4.0
Pepper I	3.0	3.5	3.0	3.0
Yolo W	4.0	4.0	3.0	4.0
LSD (.05) Var	**0.15**		**0.0 NS**	
PS	**0.7**		**0.0 NS**	
Var × PS	**0.22**		**0.0 NS**	

Var- Variety, PS- production system × Interaction

4.2.8 Mean fruits weight per plants and seed number per fruits of sweet pepper

Results in **Table 4.10** revealed that high significant difference was observed in the average weight of fruits among the different varieties used in the greenhouse and the open field. In the greenhouse it was shown that California Wonder (106.1) Crusader (92.2) Pepper 1 (83.6) had the highest average fruit weight. Significant differences were also observed among Guardian (76.3), Yolo Wonder (52.7), Embella 733 (68.9), and F1 Nobili (46.1). The least weight was observed in CR (23.9).compared to the open field, CS, California Wonder and P1 (83.6) recorded the highest weights followed by FN (54.9), Embella (54.3), Pepper 1 (45.2) but Caribbean Red (13.6) and Kukulkan (19.3) recorded the lowest fruit weight. Significant interaction was observed between location and the varieties.

However, seed number per fruits differed significantly among all the varieties used in this study. In the greenhouse, Embella 733 (193), F1 Nobili (164) Crusader (124) gained the highest seed number. Yolo Wonder (99), Pepper 1 (76) and Caribbean Red (70) also varied significantly whereas California Wonder (45) had the lowest seed number per fruits whereas, in the open field, highly significant difference was observed among the treatments. The highest seed number was observed in Embella 733 (228) and F1 Nobili (161). Significant difference was also seen among Guardian (142), Crusader (119), Yolo Wonder (99), Caribbean Red (70) and Pepper 1 (76) with the least seed number observed in California Wonder CW (45).

Significant difference was observed among the productions system both in the greenhouse and the open field. The greenhouse varieties had the lowest seed number per fruits compared to the open field which recorded the maximum seed number per fruits.

There was significant interaction found between production system and the varieties (**Table 4.10**).

Table 4.10 Effects of production systems on average fruit weight and seed number per fruits of sweet pepper

Variety	Mean fruit weight (g)		Number of seeds per fruit	
	Open Field	Green house	Open Field	Green house
Caribbean	13.6	23.9	70.0	64.0
Crusader	64.6	92.2	119.0	124.0
California	55.6	106.4	45.0	32.0
Embella	54.3	68.9	228.0	193.0
F1 Nobili	54.9	46.1	161.0	164.0
Guardian	56.6	76.3	142.0	68.0
Kukulkan	19.3	42.2	81.0	57.0
Pepper I	45.2	83.6	76.0	59.0
Yolo W	55.3	52.7	99.0	93.0
LSD (.05) Var	**17.2**		**3.2**	
PS	**8.1**		**1.5**	
Var × PS	**24.3**		**4.6**	

Var- Variety, PS - production system × Interaction

4.3 Relationship between Fruit yield and Fruit Length.

The relationship between Fruit yield and Fruit length shows that Y= fruit yield kg/ha and x= fruit length (cm). The equations indicate that yield response to production system is almost linear. There was a highly significant negative relationship between fruit yield (tons/ha) and fruit length of sweet **(Fig. 4.1).**

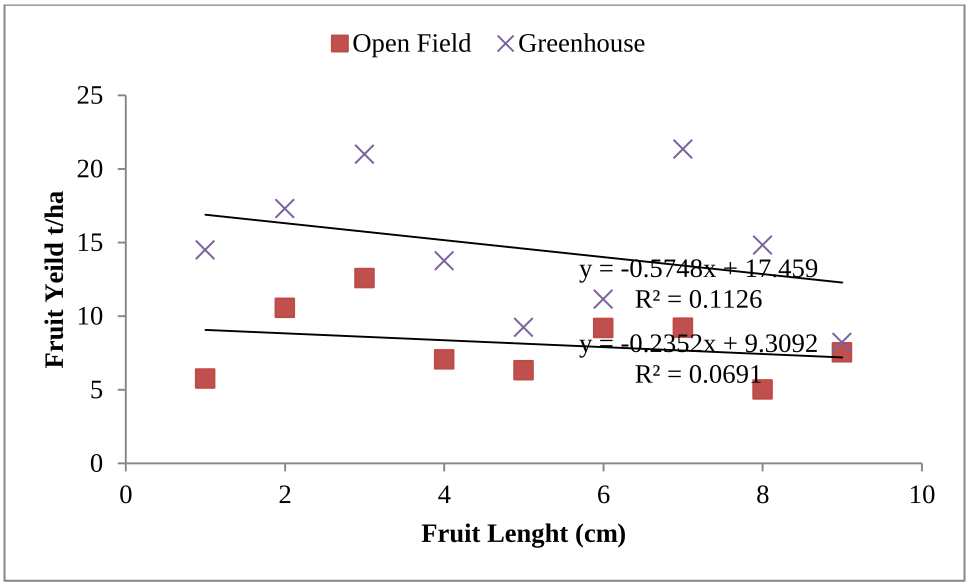


Figure 4.1 Linear relationship between Fruit yield (tons/ha) and Fruit Length averaged over 2 levels of Production system.

4.4 Relationship between Fruit yield and Fruit width.

Fruit width of 3-4 cm were found to be the upper limit for higher fruit yield for sweet pepper grown in protected cultivation during the experimental period (November–March). Moreso, the maximum fruit width that enhanced fruit yield in the open field was found to be around 2cm.

Also, a negative significant relationship between fruit yield (tons/ha) and fruit width (cm) which showed width was significant yield component for measuring of sweet pepper yield **(Fig 4.2).**

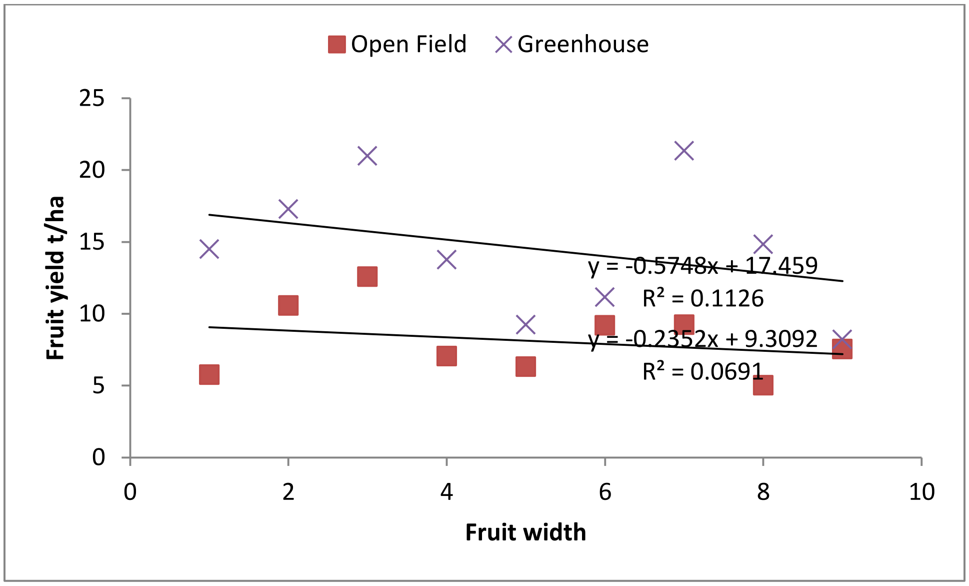


Figure 4.2 Linear relationship between Fruit yield (tons/ha) and Fruit Width averaged over 2 levels of Production system.

