EFFECT OF AGE OF TRANSPLANTS, SPACING, SUPPLEMENTARY APPLICATION OF SULPHATE OF AMMONIA AND HARVESTING INTERVALS ON GROWTH, YIELD AND SOME POSTHARVEST QUALITIES OF CHILLI PEPPPER (*C. annuum*) VAR. LEGON 18

BY

RICHARD OSEI

APRIL, 2013

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (OLERICULTURE) DEGREE.

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Declaration

I do hereby declare that this work submitted is the outcome of my own effort and that in no previous application for a similar degree in Master of Science (Olericulture) in this University or elsewhere has this work been presented, except where due acknowledgement has been made in the text.

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Dedication

This work is dedicated to the Almighty God, my fiancée Charlotte Amoanimaa, my parents, Mr. Stephen Anto and Ms. Veronica Fosua, uncles, aunties especially Joyce Adobea, siblings and friends.

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Abstract

Two field experiments, one on the effect of age of transplants and spacing on the growth and yield and the second on application of inorganic fertilizers (NPK and sulphate of ammonia) and harvesting intervals on the yield and some postharvest qualities of chilli pepper (*Capsicum annuum*) var. Legon 18 were studied in a 3x3 factorial experiment on the experimental plots at the Department of Horticulture, Faculty of Agriculture, KNUST, Kumasi. In a Randomized Complete Block Design, age of transplants and spacing constituted the factors for the first experiment and fertilizer and harvesting intervals constituted the factors for the second experiment, with 3 levels for each of the factors. Data collected were plant height, number of leaves and branches, days to flowering and fruit set, number of fruits per plant and per hectare, fruit weight per plant and per hectare, number and weight of marketable fruits per hectare, weight loss, fruit firmness, fruit decay, shelflife of fruits and nutrient composition of fruits. Plant height was significantly affected by the age of transplanting and spacing. The 3 week-old transplants and the closest spacing produced taller plants whilst the four week-old transplants (A2) had more branches and leaves per plant than the other treatments. Spacing had a significant effect on the number of branches but did not affect the number of leaves. The widest spaced plants (S3) (75cmx75cm) produced more branches per plant. The interaction showed significant differences between some of them with the four week-old transplants and 75cmx75cm (A2S3), four week-old transplants and 75cmx75cm (A3S3) having more branches and leaves. On yield, the four week-old transplants (A2) produced more and heavier fruits per plant and per hectare. With spacing, the closest spacing (S1) (45cmx45cm) produced the highest number and weight of fruits per hectare but the least fruit yield per plant. Therefore, their interaction (A2S1) had more and heavier fruits per hectare which in turn reflected on the highest total number and weight of marketable fruits per hectare. Fertilization significantly influenced the number and weight of fruits. The F2 (9g NPK + 5g S/A) plants had more and heavier fruits per plant and per hectare. Harvesting at 3 days interval (H1) produced more fruits (number and weight) per plant and per hectare. Weight loss was not influenced by fertilizer but was significantly influenced by harvesting intervals with the fruits harvested at 7 days interval (H3) recording the lowest weight loss. Fruit firmness and decay were significantly affected by both fertilization and harvesting intervals. Treatments that received 9gNPK only (F1) produced fruits with higher firmness whilst plants that received 9gNPK+10gS/A produced the least firm fruits. Fruits harvested at 7 days interval recorded the best firmness whilst fruits harvested at 3 days interval were the least firm. The 9gNPK+10gS/A (F3) plants recorded the highest fruit decay, while the 9gNPK only (F1) plants had the lowest fruit decay. Fruits harvested at 7 days interval (H3) recorded the highest fruit decay, while fruits harvested at 5 days interval had the least. Nutrient composition of fruits was also affected by fertilization and harvesting intervals. Plants treated with 9gNPK+10gS/A and harvested at 5 days interval had the highest protein content but had the lowest ash content. Treatment with 9gNPK+5gS/A and harvested at 7 days interval recorded the highest crude fibre content. Plants applied with 9gNPK and harvested at 3 days interval had the highest crude protein and ash contents. The results showed that four week-old transplants spaced at 45cmx45cm produced the highest number and weight of fruit per hectare and marketable fruits per hectare and the application of fertilizer at the rate of 9gNPK+5gS/A/plant and harvesting at 5 days interval also produced more and heavier fruits per hectare.

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CHAPTER ONE

INTRODUCTION

Pepper (*Capsicum annuum*) belongs to the *Solanaceae* family and is related to eggplant, potatoes and tomatoes. It is consumed both as fresh and dehydrated spices (Bosland and Vostava, 2000). Pepper commonly known as chilli, is the world's third most important vegetable after potatoes and tomatoes in terms of quantity of production. World production of chilli pepper is 28.4 million metric tonnes (mt) (both dry and green fruits) from 3.3 million hectares with an annual growth rate of 0.5% (FAO, 2007).

In West Africa, chilli pepper is a major vegetable crop and is an important constituent of local dishes. Recently, the crop is grown in Ghana for export to Europe and has become an important foreign exchange earner. Some of the varieties of chilli pepper grown in Ghana are Bird's eye, Legon 18, MI2, Fresno and Jalapeno (Ofori *et al.*, 2007). Yields of annual hot peppers range from about 15 to 55 t/ha. The yields are variable and dependent on cultivar which differs in size of fruits and of plants, and on the system of cultivation (Norman, 2002).

As food, pepper has little energy value but it is an excellent source of vitamin B_2, potassium, phosphorus and calcium. The high nutritive value of pepper results in a high market demand year round. Pepper fruits are used in salads, pickles, stuffing, spices, sauce, and as a dried powder (Norman, 2002).

Although Ghana has been exporting chilli peppers for over fifteen years, significant growth in the production of chilli peppers for export is a relatively recent phenomenon. The growth in exports was prompted by the development of a hybrid chilli pepper, Legon 18, developed specifically for Ghanaian soils by researchers at the University of Ghana- Legon. In addition to being well-suited to Ghanaian soils and climatic conditions, Legon 18 was bred to maintain freshness to enhance its exportability. Since becoming more widely available, Legon 18 has been increasingly produced for export by local farmers through MiDA technical training programmes and is now exported to nine countries (GEPC, 2007).

The production volume of chilli peppers remained relatively constant during the last 10 years. It increased slightly from 270,000mt in 2000 to 277,000 in 2006 and 279,000 in 2008 along with increased availability of the Legon 18 seed variety and MiDA's chilli pepper production training programmes. Currently Ghana is producing about 279,000mt (FAOstat, 2009).

According to GEPC (2007), Legon 18 has built a very good reputation for taste and quality in European markets. While regular fresh green chilli peppers have a shelflife of only three days, Legon 18 has a shelf life of more than one week. It remains crisp and fresh on the shelf, which is preferred by customers and beneficial to importers in terms of reducing losses from spoilage.

The effect of transplant age on yield is an issue often investigated by growers to maximize production potential (Vavrina, 1998). Liptay (1987) reported that moisture, which is essential for top growth of plants, is absorbed by root hairs. Such important roots hairs are destroyed during transplanting. The older the plant the more extensive its root system and the greater the root hairs lost in transplanting. Norman (1977) in his study on the effect of age of transplants on hot pepper remarked that flowering, fruiting and harvesting were delayed by transplanting and therefore recommended 5-6 weeks old transplants for hot pepper production in Ghana. When transplants are thought to be too old, concerns are raised about their subsequent growth and yield potential. Young transplants (3 to 4 weeks) reduce production costs, but will need to be grown longer in the field to reach optimum yields (Leskovar *et al*., 1991; Orzolek *et al*., 1991).

Research works done in other countries show that both growth and yield in chilli's are markedly influenced by differentially aged seedlings and transplanting date. Cultural factors, such as transplant age (McCraw and Greig, 1986, Weston, 1988), pruning (McCraw and Greig, 1986), fertility (Knavel, 1977, Sundstrom *et al*., 1994), influenced pepper yield. Lee *et al*. (2001) reported that seedling growth of chilli's was greater with increasing age of transplants. They concluded that plant height, dry weight and the number of branches increased with seedling age.

Knowledge of crop response to population density is useful for management decisions and it provides the basis for assessing the effects of intra- species competition (Jolliffe, 1988). Crop (cultivars) with vigorous growth habit are usually planted at a wider row spacing to avoid competition among neighbouring plants and also to prevent mutual shading in plant canopies. Disease prevalence and severity are also important considerations for a wider row planting option (Castilla and Fereres, 1990). Plant densities beyond certain thresholds can adversely affect fruit quality and encourage disease development in pepper plants. Inadequate fruit colour development was also observed in over densely planted hot pepper (Stoffella and Bryan, 1988). This may be due to the inability of some of the fruit to be in direct sunlight, which is important for the development of carotenoid pigments. Poor ventilation is responsible for high disease incidence associated with high planting density in tomato, especially under greenhouse conditions (Castilla and Fereres, 1990).

Plant population primarily affects the amount of radiation intercepted per plant. Light quality as modified by different plant populations may also play an important role on early plant growth and partitioning responses in plants (Villalobos *et al.*, 2002). The yield advantage due to narrow spacing is usually attributed to the development of a full canopy in early development stages (Fukai *et al.*, 2004). These full canopies, in turn, intercept more radiation and have a greater photosynthetic production than the partial canopy development that is usually observed in wider row spacing.

Nitrogen is an important mineral element that is used by almost all crops. Nitrogen, as a key component of plant proteins, plays an important role in plant growth and development. Because of nitrogen's involvement in protein synthesis, soil nitrogen deficiencies may lead to lower protein concentrations in vegetables, thereby affecting the nutritional composition of the crop. Adequate soil nitrogen supplies allow for the optimal development of vegetable color, flavor, texture, and nutritional quality. However, plants receiving excess nitrogen produced excess foliage and decreased yield (Stroehlein and Oebker 1998).

Ahmed *et al.* (2007) reported that an increase in nitrogen application resulted in maximum fruit length, fruit weight, vine length and yield of cucumber. Din *et al.* (2007) reported that NPK level of 120kgha^{-1} significantly performed better with regard to head weight, head diameter, head length, marketable yields and head yield of cabbage. Jilani *et al.* (2008) reported that nitrogen application at 100kgha^{-1} produced significantly maximum survival percentage, fruit length, fruit diameter, fruit volume, fruit weight and yield per hectare.

Of the three major nutrients, plants required nitrogen in the largest amounts. Nitrogen promotes rapid growth, increases leaf size and quality, hastens crop maturity, and promotes fruit and seed development. Because of nitrogen constituent of amino acids, which are required to synthesize proteins and other related compounds, it plays a role in almost all plant metabolic processes. Nitrogen is also an integral part of chlorophyll manufacture through photosynthesis. Excess N causes increased susceptibility of vegetable crops to fungal diseases and deterioration of post harvest quality (Collingwood, 1988).

The objectives of the two experiments were to:

(1) find out the effect of seedling age and different spacings on the growth and yield of chilli pepper (*Capsicum annuum*) var. Legon 18.

