KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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DEPARTMENT OF HORTICULTURE

PLANTING DATE AND PLANT DENSITY EFFECTS ON FLOWER ABORTION, FRUIT YIELD AND SEED QUALITY OF TWO VARIETIES OF CHILLI PEPPER (Capsicum frutescens L.) IN GHANA.

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF PHILOSOPHY IN SEED SCIENCE AND TECHNOLOGY

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DECLARATION

I hereby declare that this work is the result of my own research towards an M.Phil. degree in Seed Science and Technology and that this thesis has neither in whole nor part been presented anywhere. Works by other authors have been duly acknowledged.

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ABSTRACT

Field and laboratory experiments were carried out between April 2014 and March 2015 to evaluate the effects of planting date and density on flower abortion, fruit yield and seed quality of two chilli varieties. The field trial was laid out in 2x3x3 factorial experiment in a Randomized Complete Block Design (RCBD) with 3 replications. The factors studied included two chilli varieties (Shito Adope and Legon-18); three planting dates (May 12, 2014; June 13, 2014; and September 29, 2014); and plant spacing at three levels (60 cm x 30 cm; 70 cm x 30 cm; 80 cm x 30 cm).

The field study was conducted at the Crops Research Institute-Kwadaso Station, Kumasi, Ghana. Growth, yield and seed quality parameters were evaluated during the study period. Legon-18 exhibited higher performance than Shito Adope for parameters such as plant height (53.9 than 44.9), branch numbers (9.6 than 5.9), canopy width (42.67 than 39.30), fruit yield (3.33 than 2.86), number (73.40 than 60.21) and weight of seeds per fruit (0.37 than 0.33). In contrast, Shito Adope took fewer days to attain 50% flowering (30.07) and fruit set (33.97). Shito Adope also recorded higher flower drop (14.60).

Dates of planting significantly affected growth and seed quality parameters with seedlings planted in May and June recording taller plants (52.6 and 54.9), more branches (8.8 and 7.7), wider canopies (44.3 and 43.9), and higher fruit yield (3.70 and 3.35). Early flowering and fruit set, higher germination and vigour percentages were attained during the same period; while flower drops were more prevalent during the first and third dates of sowing with values of 14.90 and 15.80, respectively. Higher seed yields were recorded

during the September planting. Plant density showed no significant effect on all parameters studied except plant height, with the widest spacing

(80 x 30) recording the tallest heights (49.94). Six fungal species were identified; with *Collectotrichum graminicola* recording the highest pathogen incidence (282). Seeds planted in May, 2014 recorded the highest fungal pathogens occurrence. The results indicate that for quality seed production, chilli should be cultivated during periods with moderate rainfall to avoid higher disease infection; however, periods with extremely high temperatures should also be avoided as they tends to increase the rate of flower drop.

DEDICATION

I dedicate this work to my dearest father, Mr. Morlee C. Mends-Cole and my loving mother, Thelmah K. Bemah (of blessed memory) who dream was to have me educated and did everything in their power to accomplish it. I am forever grateful for your boundless love and support.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

Chili Pepper (*Capsicum frutescens* L.) is an annual herb belonging to the Solanaceae family (Islam et al., 2010). The crop originated from Central America, more specifically, Mexico and it is believed to be the first ever domesticated crop in the Americas (Pickersgill, 1997; De Lannoy, 2001). Chili pepper is now widely grown throughout the tropics, sub-tropics and the warmer temperate regions of the first world (George, 1985). Chilli thrives best in relatively warm climate within the temperature range of 18 - 27˚C and is susceptible to frost (Udoh *et al*., 2005).

Nigeria and Ghana ranked 8^{th} and 25^{th} place in the world and the two are also the leading chilli producers in West Africa with a production volume of 500,000 MT and 110,000 MT, respectively, in 2012 (FAOSTAT, 2013). These yields are quite low when compared to the world average of chilli pepper suggesting that further improvement of pepper yield in West Africa is needed (FAOSTAT, 2012). Chilli pepper is a widely cultivated crop in West Africa and is also consumed globally as fresh or processed spice. It is an important source of income and an important foreign exchange earner in both developed and developing countries (Ofori *et al.*, 2007).

According to MiDA (2010), Ghana is the 5th largest exporter of chilli peppers to the European Union (EU) with an annual export increase of 17 per cent since the year 2000. The crop is also cultivated for its medicinal and nutritional values. In traditional medicine, chili pepper is used to ease digestion, stimulate the gut, combat constipation, and relieve pain. The main chemical agent, capsaicin, plays a potential role in the development of pain-killers (Dagnoko *et al*., 2013). The high economic and nutritive value of pepper results in a high market demand all year round.

In Ghana, pepper is among the four widely cultivated vegetables in terms of production volume, and has always been part of the country"s agriculture (Schippers, 2000). Despite the reported increase in income from chilli pepper production, the average yield remains low in most West African countries (Grubben and Tahir, 2004). Major constraints associated with pepper production include environmental stress such as temperature, rainfall, humidity, soil fertility and pH, and biotic factors including pests and diseases (Adusei-Fosu and Fiscian, 2012). In addition, limited access to quality seeds, the use of inappropriate agronomic practices, and inadequate knowledge in improved farm management techniques by small-holder farmers are factors contributing to low productivity of chilli peppers (AVRDC, 1990).

Plant spacing is very important in any crop production system. Optimum plant spacing ensures proper growth and development of plants resulting in maximum yield of crops and economic use of land. The yield of pepper has been reported to be dependent on the number of plants accommodated per unit area of land (Akintoye *et al*., 2009). Wubs *et al*. (2009) reported that sufficient light, higher CO_2 concentrations, and lower planting density increase the availability of assimilates per plant and decrease flower and fruit abortion. The abscission of flowers and fruits is an important yield-limiting factor in pepper (Wien *et al.*, 1989). Numerous studies on crop growth and yield parameters indicate that the general crop husbandry practices adopted by farmers influence the quality of seed produced (van Gastel *et al*., 1996). According to Williams *et al*. (1991), plant spacing has a direct effect on the fruit and seed quality. This is so because the type of spacing chosen at a particular planting time can influence the development of diseases and subsequently affect yield and seed quality.

Planting time is also very crucial in any crop production system since it determines the extent of incidence and severity of disease infestation which in turn affects crop growth and yield. Islam *et al*. (2010) indicated that growth parameters and yield components of sweet pepper were significantly increased at earlier planting dates. Similarly, Bevacqua and Vanleeuwen (2003) stated that planting date had a significant effect on crop performance, and that the best stand establishment and highest yield were associated with the earliest planting dates.

Against this background therefore, to increase chill pepper production in West Africa there is the need to consider the development of appropriate plant spacings coupled with suitable planting times. The overall objective of the study was therefore to evaluate the effects of planting date and plant density on growth, yield and seed quality characteristics of two varieties of chilli. Specifically the objectives were to determine the effects of:

1. Different planting dates and densities on flower abortion of two chilli varieties
2. Yield and seed physical and health quality characteristics of the two chilli varieties.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and distribution of chilli pepper

Chilli pepper (*Capsicum frutescens* L.), also known as hot pepper, is an annual herb belonging to the genus Capsicum, under the Solanaceae family (Russo, 1996). It is believed to have originated in South America, more specifically, Mexico (Pickersgill, 1997; De Lannoy, 2001). Chilli is now widely grown throughout the tropics, subtropics and the warmer regions of the world (George, 1985).

The world production of fresh chilli pepper was 31.2 million mt in 2012, from an estimated 2.0 million hectares of land (FAOSTAT, 2013). The world"s top three producers of fresh chilli pepper in 2012 were China, Mexico, and Turkey with a production volume of 16.0 million mt, 2.4 million mt and 2.1 million mt, respectively, (FAOSTAT, 2013). Nigeria and Ghana ranked 8^{th} and 25^{th} respectively in the world and the two are also the leading chilli producers in West Africa with a production volume of 500,000 MT and 110,000 MT, respectively, in 2012 (FAOSTAT, 2013).

2.2 Importance and uses of chilli pepper

Chilli is widely grown primarily for its fruits and seeds, but it is used in several ways based on its hotness and color. The seeds contain capsaicin which is the main active ingredient and considered to have medicinal uses (Messiaen, 1992). Berke *et al.* (2005) reported that consumer preference for pepper fruits are considered according to the shape, color and degree of pungency. The fruits of chilli can be cooked or eaten raw as vegetable in soups and stews and the dried powder can be used as spice for seasoning and flavoring (Gibbon and Pain, 1985; Boateng, 2006). Nutritionally, chilli pepper is an excellent source of vitamins (A, B_2, B_6, C, and K) and essential minerals (potassium, phosphorus, calcium, iron, and zinc) (Bosland and Votava, 2000; Norman, 2002). Medicinally, chilli is used in the prevention and treatment of cold and fever (Udoh *et al*., 2005). It is also used to ease digestion, stimulate the gut, combat constipation, and relieve pain (Patwardhan *et al*., 2010). The crop contains high content of capsaicin ($C_{18}H_{27}N0_3$), an alkaloid which imparts the pungency or spicy taste. Capsaicin are used in the development of pain-killers (Patwardhan *et al*., 2010). Chili pepper based extracts are fast becoming popular in many integrated pest management programmes in controlling common agricultural pests (Oparaeke *et al*., 2005). The crop is a foreign exchange earner in Ghana, and is being exported to the European Union (EU) with an annual export increase of 17 per cent since the year 2000 (MiDA , 2010).

2.3 Botanical classification and flora biology

Botanically, chilli pepper (*Capsicum frutescens* L.) is a fruit-bearing vegetable that belongs to the Solanaceae family along with tomato and eggplant (Hadfield, 1993). The crop is generally self-pollinating, although cross-pollination is also common (Delaplane and Mayer, 2000). Chilli fruit is non-climacteric which implies that it does not ripen once harvested unripe (Díaz-Pérez *et al*., 2007). The genus Capsicum consists of twenty-five wild species and five domesticated species (*Annuum, Baccatum, Chinense, Frutescens and Pubescens*) which have been transformed into the immense diversity of chilli peppers grown around the world.