4.5 Relationship between Fruit yield and pericarp thickness.

The relationship between Fruit yield and Fruit length shows that Y= fruit yield kg/ha and x= pericarp thickness (cm). The equations indicate that yield response to production system is almost linear. There was a highly significant negative relationship between fruit yield (tons/ha) and pericarp thickness of sweet **(Fig 4. 3).**

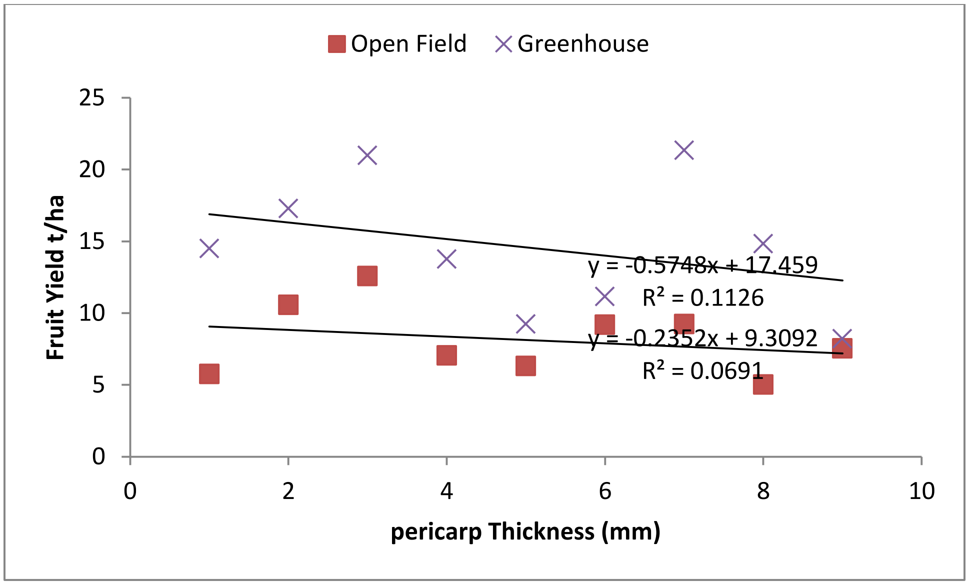


Figure 4.3 Linear relationship between Fruit yield (t/ha) and Pericarp thickness (mm) averaged over 2 levels of Production system.

4.6 Correlations among some growth and yield parameters of sweet pepper

Correlations between growth and yield traits are shown in Table 4.11. Total growth had a positive correlation with production systems and varieties.

Plant height at 6 WAT exhibited a strong negative association with chlorophyll content (-0.63) and (-0.70) at both growth stages. There was significant positive relationship with biomass dry weight at vegetative (0.45**) and reproductive growth stages (0.66**). Number of fruits per plants (0.51**), fruit weight (0.45**) and fruit yield Kg/ha (0.45**) also showed a significant positive association with plant height. Number of leaves per plant at 6 WAT showed a strong positive relationship with stem diameter (0.45**), plant height (0.86**) and pericarp thickness (-0.39**) after harvesting. It also had a significant negative association with yield per plant (-0.59**), fruit length (-0.79**) and fruit weight (-0.71**). A significant negative relationship was shown as far as seed number (-0.33**) and pericarp thickness (-0.30**) is concerned. Stem diameter showed a positive relationship with plant height (0.42**) and biomass dry weight (0.33*). A strong significant negative relationship was established between biomass dry weights at vegetative growth stage with chlorophyll content (-0.44**) and a positive association with number of fruits per plant (0.41**) and fruit weight (0.35**) at reproductive growth stage.

50% flowering had a strong positive association with number of fruits per plant (0.62*8) but negatively correlated with fruit length (-0.79**), fruit width (-0.85**), pericarp thickness (-0.89**), seed number (-0.24**), fruit weight (-0.71**) and fruit yield (-0.59**).

Biomass dry weight at vegetative stage indicated positive relationship with number of fruits per plants (0.37**) and negatively correlated with pericarp thickness (-0.31**), fruit width (-0.27**) and chlorophyll content (-0.36**). At reproductive growth stage, biomass dry weight showed a strong positive association with number of fruits per plant (0.41**), fruit weight (0.35**) yield t/ha (0.35**). A significant negative association was seen in chlorophyll content (-0.44**). The chlorophyll content at vegetation showed positive significant correlation with seed number (0.37**) and had negative relationship with fruit weight (-0.59), number of fruits per plant (-0.40) and fruit yield Kg/ ha (-0.59).

The chlorophyll content at reproduction growth phase indicated strong positive relationship with seed number per fruit (0.34**) with a significant negative correlation with yield Kg/ha (-0.47) and fruit weight (-0.47). Fruit width, therefore, had a significant positive correlation with fruit yield Kg/ha (0.35**), pericarp thickness (0.84**), fruit weight (0.35**) and negative relationship with number of fruits per plants (-0.76**). Fruit length on the other hand, showed a significant positive association with growth and yield parameters such that, yield Kg/ha (0.53**), pericarp thickness (0.69**), fruit weight (0.53**) and negative correlated to number of fruits per plants (-0.53). The fruit weight also, significantly correlated positively with fruit yield Kg/ha (1.00**). Number of fruits per plants negatively indicated significant negative relationship with seed number per fruit (-0.31*) and pericarp thickness (-0.69**). Hence the pericarp thickness of the fruit also showed strong positive relationship with seed number per fruit (0.36) and fruit yield (0.41**). Seed number had correlated positively with pericarp (0.36**) thickness and significant negative (-0.31) relationship with number of fruits per plants. Seed number per fruits was also not significant with fruit yield (Kg/ha).

Table 4.11 Correlation matrix of growth and yield of sweet pepper grown under greenhouse and open field conditions

	50%_F	6WAT_ NPL	6WAT_ SD	6WAT_P H	BDW g_R	BDW g_V	CC-_R	CC-_V	FW_cm	_F L_cm	F_Wt_g	No_Fplt	FW_g	PTmm	kg_ha	SN
6 WAT NPL	0.22ns															
6WAT_SD	0.01ns	0.45**														
6WAT_PH	0.10ns	0.86**	0.42**													
BDW_g_R	0.04ns	0.26ns	0.06	0.45**												
BDW_g_V	0.17ns	0.68**	0.33*	0.66**	0.37**											
CC_R	0.10ns	-0.46**	0.02ns	-0.63**	-0.32*	-0.21ns										
CC_V	0.14ns	-0.54**	-0.02ns	-0.70**	-0.44**	-0.36**	0.74**									
FW_cm	-0.85**	-0.35**	-0.14ns	-0.32*	-0.23ns	-0.27*	0.01ns	0.06								
FL_cm	-0.79**	-0.23ns	0.03ns	-0.06ns	0.04ns	-0.19ns	-0.07ns	-0.09ns	0.703**							
FWg	-0.71**	-0.05ns	0.10ns	0.04	-0.01ns	-0.02ns	-0.25ns	-0.20ns	0.68**	0.53**						
NFP	0.62**	0.44**	0.09ns	0.51**	0.41**	0.37**	-0.25ns	-0.40**	-0.76**	-0.56**	-0.44**					
TFW_g	-0.59**	0.20ns	0.17ns	0.45**	0.35**	0.17ns	-0.47**	-0.59**	0.35**	0.53**	0.61**	0.01ns				
PT_mm	-0.89**	-0.39**	-0.13ns	-0.30*	-0.17ns	-0.31*	0.01ns	0.03ns	0.84**	0.69**	0.66**	-0.69**	0.41**			
Kg/ha	-0.59**	0.20ns	0.17ns	0.45**	0.35**	0.17ns	-0.47**	-0.59**	0.35**	0.53**	0.61**	0.01ns	1.00**	0.41**		
SN	-0.24ns	-0.31*	-0.05ns	-0.33*	-0.24ns	-0.19ns	0.34*	0.37**	0.23ns	0.07ns	0.01ns	-0.31*	0.01ns	0.36**	0.01ns	
T/ha	-0.59**	0.20ns	0.17ns	0.45**	0.35**	0.17ns	-0.47**	-0.59**	0.35**	0.53**	0.61**	0.01ns	1.00**	0.41**	1.00**	0.01ns

ns - not significant ; * - Significant at 5% ; ** - Significant at 1% ; WAT- Weeks After Transplanting

SD- Stem diameter (cm), PH- plant Height (cm), BDW-Biomass dry weight (g), CC- chlorophyll content, FW- Fruit width (cm), FL –Fruit length (cm), NFP- number of fruit per plant, PT- pericarp thickness (mm), SN-Seed number,-Kg/ha- yield Kg/ha, R- reproductive growth stage, V- vegetative growth stage

4.7 Acceptability of fruits

4.7.1 Size of fruit

Significant differences were observed among the acceptance level of fruits based on fruit size of which California Wonder (CW) and Crusader (CS) were highly accepted (8 = Very strong to extremely strong quality) for the greenhouse varieties but the same varieties were accepted at the rank of 5 (Strong quality) and 6 (Strong to very strong quality) respectively (**Fig 4.4**). Consumers accepted these sweet pepper fruits more the greenhouse because of its size (bigger), high quality and more appealing nature. California Wonder was highly accepted among the other varieties because of its less seed characteristics.