(2) determine the effect of different levels of Sulphate of ammonia and harvesting intervals on yield and some post harvest qualities of chilli pepper (*Capsicum annuum*) var. Legon 18.

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CHAPTER TWO

LITERATURE REVIEW

Effect of age of transplants on vegetative growth and yield of chilli pepper

The main physical defect in transplanting of seedlings is root damage, which can result in moisture stress, slow development and inferior yield. Norman (1977) in his study on the effect of age of transplant on hot pepper remarked that flowering, fruiting and harvesting were delayed by transplanting and therefore recommended 5-6 weeks old transplants for hot pepper production in Ghana. Shukla *et al.* (2011) worked on the effect of age of transplants on growth and yield of chilli pepper (*Capsicum annuum*) variety California Wonder. They reported that middle aged transplants produced more fruits than the younger or older transplants. The possible reason seems to be that in younger seedlings there was less storage of food needed for vegetative growth, whereas, older transplants were matured enough and restrained vegetative extension. Moreover, middle aged seedlings on account of extended lateral branches produced more fruits per plant than younger or older ones.

Renuka and Perera (2002) evaluated three types of seedlings (30-day, 55-old seedlings after pricking out and 55-day old seedlings after pricking out with removed apical portion) for two varieties of chilli pepper (Arunalu and M12). They reported that 55-day-old seedlings with apical part recorded higher yield than 30-day-old and had 28% yields increase over the 55-day-old seedlings without apical portion. McCraw and Greig (1986) used 8 and-11-week-old transplants of four cultivars in a pepper transplant age study in Kansas. Pooling the data from the four cultivars, they found no differences due to the age of transplants in early yield (number and weight) in the first year, but a greater number of heavier fruits with 8 week-old transplants the following year. Three of the four cultivars tested showed that the 11 week-old transplants produced more total fruits per plant than the younger transplants.

Safina *et al.* (2006) conducted a research to observe the influence of different age of transplants on vegetative growth of chilli F1 hybrid Sky Line-2. Seedlings of different ages (40, 50, 60, and 70 days old) were used. Plant height at first flowering and maturity, number of days taken to flowering, number of leaves and number of branches per plant at maturity, foliage fresh and dry weight per plant and root fresh weight were affected by various ages of transplants. Forty days old seedlings recorded the highest plant height. Fifty days old seedlings exhibited best growth in terms of number of branches, and number of leaves per plant, foliage fresh and dry weight and root fresh per plant. Norman (1975) conducted an experiment on the influence of age of hot pepper transplants on growth, flowering, fruit set and yield. The seedlings were planted at 5, 6 and 7 weeks of age after pricking out. The results indicated that 5- and 6-week old transplants grew more quickly and yielded more than 7-week old ones. Flowering, fruiting and harvesting were delayed by late transplanting.

Effect of age of transplants on vegetative growth and yield of other fruit vegetables

Sinnadurai (1992) noted that the rate of recovery of vegetable seedlings varies indirectly with the age and size of the seedlings at the time of transplanting. Smaller or younger vegetable seedlings established quicker than the older and taller seedlings. Work by Adelana (1981) showed that the younger transplants grew faster and therefore produced greater dry matter than the older ones. Also, flowering and fruiting were earlier in the younger transplants.

Harmon *et al.* (1991) tested 4, 5, 6 and 7week-old eggplant transplants. They suggested that transplants <5 weeks old produced only minimal yields, while the earliest yields were obtained with 7 week-old transplants. Hotta *et al.* (1993) in Japan determined that 40 day-old eggplant seedlings were the most successful in summer trials. Lou *et al.* (1993) indicated that younger eggplants had better growth after transplanting and produced higher yield than older eggplants. Investigating the effect of age of seedlings on growth and yield of tomato, Salik *et al.* (2000) found that the medium aged seedlings (5 weeks) had the highest number of fruits per plant, marketable yield and fruit weight followed by 6 week and 4 weeks. Time taken to flowering was less in the case of 4 week seedlings than others. Number of branches was highest in 5 week old seedlings.

Pena-Lomeli *et al.* (1991) used three cultivars of tomato transplants of 2, 3, 4, 5, and 6 weeks of age. They found the 3-week- old transplants had the highest yields across cultivars. NeSmith (1994) also designed muskmelon transplant-age trial using plants 2, 4, 6, and 8 weeks old. He found age had no effect on either early or total yield. These research results imply that transplant age does not adversely influence yield in cucurbits. Commercially, 3 to 4 week old transplants are used for general cucurbit production. However, findings here support the idea that cucurbits can be held beyond this time frame without fear of yield loss, in the event of poor planting conditions. Weston and Zandstra (1989) used 4, 5, 6 and 7 week-old seedlings of tomato and found that 4 to 5 week-old transplants produced higher number and weight of fruits than younger or older transplants.

Leskovar *et al.* (1991) conducted experiment on the effect of age of seedlings and concluded that well established root system of older seedlings showed better survival as compared to younger seedlings.

Effect of spacing on vegetative growth and yield of chilli pepper

Studying the effects of plant establishment methods on the yield of pungent *Capsicum*, it was discovered that increasing spacing from 10cm to 30cm increased the number of fruits and branches per plant and reduced fruit length whilst yield, fruit weight and diameter were unaffected. The experiment was conducted on Cajun IA cayenne pepper whose seeds were direct sown at 8cm, 10cm, 15cm, 25cm, and 30cm within rows in spring (Leskovar *et al.*, 1992).

Studies on plant density for different types of pepper including bell, cayenne, pepperonicini and jalapeno have shown that plant density and plant arrangement can influence plant development, growth and the marketable yield of peppers (Khasmakhi-Sabet *et al.*, 2009). Nasto *et al.* (2009) reported that increasing plant density resulted in greater yield/ha of bell pepper. It was reported that increasing plant density decreased pepper root dry weight and there was a positive relationship between fruit weight and root weight (De-Viloria *et al.*, 2002). Dasgan and Abak (2003) also reported that pepper yield per plant was more with widest spacing of 80cmx45cm compared to 80cmx15cm. Ahmed (1984) observed that high population density could result in improved productivity of bell peppers. Locascio and Stall (1994) reported that marketable bell pepper yield/ha increased with greater plant density per unit area. Decoteau and Graham (1994) who carried out an experiment on the effect of spatial arrangement on growth and yield production of cayenne pepper saw that less fruit weight was located in the lower part of the plant canopy at higher plant population densities.

Idowu (2011) conducted an experiment to evaluate the growth and yield of hot pepper (*Capsicum frutescens*) as influenced by bed width and within row spacing. The main plot was the within row spacing (20, 30 and 40cm) and the sub plot was the bed width (60, 90 and 120cm). Intra row spacing of 40cm and 30cm gave significant higher leaf area and number of leaves per plant than spacing of 20cm. Fruit yield of pepper at 40cm and 30cm within row spacing out yielded that of 20cm by 244 and 167%, respectively. Bed width of 90cm produced the higher number of leaves, leaf area and fruit yield of pepper while bed width of 60cm produced the lower. Fruit yield of pepper on 90cm and 120cm bed width out yielded that of 60cm by 517 and 233%, respectively.

Islam *et al.* (2011) carried out an experiment to investigate growth and yield of sweet pepper as influenced by spacing. They found that number of branches, number of leaves, number of fruits and fruit weight per plant were found to be significantly increased with increasing plant spacing but plant height, number of fruits per hectare and fruit weight per hectare were found to be significantly increased with decreasing plant spacing. The highest average number of fruits (6.08) per plant was recorded from the widest spacing (50cm×50cm) which was significantly higher than those of other spacings (50cm×40cm and 50cm×30cm). The lowest number of fruits (4.63) per plant was noted under the closest spacing (50×30 cm). Reduced number of plants under wider spacing may be due to less inter and intra plant competition which resulted in increased number of fruits per plant. The highest yield (271.12g) was recorded from the widest spacing (50cm×50cm) and differed significantly from that of the other spacings. The lowest yield (191.73g) per plant was obtained from the closest spacing (50cm×30cm). The wider spacing might have facilitated the plants to develop properly with less inter and intra plant competition for utilizing the available resources resulting higher yield per plant. On the other hand, in higher population density reduced yield per plant might be attributed to lesser fruit yield per plant.

Afzal *et al.* (2004) studied the effects of various row spacing (60, 70 and 80 cm) on the growth characteristics of different chilli pepper cultivar PBC- 385 at the Agricultural Research Station (North) Mingora. They reported that highest plant height (88.96cm) was recorded at closer row spacing (60cm), while shortest plant height (85.18 cm) was recorded at 80 cm row spacing. Yahaya *et al.* (2010) studied the response of chilli pepper (*Capsicum frutescens* L.) to sheep manure and intra row spacing. An increase in yield with higher plant density was a result of increased numbers of fruit per hectare in direct-seeded paprika pepper (Cavero *et al.,* 2001). Alemayehu (2009) studied the effect of different row spacings and cultivars on growth and yield of hot pepper. The three cultivars were Jalapeno, Malaga and Serrano and the two row spacings 45cm and 70cm. Fruit number per plant increased from 112 to 127 as row spacing increased from 45cm to 70cm, indicating a compensatory growth response by individual plants to offset yield reduction due to wide row spacing.

Conducting an experiment on *Capsicum annuum* grown at in-row spacings of 7.5cm, 15cm, 22.5cm, 30cm and 45cm to determine the effect of plant population on growth and fruit yield, Motsenbocker (1996) realized that plants grown at the narrowest spacings produced the smallest plant leaf and stem biomass. These closest spacings however, recorded the highest fruit yield/ha. According to Joliffe and Gaye (1995), high population densities decreased absolute growth rates in bell peppers. Adopting plant densities of 1.4, 1.9, 2.8, 5.6 or 11.1plants/m^2, it was noted that node number was the most important yield component contributing to population density since the number of nodes resulted to the number of branches produced. Pepper plants grown in denser populations (smaller in- row plant spacings) tended to be taller (Karlen *et al*., 1987; Stoffella and Bryan, 1988) and may produce higher fruits per hectare than those grown in less- dense planting.

Stoffella and Bryan (1988) studying` the influence of plant population on growth and yields of Bell peppers (*Capsicum annuum* L.) reported that the number of marketable fruits and fruit weight per plant, root and shoot weight, shoot root ratios and stem diameters generally decreased and plant height generally increased in response to higher plant population. The number of primary and secondary branches and fruit size were generally not influenced by plant population. Marketable fruit yield/ha increased linearly in response to higher plant populations.

Kahn and Leskovar (2006) conducted an experiment on the effect of plant population on yield and fruit quality of bell pepper and showed that plant population had a significant influence on the parameters of bell pepper. For instance, the number and weight of marketable fruits per hectare increased under high population density as compared to less population density. Studying the effect of sowing time and plant spacing on yield and yield attributes of sweet pepper (*Capsicum annuum)*, Alam *et al.* (2011) observed that the number of branches per plant, number of fruits per plant, fruit length and fruit weight per plant significantly increased with increasing plant spacings but plant height, number of fruit per hectare and fruit weight per hectare significantly increased with decreasing plant spacing.