The stem of chilli is woody at the base and the leaves which are unequal in shape may be oval or oblong, exhibiting acute apex, 1.5-10 cm in length and 0.5-2.5 cm in width (Tindall, 1983). The plant bears small flowers, singly or in groups of 2-3, with long pedicels, erect and 1.5-2.5 cm in length. The pedicel length varies among cultivars, ranging from 3 to 8 cm (Berke, 2000). The calyx of the chilli flower is small, 5-toothed, yellow green, with petals that may be yellow or green white (Tindall, 1983). The crop produces two or more fruits, which can be small and narrow, up to 2-3 cm in length and 7-10 mm in diameter depending on cultivar. They may be red or yellow when ripe and are extremely pungent (Gibbon and Pain, 1985; Rice *et al*., 1986).

2.4 Environmental requirements of chilli pepper

Temperature and rainfall are the two main factors that account for seasonal variations in growth and yield of chilli across many regions (Karikari and Mathew, 1990). Chilli pepper grows best under tropical and subtropical climates. The optimum day temperatures for chilli pepper growth ranges from 20 to 30°C (AVRDC, 2005). A daytime temperatures exceeding 30°C can be tolerated, as long as night temperatures are within 21–24°C (Acheampong, 2007). A fall in temperature below 15°C or exceeds 32°C for extended periods will cause reduction in growth and yield of chilli (AVRDC, 2005). Chilli grows best in loam or silty-loam soil with good water-holding capacity. The crop can however grow on many soil types which are well drained and within a pH range of 5.5 and 6.8 (AVRDC, 2005). Chilli requires about 600 mm of water during the growing season in the form of rain or irrigation. Heavy rainfall during the flowering period causes flower shedding and poor fruit setting, and during the ripening period rotting of fruits; while too little may lead to flower and fruit drop (van Gastel *et al*., 1996). Dry conditions also result in premature small-sized fruit set, which leads to reduced yields

(Bosland and Votava, 1999).

2.5 Management and cultural practices

2.5.1 Land preparation and sowing methods

Good land preparation provides suitable soil conditions for rapid and uniform seedlings‟ establishment, good root penetration which subsequently leads to optimal growth and development of crops (Page *et al*., 2002). Site selection is very important for optimum production. Site previously cultivated to any member of the *Solanaceae* family during the previous two seasons should be avoided to minimize pest and disease infestation. A week prior to transplanting, the site should be cleared, ploughed and harrowed, followed by field layout. Depending on the history of the site, a weedicide should be apply prior to transplanting of seedlings to control obnoxious weeds (Page *et al*., 2002). In addition to synthetic fertilizers, the application of organic manure improves soil structure and enhances the growth of soil micro-flora and fauna (Coertze and Kistner, 1994).

Germination varied depending on variety, seed quality, and soil mixture. For optimum germination, seeds should be sown a well-drained, loamy soil mix with peat or compost. Seeds should be broadcasted lightly or drilled on a seedbed and covered lightly with soil (about 1 cm deep). If the seedlings were grown in shade, they should be hardened by gradually exposing them to direct sunlight over 4–5 days prior to transplanting (AVRDC, 2005). Under good conditions, seedlings are ready for transplanting four to five weeks after sowing, when the seedling developed 4–5 true leaves.

2.5.2 Weed control

Chilli establishes slowly and cannot compete with aggressive weeds. Generally, weeds compete with crops resulting in reduced yields and poor quality crops. Weeds can also harbour harmful insects and diseases (Chandran and Jett (2009). Weeds can be controlled either by physical methods or chemical control (Chandran and Jett (2009). Natural organic mulches such as rice straw besides controlling weeds also conserve soil moisture and add organic matter to the soil. Weed control can also be achieved through the use of wide range of herbicides. However, good weed control in peppers should start before the crop is planted (Bullock, 2011).

2.5.3 Pests and disease of chilli pepper

Chilli pepper is a more robust crop compared to tomato, garden egg and sweet pepper. The crop is however susceptible to a number of pests and pathogens resulting to considerable economic losses (Dagnoko *et al*., 2013). Pest and disease infestation not only lead to reduction in yield, but also affects the quality of seeds. Most diseases can be transmitted in or on pepper seeds. The most prevalent and economically important pepper bacterial diseases are bacterial wilt (*Ralstonia solanacearum.* Smith), bacterial leaf spot (*Xanthomonas campestris,* var vesicatoria. Doidge), and bacterial soft rot (*Erwinia carotovora.* Smith) (Cheewawiriyakul *et al*., 2006; Pernezny et at., 2003). Diseased plants can exhibit a variety of symptoms, including abnormal leaf growth, color distortion, stunted growth, shriveled plants and damaged fruits (James *et al.*, 2010; Dafalla, 2001). In Ghana, the diseases of economic importance to chilli pepper growers are fruit rot, damping off, anthracnose, bacterial wilt, pepper veinal mottle virus and leaf curl (Karikari and Mathew (1990).

On pests, the major ones in West Africa include thrips (*Frankliniella* spp.) which feed on the leaves, flowers or fruits; aphids (*Aphis* spp.) which feed on young leaves and shoots; whitefly (*Bemisia tabaci* Gennadius) which feeds on the leaves, and root knot nematodes (*Meloidogyne* spp) which feed on the roots. Others include the Mediterranean fruit fly (*Ceratitis capitata.* Wiedemann) which feeds on the fruit flesh, red spider mites (*Tetranychus* spp) which feed on the leaves, and fruit borers (*Lepidopterae* spp). In addition to damages caused to the plants by direct feeding, some pests such as nematodes, whiteflies, aphids and thrips are also vectors of viruses (James *et al.*, 2010). Early identification and correct diagnosis are key steps in managing potential pest and disease problems. The use of resistant cultivars or pathogen-free seeds if available, is one of the primary measures to minimize the problem (Bessin, 2014).

2.5.4 Harvest and post-harvest processing

Chilli peppers are grown as annuals and harvesting occurs about 3 months after planting. Flowering takes place 45 to 60 days after transplanting and yield continues for several months depending on cultivar and optimum environmental conditions. For fresh use, chili peppers can be harvested either at physiological maturity or at the fully ripe stage (Berke *et al.*, 2004). However, best quality seeds are obtained from fully ripened fruits. To obtain quality seeds, fruits showing signs of diseases should be sorted out after harvest. Early harvesting results in low seed germination rate, while harvesting too late will lead to poor quality fruits and seeds (AVRDC, 2005).

Shelf-life is prolonged by storing fresh fruits in cool, shaded, dry place at an ambient temperature of 28°C and 60% relative humidity (Kaaya and Kyamuhangire, 2010).

Fresh chilli fruits should not be washed unless they are to be kept in a cool environment (10°C) to avoid fresh fruit spoilage caused by anthracnose or other fungal or bacterial diseases (Biles *et al.*, 1993).

Fresh chilli fruits contain 65-80% moisture at harvest, and must be reduced to about 810% to prolong the shelf-life (Biles *et al*., 1993). Processing of chili pepper seeds can be carried out by extracting the seeds from fresh or dried fruits either by hand or mechanical maceration followed by drying. Sun-drying is the common practice of processing chilli in many developing countries and is achieved by spreading the produce on clean dry polythene sheets or a concrete floor to reduce the moisture content to about 8 -10 %. If available, a solar dryer can be used but require fairly constant sunshine. Rainfall and cloudy weather increases the drying time and the risk of post-harvest spoilage (Rashid, 1999).

2.6 Storage

Freshly harvested peppers must be stored between 7 to 10°C and 95% relative humidity. The typical shelf-life of peppers under these conditions is 3-5 weeks. Peppers are sensitive to chilling injury when exposed to temperatures below 7°C and symptoms include pitting and water-soaked tissue (Kitinoja and Kader, 2004). When stored above 13°C, chili is subject to accelerated ripening and bacterial soft rot infection. Where no cold storage facilities are available, fruit should be sorted, packed, and marketed within 24 hours of harvest (Biles *et al*., 1993).

For sun-dried chilli fruits, the products should be packed in clean, dry polythene or woven bags and stored ensuring protection from dampness. Stacked bags should be kept 50-60 cm away from the wall to allow ventilation. Longer period of storage may however lead to fruit or seed deterioration (Varmudy, 2001).

Appropriate storage conditions for chilli seeds should be under controlled conditions; maintain a constant temperature and free from excess moisture in order to maintain their vitality for many years (TNAU, 2013). Temporary storage materials for chilli seeds are airtight sealed glass jar, metal can, foil envelope and plastic containers (AVRDC, 2000). To maintain seed viability, they should be stored in a cool, dark, dry place between 35-50°F.

2.6 Seed quality

Seed marks the beginning of each plant production stage, and it is a prerequisite for obtaining high yields of all plant species. Seed quality is essential to agricultural production as poor seed limits the potential yield of crop and reduces productivity. Seed of high quality should possess good physiological, biochemical and phytopathological properties in a seed lot (Miloševic and Zlokolica, 1996; ISTA, 2004). A seed possessing these quality attributes have greater prospects of good stand establishment and producing quality crop. According to van-Gastel *et al*., (1996) quality seed can be defined as seed of an improved variety which has varietal and physical purity, low moisture content, high germination and vigour, free from weeds and seed-borne pathogens, uniform, and properly processed for distribution to farmers. The main attributes of seed quality assessment are germination, seed vigour and seed health. In general, seed viability greatly depends on percent germination, the vigour of a given seed lot and the health status of the seed (Asuboah, 2007).

There are several seed quality parameters. However, the following basic ones can be briefly considered:

- ***Analytical purity***

Purity analysis indicates how much of the material in the seed lot is intact of the species named on the label or being examined. It evaluates the cleanliness of the seed lot into pure seed, seed of other species, weed seeds and inert matter (ISTA 2007). Seeds considered as pure seeds must be without impurities such as broken seeds, chaff, weeds, and other foreign materials (ISTA 2007; Simwanza, 2012).