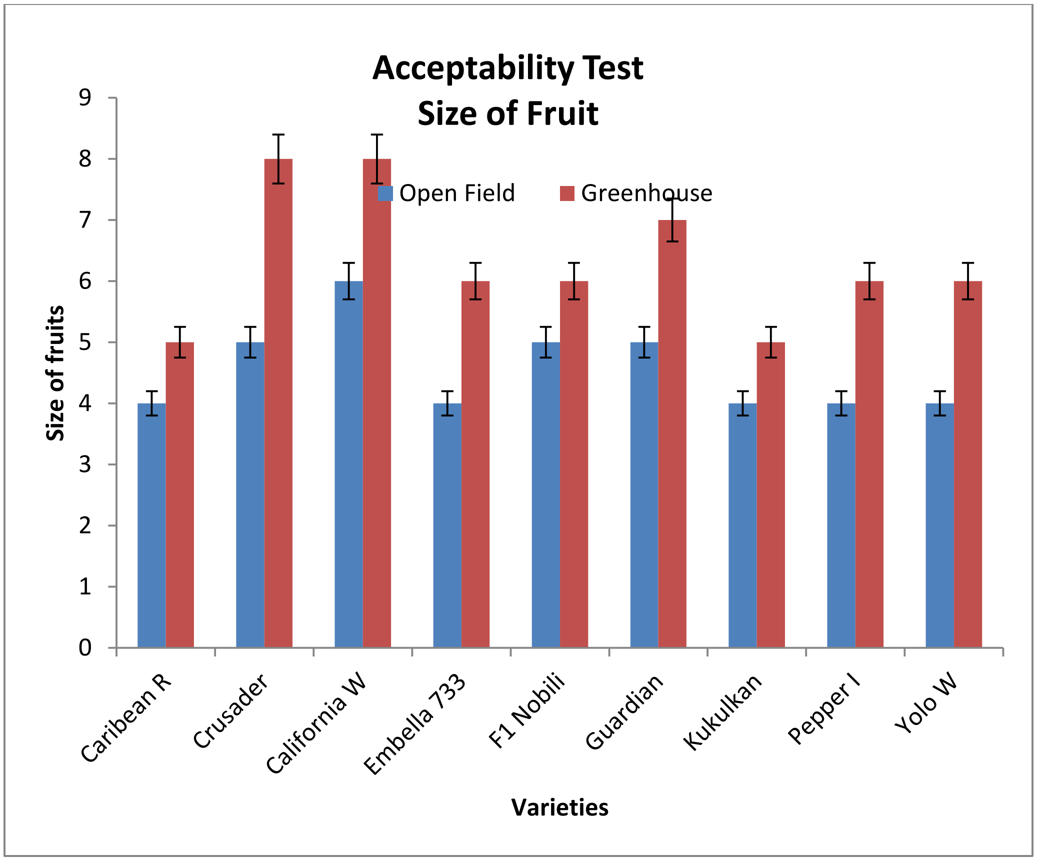


Figure 4.4 Consumer acceptance of sweet pepper varieties based on fruit size, the results were an average of 2 levels of production systems and 9 sweet pepper varieties

4.7.2 Brightness of fruit

Significant differences were observed among the acceptance level of fruits based on fruit brightness of which California was highly accepted (8 = Very strong to extremely strong quality) for the greenhouse varieties and same varieties were accepted at the rank of 4 (Strong quality) in the open field varieties **(Fig 4. 5).** Consumers accepted these sweet pepper fruits more from the greenhouse because of its high quality and more appealing nature.

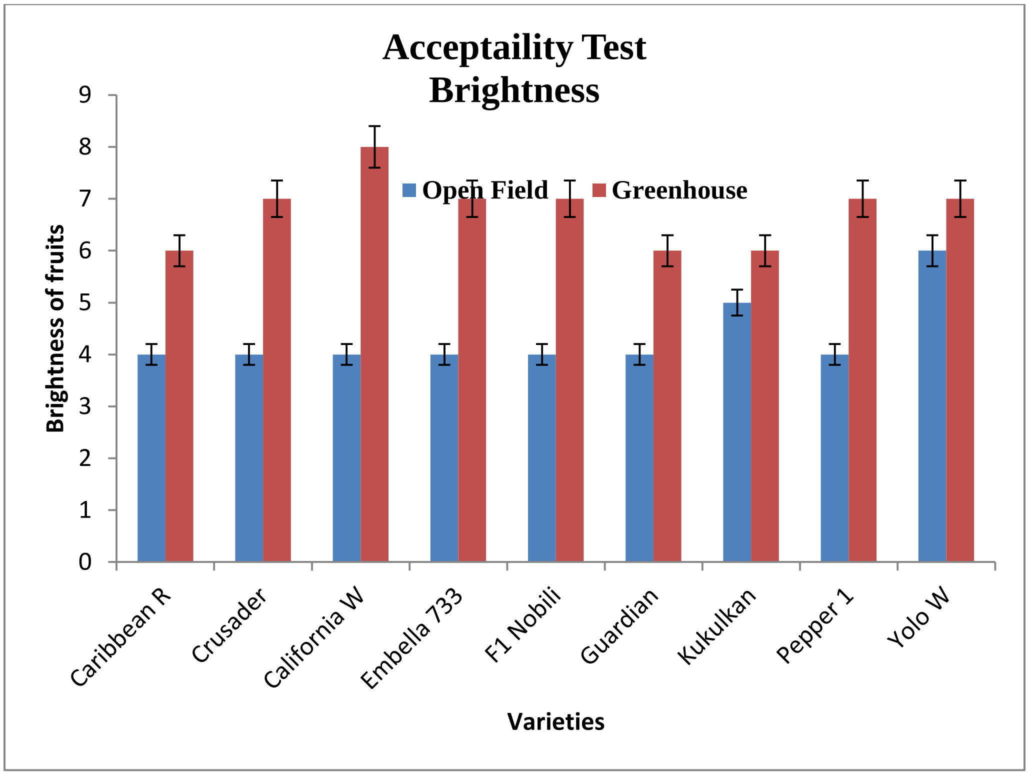


Figure 4.5 Consumer acceptance of sweet pepper varieties based on brightness of fruits, the results were an average of 2 levels of production systems and 9 sweet pepper varieties

4.7.3 Glossiness of fruit

Significant difference were observed among the acceptance level of fruits based on fruit glossiness of which California Wonder and Crusader were highly accepted (8 = Very strong to extremely strong quality) for the greenhouse varieties but same varieties were accepted at the rank of 5 (Strong quality) and 6 (Strong to very strong quality) respectively. Consumers accepted these sweet pepper fruits more especially the greenhouse because of its high quality and more appealing nature.

(Fig 4.6). Caribbean Red and Kukulkan (Rank 4 and 5) significantly recorded the lowest acceptance level both in greenhouse and open field at the rank of 5 and 4 (Moderate to strong quality and Moderate quality).