Aminifard *et al.* (2010) conducted experiment in open field to determine the effects of different densities (20cm×50cm, 30cm×50cm, 20cm×100cm and 30cm×100cm) on plant growth characteristics and fruit yield of paprika pepper (*Capsicum annuum* L.). Plant height, lateral stem length, number of branches, leaf number, flower number, yield, fruit seed number and 1000 seed weight were assessed. The results indicated that vegetative growth characteristics (number of branches, lateral stem length and leaf number) reduced as plant density increased. The highest number of branches and leaf number were obtained from widest spacing of 30cm×100cm. The highest plant height was obtained in plant density 20cm×50cm (closest spacing). It was observed that fruit weight, yield and seed number per plant decreased with increasing plant density, but total yield per hectare increased with increasing plant density.

Agarwal *et al*. (2007) investigated the influence of plant population on the productivity of green pepper (*Capsicum annuum* L.) in a greenhouse under full irrigation. Different populations (50 000, 62 500, 83 333, 100 000, 111 111, 160 000 and 200 000 plants ha^{-1}) were planted per bed with four rows per bed. Fruit number and yield per plant decreased when plant population increased from 50 000 to 200 000 plants ha^{-1}. Total fruit yield per hectare increased with an increase in plant population up to 120 000 plants ha^{-1} and thereafter it decreased as was the marketable fruit yield. Individual fruit mass was however not influenced up to a plant population of 120 000 plants ha^{-1} but decreased fast beyond this plant population. The increase in fruit number per plant and individual fruit mass as a result of increased plant population may be ascribed to a better utilization of available natural resources such as light and nutrients. Plant populations in the range of 100 000 to 120 000 plants ha^{-1} were optimum in terms of yield and quality.

Maya *et al.* (1997) worked on sweet pepper (*Capsicum annuum* var. grossum) planted at spacings of 60cm x 30cm, 60cm x 45cm and 60cm x 60cm. The results showed that plant height, dry matter production and yield per hectare were highest at the closest spacing of 60cm x 30cm, while number of branches per plant and yield per plant were highest at the widest spacing (60cm x 60cm). Other types of pepper such as bell pepper and jalapeno peppers, grown at higher plant populations produced higher fruit yields per unit area, while fruit set per plant decreased linearly in the field or green house (Jovicich *et al.,* 2004). Lorenzo and Castilla (1995) reported a significantly higher yield due to high density planting. This higher yield is attributed to increased leaf area index (LAI) which in turn improved radiation interception. Higher values of LAI in high density treatments led to an improved radiation interception and subsequently, to higher biomass and yield than in the low density treatment. Jolliffe and Gaye (1995) reported that as much as 47% variation in total fruit dry yield of pepper can be attributed to population density effects at 103 days after transplanting. At the end of the growing season, plant population density treatments accounted for 35% of the variation in the final cumulative fruit dry mass. Similarly, high density populations have been reported desirable for maximum yield/ha in cayenne (Decoteau and Graham, 1994) and bell pepper (Locascio and Stall, 1994).

Narrow row spacing (higher population density) resulted in plants that were smaller (less leaf and plant mass) more upright, and produced less fruit yield per plant but higher fruit yield (tons/ha) and number ha^{-1}. This suggests that the high yield with narrow row spacing is attributed to higher plant population and fruit production per area rather than higher pepper yield per plant or fruit size. Similar results were reported for cayenne pepper (Decoteau and Graham. 1994) bell pepper (Stoffella and Bryan, 1988) and Tabasco pepper (Sundstorm *et al.*. 1984). Further benefit of narrow spacing are increased ease of harvesting in closely spaced plant due to the plant's upright position with lower leaf area., which make locating fruits for hand removal easier (Motsenbocker, 1996).

The effect of plant population and spatial arrangement on agronomic performance of paprika (*Capsicum annuum* L.) was studied by Mavengahama *et al.* (2009). They found that marketable fruit yield increased by 48.1% when plant population was increased from 35,000 to 65,000 plants per hectare. Consequently, the significant increase in total fruit yield can be attributed to the interplay of factors, which resulted in significant increase in number of fruits per unit area and number of fruits per plant. Total fruit yield per plant and number of fruits per plant responded significantly to variation in plant population up to 65,000 plants per hectare. Above this population, fruit yield per plant declined significantly. Although the performance of the crop under spacing treatments was not consistent, however the number of fruits per plant, and fruit size were reduced at closer spacing as observed by Yahaya (2008).

Effect of spacing on vegetative growth and yield of other fruit vegetables

Plant population or plant density is another factor that affects okra seed production. Suitable plant spacing can lead to optimum seed yield whereas too high or too low plant spacing could result in relatively low yield and quality (Absar and Siddique, 1982). The observed increased in plant height as population density increased could be due to the result of intense competition within the plants, for light (Einum and Fleming, 2004), hence the increase in height. Studying the effect of spacing and weeding frequency on the growth and yield of ravaya, Kyeraa (2003) reported that although spacing did not affect plant height, closer spacing produced taller plants, wider canopy and the highest total number of fruits per plant and per hectare. Plant density is an important determinant of yield. Yield per unit area tends to increase as plant density increases up to a point and then declines (Akintoye *et al.*, 2009). Wider spacing on the other hand led to increase in fruit yield per plant with bigger fruits and more cracked fruits in tomato (Law-Ogbomo and Egharevba, 2009).

According to Kathirvelan and Kalaiselvan (2007) plant densities had significant influence on growth parameters of groundnut. For instance, plant height and number of branches per plant increased under wider spacing of 45cm×15cm as compared to the closer spacing of 30cm×10cm. They explained that as the feeding zone per plant under wider spacing was more when compared to closer spacing, the plants grew laterally and resulted in higher number of branches per plant. It was found by Kathirvelan and Kalaiselvan (2007) that plant geometry had significantly improved the fertility co-efficient. The highest fertility co-efficient was observed with spacing of 45cm×15cm, though it was at par with 45cm×10cm.

Investigating the effect of date of sowing and plant spacing on growth and yield of okra (*Abelmoschus esculentus*), Gorachand and Mallik (1990) reported that closer spacing produced taller plants of okra. Jamuna and Gopalakrishnan (2004) studying the effect of spacing on melon (*Cucumis melo* var. *conomon* Mak.) variety, *'Saubhagya* reported that highest yields (28.4t/ha) were obtained from closest spacing. Evaluation of the effect of cultivars and in-row spacing on vegetative growth and yield components in melon (*Cucumis melo* L.) found that the main vine length, diameter, number of leaves and lateral branches were highest at 1.5 m in-row spacing. Yield was significantly decreased with increased plant spacing. At in-row spacing of 1.5 m, yield was on average 25% lower than at 0.6 m spacing. Number of fruit per hectare decreased linearly while the number of fruit per plant increased linearly as plant spacing increased (Elsevier, 2006).

Field experiment was conducted to evaluate the response of 'NH47-4' variety of okra to different intra-row spacing. The treatments consisted of three intra-row spacing (30cm, 25cm and 20cm). The study showed that while the tallest okra height was produced from the intra-row spacing of 25cm, the number of branches per plant, leaf area, pod length, pod diameter, number of pods per plant, pod weight and yield decreased as intra-row spacing reduced. The greatest yield was obtained from the intra-row spacing of 30 cm (Ijoyah *et al*., 2010).

A field experiment was conducted by Paththinige *et al.* (2008) to investigate the effect of different plant spacings on yield and fruit characteristics of okra variety Pusa Sawani. The four plant spacings (90cm×60cm, 60cm×45cm, 45cm×45cm and 45cm×30cm) were used. Weight of fruits and number of fruits per plant increased at widest spacing (90cm×60cm). Total number of fruits and fruit weight per hectare also increased as plant population increased when compared to wider spacing with less plant population. Investigating the effect of spacing on the growth and yield of egg plant, *Solanum* spp, Kogbe (1983) reported that number of fruits per plant and fruit weight increased at widest spacing but number of fruit per hectare and fruit weight per hectare increased at closest spacing. Roy *et al.* (2000) working on spacing of tomato in Bihar, India obtained greater yields with higher plant population. They further found that decreases in spacing resulted in a reduction of fruit weight and number of fruits/plant. The effect of spacing (40cm×45cm and 50cm×60cm) and stem pruning (one stem, two stems, three stems and no pruning) on the yield was evaluated on indeterminate type BARI Tomato-6 variety. Wider spacing (50cm×60cm) gave the highest number and weight of marketable fruits/plant than closer spacing but in terms of per hectare, closer spacing gave the highest number and weight of marketable (Ara *et al.*, 2007).

Birbal *et al.* (1995) reported that the tallest okra plants were obtained with the spacing of 30cm×30cm but number of branches was highest at 45cm×45cm. Spacing had no effect on the days to 50% flowering. The number of fruits/plant, fruit weight and yield/ha were highest at 45cm×45cm and 60cm×30cm compared to control (30cm×30cm). The spacing of 60cm×20cm and 45cm×30cm gave similar yields. A field experiment on okra comprising four spacings (60cm×30cm, 60cm×40cm, 60cm×50cm, and 60cm×60cm) was conducted by Moniruzzaman *et al.* (2007) to find out the optimum plant spacing. Plant spacing of 60cm×30cm produced the highest yield of okra (2.86 t/ha). Raghan (1996) observed that the closer the spacing, the taller the plant. Highest yields of green pods were however, associated with the widest spacing. This was observed when the effects of the spacings (15cmx30cm, 30cmx30cm and 45cmx30cm) on the growth and yield of okra cultivar Pusa Sawani were investigated. It has been reported by Saha *et al.* (1991) that yield of okra increased with decreasing spacing. In their experiment, plants were sown at spacings of 80cmx40cm, 80cmx20cm and 80cmx10cm, giving plant populations of 31250, 62500 and 125000 plants/ha respectively. The closest spacing gave 7.15ton/ha as compared with 3.23ton/ha for the widest spacing.

Effect of spacing on yield and yield attributing characters of tomato was studied under low cost naturally ventilated greenhouse by Ganesan and Subbiah (2005). The four different spacings (75cm x 60cm, 60cm x 45cm, 45cm x 30cm, and 30cm x 15cm) were used. Plant height, number of nodes, internodes length, plant dry matter, and number of fruits, average fruit weight and yield of tomato were assessed. The results showed that increasing the spacing significantly increased the number of fruits, average fruit weight, yields per plant and dry matter but plant height was reduced. It was found that the highest fruit yield per plant was recorded in widest spacing of 75cm x 60cm and least was recorded by closest spacing of 30cm x 15cm.