- ***Germination Test***

Germination in a laboratory test is the emergence and development of seedlings from the seed embryo to a stage where those essential structures (root system; shoot axis; cotyledons; terminal buds and the coleoptile) which make up the seedlings indicates their ability to develop into normal plants under favourable conditions (ISTA, 2007). Although the test cannot precisely forecast field emergence, it indicates that under certain set conditions, a seed lot of relatively high quality will emerge better than a seed lot of poor quality (ISTA, 2007). Germination test is an important attribute in determining the viability of seed and to avoid planting seed of low viability, which may lead to crop failure (Kaaya and Kyamuhangire, 2010).

- ***Seed Vigour***

Vigour testing is an important aspect of seed quality, and it indicates the ability of a seed lot to establish seedlings in harsh growing conditions (Simwanza, 2012).

According to ISTA (2009), seed vigour is „the sum total of those properties of the seed which determine the activity and performance of the seed lot during germination and seedling emergence‟ related to the deterioration, which occurs in seed lot as it ages, not necessarily in time, but in its ability to carry out all the physiological functions that allow it to perform (ISTA, 2009). A number of tests have been developed such as the radical emergence test, accelerated ageing and conductivity test (ISTA, 2009). Vigor testing does not only measure the percentage of viable seed in a sample, it also reflects the ability of those seeds to produce normal seedlings under less than optimum or adverse growing conditions similar to those which may occur in the field (ISTA, 1995). Evaluation of results for vigour tests is mainly classified between vigorous and nonvigorous seedlings. Seed vigor testing is also used as indicator of the storage potential of a seed lot (Duurant and Gummerson, 1990).

Seeds may be classified as viable in a germination test which provides optimum temperature, moisture and light conditions to the growing seedlings; however, they may not be capable of continuing growth and completing their life cycle under a wide range of field conditions. (ISTA, 2009). Miloševic and Zlokolica (1996) reported that preharvest environment of high humidity and warm temperatures can also cause loss in seed viability and vigor. Seed mechanical damage, whether induced by harvesting or conditioning equipment, as well as improper storage conditions are among the factors that adversely affect seed vigor. In addition, genetic factors such as hard-seededness, resistance to diseases, and seed chemical composition. Results of vigour tests can also be used in deciding whether the seed lots can be sown earlier in the season, when the occurrence of stressful conditions is possible, or it should be sown later, when the soil is warmer and the conditions become more favourable for germination and seedling growth (Miloševic and Cirovic, 1994).

- ***Moisture Content***

Moisture content is the key factor in determining the possibility of seed retaining its germination from harvest to sowing time. High moisture content at harvest damages the seed coat, while during storage, it initiates fungal development, insect activity, heating and germination, which contributes to rapid seed deterioration. Low moisture content, on the other hand makes seed liable to mechanical damage during harvesting and processing (van-Gastel *et al*., 1996). Seed moisture is the foremost seed physical attribute that contributes for storage life (ISTA, 2007). The lower the seed moisture, the longer the shelf life. Short term storage can be achieved by drying the seeds to 7-8% moisture content while long term storage is possible by reducing the seed moisture even further to 6% (TNAU, 2013).

- ***Seed Health***

Seed health refers to the presence or absence of disease-causing organisms, such as fungi, bacteria and viruses, and animal pests, including nematodes and insects. Seed health testing is carried out in orders to assess seed sanitary quality (ISTA, 2007). Laboratory detection of the absence or presence of micro-organisms can help to predict field performance of seed samples relative to emergence and disease produced in the next generation, including expected losses (FAO, 2006; Burkholderia *et al.*, 2007). Sowing infected seeds can reduce germination, vigor and potential yield by transmitting pathogen from seed to plants. (van Gastel *et al*., 1996; Simwanza, 2012*)*.

The most adverse effect of seed-borne pathogen is contaminating disease free areas. Thus seed-borne pathogens act as a primary source of inoculum for disease development (ISTA, 2007). Although the level of seed-borne inoculum may be extremely low, the rate of its increase may be extremely high when combined with favourable epidemiological factors such as local agricultural practices (Burkholderia *et al.*, 2007). Seed infection usually occurs during three distinct physiological phases; seed production, seed development and seed maturation. Pathogens can be involved in all these stages of growth and can transmit from planted to the new crop, hence developing a systemic infection that can colonize the seed (McGee, 1995).

2.7 Plant Density

2.7.1 Effects of planting density on plant growth and yield

Plant density has been found to influence plant growth, development and yield of many vegetable crops including chilli (Bosland and Votava, 1999; Khasmakhi-Sabet *et al*., 2009). The spatial arrangement of plant is an important crop management factor that has been used to increase yield per unit area (Cebula, 1995; Akintoye *et al*., 2009). A study by Gaye *et al*. (1991) found that wider spacing distance increased yield per plant but decreased production per unit area. The closeness of neighbouring plants affected their interactions within the root and shoot micro-environments especially in the case of competitive or allelopathic interactions thus adversely affecting plant growth and development. Plant density per unit area determined the optimal above ground conditions that allowed the plant to acquire the essential growth elements such as light and CO_2 that influenced the productivity of dry matter and hence the final yield (Ibrahim, 2012). Heuvelink (1995) reported that at a higher plant density, plant growth rate was decreased due to reduced light interception per plant as a result of the dense canopy. To achieve maximum crop productivity, it was essential to identify the optimum plant population per unit area which resulted in the highest net return.

Norman (1992) stated that plant density had direct influence on yield and quality of fruits and seeds.

2.7.2 Effects of planting density on flower abortion

Flowering is a vital physiological process in crop existence and assurance for reproduction (Marcelis *et al*., 2005). The process also determined fruit set and crop yield (Ishiyaku *et al*., 2005; Ferrara *et al*., 2011). Flowering in plant was dependent on the interaction of many complex processes which were influenced by both genetic and environmental factors (Uarrota, 2010). The environmental conditions in a particular region as well as the cultural practices adopted could influence the abortion of flowers and fruits, which were important yield-limiting factors in many crops including pepper (Wien *et al*., 1989). Abortion is defined as the cessation of development and growth of an organ, after which it usually abscises. A reproductive organs that abort are buds, flowers and young fruits.

According to Ibrahim (2012), the number of plant stands per unit area determined the optimal above ground conditions that allowed the plant to acquire the essential growthenhancing elements that influenced the overall productivity. Norman (1992) reported that plant density had direct influence on flower development, fruit yield and seed quality. A study by Marcelis *et al*. (2004) reported that increasing plant density in sweet pepper decreased dry matter production per plant but increased flower and fruit abortion. A high plant population per unit area might give to excessive shading which causes poor growth, increased flower and fruit drops and subsequently low yields. Heuvelink (1995) reported that plant growth rate was decreased at a higher plant density due to reduced light interception per plant as a result of the dense canopy. The dense canopy led to low light intensity on the photosynthetic structures, resulting to increased competition for assimilates between the flowers and the adjacent young leaves (Turner and Wien, 1994). The reduction in assimilates partitioning to the developing flowers and fruits might give rise to increased flower and fruit abortion thus reducing fruit yield (Turner and Wien, 1994).

The abortion of flowers and fruits was also influenced by a number of biotic and abiotic factors. The biotic factors included pests and diseases and the genetic composition of the cultivar. Wien *et al*. (1989) reported that open flowers were the most susceptible to abortion, while Aloni *et al*. (1991) found that flower buds were the most susceptible to abortion. Abortion due to environmental stresses include extremes of temperature, lack of moisture or low light conditions (Wien, 1990). Dagdelen *et al.* (2004) indicated that the yield of pepper was reduced when the crop was exposed to moisture stress during flowering and fruit formation stage.

2.7.3 Effects of planting density on seed quality

Seed is the primary and most essential starting point of a wide range of horticultural crops, including chilli pepper. Seed quality is a limiting factor affecting not only germination capacity but also emergence potential, field stand and uniformity, seedling growth and finally crop productivity (Zaghdani, 2002). The production of quality seeds depended largely on the use of proper production techniques which included the adoption of appropriate spacing distance to achieve high yield, production of seeds of high quality and high varietal purity which were free from pests and diseases (van Gastel *et al*., 1996).

The population and spatial arrangement of plants could greatly influence the development, growth and marketable yield of chilli pepper (Bosland and Votava, 1999). A higher plant population density might lead to increased competition for essential plant growth factors including water, mineral nutrients, light, and CO_2 supply among plants.

This would result in limited supply of assimilates to individual plants due to reduced photosynthesis, which in turn would increase competition between fruits growing simultaneously on the plant thereby affecting seed formation, fruit quality and yield (Williams *et al.*, 1991; Miccolis *et al*., 1999). According to Pedigo (1996), high plant density favoured poor light penetration which resulted in poor pollination by insects, thereby increasing fruit shedding. Seed development also became incomplete resulting in non-uniform ripening of fruits on all parts of the plant. Furthermore, closer spacing created a more humid environment which favoured the development of some pathogens whose effects could be detrimental to the production of quality seed (Pedigo, 1996).

Conversely, Williams *et al.* (1991) reported that wider spacing permitted easier entry of pathogens that could cause severe damage in fruits and seeds which could result in low yield and poor quality of seeds. van Gastel *et al*. (1996) stated that wider spacing led to increased competition between plants and weeds for the essential growth factors and in such situation, plants usually suffered. They further stated that wider spacing promoted the production of numerous lateral branches which delayed flowering and resulted in non-uniform maturity of seeds (van Gastel *et al*., 1996). Akintoye *et al*. (2009) also emphasized that knowledge of crop response to population density as an important crop management factor that could be used to increase yield per unit area as well as enhancing the quality of seed.

2.8 Planting date

2.8.1 Effects of planting date on plant growth and yield

The identification of an appropriate sowing time is one key factor influencing crop productivity. Islam *et al*. (2010), reported that knowledge of the optimum sowing date was an important aspect of any crop production system as it ensured proper growth and development of plant resulting in maximum yield and profitability. The time selected for cultivation determined the climatic and environmental conditions (i.e. temperatures, rainfall, relative humidity and light intensity) which were likely to be encountered during crop growth and development and ultimately yield.