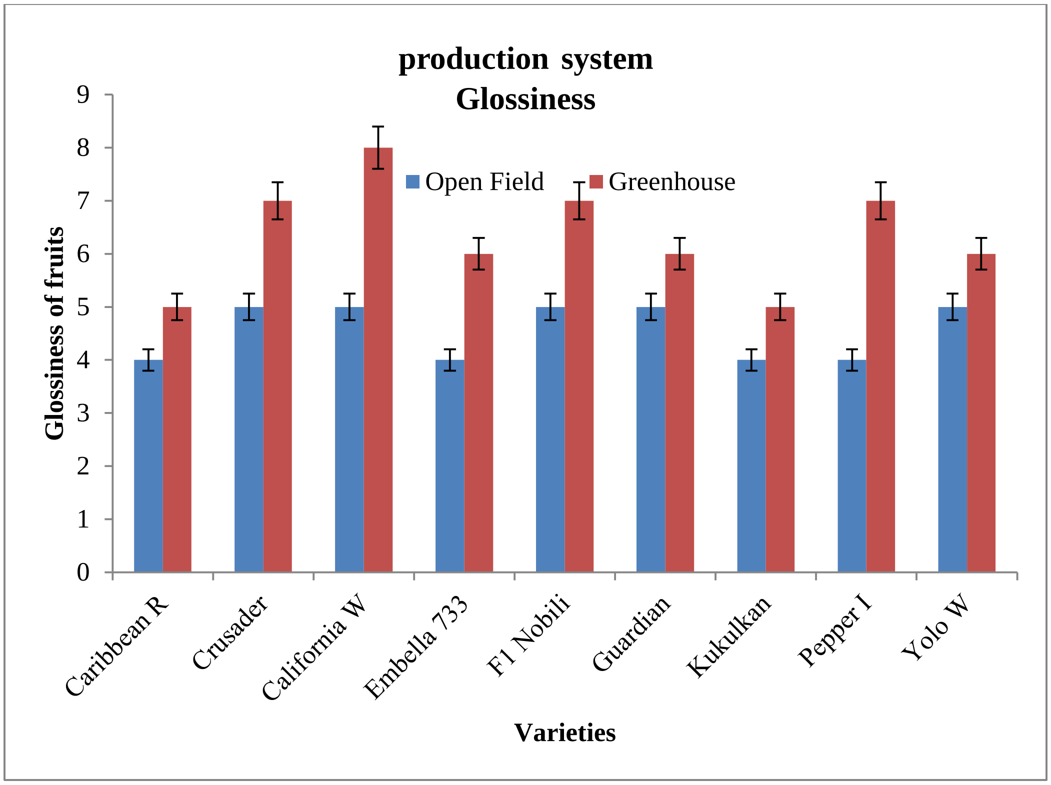
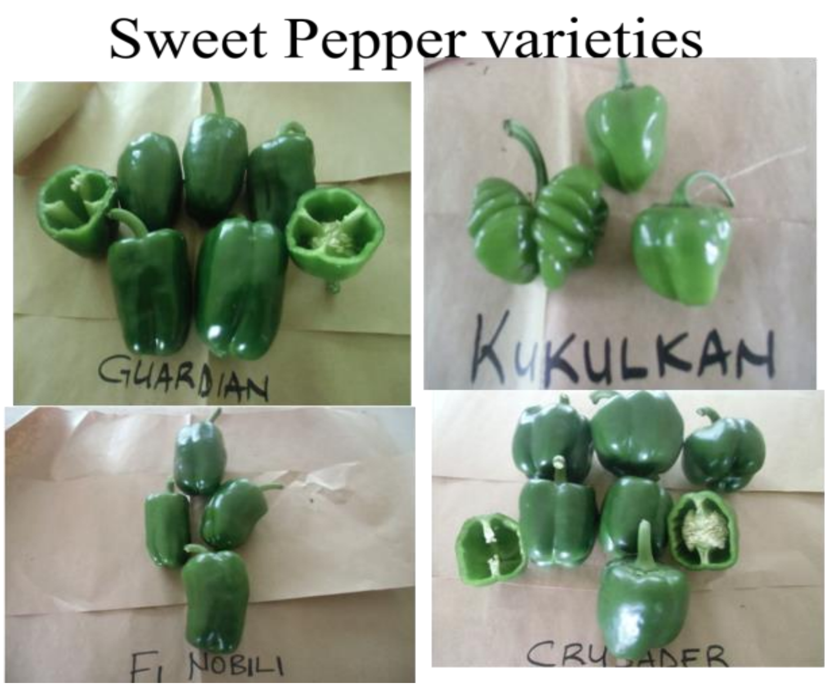


Figure 4.6 Consumer acceptance of sweet pepper varieties based on glossiness of fruits, the results were an average of 2 levels of production systems and 9 sweet pepper varieties

Pepper 1, Yolo Wonder, Embella 733, California Wonder



Guardian, Kukulkan, F1 Nobili, Crusader

Plate 1 Sweet pepper varieties

4.8 Economic analysis of using greenhouse and open field for cultivation of sweet pepper

A partial budget analysis was used to examined the effects of changes in costs of certain production inputs on the variation in profit of the production system (Barrett et al., 2012; Cantliffe *et al*,. 2008) This technique was developed to put emphasis on the part of the budget that differs between treatments of interest, rather than the whole budget. A partial budget analysis was conducted using data acquired during the experimental period to compare the potential partial net returns from greenhouse vs. open field production systems. (**Table 4.12-4.20**). The part of the budget varied between the greenhouse and open field treatments of interest was the greenhouse structure that is different types of greenhouse with different prices and the price of the land which also differ from location to location. Therefore the budget considered was to emphasize on items of interest. Detailed budget is found in **Appendix 9**. Other costs for supplies and labor were not encompassed in the partial budget analysis because they were consistent across all treatments in the study and will vary considerably from farmer to farmer. These other production, harvest, and packing costs (e.g. site preparation, greenhouse structure, irrigation and climate control systems, electrical and drainage systems,, trellis accessories n labour, IPM strategies, pollinators used in the greenhouse, energy (provision of fans for aeration), packing cartons to convey fruits, labour, etc.) must be factored in by the grower to achieve a full net return. The was high net revenue achieved in the greenhouse with low relatively low return on investment as compared to open field with high return on investment with low net revenue. Detailed budget is shown in (**Appendix 25 and 26**).

Table 4.12 Estimated cost of production of California Wonder gross revenue and return on investment grown under greenhouse and open field

PS	Economic Yield/kg/ha	Price/kg(ha) (GH¢)	Total Revenue (GH¢)	Production cost (GH¢)			Total Cost (GH¢)	Net Revenue (GH¢)	Return on inv. %
				Input	Labour	Transport			
GH	20990.00	5.00	104950	1695.00	375.00	780.00	2850.00	102100	2.79
OF	12570.00	5.00	62850	1695.00	850.00	780.00	3325.00	59525	5.58

* Note; Exclusion of greenhouse structure and land since they are fixed asset and variation in prices

Table 4.13 Estimated cost of production of Crusader, gross revenue and return on investment grown under greenhouse and open field

PS	Economic Yield/kg/ha	Price/kg(ha) (GH¢)	Total revenue (GH¢)	Production cost (GH¢)			Total cost (GH¢)	Net Revenue (GH¢)	Return on inv. %
				Input	Labour	Transport			
GH	17290	5.00	86450	1695.00	375.00	780.00	2850.00	83600	3.40
OF	10560	5.00	52800	1695.00	850.00	780.00	3325.00	49475	6.72

Table 4.14 Estimated cost of production of Kulkukan, gross revenue and return on investment grown under greenhouse and open field

PS	Economic Yield/kg/ha	Price/kg(ha) (GH¢)	Total Revenue (GH¢)	Production cost (GH¢)			Total Cost (GH¢)	Net Revenue (GH¢)	Return on inv. %
				Input	Labour	Transport			
GH	21340	5.00	106700	1695.00	375.00	780.00	2850.00	103850	2.74
OF	9180	5.00	45900	1695.00	850.00	780.00	3325.00	42575	7.80