The effects on the yield, plant height and canopy spread of aubergines were investigated by Abutiate (1988). He reported that closer spacing significantly out yielded all other treatments in terms of number and weight of marketable fruits. He also reported that yield of unmarketable fruits increased sharply with closer spacing whilst the widest spacing gave the lowest yields of both marketable and unmarketable fruits per hectare. Mouneke and Udeogalanya (1991) also reported that increasing plant density increased leaf area index (LAI) significantly as well as weight of fresh pod/ha of okra. Leaf area/plant and number of branches/plant however, decreased in increasing densities. Rao *et al.* (1989) observed that plant height and pod yield of okra increased with increasing density. It was also, realized that branch number, pod length and pod number were greater at lower densities. Gadakh *et al.* (1990) indicated that higher yields up to 18.53t/ha were obtained with the spacing of 30cm×10cm, out of four plant spacings (30cm×5cm, 30cm×10cm, 30cm×15cm and 30cm×30cm) for okra.

Effect of fertilizer levels on yield and quality of chilli pepper

Early availability of N appears necessary for plant growth, fruit size and yield of pepper. The yield was greater with a single N application than split applications when plants were grown under mulch (Locascio *et al.*, 1985). Nitrogen influences flower development of several vegetable crops including pepper, tomato and cucumber (Kinet *et al.,* 1985). However, the effect of fertilizer upon flowering and fruit set of green pepper has produced contradictory results. Nitrogen is known to be the most important nutrient affecting fruit yield in pepper. The yield of chilli fruits increased with increasing nitrogen levels and the highest fruit yield was recorded with 120 kg N ha^{-1}+ 60 kg P ha^{-1}, (Singh *et al.,* 2000). Fertilizer is one of the major factors of crop production. Among the factors, nitrogen is very much essential for good plant establishment and expected growth (Uddin and Khalequzzaman, 2003).

Kulvinder and Srivastova (1988) reported that the combination of N and P fertilizers at higher levels resulted in maximum yield being the most economic treatment for *capsicum*. Yield of fruits significantly increased with increasing rates of nitrogen (Sharma *et al.*, 1996). They found out that the highest yield and highest income invested was recorded at the highest nitrogen rate on chilli. They concluded that the best treatment to promote yield and profitability was 120kgN and 30kg P_2O_5/ha. Yields ranged from 36.19kg/ha in the unfertilized control to 88.49kg/ha with the application of NPK. Kulvinder and Srivastova (1988) working on *capsicum* realized that parameters such as plant height, number of branches, number of fruits per plant, fruit length and diameter and yield increased with increasing rates of fertilizer application.

A field experiment was conducted to study the effects of nitrogen and phosphorus on the fruit size and yield of *Capsicum*. The treatments comprised 4 levels of N (0, 50, 100 & 150 kg ha^{-1}) and 3 levels of P (0, 30 and 60 kg ha^{-1}). Length and breadth of fruit and number of fruits per plant increased significantly with increasing nitrogen doses up to 100 kg N ha^{-1}. However, average weight of fruit content increased significantly up to 150 kg N ha^{-1}. On the other hand, average weight of fruit and yield increased significantly with increasing levels of P up to the treatment 30 kg P ha^{-1}, whereas length of fruit and number fruits per plant increased significantly up to the 60 kg P ha^{-1}. Considering the combined effect of nitrogen and phosphorus, the maximum significant length of fruit, breadth of fruit, number of fruits per plant and, average weight of fruit as well as yield were found in the treatment combination of 150 kg N and 30 kg P ha^{-1} (Roy *et al*., 2011).

In a 2 –year trial on the effect of fertilizer rate, application timing and plant spacing on yield and nutrient content of bell pepper, *Capsicum annuum* transplants were established at in – row spacing of 31cm or 46cm on bare soil and drip irrigated on a twice weekly schedule. A base rate of NPK was applied either in 1 (pre-plant application) or 2 (pre-plant and at first flower set) or 3 (pre-plant, at first flower set and after midseason harvest) split applications. Additional fertilizer was applied in excess of the base rate on a predetermined schedule or after yield decline "as needed". Response of *Capsicum* hybrid Indira to plant spacing (45 x 50, 60 x 50 and 75 x 50cm) and graded doses of nitrogen (100, 150, 200 and 250 kg N ha^{-1}) and phosphorus (100, 150 and 200 kg P_2O_5 ha^{-1}) was studied on a sandy loam soil. Generally, increased levels of nitrogen application up to 200 kg N ha^{-1}, significantly improved plant growth, yield and yield attributes but further increase in nitrogen level did not bring significant improvement in these characters. Application of phosphorus significantly influenced only yield and yield attributes up to 150 kg P_2O_5 ha^{-1} (Chaudhary *et al.*, 2007).

Effect of fertilizer levels on yield and quality of other fruit vegetables

There are many factors responsible for the decline in quality and yield of crops. Apart from other factors, nutrients play a vital role in the production of certain crops and their application is one of the quickest and easiest ways in increasing yield per unit area. Among nutrients, nitrogen is one major nutrient required by plants for their growth, development and yield (Singh *et al.*, 2003). Nitrogen (N) is an important plant nutrient which can be absorbed primarily in the form of nitrate. It constitutes about 1.5-6% of the dry weight of many crops (Tisdale and Nelson, 1990). Moreover, nitrogen is the main constituent of all amino acids in proteins and lipids that act as structural compounds of the chloroplast (Basela and Mahadeen, 2008). The productivity of eggplant is highly responsive to N fertilization. Pal *et al*. (2002) reported that eggplant fruit yield increased with increase in N up to 187.5kg N ha^{-1} and beyond this yield decreased. Similarly Chaudhari *et al*. (1995) also studying the performance of okra varieties in relation to fertilizer application found that yields increased with the application of fertilizers.

Ahmed *et al.* (2007) reported that an increase in nitrogen application resulted in maximum fruit length, fruit weight, vine length and yield of cucumber. Jilani *et al.* (2008) reported that nitrogen application at 100 kg ha^{-1} produced significantly maximum survival percentage, fruit length, fruit diameter, fruit volume, fruit weight and yield per hectare in brinjal. Waseem *et al.* (2008) also reported that 100 kg N ha^{-1} had significantly maximized cucumber fruit length, fruit weight and vine length, which are indirectly related to the yield, but 80 kg N ha^{-1} was the most economical dose for minimizing the days to flowering, days to fruit setting and days to fruit maturity and getting higher number of fruits and ultimately higher yield.

Generally, excessive amounts of inorganic fertilizers are applied to vegetables in order to achieve a higher yield (Stewart *et al.*, 2005) and maximum value of growth (Badr and Fekry, 1998; Dauda *et al*., 2008). Rosati *et al.* (2002) observed that plant yield increased with increasing N fertilization.

They suggested 120kgN per hectare for better yield. Umamaheswarappa and Krishnappa (2004) reported that application of nitrogen fertilizers increased the growth and yield of cucumber (cv. Poinsette). Semiha *et al.* (2006) obtained higher fruit number (59.4 fruits / m^2) and yield (71.2 t/ha) with the application of 200mgN per litre. Aujla *et al.* (2007) revealed that fruit yield increased significantly with increasing nitrogen level up to 150kg per hectare, in egg plant.

The work was carried out to evaluate the effects of applications of nitrogen (urea) and potassium doses (potassium chloride) on the yield and quality of Gold Mine, yellow melon fruits under drip irrigation. Nitrogen doses (0, 50, 100, and 150kg N ha^{-1}) were combined in a factorial arrangement with potassium doses (0, 50, 100, and 150kg K_2O ha^{-1}). Nitrogen increased the number and total mass of fruits, number of marketable melon fruits, and fruit length/width shape ratio; decreased pulp firmness; but did not change pulp total soluble solids content (Buzetti *et al*. 2007).

Eifediyi and Remison (2009) observed that the effect of different NPK levels of 0, 100, 200, 300 and 400 kg ha^{-1} on the number of fruits, fruit length, fruit girth and fruit weight of cucumber was significant. The number of fruits per plant, fruit length, fruit girth, fruit weight per plant and total yield per hectare increased significantly with increase in inorganic fertilizer application up to a point and yield decreased at the highest level.

An experiment was conducted at the Hill Agricultural Research Station, Khagrachari to find out the effect of nitrogen (60, 80, 100 and 120 kg ha^{-1}) and phosphorus (80, 100 and 120 kg ha^{-1}) on the growth and yield of okra in hill slope condition during the rainy season. The highest yield

(16.73 t/ha) was obtained from 100 kg N ha^{-1}, which was statistically identical to 120 kg per hectare. In case of phosphorus, the highest yield of 15.77 t ha^{-1} was obtained from 120 kg P_2O_5 ha^{-1} and was closely followed by the dose of 100 kg P ha^{-1} (4.73 t/ha). Considering the treatment combinations, the highest yield (19.22 t ha^{-1}) was produced by $N_{100}P_{120}$ (Firoz, 2009).

An experiment was conducted to determine the effect of NPK fertilizer application rates and method of application on growth and yield of okra (*Abelmoschus esculentus* (L.) Moench). Okra seed variety LD88 were treated to three levels of NPK fertilizer rates (0, 150 and 300 kg NPK ha^{-1}) and two methods of fertilizer application (ring and band method). The result indicated that the fertilizer NPK significantly increased yield and yield components with 150NPKkgha^{-1} giving optimum yield of okra (Omotoso and Shittu, 2007).

Aminifard *et al.* (2010) carried out an experiment to evaluate the effect of nitrogen fertilizer on growth and yield of eggplant (*Solanum melongena* L.) under field conditions. Nitrogen was applied in four rates (0, 50, 100 and 150 Kg ha^{-1}). They observed that increasing the N levels of the fertilizers to 50 kg N ha^{-1} significantly increased the yield of eggplant while yield decreased at the highest rate of nitrogen. This decrease in yield might be due to excess levels of nitrogen in the plant. The marked effect of nitrogen on yield might be due to the cumulative stimulating effect of nitrogen on the vegetative growth characters which form the base for flowering and fruiting.

Effect of harvesting intervals on yield and quality of fruit vegetables

Moneruzzaman *et al*. (2009) stated that tomato fruit firmness decreases during storage and that firmness depends on the stage of maturity, variety of tomato and environmental factors such as temperature. Some authors also found an increase of fruit firmness with fruit age (Gu *et al*., 1999, Tadesse *et al*., 2002). Studying the effect of harvesting stage and storage conditions on the post harvest quality of tomato (*Lycopersicon esculentum Mill*) cv. Roma VF, Moneruzzaman *et al.* (2009) reported that the highest weight loss, decay and shelf life was measured in mature green. The highest values for rotting (decay) and total sugar content were distinguished in full ripen tomato. The half ripen tomato showed the highest value of vitamin C and titrable acidity. The percentage of decay (rotting) and weight loss, pH, titrable acidity and total sugar were increased with gradual increase in storage time, irrespective to maturity stages.

Anju-Kumari *et al.* (1993) reported that the shelf life of all tomato cultivars were longest when harvested at green mature stage. The fruit acid content is lower in immature fruit and highest when the color starts to appear, with a rapid decrease when the fruit ripens. Winsor *et al.*, (1989) found that the maximum acidity can be recorded at the pink stage of tomato fruits. Sinaga (1986) reported that sugar content increased during maturation from the green mature to the red ripen stage. Sugar content varied depending on the harvesting stage. Dalal *et al.* (1995) found that the reduction of sugar content ranged about 2.4% to 3.65 from large green to red ripe fresh fruits.