Islam *et al*. (2010) indicated that early sowing resulted in significant increase in yield per plant in sweet pepper. Early sowing recorded the highest yield (16.33 t/ha) while the lowest yield (7.19 t/ha) was associated with late sowing date (Islam *et al*., 2010). Hamma *et al*. (2012) also reported significant yield difference between early and late sowing dates. The authors observed significantly higher increases in most of the growth and yield parameters per plant for early sowing date in sweet pepper.

One of the major environmental factors associated with sowing time which influenced crop growth and development is temperature. Variations of temperature (either high or low) within the crop growth environment could affect germination, stand establishment and yield. Berke *et al.* (2005) stated that when temperature fell below 15°C or exceeded 32°C for extended periods, growth, fruit and seed yield were usually reduced. Temperatures below the requirement of a crop generally reduced the rate of germination, retarded plant growth and increased crop susceptibility to diseases. Shaked *et al*. (2004) reported significant reduction in fruit sizes of sweet pepper at temperatures below 10°C due to inefficient pollination and fertilization. Conversely, high temperature or warm weather at the time of sowing favored flowering, pollination, seed setting and seed maturity (van Gastel *et al.,* 1996).

The cropping season and sowing time was also influenced by the rainfall pattern, soil moisture and relative humidity in the crop growth environment. Karikari and Mathew (1990) reported that the factor of humidity in vegetable production was closely linked with rainfall intensity and pattern. Mathai (1998) stated that moisture in the atmosphere and soil influenced germination, flowering, fruit and seed setting of vegetable crops. Diseases and pests occurrence, as well as seed maturation were also affected by relative humidity. A study by Jovicich *et al*. (2004) found that pepper fruits were affected by air temperature, daylight and relative humidity (RH) during anthesis, fruit set, development and maturation.

Day length and light intensity could also have strong influence on plants during the vegetative and reproductive phases (Galanopoulou-Sendouca, 1996). Mutters and Hall (1992) reported that pollination and fertilization were sensitive to high temperatures, while low light intensity enhanced pepper flower abortion and thus reduced fruit yield.

2.8.2 Effects of planting date on flower abortion

Flower and fruit abortion is a yield-limiting factor in many crops (Halbrecq *et al.*, 2005; Bacci *et al.*, 2006). Abortion of flowers and fruits can be caused by unfavourable environmental conditions such as low light conditions, temperature and moisture stress (Aloni *et al.*, 1996; Guilioni *et al.*, 1997). Wien (1990) reported that abortion of flowers and fruits might occur when pepper was exposed to environmental stress during the flowering and fruiting stage. According to Dagdelen *et al.* (2004), yield was reduced when the crop was exposed to moisture stress during the flowering and fruiting stage as a result of high flower and fruit abortion.

The time of flowering is of great importance in annual crops because it affect reproductive development including flower formation and retention. Flower retention and fruit set are highly sensitive to environmental stress, particularly temperature (Van Doorn and Stead, 1997). During reproductive development, low temperature stress is one of the most significant abiotic stresses affecting plant growth, flowering and yield of many cold-sensitive vegetable species including pepper, eggplant, and tomato and induces flower abortion, pollen sterility, pollen tube distortion and ovule abortion (Tarchoun *et al*., 2003; Schwarz *et al*., 2010; Thakur *et al*. 2010). High temperature and low light conditions have been reported to enhance flower abortion and also to affect photosynthetic rates (Kitroongruang *et al*., 1992; Havaux, 1993). In a study on the effects of temperature stress on sweet pepper, Marcelis *et al.* (2004) found that a constant temperature of 33°C for 4 days caused 100% abortion of buds and flowers. Erickson and Markhart (2001) also reported increased abortion in buds, flowers, and young fruits of pepper caused by high temperatures (> 30°C) associated with cropping season.

2.8.3 Effects of planting date on seed quality

Seed is any regenerative part of a plant that is capable of developing into another plant and can be used for propagation. Seed quality has a profound effect on seed performance, stand establishment and ultimately economical yield (Zaghdani, 2002). Basu (1995) identified three major factors influencing seed quality. These were preharvest conditions; harvesting and processing; and postharvest storage conditions. The pre-harvest conditions involved quality of the initial seed, moisture status of soil, temperature and photoperiod; while harvesting, processing and postharvest storage conditions included seed moisture and drying, and storage temperature (Basu, 1995). The cropping season or sowing time influenced the climatic conditions affecting crop growth, yield and seed quality (Castillo *et al*., 1994). Adequate temperature and soil moisture promoted seed germination (Mathai, 1998); day length and light intensity influenced vegetative and reproductive growth; while dry weather with low humidity were necessary for seed maturation, ripening and harvesting. In contrast, wet conditions were likely to cause rotting, fungi proliferation and harvesting problems (van Gastel *et al.*, 1996). Galanopoulou-Sendouca (1996) reported that cloudy and wet weather provided unfavourable conditions for seed drying, thus affected the quality of seed. According to Karikari and Mathew (1990), high humidity prevalent during the rainy season created conditions which favoured fungal diseases on foliage and fruits; thereby affecting the quality of the seed. Castillo *et al*. (1994) reported that date of sowing and harvest could influence pea seed quality.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

The study comprised field and laboratory experiments, the field study was carried out at the Crops Research Institute (CRI)-Kwadaso Station, located near Kumasi, Ghana. Kwadaso is located in the Ashanti Region and is situated between Latitude 6°42'N and

Longitude 1°39'W and falls within the semi-deciduous Forest ecological zone of Ghana. The soils at the location is characterized by ferric acrisols with well-drained structure. The location has a bimodal rainfall pattern, with the major season stretching from April to July, and the minor season from August to November. The laboratory analyses were carried out at the Department of Horticulture, CSIR-Crops Research Institute, Kwadaso (germination test and 1000 seed weight), Department of Crop and Soil Sciences (Seed conductivity test and seed health test), Kwame Nkrumah University of Science and Technology.

3.2 Soil sampling and analysis

Soil samples were randomly collected from each of the two experimental sites at a depth of 0-25cm. The samples from each site were then bulked together and prepared for analysis at the Soil Testing Laboratory at the Soil Research Institute (SRI), Kwadaso. The samples were analyzed for pH, organic carbon, total nitrogen, exchangeable cations, and exchangeable acidity (Appendix 25).

3.3 Experimental design and treatments

The field trial was laid out in a 2x3x3 factorial arrangement in a Randomized Complete Block Design (RCBD) with 3 replications. The factors were varieties at two levels (*Shito Adope* and *Legon-18*); planting dates at three levels (12^{th} May; 13^{th} June; 29^{th} September, 2014); and plant spacing at three levels (60 cm x 30 cm; 70 cm x 30 cm; 80 cm x 30 cm). Each variety was cultivated on a plot of land measuring 460m^2 (20m x 23m) during each planting season. The isolation distance between the two field plots was 250 meters apart to avoid cross pollination between the varieties (AVRDC, 2000). Each variety was planted on three different plot size, measuring 36m^2 (6mx6m); 42m^2

(7mx6m), and 48m^2 (8mx6m), to conform to the three planting densities. The plant population within each experimental plot was 200 plants and the experimental plots were separated by one meter rows.

3.4 Nursery management

Two raised nursery beds with sterilized, well-drained loamy soils were prepared for the sowing of seeds. Due to the nature of the study, seeds were sown at different dates (10th April, 12th May, and 20th August 2014).

The nursery beds were covered with palm fronds to provide shade and protect the young seedlings from harsh weather conditions. All recommended nursery management practices including irrigation, weeding, thinning were carried out as and when necessary. Transplanting of seedling was carried out four weeks after sowing. A week prior to transplanting, the shade was gradually removed to expose the young seedlings to harsh environmental conditions. *Golan 20 SP*, an insecticide with active ingredient of 20% acetamiprid, was applied at the rate of 20 ml/15 L of water to control insect pests; and a systemic fungicide. Victory 72 WP, containing, 8% metalaxyl and 64% mancozeb, was used at the recommended rate of 40 g/15L water to control fungal diseases.

3.5 Land preparation and crop husbandry practices

The sites were cleared, ploughed and harrowed. These activities were carried out to manage weeds, provide good soil aeration, seedlings establishment and adequate root penetration. Field layout was done a day prior to transplanting. Transplanting for the major season was carried out on 12th May and 13th June 2014, respectively; while transplanting for the minor season was carried out on 29th September 2014. Manual weeding (hoeing and hand pulling) was carried out two weeks after transplanting and continued at three weeks interval until the final harvest. Irrigation was also done once every month using sprinklers to maintain adequate soil moisture and to promote uniform growth and development.

A basal application of NPK (15:15:15) was done two weeks after transplanting through band placement at the rate of 35 kg ha^{-1} [5g per plant]. The second fertilizer (Ammonia nitrate, 34% N) application was carried out six weeks after transplanting at the rate of 48 kg ha^{-1} [3g per plant]. After transplanting, the field was sprayed with Golan 20 SP and Victory 72 WP at four weeks interval at the recommended rates of 20 ml/15 liter of water and 40g/15L water, respectively to control insect pests and fungal diseases. All other recommended crop husbandry practices were carried out, as and when necessary. Harvesting of matured fruits began at 12 weeks after transplanting (WAP) and was carried out manually by hand picking. The harvesting was done over a four week period. Care was taken to prevent damage to the branches due to their brittle nature.

Fruits from 30 sample plants were harvested separately from each plot and were placed in polythene bags for post-harvest data collection and analysis.

3.6 Data Collection

The following vegetative, reproductive, yield and seed quality data were collected during the pre-harvest and post-harvest stages of the study:

3.6.1 Plant height

Plant height was taken at 3, 6, and 9 weeks after transplanting (WAT). A total of 30 tagged plants were selected from six middle rows of each plot. Using a meter rule, the measurements were taken from the base to the apex of the plant and the weekly mean recorded.

3.6.2 Number of branches

The number of branches per plant was taken at 4 and 8 weeks after transplanting by counting the number of primary branches on the main stem of each of the thirty tagged plants and the mean recorded.

3.6.3 Canopy spread

Using a meter rule, the canopy width data was taken by measuring two perpendicular distances across the widest point of the leaf on each of the thirty tagged plants and the mean recorded. This data was taken at 4 and 8 weeks after transplanting.