Table 4.15 Estimated cost of production of Caribbean Red, gross revenue and return on investment grown under greenhouse and open field

PS	Economic Yield/kg/ha	Price/kg(ha) (GH¢)	Total Revenue (GH¢)	Production cost (GH¢)			Total Cost (GH¢)	Net Revenue (GH¢)	Return on inv. %
				Input	Labour	Transport			
OF	5760	5.00	28800	1695.00	375.00	780.00	2850.00	25950	10.98
GH	14790	5.00	73950	1695.00	850.00	780.00	3325.00	70625	4.70

Table 4.16 Estimated cost of production of Embella 733, gross revenue and return on investment grown under greenhouse and open field

PS	Economic Yield/kg/ha	Price/kg(ha) (GH¢)	Total Revenue (GH¢)	Production cost (GH¢)			Total Cost (GH¢)	Net Revenue (GH¢)	Return on inv. %
				Input	Labour	Transport			
GH	13760	5.00	68800	1695.00	375.00	780.00	2850.00	65950	4.32
OF	7050	5.00	35250	1695.00	850.00	780.00	3325.00	31925	10.41

Table 4.17 Estimated cost of production of F1 Nobili, gross revenue and return on investment grown under greenhouse and open field

PS	Economic Yield/kg/ha	Price/kg(ha) (GH¢)	Total Revenue (GH¢)	Production cost (GH¢)			Total Cost (GH¢)	Net Revenue (GH¢)	Return on inv. %
				Input	Labour	Transport			
GH	9230	5.00	46150	1695.00	375.00	780.00	2850.00	43300	6.58
OF	6310	5.00	31550	1695.00	850.00	780.00	3325.00	28225	11.78

Table 4.18 Estimated cost of production of Guardian pepper, gross revenue and return on investment grown under greenhouse and open field

PS	Economic Yield/kg/ha	Price/kg(ha) (GH¢)	Total Revenue (GH¢)	Production cost (GH¢)			Total Cost (GH¢)	Net Revenue (GH¢)	Return on inv. %
				Input	Labour	Transport			
GH	13760	5.00	68800	1695.00	375.00	780.00	2850.00	65950	4.32
OF	9180	5.00	45900	1695.00	850.00	780.00	3325.00	42575	7.80

Table 4.19 Estimated cost of production of Pepper 1, gross revenue and return on investment grown under greenhouse and open field

PS	Economic Yield/kg/ha	Price/kg(ha) (GH¢)	Total Revenue (GH¢)	Production cost (GH¢)			Total Cost (GH¢)	Net Revenue (GH¢)	Return on inv. %
				Input	Labor	Transport			
GH	14820	5.00	74100	1695.00	375.00	780.00	2850.00	71250	4.00
OF	5020	5.00	25100	1695.00	850.00	780.00	3325.00	21775	15.26

Table 4.20 Estimated costs of production of Yolo Wonder gross revenue and return on investment grown under greenhouse and open field

PS	Economic Yield/kg/ha	Price/kg(ha) (GH¢)	Total Revenue (GH¢)	Production cost (GH¢)			Total Cost (GH¢)	Net Revenue (GH¢)	Return on inv. %
				Input	Labor	Transport			
GH	8200	5.00	41000	1695.00	375.00	780.00	2850.00	38150	7.47
OF	7530	5.00	37650	1695.00	850.00	780.00	3325.00	34325	9.68

CHAPTER FIVE

DISCUSSION

5.1 Sweet pepper plant growth indices under open field

The plant heights stem diameter, leaf number per plants, number of fruits per plant were significantly enhanced and this could be attributed to the growing environment. The minimum and maximum temperature recorded in this research was between 22.54 ºC and 34.80 in the open field. However, Rylski and Spigelman, 1982 pointed out that at a day temperature of 24 °C, pollen viability and fruit set are higher at 15 °C than at 18-24 ºC during the night and day may influenced. Shaked et al., 2004, reported that temperatures below 10 ºC fruit size decreases due to inefficient pollination and fertilization, which causes a reduction in fruit length (Aloni et al., 1999) and possible fruit malformation as revealed by Rylski and Aloni, (1994).

For instance, there was a significant increase in plant height in the open field as Kulkukan recorded the highest height and Crusader also followed whereas Pepper 1 had shortest height. Plant height helps it in light attraction in that the taller the plant, the easier it attracts light, this was in line with Ogbodo (2009) who revealed that tall plant have easy access to intercept light for photosynthesis. Plant height had significant positive relationship with biomass dry weight at (0.45**) and significantly exhibited a strong negative association with chlorophyll content (-0.63**) and (-0.70**) at both vegetative and reproductive growth stages. In the open field Kulkukan had the thickest girth followed by Crusader with Pepper 1 recording the thinnest girth. The open field revealed significant observation made on leave number where Kulkukan had highest number of leaves followed by Caribbean Red with F1 Nobili recording the least number of leaves. The research revealed that the Kulkukan variety produces a lot of leaves in both the greenhouse and the open field. The biomass dry weight revealed that at reproductive growth stage, biomass dry weight showed a strong positive association with number of fruits per plant (0.41**), fruit weight (0.35**) yield t/ha (0.35**). Days to 50% flowering in the open field, showed a significant difference such that Guardian pepper and Yolo Wonder were found to flower early followed by Crusader and Embella 733. Caribbean Red and Kulkukan showed late flowers.

5.1.1 Sweet pepper yield and yield attributes under open field

Number of fruits per plants significantly was influenced with the varieties studied under the open field production system. Kulkukan and Caribbean Red had the highest number of fruits per plants followed by Crusader and Guardian Pepper. California Wonder, Embella 733 and Yolo Wonder each had equal number of fruits per plants. Pepper 1 and F1 Nobili also had lowest number of fruits per plants. Kulkukan variety dominated in the fruit number per plant. In the open field, significant difference was observed which revealed that California Wonder, Crusader, Kulkukan and Guardian pepper had the highest fruit yields, followed by Yolo Wonder, Embella 733 and F1 Nobili. Low fruit yield recorded in the open field was observed in Pepper 1 and Caribbean Red respectively. Significance difference was observed among the fruit length of the varieties. California Wonder and Crusader recorded the longest fruit length followed by Pepper 1, Embella 733, F1 Nobili and Yolo Wonder. But Caribbean Red and Kulkukan had the shortest fruit length. The lengthiness of the fruit could be attributed to varietal difference. Fruit length showed a significant positive association with growth and yield parameters such that, yield Kg/ha (0.53**), pericarp thickness (0.69**), fruit weight (0.53**) and negative correlated to number of fruits per plants (-0.53). The fruit weight also, significantly correlated positively with fruit yield Kg/ha (1.00**). Fruit number per plant differed significantly in the open field where, Kulkukan and Caribbean Red had the highest number of fruits per plants Embella 733 and Yolo Wonder each had the lower number of fruits per plant.

Fruit length revealed significant variation among the varieties in the open field. California Wonder showed the longest length and CS as well recorded the longest fruit length and Caribbean Red had the shortest fruit length. Pepper 1 recorded the thickest width followed by Yolo Wonder with Caribbean Red with the shortest width. Fruit length showed a significant positive association with yield parameters such that, yield Kg/ha (r = 0.53**), pericarp thickness (r = 0.69**), fruit weight (r = 0.53**) and negative correlated to number of fruits per plants (r = -0.53). Guardian pepper, Yolo Wonder recorded the largest pericarp thickness. Significant difference also existed among Embella, F1 Nobili, and Crusader, California Wonder and Pepper 1. Both Kulkukan and Caribbean Red respectively had the thinnest pericarp thickness. The highest seed number was observed in Embella and F1 Nobili. The seed number per fruits, however, differed among Guardian pepper, Crusader, Yolo Wonder, Caribbean Red and Pepper 1 with the least seed number observed in California Wonder.). In many crop species, including sweet pepper, fruit size and fruit set have been reported to be positively correlated with seed number (Van der Steen, 1991; Shipp and Papadopoulos, 1994) but different researchers found contrary results such that Baer and Smeets (1978) and Bakker (1989) found no correlation between seed number and fruit size in sweet pepper which confirm this research that there is no correlation between seed number and fruit yield.