CHAPTER THREE

MATERIALS AND METHODS

Location

Two experiments were conducted on the experimental fields of the Department of Horticulture, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology Kumasi, Ghana. The first one was from May 2009 to December, 2009 and the second from May 2010 to November 2010 to determine the effect of

- age of transplants and different spacings on the growth and yield of chilli pepper (*Capsicum annuum*) var. Legon 18.
- different levels of sulphate of ammonia and harvesting intervals on yield and some postharvest qualities of chilli pepper (*Capsicum annuum*) var. Legon 18.

The area falls within latitudes 6' 35N to 6' 40N and longitude 1' 30W to 1' 35W and sited within elevation of 250m to 300m above sea level (Meteorological department Kumasi, 2009). The region falls within equatorial climate zone with a bimodal rainfall regime. The major season rains occur from mid March to the end of July with a peak fall in June. The minor season rains begin in September and end in mid November with a peak in October. The rainfall regimes are separated by a period of dry weather from December to March.

Climatic data at the Experimental site

Table 1: Climatic data during the growth period of 2009

Month	Rainfall (mm)	Temperature (^{0}C)		Relative Humidity (%)	
		Max.	Min.	0900 hr.	1500 hr.
May	99.0	33.0	22.7	81	60
June	367.9	31.7	22.1	87	66
July	226.1	29.6	21.4	88	72
August	19.0	28.6	21.7	90	74
September	59.7	30.0	21.9	88	69
October	201.7	31.1	22.9	88	65
November	40.4	31.6	22.4	85	61
December	30.0	32.9	23.1	87	55
Total	1043.8	248.5	178.2	694	522

Source: Meteorological station; Agric. Engineering Department (KNUST)

Table 2: Climatic data during the growth period of 2010

Month	Rainfall (mm)	Temperature (^0C) Max.	Min.	Relative Humidity (%) 0900 hr.	1500 hr.
May	132.6	33.1	23.4	84	63
June	203.3	31.2	22.8	88	64
July	166.8	29.7	21.5	87	69
August	134.9	29.0	21.5	90	71
September	201.8	29.7	21.9	89	71
October	163.3	31.0	22.0	87	67
November	111.1	31.5	21.7	86	65
Total	1113.8	215.2	154.8	611	470

Source: Meteorological station; Agric. Engineering Department (KNUST)

Soil and history of the site

The soil of the experimental area which is Akroso series is sandy loam in structure and belongs to the forest Ochrosol (Ablor, 1972). It is deep, well drained with good to moderately good water holding capacity. The site had been under cultivation to various vegetable crops such as okra, spring onions, tinda, cowpea, garden egg and tomato for a considerable number of years. Vegetable jute was the immediate crop planted after which the experiment was conducted.

Source of planting materials

Seeds of chilli pepper (variety: Legon 18) were collected from Mr. Wisdom, a chilli pepper farmer at Dome, Accra in the Greater Accra Region.

Nursery

Seedlings were raised on well prepared nursery beds. The seeds were sown on 20th, 27th, May and 3rd June, 2009 in order to obtain 3, 4 and 5 week-old transplants after pricking out. After sowing, the beds were watered. A shed made from palm fronds, was erected on top of the beds to provide shade to protect the seedlings from harsh weather conditions. Watering was carried out every other day depending on the climatic conditions. Seedlings were pricked out 13 days after each sowing on larger nursery beds to allow seedlings enough space for development. Watering, hand picking of weeds, stirring of the soil to enhance aeration were carried out regularly. Neemazal (neem seed oil) with active ingredient azadirachtin, an organic insecticide and Shavit F 71.5 WP fungicide at the rate of 1g per litre of water were used to control pests and fungal diseases respectively. A basal dose of 2kg of well-rotted poultry manure was applied to the 1.2m×1.2m bed.

Land preparation and Demarcation of Experimental Area/Layout

The field was ploughed and harrowed. The field was demarcated, lined and pegged a day before transplanting. The experimental area measured 24.2m×7.4m (178.08m^2). The area was divided into three blocks. Each block was further divided into nine plots, each plot measuring 1.8m×1.8m (3.24m^2). A distance of 1m was left between blocks and plots.

Experiment one

Experimental Design and Treatments

The experimental design was a 3x3 factorial in a Randomized Complete Block Design (RCBD) with 3 replications. Age of transplants and spacing constituted the factors with their varying levels. There were 3 ages of transplants and 3 spacings resulting in 9 treatment combinations.

Factor A: Age of transplants were:

(i). 3 weeks old after pricking out (A1)

(ii). 4 weeks old after pricking out (A2)

(iii). 5 weeks old after pricking out (A3)

Factor B: the different spacings were:

(i). 45cm × 45cm (S1)

(ii). 60cm × 60cm (S2)

(iii). 75cm × 75cm (S3)

Table 3: Treatment combinations and their corresponding plant populations

Age of Transplants (weeks after pricking out)	Spacing (cm)	Plant population (ha^{-1})
3 week-old	45cm × 45cm	49,383
	60cm × 60cm	27,778
	75cm × 75cm	17,778
4 week-old	45cm × 45cm	49,383
	60cm × 60cm	27,778
	75cm × 75cm	17,778
5 week-old	45cm × 45cm	49,383
	60cm × 60cm	27,778
	75cm × 75cm	17,778

Transplanting

Uniform and healthy seedlings which were 3, 4 and 5 week-old after pricking out were transplanted to the respective spacings on 7th July, 2009 early in the morning to reduce excessive loss of water from the transplants. Seedlings that were cut by crickets in the first two weeks after transplanting were continually replaced until the plants were well established.

CULTURAL PRACTICES

Weed control

Weeds were controlled on the beds mainly by hand-hoeing. Uprooting of weeds around the plants was occasionally done.

Irrigation

The experimental period experienced rainy, humid, warm and dry spells within the wet season so watering was occasionally done using rubber hose and watering can.

Fertilizer Application

Decomposed poultry manure was applied at the rate of 8g/plant with two split supplemented side dressing of Sulphate of ammonia (20%N) each at the rate of 5g/plant (80kg/ha) according to the rate recommended by Norman (2002).

Pests and Diseases Control

Insect pests were controlled during the experimental period using neem seed oil at the rate of 1.3ml per litre of water at each spraying. Diseases were controlled with Shavit F 71.5 WP fungicide at the rate of 2g per litre of water. A CP15 Knapsack sprayer was used in spraying the pesticides. In the first spraying at one week after transplanting, only fungicide was used, but the rest of the spraying was done combining the neem seed oil and Shavit F 71.5 WP fungicide till the end of the experiment.

Harvesting

Six plants were randomly sampled from each of the 27 plots. Harvesting of green fruits in all the treatments started 11 weeks after transplanting and continued at 5 days intervals. Though chilli pepper can stay in the field up to a year or more, harvesting was done till yield started to decline when plants were 23 weeks old transplanting.

PARAMETERS STUDIED

Plant height

Plant height was recorded on the six sampled plants from each plot using measuring tape fixed firmly onto a straight wooden edge. The measurements were taken from the soil level to the highest point of the stem apex and the mean was recorded.

Number of main branches

Total number of main branches was counted from the six sampled plants from each plot and the mean was then calculated.

Number of leaves

Total number of leaves on the six sampled plants from each treatment plot was counted and the mean was recorded.

Days to flowering and fruit set

These were recorded as the number of days after transplanting to 50% flower opening and 50% fruit set on the six sampled plants.

Number of fruits per plant and hectare

These were obtained after the fruits harvested from the six sampled plants were counted from each treatment plot and divided by the six plants and then projected on per hectare basis.

Mean weight of fruits per plant and hectare

These were determined by weighing harvested produce from the six sampled plants for each plot using electronic balance and then calculated on per plant and per hectare basis.

Number and weight of marketable fruits per hectare

These were determined by selecting harvested fruits that were uniform in colour, shape, size and pest and disease free from the six sampled plants and then calculated on per hectare basis.

Total marketable fruits were weighed using electronic balance and then calculated on per hectare basis.

Experiment two

Experimental Design and Treatments

The experimental design was also a 3x3 factorial in a Randomized Complete Block Design (RCBD) with 3 replications. Fertilization and harvesting constituted the factors with their varying levels. There were 3 rates of fertilizer and 3 harvesting intervals resulting in 9 treatment combinations.

Factor A: Rate of fertilizer per plant

	NPK		S/A
F1=	9g	+	0g
F2=	9g	+	5g
F3=	9g	+	10g

NPK= Nitrogen, Phosphorus and Potassium

S/A= Sulphate of ammonia

Factor B: Harvesting intervals

H1= 3 days harvesting interval

H2= 5 days harvesting interval

H3= 7 days harvesting interval

Fertilizer application

NPK (15:15:15) fertilizer at the rate of 9g/plant was used as basal fertilizer for all the treatments (F1, F2 and F3). Sulphate of ammonia at the rate of 5g/plant was applied three weeks after the NPK 15:15:15 application to treatments F2 and F3. Sulphate of ammonia was again applied at the rate of 5g/plant to F3 after first harvest.

Yield

Yield and yield components were assessed as under experiment one.

POSTHARVEST PARAMETERS

Weight loss of fruits

After harvest weight loss was determined by finding the difference between the final weight and the initial weight of fruits during the storage period (two weeks) when some of the fruits started rotting or decaying and expressed as a percentage.

Firmness of fruits

Fruit firmness was determined by pressing the fruit with the thumb and the middle finger to know how hard or soft the fruits were. The finger press method was used because of delay in getting the instrument (penetrometer) and time factor. The fruits were rated on the scale of 1-4 as;

1= very firm

2= firm

3= soft

4 and above= very soft

Decay of fruits (%)

Fruits were inspected daily and considered as decayed when fungal mycelia appeared on the skin/fruit surface.

Shelflife of fruits

The shelf life was calculated by counting the days required to attain the last stage of rotting, but up to the stage when fruits remained still acceptable for consumption.

Nutrient analysis

Thirty samples of fruits were taken from each treatment harvested and were analysed for available nutrients (crude protein, crude fat, crude fibre, Ash content).

Statistical Analysis

Analysis of variance was carried out on all numerical data using GenStat (2007) package. The Least Significant Difference (LSD) at 5% was used to compare treatment means.

CHAPTER FOUR

RESULTS

Experiment one

General Observations

In the experiment conducted to study the effect of age of transplants and spacing on the growth and yield of chilli pepper (*Capsicum annuum*) variety Legon 18, it was observed that most of the seedlings were well established two weeks after transplanting. However, the youngest transplants (three weeks old after pricking out) were seriously cut down by crickets. The transplants that were cut were later replaced with seedlings of the same age from the nursery.