3.6.4 Stem girth

Using a Vernier caliper, stem diameter was measured at the base of each of the thirty tagged plants and recorded in millimeters (mm). This parameter was taken at 4 and 8 weeks after transplanting.

3.6.5 Days to 50% flowering

The days to 50% flowering was recorded by visually observing and counting the number of plants with opened flowers within each plot. The data was taken when 50% of the plants had opened flowers and the days were determined by using the date of transplanting as baseline.

3.6.6 Days to 50% fruit set

The days to 50% fruit set was recorded by visually observing and counting the number of plants with set fruits within each plot. The data was taken when 50% of the plants had fruits set and the days were determined by using the date of transplanting as reference point.

3.6.7 Number of aborted flowers (flower drops)

The number of aborted flowers were recorded weekly from the thirty tagged plants. Data collection was achieved by carefully placing a screen net around each of the tagged plant to trap the aborted flowers. The exercise was carried out from flower initiation up to first harvest and the sum total of all aborted flowers was computed.

3.6.8 Number of fruits per plant

The number of fruits per plant was obtained by counting all the harvested fruits from each tagged plant and recorded.

3.6.9 Fruit weight per plant

Using an electronic balance, the mean fruit weight was determined by weighing the total harvested fruits per plant from each of the thirty tagged plants and dividing by the total number of fruits per plant.

3.6.10 Fruit yield per hectare (total fruit yield)

The total fruit yield per hectare was calculated using the following formula:

$$Total\ fruit\ yield\ (MT/ha) = \frac{Wfp\ (kg)\ x\ TA\ (10000m2)}{Ap(m2)} \div 1000$$

Where: Y_{tf} = Total fruit yield per hectare (MT/ha); W_{fp} = Weight of fruit per plant; TA = Total area expressed in hectare (10,000m^2); A_P = Area occupied by individual plant.

3.6.11 Number of seeds per fruit

Ten fresh fruits were randomly selected from the harvested tagged plants in each plot. These were cut opened with a knife and the seeds were carefully extracted from the placenta and placed on a screen net and allowed to air-dry under a shade at ambient temperature for 5 days. The dried seeds from the ten plants were counted and the mean recorded.

3.6.12 Weight of seeds per fruit

Seeds extracted from the ten fruits were air-dried and weighed and the mean recorded.

3.6.13 1000 seed weight

Hundred air-dried seeds each of eight replicates from each treatment were weighed separately. The mean weight of the 100 was calculated and multiplied by a factor of 10 to obtain the 1000 seed weight for each treatment.

3.6.14 Seed Vigour

Conductivity test was used in determining the vigour of the seeds. Four replicates of 50 seeds of each entry were drawn at random and tested for electrical conductivity. Seeds were placed in Erlenmeyer flasks containing 75 ml ultra-pure deionized water equilibrated to 25 °C, then maintained at 25 °C for 24 h. After 24 h of soaking, the flasks was swirled for 10-15 sec and seeds then taken out of water with a clean forcep. An electrical conductivity dip cell was inserted into the seep water until a stabilized reading achieved and recorded. The mean of the two control flasks (sterilized distilled water) when measured served as background reading. Conductivity was calculated using the formula below (ISTA, 2007).

$$\text{Conductivity } (\mu S/cm^{-1}g^{-1}) = \frac{\text{(Conductivity reading - background reading)}}{\text{(Weight (g) of replicate)}} \text{ check}$$

According to Milosevic *et al.* (2010), if the calculated value is < 25 $\mu S/cm^{-1}g^{-1}$, seed has a high vigour, thus, the seed is suitable for early sowing in unfavourable conditions; 25 –29 $\mu S/cm^{-1}g^{-1}$, seed can be used for early sowing with risk in unfavourable conditions; 30 – 43 $\mu S/cm^{-1}g^{-1}$, seed is not suitable for early sowing especially in unfavourable conditions; > 43 $\mu S/cm^{-1}g^{-1}$, seed has a low vigour i.e.it is not suitable for sowing (Milosevic *et al.,* 2010).

3.6.15 Germination Test

Four air-dried seeds from each plot were placed on wet blotted papers in eight petri dishes and stored under ambient temperature in the laboratory for 14 days. First count of emerged seedlings was carried out on the 7th day; while the final count and seedlings" evaluation were carried out on the 14th day and calculated on percentage basis. Seedlings" scoring, ranging from normal seedlings, to abnormal seedlings, dead seeds and hard seeds was carried out using the *ISTA Standard* (ISTA, 2007).

$$\text{Germination \%} = \frac{\text{Number of germinated seeds}}{\text{Number of total seeds planted}} \times 100$$

3.6.16 Seed Health Test

Seed health test was carried out using the Blotter test method (ISTA, 2004). Four hundred seeds from each treatment were plated on well water-soaked blotters (4 petridish). Seeds were incubated for 7 days in an incubation room at 20°C±1-2°C under 12hr alternating cycles of light using Near Ultra Violet light bulbs and darkness. At the end of the incubation period, each seed was thoroughly examined under a stereomicroscope for the total fungus population of each treatment. Further identification of fungi spores (fruiting bodies) was made using the compound microscope as described by Mathur and Kongsdale (2001).

3.7 Statistical Analysis of Data

Data collected from the field and laboratory experiments were subjected to analysis of variance using Statistix Student Version 9.0. Tukey's HSD (Honest Significant Difference) was used for mean separation at probability level of 0.05 and 0.01 for field and laboratory experiments, respectively.

CHAPTER FOUR

4.0 RESULTS

4.1 Climatic information of experimental period

The average monthly weather data, presented in Table 4.1 was collected at the study location (Kwadaso), and covers the period from January 2014 to December 2014. The highest rainfall was recorded during the month of April (280.1mm); followed by June (264.9mm) and September (206.5mm). The lowest rainfall data (16.7mm) was recorded during the month of December 2014. Monthly temperatures during the same period range from the lowest (22.7ºC) recorded in September 2014 to the maximum temperatures (32.8ºC) recorded in December 2014 (Table 4.1).

Table 4.1: Monthly Weather data of the study location for 2014

Monthly Weather Data 2014 (Kwadaso Station)

Months (2014)	**Rainfall (mm)**	**Tmax. (ºC)**	**Tmin. (ºC)**
January	40.1	31.0	24.4
February	48.0	32.0	24.6
March	70.1	31.5	24.3
April	280.1	28.1	24.2
May	132.5	30.1	24.4
June	264.9	28.3	23.8
July	113.0	29.5	23.9
August	92.0	30.5	23.8
September	206.5	28.9	22.7
October	173.3	31.2	23.4
November	139.0	31.6	23.8
December	16.7	32.8	22.9

Source: Soil Research Institute, Kwadaso

4.2 GROWTH AND YIELD PARAMETERS OF CHILLI PEPPER

4.2.1 PLANT GROWTH OF PEPPER

4.2.1.1 Plant height at 3 WAT

There were significant planting dates x variety interactions for plant height at 3 WAT. At 3WAT, Legon-18 planted in May produced the tallest plant (14.1cm), significantly different from the shortest plants produced by Shito Adope planted in June (11.9cm) and Legon-18 planted in September (11.9cm). Plants of Legon-18 planted in May were however similar in height to those of Legon-18 planted in June (Table 4.2). Between varieties, plants of Legon-18 were taller than Shito Adope. Among the planting dates, there were differences in plant height, with the crops planted in May recording the tallest plants, though not significantly different from crops planted in June. Crops planted in September recorded the shortest heights (Table 4.2).

Table 4.2: Effects of variety and planting date on plant height of chilli pepper at 3 WAT

	Plant height (cm) at 3 WAT		
Planting Dates (2014)	Shito Adope	Legon-18	Mean
May	13.0	14.1	13.6
June	11.9	13.9	12.9
September	13.0	11.9	12.5
Mean	12.6	13.3	
Tukey HSD (0.05): Variety = 0.51; Planting date = 0.76; Variety x Planting date = 1.32			

4.2.1.2 Plant height at 6 WAT

There were also significant planting dates x variety interactions for plant height at 6 WAT (Table 4.3). Legon-18 planted in June produced the taller plants (33.1cm), though not significantly different from Legon-18 planted in September (31.9) whereas Shito Adope planted in June (24.6cm) produced the shorter plants (Table 4.3). Between varieties, Legon-18 produced the taller plants (30.7cm) while Shito Adope produced the shorter plants (25.5cm). Among the planting dates however, there were no significant differences in plant height.

Table 4.3: Effects of variety and planting date on plant height of chilli pepper at 6 WAT

	Plant height (cm) at 6 WAT		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	26.3	27.2	26.8
June	24.6	33.1	28.9
September	25.5	31.9	28.7
Mean	25.5	30.7	

Tukey HSD (0.05):Varieties = 1.78; Planting dates = 2.63;Varieties x Planting dates= 4.5

4.2.1.3 Plant height at 9 WAT

There were significant variety x planting date interactions for plant height at 9WAT. Legon-18 planted in May produced the taller plant (58.8cm), though not significantly different from Legon-18 planted in June (54.9) whereas Shito Adope planted in September produced the shorter (43.1cm). Between the varieties, Legon-18 recorded the tallest height (53.9cm) while Shito Adope recorded the shorter height (44.9cm) (Table 4.4). Between the planting dates, May planting produced the taller plants, though not significantly different from June planting. Planting in September produced the shorter plants (Table 4.4).

Table 4.4: Effects of variety and planting date on plant height of chilli pepper at 9WAT

	Plant height (cm) at 9WAT		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	46.4	58.8	52.6
June	45.3	54.9	50.1
September	43.1	48.1	45.6
Mean	44.9	53.9	

Tukey HSD (0.05): Varieties = 2.41; Planting dates = 3.56; Varieties x Planting dates = 6.20

There were also significant differences in planting spacing for plant height at 9 WAT. Plants planted at a spacing of 80 cm x 30 cm produced the taller plants (52.61cm), though not significantly different from those planted at a spacing of 70 cm x 30 cm. The shortest plants (47.10cm) were produced by plants planted at a spacing of 60 cm x 30 cm (Table 4.5).