5.1.2 Optimum growth of pepper as influenced by greenhouse production system

The probable tallness of plant height, stem thickness and improved number of leaves of sweet pepper grown in the greenhouse compared to the open field may be attributed favorable environmental conditions as Heurn (2004), indicated that crops inside greenhouse are better protected from outside influences with adequate water. It was also found that, in many parts of the world, insect nets or screens are commonly used in crop production for reducing excessive solar radiation, weather effects on produce, or to keep away insects (http://www.aces.edu/go/87).

In China, Feng-cheng *et al*. (2010) demonstrated 90% reduction in the occurrence of tomato yellow leaf curl virus due to the near elimination of whiteflies under a 50-mesh net house. Martin *et al*., 2006 reported that in Africa, mobile net houses made of mosquito nets (25-mesh) were effective as physical barrier against the diamondback moth, cutworms, and loopers providing 66 to 97% control of moths and caterpillars which may otherwise reduce fruit quality. As a result of a rising demand for all year round supply of fresh produce, more specifically vegetable and the necessity of plant protection, the use of protective housing for cropping systems has gained worldwide importance. The use the greenhouse for the cultivation of sweet pepper in this research proved significant in that, there were minimal pest and disease infections on fruits as Gruda, (2005) stated that protected cultivation is particularly important for the production of fresh vegetables. The greenhouse had significant effects on the growth of the sweet pepper varieties. The correlation studies conducted supported the results by indicating strong positive correlation of plant height (0.42**), number of fruits per plant (0.41**) and biomass dry weight (0.33*). In the open field, Kulkukan and F1 Nobili had the highest dry biomass weight followed by Crusader, Pepper 1 and Caribbean Red while Embella 733 recorded the lowest biomass weight. It was noted in this research that Kulkukan significantly had the highest biomass dry weight. The correlation analysis at reproductive growth stage, biomass dry weight showed a strong positive association with number of fruits per plant (0.41**), fruit weight (0.35**) yield t/ha (0.35**).

5.2 Growth in the Greenhouse

Greenhouse is generally regarded as necessary to provide warm environment in the cold climates, it has been shown that with properly cooling system, it is possible to improve plant growing conditions under extremely hot conditions (Mears 1990). The minimum and maximum temperature recorded in this research was between 18.31 ºC and 22.54 ºC in the greenhouse which is in line with the results of Mateen *et al* (2005), who also revealed that sweet pepper generally requires temperature, ranging 25-35 °C. Growing of Capsicum under cover has been reported to give good quality produce with higher productivity in several countries.

The greenhouse, however, had significant results among all the varieties studied as this was in confirmation with Kurubetta and Patil (2009) who reported that sweet pepper hybrids under different protected cultivation recorded significant results among the tested hybrids under these structures.

5.2.1 Sweet pepper yield and yield attributes in the greenhouse

The greenhouse served as a favourable environment therefore enhancing yield and yield components. Significant observation were made on number of fruits per plant, fruit yield (kg/ha), fruit weight, fruit length and width, pericarp thickness and seed number per fruits. It was evident in this research that all the green house treatments cultivated had significant high yield compared to the open field treatment.

Kukulkan recorded the highest number of fruit per plants followed by Caribbean Red with Yolo Wonder and guardian pepper had the least number of fruits. Kanwar *et al*, (2014) found higher number of fruits per plant in bell pepper under greenhouse condition. There was a strong positive correlation with number of fruits per plants (r = 0.51**), fruit weight (r = 0.45**) and fruit yield Kg/ha (r = 0.45**) as the greenhouse had a positive effects on the varieties. Highest fruit yield per treatments replicate was significantly obtained by Kulkukan, California Wonder and Crusader which showed superior traits in its effect in the greenhouse with Yolo Wonder and Nobili got the lowest fruit yield in the greenhouse. Brar *et al*, (2005) reported highest yield in *Capsicum* var. *bombay* under polyhouse condition.

The greenhouse increased the yield of these of the varieties compared to same varieties in the open field. There was also a high yield difference between the greenhouse varieties and the open field varieties ranging from 50% - 150% respectively and this may be due to the favourable environmental conditions as Singh *et al*, (2003) found that protected structures act as physical barrier and play a key role in integrated pest management by preventing spreading of insects, pests and viruses causing severe damage to the crop. This wasn't different from the findings of Zakaria (2003), which revealed that the fully controlled greenhouse increased the fresh yield of sweet pepper by 176.8% and 228.5% as compared to partially controlled environment. Also the fully controlled greenhouse gave the highest percentage of grade (85.66%) as compared with the flat-roof net-house (67.33%) and modified Quonset greenhouse (55.90%). In the greenhouse Kulkukan, California Wonder, Crusader recorded the highest fruit yield and Caribbean Red and Guardian pepper fruit weight recorded the lowest yield as far as fruit yield on kg/ha is concerned. Chandra *et al.,* 2000 and Singh *et al.,* 2004 and 2010 indicated that polyhouses and poly-tunnels are most suitable solutions for yield increase of sweet pepper since the crops are being protected. In the greenhouse, however, California Wonder and Crusader had the longest fruit length with Caribbean Red recorded the shortest fruit length. The fruit width also showed significantly increased with Pepper 1, Yolo Wonder and Crusader recorded the longest fruit width while the shortest width was observed in Caribbean Red. Khokhar *et al* (2006) reported significant difference in fruit size (length and width) in different tomato hybrids studied. This indicates that, Fruit width, therefore, had a significant positive correlation with fruit yield Kg/ha ($r = 0.35^{**}$), pericarp thickness ($r = 0.84^{**}$), fruit weight ($r= 0.35^{**}$) and negative relationship with number of fruits per plants ($r= -0.76^{**}$). Number of locules per fruits: Non significant result was recorded in case of number of locules per fruits. This shows that the varieties tried had similar performance regarding number of locules

Pericarp thickness differed significantly of which Guardian pepper, Crusader and California Wonder had the thickest pericarp thickness the thinnest pericarp thickness was observed in Caribbean Red and Kulkukan. Chaudhry *et al*, (2003) also found variation in pericarp thickness in tomato studies. Seed number per fruits differed significantly among all the varieties used in this study. The Embella 733, F1 Nobili gained the highest seed number whereas California Wonder (45) had the lowest seed number per fruits. Seed number per fruits varied significantly according to variety. This supports the findings of Marcelis and Baan, (1995) who reported that under normal growing conditions the amount of seed per fruit is highly variable

5.3 Consumer Acceptability of Fruits

The current results revealed that greenhouse specifically improved the physical appearance of the fruits in relation to the open field treatments. In general it was therefore found in the consumer acceptability was based on physical appearance characteristics such as colour, size, shape, lack of blemishes, and glossiness are the main indices of consumers demand for particular products.