Effect of age of transplants and spacing on vegetative growth and yield of chilli pepper

Plant height

The three week-old transplants (A1) and the closest spacing (S1) were significantly ($P<0.05$) the tallest, while the least plant height was obtained in the four week-old transplants (A2) and the widest spacing (S3). The A1S1 plants were the tallest and the A2S3 the shortest (Table 4).

Number of branches

The results showed that significant differences existed ($P<0.05$) between the treatments (Table 4). The four week-old transplants (A2) recorded the highest number of branches per plant, while the five week-old transplants (A3) recorded the least. The highest number of branches was found in the widest spacing (S3), while the closest spacing recorded the least. The four week-old transplants and the widest spacing (A2S3) recorded the highest number of branches, while the four week-old transplants and the closest spacing (A2S1) recorded the least number of branches (Table 4).

Table 4: Effect of age of transplants and spacing on plant height, branches and number of leaves

Treatment	Plant height (cm)	Number of branches	Number of leaves
Age of transplants (weeks after pricking out)			
3 week-old (A1)	75.50	9.22	365.00
4 week-old (A2)	68.80	9.75	599.00
5 week-old (A3)	69.30	8.72	571.00
CV%	8.70	8.00	26.10
LSD (5%)	6.10	0.71	97.80
Spacing			
45cm×45cm (S1)	79.20	7.52	473.00
60cm×60cm (S2)	68.10	8.23	495.00
75cm×75cm (S3)	66.20	11.93	567.00
CV%	8.70	8.00	26.10
LSD (5%)	6.10	0.71	NS
Interactions			
A1S1	80.80	8.22	367.00
A1S2	69.40	7.89	342.00
A1S3	65.70	10.06	385.00
A2S1	76.90	6.66	529.00
A2S2	67.30	8.03	549.00
A2S3	60.70	11.50	720.00
A3S1	76.90	7.67	523.00
A3S2	68.80	8.78	593.00
A3S3	65.10	11.22	596.00
LSD%	10.60	1.23	169.50

Number of leaves

Number of leaves produced was significantly affected by age of transplants but was not significantly affected by the spacings with the A2 plants producing significantly more leaves ($P<0.05$) than the A3 and A1 plants (Table 4). The A3 plants also had significantly more leaves than the A1 plants. The interaction of the factors significantly affected the number of leaves (Table 4) with the A2S3 producing the highest number of leaves.

Days to flowering and fruit set

Table 5 shows that number of days to flowering and fruiting were significantly ($P<0.05$) affected by age of transplants but not by the spacings. Five week-old transplants took the shortest time to flowering and fruiting, while three week-old transplants took longest time to flowering and fruiting. Interaction between five week-old transplants and the widest-spaced plants took the shortest time to flowering and fruit set (Table 5).

Table 5: Effect of age of transplants and spacing on number of days to flowering and fruit set

Treatments	Number of days to flowering	Number of days to fruit set
Age of transplants (weeks after pricking out)		
3 week-old (A1)	44.30	54.10
4 week-old (A2)	36.70	48.10
5 week-old (A3)	30.20	40.90
CV%	6.50	7.40
LSD (5%)	2.50	3.50
Spacing		
45cm×45cm	38.40	48.80
60cm×60cm	37.70	47.30
75cm×75cm	36.10	47.70
CV%	6.50	7.40
LSD (5%)	NS	NS
Interactions		
A1S1	44.90	54.80
A1S2	43.60	52.80
A1S3	44.40	54.80
A2S1	35.40	47.60
A2S2	34.30	46.40
A2S3	40.40	50.20
A3S1	30.50	41.40
A3S2	32.20	42.90
A3S3	27.80	38.30
LSD%	4.10	6.20

Number of fruits per plant

Age of transplants and spacing significantly ($P<0.05$) influenced number of fruits per plant (Table 6). The four week-old transplants (A2) produced the highest number of fruits per plant but was not significantly different from the five week-old transplants (A3), while the three week-old transplants produced the least. Similarly, the widest-spaced transplants (S3) produced the highest number of fruits per plant, while the closest-spaced transplants (S1) produced the least number of fruits per plant (Table 6). The treatment interaction that produced the highest number of fruits per plant was the four week-old transplants with the widest spacing (A2S3), while the least was obtained by the three week-old transplants and the closest spacing (A1S1) (Table 6).

Number of fruits per hectare

The results showed that number of fruits per hectare was significantly ($P<0.05$) affected by age of transplants and spacing (Table 6). The four week-old transplants (A2) and the closest spacing (S1) recorded the highest number of fruits per hectare, while the three week-old transplants (A1) and the widest-spaced plants recorded the lowest value. There were significant differences among the interactions. The four week-old transplants and the closest-spaced transplants (A2S1) produced more fruits per hectare, while the three week-old transplants and widest-spaced transplants (A1S3) had the least (Table 6).

Fruit weight per plant and per hectare

Both age of transplants and spacing significantly ($P<0.05$) influenced weight of fruits per plant and per hectare (Table 6). The four week-old transplants (A2) recorded the heaviest fruits per plant as well as per hectare, while the three week-old transplants (A1) recorded the least. The widest-spaced transplants (S3) recorded the highest weight of fruits per plant, while the closest-spaced transplants (S1) gave the least weight of fruits per plant. Again, the closest-spaced transplants (S1) produced the highest fruit weight per hectare and the widest-spaced transplants (S3) recorded the lowest fruit weight per hectare.

Table 6: Effect of age of transplants and spacing on number of fruits per plant and per hectare and weight of fruits per plant and per hectare

Treatment	Number of fruits per plant	Number of fruits (ha^{-1})	Fruit weight (g) per plant	Fruit weight per hectare (t)
Age of transplants (weeks after pricking out)				
3 week-old (A1)	177	5388228	448.0	1.4
4 week-old (A2)	271	8098872	682.0	2.0
5 week-old (A3)	227	6878838	583.0	1.7
CV%	26	22	27.3	22.5
LSD (5%)	59	1493650	155.9	0.4
Spacing				
45cm×45cm (S1)	191	9420138	475.0	2.3
60cm×60cm (S2)	234	6490155	568.0	1.6
75cm×75cm (S3)	251	4455645	671.0	1.2
CV%	27	22	27.3	22.5
LSD (5%)	59	1493650	155.9	0.4
Interactions				
A1S1	151	7,000,000	402.0	2.0
A1S2	195	5,000,000	484.0	1.3
A1S3	186	3,000,000	457.0	0.8
A2S1	235	10,000,000	578.0	2.9
A2S2	243	7,000,000	589.0	1.6
A2S3	334	6,000,000	880.0	1.6
A3S1	187	9,000,000	445.0	2.2
A3S2	262	7,000,000	630.0	1.8
A3S3	232	4,000,000	675.0	1.2
LSD%	102	2587078	270.0	0.7

Total number of marketable fruits per hectare

Age of transplants and spacing significantly ($P<0.05$) influenced the total number of marketable fruits per hectare (Table 7). The four week-old transplants (A2) recorded the highest number of marketable fruits per hectare, while the three week-old transplants (A1) recorded the lowest values. The closest-spaced transplants (S1) produced the highest number of marketable fruits per hectare, while the widest-spaced transplants (S3) recorded the lowest value (Table 7).

Total weight of marketable fruits per hectare

Table 7 shows that total weight of marketable fruits per hectare was significantly affected by both age of transplants and spacing. The four week-old transplants (A2) recorded the highest weight of marketable fruits per hectare, while the three week-old transplants (A1) recorded the lowest weight. The closest-spaced plants (S1) recorded significantly higher weight of marketable fruits per hectare. The treatment interaction that recorded the highest weight of marketable fruits per hectare was the four week-old transplants with the closest spacing (A2S1) (Table 7).

Table 7: Effect of age of transplants and spacing on total number of marketable fruits per hectare and weight of marketable fruits per hectare

Treatment	Total number of marketable fruits per hectare	Total weight of marketable fruits per hectare (t)
Age of transplants (weeks after pricking out)		
3 week-old (A1)	4187782.0	1.2
4 week-old (A2)	6361160.0	1.7
5 week-old (A3)	5296177.0	1.4
CV%	22.5	23.6
LSD (5%)	1186855.8	0.3
Spacing		
45cm×45cm (S1)	7401372.0	2.0
60cm×60cm (S2)	5296177.0	1.3
75cm×75cm (S3)	4996852.0	1.0
CV%	22.5	23.6
LSD (5%)	1186855.8	0.3
Interactions		
A1S1	5985186.0	1.7
A1S2	4265093.0	1.2
A1S3	2313067.0	0.7
A2S1	9071606.0	2.4
A2S2	5148704.0	1.4
A2S3	4863171.0	1.4
A3S1	7147326.0	1.8
A3S2	5576760.0	1.4
A3S3	3164445.0	1.0
LSD%	2055694.6	0.6

Experiment two

Number of fruits per plant and per hectare

Fertilizer application had a significant effect on the number of fruits per plant and per hectare (Table 8). Number of fruits increased significantly ($P<0.05$) with increase in the rate of S/A fertilizer application to a point and decreased at the highest rate. The F2 (9gNPK +5gS/A) plants produced more fruits than the F1 (9gNPK+0gS/A) plants but produced similar number of fruits as the F3 (9gNPK +10gS/A) plants. Harvesting intervals also had significant influence on the number of fruits. Statistically, harvesting at 3 and 5 days interval produced similar fruit number per plant and per hectare, while harvesting at 7 days interval recorded the lowest (Table 8).

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Fruit weight per plant and per hectare

Total weight of fruits per plant and per hectare were significantly affected by fertilizer application but were not significantly affected by the harvesting intervals (Table 8). Applying 9gNPK + 5gS/A/plant (F2) and 9gNPK + 10gS/A/plant (F3) did not result in significant differences but both significantly ($P<0.05$) produced heavier fruits per plant and per hectare than plants applied with 9gNPK+0gS/A (F1). Fruits produced from the treatment interaction of 9gNPK+5gS/A with 5 days harvesting interval (F2H2) were heavier than the rest in terms of fruits per plant and per hectare.

Table 8: Effect of fertilizer rates and harvesting intervals on number of fruits per plant and per hectare and fruit weight per plant and per hectare

Treatments	**Number of fruits per plant**	**Number of fruits (ha^{-1})**	**Fruit weight (g) per plant**	**Fruit weight per hectare (t)**
Fertilizer				
9g NPK + 0g S/A (F1)	67	1197037	237	4.2
9g NPK +5g S/A (F2)	127	2263704	443	7.9
9g NPK+10gS/A (F3)	102	1821235	374	6.7
CV%	28	28	29	29
LSD (5%)	29	507015	103	1.8
Harvesting				
3 days harvesting interval (H1)	113	1987161	388	6.9
5 days harvesting interval (H2)	103	1857284	366	6.7
7 days harvesting interval (H3)	82	1437531	300	5.1
CV%	28	28	29	29
LSD (5%)	29	507015	NS	NS
Interactions				
F1H1	77	1362963	263	4.7
F1H2	64	1137778	227	4.0
F1H3	61	1090370	220	3.9
F2H1	114	2020741	418	7.4
F2H2	145	2577778	501	8.9
F2H3	82	1451852	295	5.2
F3H1	112	1991111	410	7.3
F3H2	100	1783704	343	6.1
F3H3	137	2429630	484	8.6
LSD%	49	878176	177	3.2

Weight loss of fruits (%)

Percentage weight loss was not significantly affected ($P<0.05$) by fertilizer application but was significantly affected by harvesting intervals (Table 9). Fruits harvested at 3 days interval did not differ significantly from those harvested at 5 days interval but were significantly different ($P<0.05$) from those harvested at 7 days interval. The treatment interaction that recorded the lowest weight loss of fruits was observed in the 9gNPK+5gS/A and those harvested at 5 days interval (F2H2).