Table 4.5: Effect of planting spacing on plant height of chilli pepper at 9 WAT

Plant Height (cm) at 9WAT	
Planting Density	Plant Height (cm)
SP_1 (60 x 30)	47.10
SP_2 (70 x 30)	50.10
SP_3 (80 x 30)	52.61
Tukey HSD (0.05)	**3.56**

4.2.2 Number of branches per plant

4.2.2.1 Number of branches at 4WAT

There were significant variety x planting date interactions for number of branches at 4 WAT. Legon-18 planted in June (8.6) produced higher number of branches per plant, significantly greater than the other treatments except Legon-18 planted in May. The least number of branches per plant was produced by Shito Adope planted in May (4.2), though not different from Shito Adope planted in September (Table 4.6). Between varieties, Legon-18 produced (7.7) more branches per plant, significantly greater than those of Shito Adope (5.5) (Table 4.6). Between the planting dates, planting in June resulted in the production of the highest number of branches, significantly different from those produced by planting in May and September which produced the least (Table 4.6).

Table 4.6: Effects of variety and planting date on the number of branches per plant of chilli pepper at 4WAT

	Number of branches at 4WAT		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	4.2	7.8	6.0
June	7.1	8.6	7.9
September	5.1	6.7	5.9
Mean	5.5	7.7	

Tukey HSD (0.05): Varieties = 0.49; Planting dates = 0.72; Varieties x Planting dates =1.26

4.2.2.2 Number of branches per plant at 8WAT

There were also significant variety x planting date interactions for number of branches per plant at 8 WAT. Legon-18 planted in June (10.5) produced the highest number of branches per plant, significantly greater than the other treatments except Legon-18 planted in May (10.3). The least number of branches per plant was produced by Shito Adope planted in May (5.1), though not different from Shito Adope planted in September (5.6) (Table 4.7).

Between varieties, Legon-18 produced higher number of branches per plant (9.6) significantly greater than Shito Adope which produced the least (5.9) (Table 4.6). Between the planting dates, planting in June resulted in the production of the highest number of branches, significantly different from those produced by planting in May whih in turn were different from those planted in September which produced the least (Table 4.7).

Table 4.7: Effects of variety and planting date on the number of branches per plant of chilli pepper at 8WAT

	Number of branches at 8WAT		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	5.1	10.3	7.7
June	7.0	10.5	8.8
September	5.6	8.1	6.9
Mean	5.9	9.6	

Tukey HSD (0.05): Varieties = 0.39; Planting dates = 0.57; Varieties x Planting dates = 0.99

4.2.3 Canopy spread

4.2.3.1 Canopy spread at 4WAT

There were significant variety x planting date interactions for plant canopy spread at 4 WAT (Table 4.8). Legon-18 planted in May (40.4 cm) produced the widest canopy spread at 4WAT, significantly bigger than the other treatments except Legon-18 planted in June (37.3 cm). The least canopy spread was produced by Shito Adope (26.3 cm) planted in September and Legon-18 (26.3 cm) also planted in September (Table 4.8). Between varieties, Legon-18 produced the widest canopy spread (34.7 cm) significantly different from the least produced by Shito Adope (29.5 cm). Among the planting dates, planting in May (34.2 cm) or June (35.8 cm) produced the widest canopy spread, significantly different from that produced by September planting which produced the least canopy spread (Table 4.8).

Table 4.8: Effects of variety and planting date on the canopy spread of chilli pepper at 4WAT

Canopy spread (cm) at 4WAT			
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	28.0	40.4	34.2
June	34.3	37.3	35.8
September	26.3	26.3	26.3
Mean	29.5	34.7	

Tukey HSD (0.05): Varieties= 1.99; Planting dates = 2.94; Varieties x Planting dates = 5.12

4.2.3.2 Canopy spread at 8WAT

There were also significant variety x planting date interactions for plant canopy spread at 8 WAT (Table 4.9). Legon-18 planted in June (47.7 cm) produced the widest canopy spread at 4WAT, significantly bigger than the other treatments except Legon-18 planted in May (44.8 cm). The least canopy spread was produced by Shito Adope (34.0 cm) planted in September and Legon-18 (35.5 cm) also planted in September (Table 4.9). Between varieties, Legon-18 produced the widest canopy spread (42.7 cm) significantly different from the least produced by Shito Adope (39.3 cm). Among the planting dates, planting in May (43.9 cm) or June (44.3 cm) produced the widest canopy spread, significantly different from that produced by September planting which produced the least canopy spread (34.8 cm) (Table 4.9).

Table 4.9: Effects of variety and planting date on the canopy spread of chilli pepper at 8WAT

Canopy spread (cm) at 8WAT			
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	43.1	44.8	43.9
June	40.9	47.7	44.3
September	34.0	35.5	34.8
Mean	39.3	42.7	

Tukey HSD (0.05): Varieties = 3.00; Planting dates = 4.44; Varieties x Planting dates = 7.74

4.2.4 Stem girth

4.2.4.1 Stem girth at 4WAT

There were significant variety x planting date interactions for stem girth at 4 WAT. Shito Adope planted in May (7.2 mm) produced the biggest stem girth, significantly greater than the other treatments except Legon-18 planted in June. The smallest girth was produced by Shito Adope planted in June (4.2 mm), though not different from Legon-18 planted in September (Table 4.10). Between varieties, there were no diiferences in stem girth. Between the planting dates however, planting in May resulted in the production of the biggest stem girth, significantly different from those produced by planting in June and September which produced the least (Table 4.10).

Table 4.10: Effects of variety and planting date on stem girth of chilli pepper at 4WAT

	Stem girth (mm) at 4WAT		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	7.2	5.4	6.30
June	4.2	7.1	5.65
September	5.6	4.8	5.20
Mean	5.67	5.77	

Tukey HSD (0.05): Varieties = 0.41; Planting dates = 0.61; Varieties x Planting dates =1.10

4.2.4.2 Stem girth at 8WAT

There were significant variety x planting date interactions for stem girth at 8 WAT. Legon-18 planted in June (9.3 mm) produced the biggest stem girth, significantly greater than the other treatments except Legon-18 planted in September. The smallest girth was produced by Shito Adope planted in June (5.8 mm), though not different from Shito Adope planted in September (Table 4.11). Between varieties, Legon-18 produced significantly bigger stems than Shito Adope. Between the planting dates however, there were no differences in stem girth (Table 4.11).

Table 4.11: Effects of variety and planting date on stem girth of chilli pepper at

8WAT

Stem girth (mm) at 8WAT			
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	7.3	7.7	7.50
June	5.8	9.3	7.60
September	7.1	8.4	7.80
Mean	6.7	8.5	7.60

Tukey HSD (0.05): Varieties = 0.56; Planting dates = 0.82; Varieties x Planting dates = 1.4

4.2.5 Number of days to 50% flowering

There were significant variety x planting date interactions for the number of days to 50% flowering. Shito Adope planted in May was the earliest to flower (27.9 days), significantly different from the other treatments except Shito Adope planted in June. Legon-18 planted in September took the longest time to flower (42.3 days) though not different from Legon-18 planted in June (Table 4.12). Between varieties, Shito Adope was the earliest to flower significantly earlier than Legon-18 which took the longest time to flower. Between the planting dates, May plantings were the earliest to flower, significantly different from June and September plantings (Table 4.12).

Table 4.12: Effects of variety and planting date on the number of days to 50% flowering of chilli pepper

Days to 50% flowering			
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	27.9	37.3	32.6
June	29.4	41.7	35.6

September	32.9	42.3	37.6
Mean	30.07	40.43	

HSD (0.05): Varieties = 1.63; Planting dates = 2.40; Varieties x Planting dates = 4.19

4.2.6 Days to 50% fruit set

There were significant variety x planting date interactions for number of days to 50 % fruit set. Legon-18 planted in June took the longest time to achieve 50% fruit set, though not different from Legon-18 planted in September. Shito Adope planted in May took the shortest time to achieve 50% fruit set. Between varieties, Shito Adope took less time to attain 50% fruit set whiles Legon-18 took more time to achieve the same percentage fruit set (Table 4.13). Among planting dates, May plantings took fewer days to achieve 50% fruit set (40.3), whereas, September plantings took more days to achieve 50% fruit set (Table 4.13).

Table 4.13: Effects of variety and planting date on the number of days to 50% fruit set of chilli peppers

	Days to 50% fruit set		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	32.4	48.2	40.3
June	32.6	51.2	41.9
September	36.9	50.9	43.9
Mean	33.97	50.10	

HSD (0.05): Varieties = 1.69; Planting dates = 2.49; Varieties x Planting dates = 4.35

4.2.7 Number of flowers aborted

There were significant variety x planting date interactions for mean number of days to 50 % fruit set. Legon-18 planted in June recorded the least number of aborted flowers though not different from that of Shito Adope planted in June (Table 4.14). Shito Adope planted in May recorded the highest number of aborted flowers yet similar to those resulting from Legon-18 planted in September. Between varieties, Shito Adope aborted significantly more flowers than Legon-18. (Table 4.14). Among planting dates, May and September plantings recorded more aborted flowers, significantly greater than those from June planting (Table 4.14)

Table 4.14: Effects of variety and planting date on the number of flowers aborted of chilli pepper

	Number of flowers aborted		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	16.3	13.5	14.90
June	11.9	9.5	10.70
September	15.6	16.0	15.80
Mean	14.60	13.0	

HSD (0.05): Varieties = 1.60; Planting dates = 2.33; Varieties x Planting dates = 4.05

4.2.8 Number of fruit per plant

There were significant variety x planting date interactions for number of fruit per plant. The highest number of fruits (38.4) was produced by Shito Adope planted in May whilst the least number (18.6) was produced by Legon-18 planted in September (Table 4.15). Plants of Legon-18 planted in June had similar number of fruit per plant as those of Shito Adope planted in May. Between varieties, Shito Adope produced the highest mean fruit number (31.0), significantly different from the least number of fruits (25.1) produced by Legon-18 (Table 4.15). Among the planting dates, higher number of fruits per plant (32.25) were recorded by May planting, though not significantly different from those of June plantings. The least number of fruits per plant (22.95) was produced September plantings (Table 4.15).