California Wonder and Crusader were highly accepted at the rank of 8 for greenhouse and 7 in the open field. The least accepted variety was found to be Caribbean Red and Kukulkan though they had higher yields. Consumers accepted these sweet pepper fruits more the greenhouse because of its size (bigger), high quality and more appealing nature. California Wonder was highly accepted among the other varieties because of its less seed characteristics. Caribbean Red and Kukulkan on the other hand were least accepted due to its small fruit size. This indicates that the greenhouse varieties were highly appealing fruits than the open field varieties therefore consumers rated the former high quality fruits and the latter as moderately good fruits and this may be linked to the fact that the production system used has tremendously influenced the fruit quality hence its acceptance. This result was similar to the findings of Smither-Kopperl and Cantliffe, 2004, who concluded that, Consumers are willing and prepared to pay more for greenhouse-grown sweet peppers, due to their high quality and seasonal availability. Jovicich *et al*, 2004 also reported similar research findings in Florida that an averaged year-round wholesale fruit prices went up three 3 times greater than colored field-grown fruits and 5 times greater than field-grown green fruits. USDA, (2005c), reported that greenhouse-grown colored bell peppers in Mexico established 60% premium over field bell peppers from Mexico but Cantliffe *et al* (2008), revealed that in Florida field producers are offered a premium price for mature red, yellow and orange colored peppers over mature green peppers, but, by delaying harvest, field producers increase their risk, through reduced yield or loss from weather, pest and disease, viruses or insects, which leads to unacceptable and unmarketable fruit. Jovicich *et al*. (2005) reported that greenhouse production is a profitable venture.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The greenhouse system significantly affected almost all the growth parameters; however, this revealed that, Crusader, Kulkukan and California Wonder, had a higher, growth, development and fruit yield than Caribbean Red, Embella 733 and Guardian pepper which gave a substantial yield as well. Yolo Wonder and F1 Nobili attained the lowest fruit yield in the greenhouse. This work also revealed that, varieties such as California Wonder, Crusader and Kulkukan significantly recorded high growth, development and fruit yield. Nonetheless, Guardian pepper, Yolo Wonder, Embella 733 and F1 Nobili also responded significantly in terms of growth and yield in the open field compared to Pepper 1 and Caribbean Red which had relatively low yields in the open field.

In all the parameters measured indicated that varieties grown in the green house had a higher 50 – 150% yield increase compared to the open field varieties. It is therefore concluded that protected structure considerably improved production yield of sweet pepper as compared to open fields during minor season. This study also demonstrates that in the greenhouse California Wonder and Crusader were highly preferred and accepted by consumers and this may be attributed to its high quality, larger fruits size and low seed number per fruit while in the open field Yolo Wonder and California Wonder were preferred. Finally, consumer demand for greenhouse sweet pepper is very high since high quality fresh pepper is produced and available all year round (major and lean seasons) compared to open field since the crops are protected from adverse environmental conditions.

6.2 Recommendations

Based on the results from the work conducted, it is recommended that;

- Sweet pepper varieties such as Crusader, Kulkukan and California Wonder can be grown in the green house for increased yield and higher consumer acceptance. alternatively, Yolo Wonder, California Wonder Crusader and Kulkukan are best suited for open fields for high yields and good returns on investment
- Future research could also focus on employing different greenhouse types to compare open field production systems.

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APPENDICES

Appendix 1: Initial Plant Height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	72.846	36.423	10.15	
REP.*Units* stratum					
VARIETY	8	86.543	10.818	3.01	0.011
LOC	1	20.907	20.907	5.82	0.021
VARIETY.LOC	8	35.897	4.487	1.25	0.301
Residual	34	122.034	3.589		
Total	53	338.226			

Appendix 2:Plant height at 2WAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	42.043	21.022	3.29	
REP.*Units* stratum					
VARIETY	8	317.837	39.730	6.21	<.001
LOC	1	158.449	158.449	24.78	<.001
VARIETY.LOC	8	101.443	12.680	1.98	0.079
Residual	34	217.417	6.395		
Total	53	837.188			

Appendix 3: Plant Height at 4WAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	138.58	69.29	2.89	
REP.*Units* stratum					
VARIETY	8	1320.48	165.06	6.89	<.001
LOC	1	1204.73	1204.73	50.26	<.001
VARIETY.LOC	8	148.89	18.61	0.78	0.626
Residual	34	814.92	23.97		
Total	53	3627.60			

Appendix 4: Plant Height at 6 WAT

Variate: 6WAT_PH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	209.13	104.56	2.92	
REP.*Units* stratum					
VARIETY	8	5781.21	722.65	20.21	<.001

LOC	1	6529.60	6529.60	182.65	<.001
VARIETY.LOC	8	1827.53	228.44	6.39	<.001
Residual	34	1215.48	35.75		
Total	53	15562.96			

Appendix 5: Initial Plant Girth

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.0255259	0.0127630	13.53	
REP.*Units* stratum					
VARIETY	8	0.0229037	0.0028630	3.03	0.011
LOC	1	0.0000667	0.0000667	0.07	0.792
VARIETY.LOC	8	0.0021333	0.0002667	0.28	0.967
Residual	34	0.0320741	0.0009434		
Total	53	0.0827037			

Appendix 6: Plant girth @ 2WAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.024604	0.012302	4.71	
REP.*Units* stratum					
VARIETY	8	0.037270	0.004659	1.78	0.115
LOC	1	0.000417	0.000417	0.16	0.692
VARIETY.LOC	8	0.008633	0.001079	0.41	0.905
Residual	34	0.088863	0.002614		
Total	53	0.159787			

Appendix 7: Plant Girth @ 2WAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.024604	0.012302	4.71	
REP.*Units* stratum					
VARIETY	8	0.037270	0.004659	1.78	0.115
LOC	1	0.000417	0.000417	0.16	0.692
VARIETY.LOC	8	0.008633	0.001079	0.41	0.905
Residual	34	0.088863	0.002614		
Total	53	0.159787			

Appendix 8: Plant girth @ 4WAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.011644	0.005822	1.82	

REP.*Units* stratum					
VARIETY	8	0.025872	0.003234	1.01	0.444
LOC	1	0.011822	0.011822	3.71	0.063
VARIETY.LOC	8	0.024328	0.003041	0.95	0.488
Residual	34	0.108470	0.003190		
Total	53	0.182137			

Appendix 9: Plant Girth @ 6WAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.076844	0.038422	5.07	
REP.*Units* stratum					
VARIETY	8	0.140167	0.017521	2.31	0.043
LOC	1	0.000002	0.000002	0.00	0.988
VARIETY.LOC	8	0.058648	0.007331	0.97	0.478
Residual	34	0.257889	0.007585		
Total	53	0.533550			

Appendix 10: Number of Leave per Plant (Initial) WAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	11.9570	5.9785	7.36	
REP.*Units* stratum					
VARIETY	8	25.5526	3.1941	3.93	0.002
LOC	1	0.0741	0.0741	0.09	0.765
VARIETY.LOC	8	12.2459	1.5307	1.88	0.095
Residual	34	27.6163	0.8122		
Total	53	77.4459			

Appendix 11: Number of Leave per Plant @ 2WAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	14.388	7.194	2.86	
REP.*Units* stratum					
VARIETY	8	66.379	8.297	3.30	0.007
LOC	1	0.090	0.090	0.04	0.851
VARIETY.LOC	8	12.397	1.550	0.62	0.758
Residual	34	85.479	2.514		
Total	53	178.733			

Appendix 12: Number of Leave per plant @ 4WAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	57.94	28.97	1.82	
REP.*Units* stratum					
VARIETY	8	536.75	67.09	4.22	0.001
LOC	1	13.90	13.90	0.87	0.356
VARIETY.LOC	8	280.00	35.00	2.20	0.052
Residual	34	540.38	15.89		
Total	53	1428.97			

Appendix 13: number of leave per plant @ 6WAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	369.98	184.99	2.77	
REP.*Units* stratum					
VARIETY	8	5710.90	713.86	10.68	<.001
LOC	1	2364.14	2364.14	35.38	<.001
VARIETY.LOC	8	3467.18	433.40	6.49	<.001
Residual	34	2271.71	66.81		
Total	53	14183.90			

Appendix 14: Chlorophyll Content of leaves @ vegetative growth stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	71.22	35.61	0.54	
REP.*Units* stratum					
VARIETY	8	1432.35	179.04	2.72	0.020
LOC	1	7821.67	7821.67	118.93	<.001
VARIETY.LOC	8	273.88	34.24	0.52	0.833
Residual	34	2236.16	65.77		
Total	53	11835.29			

Appendix 15: Chlorophyll Content of leaves @ Reproductive growth stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1852.7	926.4	7.65	
REP.*Units* stratum					
VARIETY	8	2531.0	316.4	2.61	0.024
LOC	1	19373.3	19373.3	160.07	<.001
VARIETY.LOC	8	1563.0	195.4	1.61	0.157
Residual	34	4115.1	121.0		
Total	53	29435.2			