Firmness of fruits

The results showed that there were significant effects ($P<0.05$) with fertilizer application and harvesting intervals in firmness of fruits. Fruits from plants applied with 9gNPK only (F1) were not significantly different from F2 (9gNPK+5gS/A) in firmness but were significantly firmer than fruits from plants applied with 9gNPK +10gS/A (F3). Fruits harvested at 7 days interval were not significantly different in firmness from fruits harvested at 5 days interval but were significantly firmer ($P<0.05$) than fruits harvested at 3 days interval (Table 9).

Decay of fruits (%)

Rates of fertilizer application and harvesting intervals significantly ($P<0.05$) influenced fruit decay. Fruits from plants applied with 9gNPK+5gS/A (F2) and 9gNPK+10gS/A (F3) did not show significant difference in their decay rate, but fruits from F1 plants had significantly lower decay rate than fruits from the F3 plants. Fruits harvested at 7 days interval (H3) recorded the highest fruit decay. The H1 and H2 fruits recorded similar percentage fruit decay. Interaction between plants applied with 9gNPK+10gS/A and 7 days harvesting interval (F3H3) recorded the highest fruit decay (Table 9).

Shelflife of fruits

Fertilizer application and harvesting intervals significantly ($P<0.05$) influenced the shelflife of fruits. Plants applied with 9gNPK+0gS/A took the longest time in storage before rotting/decaying, while plants applied with 9gNPK+10gS/A took the shortest time to start decaying (Table 9). Fruits harvested from plants applied with 9gNPK+0gS/A were not significantly different in shelf life from fruits harvested from plants applied with 9gNPK+5gS/A but both were significantly different ($P<0.05$) from those harvested from plants applied with 9gNPK+10gS/A (Table 9). Fruits harvested at 5 days interval took the longest time in storage before decaying, while those harvested at 3 days interval took the shortest time. Fruits harvested at 5 days interval did not differ significantly ($P<0.05$) from those harvested at 7 days interval but were significantly different from those harvested at 3 days interval in the shelflife of fruits (Table 9).

Table 9: Effect of fertilizer rates and harvesting intervals on weight loss, firmness decay and shelf life of fruits

Treatments	Weight loss (%)	Firmness	Decay (%)	Shelf life (Days after harvest)
Fertilizer				
9g NPK + 0g S/A (F1)	4.1	2.5	28.9	18.78
9g NPK +5g S/A (F2)	4.2	2.7	38.0	17.22
9g NPK+10gS/A (F3)	5.7	3.4	57.6	15.11
CV%	36.2	26.2	54.6	4.00
LSD%	NS	0.7	21.0	2.53
Harvesting				
3 days harvesting interval (H1)	5.6	3.5	40.7	14.22
5 days harvesting interval (H2)	4.6	2.8	28.9	18.33
7 days harvesting interval (H3)	3.8	2.5	54.8	16.56
CV%	36.2	26.2	54.6	4.00
LSD (5%)	1.7	0.7	21.0	2.53
Interactions				
F1H1	4.9	2.5	36.7	14.67
F1H2	5.1	2.6	26.7	18.33
F1H3	4.5	2.4	40.0	14.33
F2H1	4.4	2.7	26.7	15.67
F2H2	3.6	2.5	33.3	18.89
F2H3	4.4	2.9	50.0	17.00
F3H1	7.2	2.9	53.3	18.33
F3H2	4.0	3.2	41.2	16.67
F3H3	3.7	3.0	66.7	17.33
LSD%	2.9	1.2	36.0	4.38

Nutrient analysis of fruit samples of pepper

Nutrient content in the fruits was influenced by fertilization and harvesting intervals. Plants fed with 9gNPK+10gS/A/ and harvested at 5 days interval (F3H2) had the highest crude protein content, while plants applied with 9gNPK only and harvested at 5 days interval (F1H2) had the least (Table 10). The highest crude fibre content was produced from plants which received 9gNPK+5gS/A and harvested at 7 days interval (F2H3). Plants applied with 9gNPK only and harvested at 3 days interval had the highest ash content, while plants fed with 9gNPK+10gS/A and harvested at 5 days interval recorded the lowest ash content. The highest crude fat was recorded by plants applied with 9gNPK only and harvested at 3 days interval, while plants applied with 9gNPK only and harvested at 7 days interval recorded the least (Table 10).

Table 10: Effect of fertilizer rates and harvesting intervals on nutrient composition of fruits

Treatments	%Crude protein	%Crude fibre	%Ash content	%Crude fat
F1H1	15.20	23.32	6.50	8.00
F1H2	14.10	24.74	5.00	4.00
F1H3	14.50	26.80	6.00	2.00
F2H1	14.20	25.51	5.50	4.00
F2H2	14.20	27.18	5.50	3.50
F2H3	14.50	29.57	5.50	5.00
F3H1	16.80	27.23	3.50	5.00
F3H2	17.00	27.89	2.00	5.00
F3H3	16.50	22.22	3.50	4.00

CHAPTER FIVE

DISCUSSION

Experiment one

Effect of age of transplants and spacing on vegetative growth

Age of transplants and spacing significantly ($P<0.05$) affected the height of pepper plants. The younger transplants (3 week-old) in this study produced the tallest plants but the least number of leaves. The tallest plants produced by younger transplants may be attributed to the fact that the younger transplants had more time for vegetative growth, whereas, the older transplants were a bit more matured and therefore might have had limited vegetative growth due probably to the formation of secondary substances like chlorophyll which might have switched them over to reproductive phase (flowering and fruiting) earlier and had little time for vegetative growth to attain to the level which younger transplants might have already attained. In most perennial vegetable plants, vegetative growth may usually be curtailed when flowering and fruiting start. The substances that trigger flowering in plants are known to be hormones like auxins and ethylene. Auxins had the ability to promote flower formation. However, it known that auxin induced ethylene production is responsible for the formation of flowers in plants (Bernier and Kinet, 2003). These results are in agreement with those reported by Murneek (2004) who observed a marked retardation in growth of both the central stem and lateral branches during flowering and fruiting. The rate of elongation of the main axis of the plants decreased in exact proportion to the amount of flowers formed and fruits set.

The widest spacing (75cmx75cm) gave the shortest plants and produced higher number of branches and leaves. The higher number of branches and leaves produced by the widest-spaced plants could be attributed to the lower population density, which might have allowed the plants to explore available nutrients and water for photosynthesis. This observation is consistent with the findings of

Kathirvelan and Kalaiselvan (2007) who observed that under the widest spacing; there could be more feeding zone which encourages lateral growth resulting in the production of more branches and leaves per plant. In contrast, the closest spacing (45cmx45cm) produced taller plants but fewer branches and leaves. The taller plants, fewer branches and leaves produced by the closest-spaced plants could be attributed to the high population density, which might have increased competition for available resources like light, nutrients and water. Conversely, Kathirvelan and Kalaiselvan (2007) noted that closest spacing could intensify intra-plant competition and reduce the feeding zone which could result in fewer branches and leaves per plant.

Effect of age of transplants and spacing on yield parameters

Age of transplants significantly ($P<0.05$) influenced number of fruits per plant and per hectare. The four week-old transplants (A2) produced higher number of branches which probably resulted in the production of more nodes and more leaves, therefore, producing higher number of fruits and a greater fruit weight since leaves are the primary photosynthetic organ of most plants. Early flowering from the five week-old transplants (older transplants) gave earlier fruits which might have limited vegetative growth period resulting in fewer branches, hence lower yield compared to the four week-old transplants. This observation agrees with the work by Shukla *et al.* (2011) who reported that middle aged transplants produced more number of fruits than the younger or older transplants. The possible reason seems to be that in the case of younger seedlings there was less storage of food needed for vegetative growth, whereas, older transplants were too matured which might have limited vegetative growth. Moreover, middle aged seedlings on account of extended lateral branches produced highest number of fruits per plant than younger or older ones.

Spacing significantly influenced the number and weight of fruits per plant and per hectare. Number of fruits per plant increased with wider spacing but closer spacing yielded more fruits per unit area. The more branches per plant obtained from the widest-spaced transplants might have also contributed to its highest number and weight of fruits produced. Plants grown at the widest spacing might have received more nutrients and light for optimal growth and development, thereby producing more and heavier fruits. Similarly, the more leaves produced from the widest-spaced transplants might have also accounted for its greatest fruit weight. The highest green pepper fruit number and weight per hectare were obtained at the highest plant population. This could be attributed to high photosynthetic rates probably as a result of more effective light interception which might have increased leaf area index. Aminifard *et al*. (2010) and Agarwal *et al*. (2007) also reported that green pepper fruit number and weight per hectare increased as plant population increased. The increase in fruit number and weight per hectare as a result of an increased plant population may be attributed to better utilization of available light and nutrients.

Number and weight of marketable fruits per hectare were influenced by age of transplants and spacing. The four week-old transplants (A2) produced more and higher weight of marketable fruits per hectare since they produced more fruits per plant. The closest-spaced plants produced more and heavier marketable fruits per hectare. The progressive increase in the number and weight of marketable fruits per hectare as planting density increased could be attributed to the fact that at higher planting density, individual plant performance is decreased but the higher number of plants per unit area to compensate for lower individual performance, consequently, yielding more fruits than the other planting densities. These results are in agreement with those of Agarwal *et al*. (2007) and Lorenzo and Castilla (1995) who reported that marketable green pepper yield was significantly higher under a high plant population than under a low plant population. The higher yield under a high plant population could be attributed to a high leaf area index which resulted in improved light interception which might have led to a higher biomass production and yield than under a low plant population.