Table 4.15: Effects of variety and planting date on the mean fruit number of chilli pepper varieties

	Mean fruit number per plant		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	38.4	26.1	32.25
June	27.4	30.6	29.1
September	27.3	18.6	22.95
Mean	31.0	25.1	
HSD (0.05): Varieties = 3.67; Planting dates = 5.42; Varieties x Planting dates = 9.44			

4.2.9 Fruit weight per plant

There were significant variety x planting date interactions for fruit weight per plant. Legon-18 planted in June produced the highest fruit weight (88.8g) though not significantly different from those of Legon-18 and Shito Adope planted in May (Table 4.16). Plants of Legon-18 planted in September produced the least fruit weight (45.2g). Between varieties, Legon-18 produced the highest mean fruit weight (69.1g) significantly greater than Shito Adope which recorded the least fruit weight (60.1g) (Table 4.16). Among the planting dates, May plantings produced the highest fruit weight (77.55g), significantly greater than the least produced by September plantings (46.15g) (Table 4.16).

Table 4.16: Effects of variety and planting date on the mean fruit weight of chilli pepper

	Mean fruit weight (g)		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	82.2	72.9	77.55
June	51.1	88.8	69.95
September	47.1	45.2	46.15
Mean	60.1	69.1	64.55

HSD (0.05): Varieties = 7.6; Planting dates = 4.1; Varieties x Planting dates = 19.49

4.2.10 Total fruit yield (t/ha)

There were significant variety x planting date interactions for total fruit yield. Legon-18 planted in June produced the highest yield (4.3 mt ha^{-1}), significantly different from the least yield (2.2 mt ha^{-1}) produced by Legon-18 planted in September (Table 4.17). Among the varieties, Legon-18 produced the highest total fruit yield (3.33 mt ha^{-1}) significantly greater than the lowest yield (2.86 mt ha^{-1}) was produced by Shito Adope (Table 4.17). Between the planting dates, the highest total fruit yield (3.70 mt ha^{-1}) was produced by May plantings, though not significantly different from those of June plantings. The lowest total fruit yield (2.25 mt ha^{-1}) was produced by September plantings (Table 4.17).

Table 4.17: Effects of variety and planting date on the total fruit yield of chilli peppers.

Total fruit yield (mt ha^{-1})

Planting Dates(2014)	Shito Adope	Legon-18	Mean
May, 2014	3.9	3.5	3.70
June, 2014	2.4	4.3	3.35
September, 2014	2.3	2.2	2.25
Mean	2.86	3.33	

HSD (0.05): Varieties = 0.37; Planting dates = 0.55; Varieties x Planting dates = 0.96

4.2.11 Number of seed per fruit

There were significant variety x planting date interactions for number of seeds per fruit. Legon-18 planted in September produced the highest number of seeds per fruit (77.3), significantly different from the least seed number (52.4) produced by Shito Adope planted in June (Table 4.18). Between the varieties, Legon-18 produced the highest seeds per fruit (73.40), significantly greater than the least produced by Shito Adope (60.21). Among planting dates, the highest number of seeds per fruit (71.30) was produced by September plantings, significantly different from the least produced by June plantings (Table 4.18).

Table 4.18: Effects of variety and planting date on the mean seed number per fruit of chilli pepper

	Mean seed number per fruit		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	63.1	69.4	66.20
June	52.4	73.5	62.94
September	65.0	77.3	71.30

Mean	60.21	73.40	

HSD (0.05): Varieties = 3.53; Planting dates = 5.23; Varieties x Planting dates = 9.1

4.2.12 Seed weight per fruit

There were significant variety x planting date interactions for seed weight per fruit. Legon-18 planted in May and September as well as Shito Adope planted in September produced significantly the highest seed weight per fruit. (Table 4.19). The least seed weight were produced by Shito Adope planted in May and June and Legon-18 planted in June. Between varieties, Legon-18 produced the highest seed weight (0.37g) significantly gtreater than the least produced by Shito Adope (0.33g). Among planting dates, the highest seed weight per fruit (0.40g) was obtained from September plantings, significantly greater than the least produced by June planting. Seed weight from May planting was similar to that obtained from September planting (Table 4.19).

Table 4.19: Effects of variety and planting date on the seed weight per fruit of chilli pepper

	Mean seed weight per fruit (g)		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	0.3	0.4	0.35
June	0.3	0.3	0.30
September	0.4	0.4	0.40
Mean	0.33	0.37	

Mean SD wt.: Tukey HSD (0.05): Var. = 0.03; PD = 0.50; Var. x PD = 0.09

4.2.13 1000 seed weight

There were significant variety x planting date interactions for 1000 seed weight. Shito Adope planted in September produced the highest 1000 seed weight though similar to that produced by Shito Adope planted June (Table 4.20). The least seed weight were produced by Legon-18 planted in May which was not different from that produced by Shito Adope planted in May. Between varieties, Shito Adope produced the highest 1000 seed weight (5.03g) significantly greater than the least produced by Legon-18 (4.50g). Among planting dates, the highest 1000 seed weights were obtained from June and September plantings, significantly greater than the least obtained from May planting (Table 4.20).

Table 4.20: Effects of variety and planting date on the 1000 seed weight of chilli pepper

	1000 seed weight (g)		
Planting Dates(2014)	Shito Adope	Legon-18	Mean
May	4.6b	4.0	4.30
June	5.2	4.8	5.00
September	5.3	4.7	5.00
Mean	5.03	4.50	

HSD (0.01): Varieties = 0.25; Planting dates = 0.37; Varieties x Planting dates = 0.64

4.2.14 Seed Vigor (%)

There were no significant interactions between the treatments for seed vigour. Similarly, there were no significant differences between the main effects for seed vigour. Electrical conductivity values were 30.34 µS/cm-^{1}g-^{1} for Legon-18 and 31.4 µS/cm-^{1}g-^{1} for Shito Adope.

4.2.15 Seed germination (%)

Significant difference was observed between planting dates for percent seed germination. The highest seed germination percentage (89.9%) was produced on seeds planted in June, significantly different from seeds planted in September. Seeds planted in May produced similar germination percentage to those planted in June. The lowest seed germination percentage (82.8%) was produced by seeds planted in September (Table 4.21).

Table 4.21: Effects of planting date on percent seed germination of chilli pepper

	Seed Germination (%)
Planting dates(2014)	Mean
May	88.1
June	89.9
September	82.8
HSD(0.01):	**6.35**

4.2.16 Occurrence of fungal pathogens on two chilli varieties.

A total of six fungal pathogen species were identified on the two chilli varieties. The pathogens included *Aspergillus flavus*, *Aspergillus niger, Aspergillus tamari*, *Collectotrichum graminicola*, *Curvularia lunata and Rhizopus* (Appendix 24). Of the six pathogens, *Collectotrichum graminicola* recorded the highest pathogen incidence on the two chilli varieties, followed by *Aspergillus niger*; while *Aspergillus tamarii* was the least. Generally, the highest occurrence of fungal pathogens was observed on seeds cultivated in May while the lowest occurrence was recorded on seeds cultivated in September. For varieties and spacing, *Aspergillus niger* recorded the highest number of occurrence (256) on seeds of Legon 18 at the closest spacing regime, followed by *Collectotrichum graminicola* (162) also at the closest spacing. *Aspergillus tamirii* recorded the lowest occurrence on seeds of Legon-18. For Shito Adope, *Collectotrichum graminicola* (282) recorded the highest pathogen incidence on seeds obtained from plants cultivated in May at the closest spacing regime, followed by

Aspergillus niger (134) on seeds obtained on seeds obtained from plants cultivated in June at the closest spacing regime while the lowest occurrence was *Aspergillus tamari* (Appendix 24).

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 Growth characteristics of the chilli pepper varieties

There were variations between varieties for plant height and stem diameter at the different growth stages. The observed differences could be attributed to the differences in genetic constitution of the varieties. Tindall (1983) reported that the ultimate height attained by different lines depended greatly on their growth characters. Similar findings were observed by Vos and Frinking (1997) and El-Tohamy *et al*. (2006) who stated that the increase in plant height could be due to the varietal variability to absorb nutrients from the soil. Of the two varieties, Legon-18 produced taller plants at all growth stages. The mean height recorded at maturity for Legon-18 was 53.9cm. This is in agreement with the findings of Nkansah *et al*. (2011) and Nsabiyera *et al*. (2012) who reported that the average plant height of pepper at maturity ranges from 32.1 - 68.3cm. Furthermore, Legon-18 recorded the biggest stem girth (8.5mm) at eight weeks after transplanting

(WAT). Nkansah *et al*. (2011) also reported similar findings by indicating that taller heights were positively correlated with thicker stem girths in pepper cultivars. Rudall (1994) also stated that increase in stem width often accompanied increase in height and caused a reduction in lodging.

Plant heights also differed between planting dates with the May planting (first planting date) recording the tallest plants. This agrees with the results of Islam *et al*. (2010), who stated that growth parameters of sweet pepper were significantly increased at earlier sowing dates. The observed differences in height at the different planting times could also be attributed to the effects of varying environmental conditions at the different planting periods. Similar findings were reported by Vos and Frinking (1997) who indicated that the growth of a crop variety is influenced by environment. Jovicich *et al*. (2004) also observed that the growth of sweet pepper was affected by rainfall, temperature, daylight and relative humidity. The intercative effects of the variety and planting date on plant height and stem diameter demonstrated that the growth of pepper largely depended on the genetic make-up and the environmental conditions under which it is grown (Rajasekar *et al*., 2013). Branches were more profuse in Legon-18 compared to Shito Adope and this could be related to the genetic make-up of the varieties. Delelegn (2011) indicated that variety was one of the major factors determining the number of primary branches in hot peppers. El-Tohamy *et al*. (2006) also reported that the differences observed in branching of pepper plants may be due to genetic variations or environmental influence which could explain the differences in branching observed for the different planting dates.