Appendix 16: Fruit Length (cm)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	23.9127	11.9564	16.92	
REP.*Units* stratum					
VARIETY	8	98.4073	12.3009	17.41	<.001
LOC	1	16.4673	16.4673	23.30	<.001
VARIETY.LOC	8	4.0912	0.5114	0.72	0.670
Residual	34	24.0281	0.7067		
Total	53	166.9065			

Appendix 16: Fruit Width (cm)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.39077	0.19539	2.21	
REP.*Units* stratum					
VARIETY	8	67.18384	8.39798	94.96	<.001
LOC	1	3.42519	3.42519	38.73	<.001
VARIETY.LOC	8	0.94081	0.11760	1.33	0.263
Residual	34	3.00683	0.08844		
Total	53	74.94744			

Appendix 17: Biomass Dry Weight @ Vegetative growth stage (g)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1.9360	0.9680	6.71	
REP.*Units* stratum					
VARIETY	8	25.7751	3.2219	22.34	<.001
LOC	1	2.3271	2.3271	16.14	<.001
VARIETY.LOC	8	3.0820	0.3853	2.67	0.022
Residual	34	4.9028	0.1442		
Total	53	38.0231			

Appendix 18: Biomass Dry Weight @ Reproductive growth stage (g)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	2.1799	1.0899	1.64	
REP.*Units* stratum					
VARIETY	8	45.7985	5.7248	8.63	<.001
LOC	1	18.9985	18.9985	28.65	<.001
VARIETY.LOC	8	21.5816	2.6977	4.07	0.002
Residual	34	22.5471	0.6631		
Total	53	111.1055			

Appendix 19: Pericarp thickness (mm)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.03704	0.01852	1.00	
REP.*Units* stratum					
VARIETY	8	33.19481	4.14935	224.06	<.001
LOC	1	2.06116	2.06116	111.30	<.001
VARIETY.LOC	8	1.48926	0.18616	10.05	<.001

Residual	34	0.62963	0.01852		
Total	53	37.41190			

Appendix 20: Number of Seeds per plants

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	25.481	12.741	1.65	
REP.*Units* stratum					
VARIETY	8	139788.148	17473.519	2257.34	<.001
LOC	1	4666.741	4666.741	602.88	<.001
VARIETY.LOC	8	7256.593	907.074	117.18	<.001
Residual	34	263.185	7.741		
Total	53	152000.148			

Appendix 21: Days to 50% flowering

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	34.778	17.389	8.97	
REP.*Units* stratum					
VARIETY	8	906.667	113.333	58.48	<.001
LOC	1	181.500	181.500	93.66	<.001
VARIETY.LOC	8	88.667	11.083	5.72	<.001
Residual	34	65.889	1.938		
Total	53	1277.500			

Appendix 22: Number of Fruits per plants

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	60.33	30.17	0.71	
REP.*Units* stratum					
VARIETY	8	4591.00	573.88	13.50	<.001
LOC	1	208.07	208.07	4.90	0.034
VARIETY.LOC	8	183.59	22.95	0.54	0.818
Residual	34	1445.00	42.50		
Total	53	6488.00			

Appendix 23: Average fruit weight (g)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1630.7	815.4	3.78	
REP.*Units* stratum					
VARIETY	8	20374.7	2546.8	11.80	<.001
LOC	1	4989.3	4989.3	23.11	<.001
VARIETY.LOC	8	4219.9	527.5	2.44	0.033
Residual	34	7340.2	215.9		
Total	53	38554.8			

Appendix 23: Fruit Yield kg/ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	58566560.	29283280.	7.68	
REP.*Units* stratum					
VARIETY	8	167044713.	20880589.	5.47	<.001
LOC	1	416267842.	416267842.	109.11	<.001
VARIETY.LOC	8	95096569.	11887071.	3.12	0.009
Residual	34	129715426.	3815160.		
Total	53	866691111.			

Appendix 24: Field layout

*** OP; open field, GH- greenhouse, GD- guardian, CS- crusader, CW- California wonder, KK-**

FIELD LAYOUT {2×9 FACTORIAL}					
REP I		**REP II**		**REP III**	
1 OFPI	**10 OFGD**	**1 OFCR**	**10GHPI**	**1 OFCW**	**10 OFYW**
2 OFFN	**11 GHCS**	**2 GHYW**	**11 OFCS**	**2 OFEM**	**11 OFCS**
3 GHEM	**12 OFEM**	**3 OFFN**	**12 OFYW**	**3 GHKK**	**12 GHFN**
4 OFCR	**13 OFYW**	**4 GHEM**	**13 OFEM**	**4 GHCS**	**13 GHCR**
5 GHYW	**14 OFCW**	**5 OFPI**	**14 GHKK**	**5 OFFN**	**14 GHCW**
6 OFKK	**15 GHKK**	**6 GHFN**	**15 OFGD**	**6 GHEM**	**15 OFPI**
7 GHCR	**16 GHGD**	**7 GHCS**	**16 GHGD**	**7 GHGD**	**16 GHYW**
8 GHFN	**17 GHPI**	**8 GHCW**	**17 GHCR**	**8 OFCR**	**17 OFKK**
9 GHCW	**18 OFCS**	**9 OFCW**	**18 OFKK**	**9 GHPI**	**18 OFGD**

Kulkukan, CR-
Caribean red, P1 pepper 1, FN f1 Nobili, EM- Embella 733

Appendix 25: Budget for using greenhouse for sweet pepper production

Greenhouse			
Item/Activity	**Quantity**	**Unit Cost (GH¢)**	**Total Cost (GH¢)**
Input (A)			
seed	6	50.00	300.00
Knapsack	2	200.00	400.00
Seed trays	100	5.00	500.00
Watering can	2	50.00	100.00
Chemicals			
1. Fertilizer	2	100.00	200.00
2. Herbicides	3	25.00	75.00
3. Insecticides	3	20.00	60.00
4. Fungicides	3	20.00	60.00
Sub Total (A)			**1695.00**
Labor (B) **Land preparation**			
Land clearing	-	-	-
Weedicide application	-	-	-
stumping	-	-	-
Lining	-	25.00	75.00
Nursing seeds	1	25.00	25.00
Transplanting	4	25.00	100.00

Fertilizer application	2	25.00	50.00
Fungicide application	2	25.00	50.00
Insecticide application	2	25.00	50.00
Weeding/weed control	2	25.00	50.00
Sub Total B			**375.00**
Harvesting cost (C)			
Harvesting	6	30	180.00
Transportation to mkt.	6	100.00	600.00
Sub Total C			**780.00**
Total cost **A+B+C**			**2825.00**

Appendix 26: Budget for using open field for sweet pepper cultivation

Open field			
Item/Activity	**Quantity**	**Unit Cost (GH¢)**	**Cost (GH¢)**
Input (A)			
seed	6	50.00	300.00
Knapsack	2	200.00	400.00
Seed trays	100	5.00	500
Watering can	2	50.00	100.00
Chemicals			
1. Fertilizer	2	100.00	200.00
2. Herbicides	3	25.00	75.00
3. Insecticides	3	20.00	60.00
4. Fungicides	3	20.00	60.00
Sub Total (A)			**1695.00**
Labor (B) **Land preparation**			
Land clearing	1	100.00	100.00
Weedicide application	3	25.00	75.00
stumping	1	200.00	200.00
Lining and pegging	3	25.00	75.00
Nursing seeds	1	25.00	25.00
Transplanting	4	25.00	100.00

Fertilizer application	2	25.00	50.00
Fungicide application	2	25.00	50.00
Insecticide application	2	25.00	50.00
Weeding/weed control	2	25.00	50.00
Sub Total B			**850.00**
Harvesting cost (C)			
Harvesting	6	20	180.00
Transportation to mkt.	6	100.00	600.00
Sub Total C			**780.00**
Total cost **A+B+C =**			**3325.00**