Experiment two

Effect of fertilizer and harvesting intervals on yield parameters

Fertilization and harvesting had significant influence on number of fruits per plant and per hectare. Increasing the rate of fertilizer significantly influenced the number of fruits per plant and per hectare. Applying 9gNPK+5gS/A to plants resulted in the highest number and weight of fruits per plant and per hectare. On the other hand, however, applying 9gNPK only to plants produced the lowest number and weight of fruits per plant and per hectare. Increasing the levels of fertilizers to 9gNPK+5gS/A significantly increased the number and weight of fruits, while number and weight of fruits decreased at the highest level (9gNPK+10gS/A). This decrease in fruit number might be due to excess level of nitrogen in the soil. The marked effect of nitrogen on fruits might be due to the cumulative stimulating effect of nitrogen on the vegetative growth characters. It means excess nitrogen in the soil might have enhanced vegetative growth, reduced reproductive growth and hence reduced the yield. This is in spite of the fact that the soil was fairly rich in nitrogen (ranged between 0.08% to 0.13%). This observation is consistent with the findings of Eifediyi and Remison (2009) who reported that the number of fruits of cucumber increased significantly with increase in the application of inorganic fertilizer up to a point and yield decreased at the highest level of fertilizer application. The decrease in yield at the highest level of fertilizer application could be attributed to excess nitrogen in the soil which might have encouraged vegetative growth and hence reduced the yield. It was also observed by Aminifard *et al.* (2010) that fertilization with

100kgN ha^{-1} resulted in the highest average fruit weight of eggplant but the weight decreased when 150kgN ha^{-1} was applied.

Harvesting intervals significantly ($P<0.05$) influenced the number of fruits produced. The highest number and weight of fruits per plant and per hectare were recorded from plants harvested at 3 days interval and the lowest were recorded from plants harvested at 7 days interval. This variation occurred because frequent harvesting might have encouraged the plants to continue flowering and fruiting. Thus the regular removal of edible fruits reduces competition; thereby enabling fruits remaining on the plant to receive more assimilates resulting to a higher number of fruit set. This fact is responsible for the production of greater number of fruits by the plant left for fresh fruits because of continuous harvest which removed older fruits that could have competed with the younger ones for nutrients. This observation is in line with the findings of Udengwu (2009) observed that okra plants that are constantly harvested will continue to bear if they have the proper fertility and moisture supply.

Effect of fertilizer and harvesting intervals on some postharvest parameters

Fertilizer application did not have any significant effect on weight loss of fruits but harvesting interval significantly influenced weight loss of fruits. Fruits harvested at 3 days interval had the highest percentage weight loss and the fruits harvested at 7 days interval recorded the least. This could be attributed to the high content of water in fruits harvested at 3 days with succulent tissues which could be more susceptible to water loss than fruits with tough/ matured skin. Weight loss in fruits may be caused by the loss of water in fruits through transpiration. Water loss is the principal cause of softening and shriveling (Wilson *et al.,* 1991). Weichmann (1987) reported that fruit vegetables in general, have a low surface volume ratio and are susceptible to water loss. Javamandi and Kubota (2006) reported that higher transpiration rates in room temperature storage of tomato fruits could be the main cause of higher weight loss. Maalekuu *et al.* (2004) reported that the effect of weight loss in commercial sweet pepper cultivars cause damage to fruit appearance and subsequent loss of market value.

Firmness in most fruit vegetables is caused by the presence of pectin in the cell wall. This pectin serves as intercellular bonding material in many fruits (Slimestad and Verheul, 2005). The result shows that fruit firmness decreased with increasing levels of the fertilizer application. Firmer fruits were observed in fruits harvested from plants applied with 9gNPK+0gS/A, while the highest level of fertilizer (9gNPK+10gS/A) treatment had the least fruit firmness. This might be due to the effect of nitrogen in increasing the water content of fruits. This is in agreement with work by Buzetti *et al*. (2007) who reported that increasing the rate of nitrogen fertilizer might have increased water content thereby decreasing the pulp firmness of melon fruit.

Increasing harvesting intervals significantly increased the firmness of fruits. Fruits harvested at 7 days interval were firmer than those harvested at 3 and 5 days intervals. This may be due to over development of fruits which in turn harden the fruits surface. Moneruzzaman *et al*. (2009) reported that fruit firmness depends on the stage of maturity, variety and environmental factors such as temperature. Some authors also found an increase in fruit firmness with increase in fruit age in some fruit vegetables (Gu *et al*., 1999 and Tadesse *et al*., 2002).

Fertilization and harvesting intervals had significant effect on fruit decay. The F3 (9gNPK+10gS/A) plants had the highest fruit decay and F1 (9gNPK only) plants recorded the lowest fruit decay. The increase in decay of fruits may be due to the high level of nitrogen in the soil which might have encouraged plants to produce fruits with soft succulent tissues which made them susceptible to decay. Fruits harvested at 7 days interval had higher fruit decay. This could be due to over development of fruits on the plants before harvesting. Incidence of decay in is directly depended on harvest time. The higher incidence of decay in later harvested fruits can be explained by more intensive all the physiological processes in over mature fruits (Kvikliené, 2004). Shelflife is a period of time which starts from harvesting and extends up to the start of rotting of fruits. Fruits harvested from plants applied with 9gNPK+10gS/A took the shortest time in storage to start rotting. This could be attributed to high nitrogen level in the soil which encouraged plants to produce fruits with soft succulent tissues which probably made them susceptible to decay. Fruits harvested at 3 days interval also took the shortest time in storage to start rotting and this could be due to high content of water at the succulent stage of the fruits.

Effect of fertilizer and harvesting intervals on nutrient composition

The values obtained in the nutrient analysis for crude protein, crude fibre, crude fat and ash are higher compared to that reported by Nsiah (2009) for ravaya. The protein contents were very high compared to the value (1.5%) reported by Nsiah (2009) for ravaya. The highest protein contents obtained might be due to the highest rate of nitrogenous fertilizer applied since nitrogen is the main constituent of all amino acids in proteins (Basela and Mahadeen, 2008). The crude fibre content decreased with increasing nitrogenous fertilizer. According to Olaniyi (2008), application of nitrogenous fertilizer caused accumulation of nutrients which resulted in better quality fruits with less fibre.

CHAPTER 6

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

Two experiments were conducted on the experimental fields of the Department of Horticulture, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology Kumasi, Ghana. The first one was from May 2009 to December, 2009 and the second from May 2010 to November 2010.

The experiments were all 3x3 factorial in a Randomized Complete Block Design (RCBD). Age of transplants and spacing constituted the factors for the first experiment and fertilizer and harvesting intervals the factors for the second experiment. There were nine treatment combinations in each experiment and each was replicated three times.

Age of transplants and spacing significantly influenced plant height. The three week-old transplants were taller than the four and five week-old transplants. The closest-spaced plants were also taller than plants with the other spacings. Interaction showed that the three week-old transplants and the closest-spaced (A1S1) plants were significantly taller than the others. The four week-old transplants had more branches and leaves than the three and five week-old transplants. Spacing significantly affected the number of branches but did not affect the number of leaves. The widest-spaced plants produced the highest number of branches per plant and the closest-spaced plants produced the least. The four week-old transplants and the widest spacing (A2S3) produced the highest number of branches per plant. Days to flowering and fruit set were influenced by age of transplants but not the spacing. Five week-old transplants took the shortest time to flowering and fruiting, while the 3 week-old transplants took the longest time to flowering and fruiting

Numbers of fruits per plant and per hectare were significantly higher in the four week-old transplants (A2). The widest and the closest-spaced plants respectively produced the highest numbers of fruits per plant and per hectare.

The four week-old transplants and widest spacing (A2S3) produced more fruits per plant but on per hectare basis, the four week-old transplants and the closest spacing (A2S1) had more fruits than the others. Weight of fruits per plant and per hectare was influenced by age of transplants, spacing and their interaction. The four week-old transplants and the widest spacing (A2S3) had more weight of fruits per plant but in terms of per hectare the four week-old transplants and the closest spacing (A2S1) had heavier fruits.

Age of transplants and spacing had significant effect on marketable yield per hectare. The four week-old transplants and the closest spacing (A2S3) produced more marketable fruits per hectare.

Fertilization, harvesting intervals and their interaction had significant effect on numbers of fruits per plant and per hectare. Applying 9gNPK+5gS/A (F2) resulted in more fruits being produced per plant and per hectare than any of the fertilizer applications. Harvesting at 3 days interval (H1) recorded the highest number of fruits per plant and per hectare. Plants which received 9gNPK+5gS/A had greater weight of fruits per plant and per hectare and plants applied with 9gNPK only had the least. Weight loss was not influenced by fertilization but was significantly influenced by harvesting intervals. Fruits harvested at 3 days interval recorded the highest weight loss and those harvested at 7 days interval had the least. Fertilization and harvesting significantly affected fruit firmness and decay. Plants which received 9gNPK only produced fruits with better firmness. Fruits harvested at 7 days interval also had high firmness. The 9gNPK+10gS/A (F3) plants recorded the highest fruit decay, while the 9gNPK only (F1) plants had the lowest fruit decay. Fruits harvested at 7 days interval (H3) recorded the highest fruit decay, while fruits harvested at 5 days interval had the least. Fruits harvested from plants applied with 9gNPK only (F1) took the longest time in storage before starting to rot, while those harvested from plants applied with 9gNPK+10gNPK (F3) started rotting early. Fruits harvested at 5 days interval (H2) spent a long time in storage before starting to rot, while those harvested at 3 days interval spent a short time in storage before starting to rot.

Nutrient composition of fruits was also affected by fertilization and harvesting intervals. Plants applied with 9gNPK+10gS/A and harvested at 5 days interval had the highest protein content but the lowest ash content. Plants applied with 9gNPK+5gS/A and harvested at 7 days interval recorded the highest crude fibre content. Plants applied with 9gNPK+0gS/A and harvested at 3 days interval had the highest content of ash and crude fat.

Conclusion

The results of the study showed that the age at transplanting and spacing had a significant effect on the growth and yield of chilli pepper (*Capsicum annuum*) var. Legon 18. The four week-old transplants after pricking out produced the highest number and weight of fruits per plant and marketable fruits per hectare. The closest spacing (45cm x45cm) produced the highest total number and weight of fruits per hectare and marketable fruits per hectare. It was also found that the widest spacing (75cm x75cm) produced the highest number of fruits per plant but the least number of fruits per hectare.

The fertilizer rate of 9gNPK+5gS/A and harvesting at 5 days interval produced more fruits and greater fruit weight per hectare. The results indicated that fertilization and harvesting intervals had a remarkable influence on yield and some postharvest qualities of pepper fruits.

Recommendations

- It is recommended that chilli pepper variety Legon 18 should be transplanted when the seedlings are four week-old after pricking out using 45cm×45cm for optimum yield of fruits.
- It is also recommended that further research should be carried out on the age of transplanting and spacing for chilli pepper variety Legon 18 at different locations and during the dry season.
- It is recommended that 9gNPK+5gS/A and 5 days harvesting intervals should be used for the production of pepper var. Legon 18.

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APPENDIX

APPENDIX A: Soil sample analysis of experimental area

Soil depth (cm)	Percent			PH	Exchangeable (Cmol/kg)				Exch. Acidity (Cmol/kg)	Available P mg/kg	Potassium mg/kg	CEC Cmol/kg
	C	O.M	N		Ca	K	Mg	Na				
0-15	1.49	2.57	0.13	6.24	2.09	1.16	0.28	0.5	0.25	6.09	109.55	4.29
15-30	0.98	1.69	0.08	5.19	1.88	1.01	0.18	0.5	0.30	3.96	69.34	3.89