The widest plant canopies were produced by Legon-18 at the different growth stages. Canopy variation is essential as it influences the yielding potential of a crop; as varieties with wider canopy spreads tend to produce heavier fruits than those with narrower canopies due to increased photosynthesis and consequently increased assimilates production (Delelegn, 2011). Orak and IIker (2004) also indicated that a large canopy width provides leaf area surfaces which enhance the interception of solar radiation, with subsequent increase in the amount of photosynthetic activities. The observed differences in canopy width among the chilli varieties may be due to differences in genetic make-up. This is in agreement with Decoteau and Graham (1994) and Nsabiyera *et al*. (2012), who reported that the width of canopies among pepper varieties are oftentimes associated with genetic variations among varieties.

5.2 Reproductive and yield performance of the two chilli varieties

Significant differences were observed between varieties for days to 50% flowering and days to 50% fruit set. The observed variations in days to 50% flowering and 50% fruit set could be attributed to both genetic make-up of the cultivars and the environmental conditions. Shito Adope took fewer days to attained 50% flowering and 50% fruit set than Legon-18. Delelegn *et al*. (2014) reported that earliness or lateness in the days to 50% flowering could be due to their inherited characters and the early adaptation to the growing environment to enhance their growth and development. Dewitt and Bosland (2009) also observed that earliness to flowering and fruiting is related to variety differences. Days to 50% flowering and 50% fruit set also varied between the different planting dates. The earliest flowering and fruit set were observed in the May plantings and could be due to the prevailing temperatures in June (28.3^{o}C - day temperatures) which that favoured the flower initiation and development of the crop. Uarrota (2010) indicated that flower formation and fruit set in plants are dependent on the interaction of many complex processes which are influenced by the genetic and environmental factors.

In contrast, the longer days to 50% flowering and fruit set observed during the late sowing date might have been influenced by higher temperatures experienced in November and December (31.6ºC and 32.8ºC- day temperatures). According to AVRDC (2005), fruit set is delayed when daily temperatures exceeds 32°C for extended periods. Konsens *et al*. (1991) and Khah and Passam (1992) also reported a reduction or delay in fruit set during periods of high temperatures.

There were observed variations between varieties and planting dates for number of flower aborted. Of the two varieties, Shito Adope recorded a higher number of flowers aborted as compared to Legon-18. These findings revealed that flower abortion is influenced by a crop‟s genetic make-up and physiological processes within a plant. These results agree with the findings of Tarchoun *et al*. (2012), who stated that abortion of floral structures depends on variety. The dates of planting also affected the number of flowers aborted and could be related to the high temperatures observed in relartion to certain planting times. Similar results were reported by Erickson and Markhart (2002), who indicated that moisture and temperature stress induced high flower abortion in peppers. Van Doorn and Stead (1997) also observed that flower retention and fruit set are highly sensitive to environmental factors, particularly temperatures.

There were significant interactive effects of varieties and planting dates for mean number of fruit, fruit weight per plant, and total fruit yield per hectare**.** The observed differences in fruit number between varieties could be explained by the genetic diversity of the two varieties. Delelegn *et al*. (2014) observed that variations in fruit number per plant is affected by the canopy architecture; because, as the number of branches increased, there might be a possibility of increasing the number of fruit producing buds which are the positions for fruit production. The variations in fruit weight and total fruit yield between the two cultivars points to the fact that fruits with larger sizes tend to possess more weight than those with smaller sizes. According to Mariame and Gelmesa (2006), variations in fruit yield in pepper could be attributed to differences in genetic variability and their agro ecological adaptations. This is in agreement with the observed low performance of the two varieties during the September planting, a period that was characterized by extremely high temperatures and low soil moisture. Nkansah *et al*. (2011) reported similar results, indicating that the observed differences in fruit number and weight during different growing seasons can be attributed to differences in the amount of rainfall. The findings of Square (1990) and Tiryaki and Andrews (2001), also corroborate the present findings that observed climatic variables, especially temperatures and rainfalls are important in determining crop productivity and that extremely high or low temperatures can negatively affect plants growth and yield.

5.3 Performance of the seed quality characteristics of the two chilli varieties Seed numbers per fruit and seed weight per fruit differed significantly between varieties, planting dates, and their interaction. The observed variation due to varietal effects of these two parameters could be attributed to differences in the genetic composition of the cultivars. The present study identified Legon-18 as the highest performer in terms of fruit mass, seed weight and seed number and the results suggest that these traits are positively associated and are influenced by genotype. This is in agreement with Alan and Eser (2007), who pointed out that pepper fruit size and fruit set positively correlated with seed number. The size and weight of seeds are very important parameters in that they determine food reserved within the seed coat and influence the rate of germination and vigour. Nkansah *et al*. (2011) also reported that *Capsicum* species with heavier seed weight tend to have more food reserves which could prolong seed viability.

The observed differences among sowing dates for seed number per fruit and seed weight per fruit may be due to the fact that each of the growing seasons was characterized by fluctuating environmental conditions including rainfall, temperature, relative humidity and soil moisture. Among the different dates of sowing, the September planting recorded both the highest seed number and highest seed weight per fruit. The same period was characterized by moderate rainfall, lower humidity, suitable temperature; all of which tend to seed formation and development favour. According to Rashid and Singh (2000), periods of moderate rainfall and humidity are much more suitable for quality seed production as most vegetable crops require a sunny period and moderate temperature for good seed formation and development. The interaction effects points to the genotypes‟ adaptation and response to changing environmental conditions, as exhibited by the superior performance of Legon-18 over Shito Adope during the three growing seasons.

In terms of seed quality, the vigour of a seeds is an important factor as it influences stand establishment and the yield potential of a crop. There were no differences between planting dates, and variety and planting date interaction for seed vigour. This implies that planting dates or environmental influences did not affect the vigour of the seed. The vigour values however indicate that the seeds were of meduim vigour and as such cannot survive under unfavourable environmental conditions are ((Milosevic *et al*., 2010).

Significant variations were however observed among the sowing dates for seed germination. The observed variations between the different dates of sowing for germination rate could be due to environmental stress. Doijode (2001) indicated that seed germination rapidly decreases if seeds are exposed to adverse environmental conditions.

Delelegn *et al*. (2014) also reported similar results in a study involving ten hot pepper varieties.

Seed health is an important factor in the control of plant diseases since infected seeds are less viable, has low germination, reduced vigour and reduced yield (van Gastel *et al.*, 1996). Pest and disease infestation not only lead to reduction in yield, but also affect the quality of seeds. Most of these diseases can be transmitted in or on pepper seeds. A total of six fungal pathogen species were identified during the present study.

Collectotrichum graminicola recorded the highest pathogen incidence; while *Aspergillus tamarii* was the least. The fungi identified on seed samples are a reflection of the possible diseases that could affect the seeds and seedlings emerging from such infected seeds. According to Al-kassam and Monawar (2000), fungal pathogens (mainly *Aspergillus*, *Rhizopus* and *Collectotricum*) are pathogenic to chilli seeds and cause diseases such as seed rot, damping off, root rot, fruit rot, wilt and foliar diseases in pepper.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

Two chilli varieties were used in the study to evaluate the effects of planting dates and densities on flower abscission, fruit yield and seed quality. The following conclusions could be drawn from the series of experiments undertaken in this study.

Legon-18 exhibited higher performance than Shito Adope in terms of vegetative growth and yield parameters including plant height, number of main branches, canopy width, stem girth, fruit weight per plant, fruit yield per hectare, number of seeds per fruit and seed weight per fruit. Shito Adope, on the other hand, took fewer days than Legon-18 to attain 50% flowering and fruit set, an indication of early maturity.

Shito Adope also recorded high numbers of flowers aborted as well as high number of fruits per plant. May and June plantings resulted in higher vegetative and reproductive performance than September planting.

Higher seed germination percentages were obtained from seed arising from May and June plantings. September planting resulted in high seed yield parameters such as number of seeds per fruit, seed weight per fruit and 1000 seed weight. The highest occurrence of fungal pathogens was observed on seeds obtained from May planting while the least occurrence was recorded on seeds from September planting.

6.2 Recommendations for research o Based on the environmental influences, the study should be repeated in other months to gather additional information on the performance of the two chilli

varieties; o Other varieties of chilli pepper of economic importance should be studied for seed quality performance.

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APPENDICES

Appendix 1: Factorial Analysis of Variance for Plant Height at 3WAT

Source	DF	SS	MS	F	P
Rep	2	11.5687	5.7843		
Variety	1	5.4785	5.4785	6.37	0.0164
Spacing	2	1.6138	0.8069	0.94	0.4010
Planting	2	10.7294	5.3647	6.24	0.0049
Variety*Spacing	2	2.7577	1.3789	1.60	0.2159
Variety*Planting	2	23.2367	11.6184	13.52	0.0000
Spacing*Planting	4	3.7579	0.9395	1.09	0.3756
Variety*Spacing*Planting	4	5.0231	1.2558	1.46	0.2356
Error	34	29.2207	0.8594		
Total	**53**	**93.3865**			

Grand Mean 12.959 CV 7.15

Appendix 2: Factorial Analysis of Variance for Plant Height at 6WAT

Source	DF	SS	MS	F	P
Rep	2	3.180	1.590		
Variety	1	373.460	373.460	36.03	0.0000
Spacing	2	0.160	0.080	0.01	0.9923
Planting	2	48.968	24.484	2.36	0.1095
Variety*Spacing	2	1.601	0.800	0.08	0.9259
Variety*Planting	2	139.869	69.934	6.75	0.0034
Spacing*Planting	4	33.439	8.360	0.81	0.5297
Variety*Spacing*Planting	4	4.879	1.220	0.12	0.9753
Error	34	352.462	10.367		
Total	**53**	**958.017**			

Grand Mean 28.086 CV 11.46

	P
	0.0000

Appendix 3: Factorial Analysis of Variance for Plant Height at 9WAT

Source	DF	SS	MS	F	
Rep	2	197.92	98.96		
Variety	1	1100.44	1100.44	57.95	
Spacing	2	155.00	77.50	4.08	0.0258
Planting	2	454.70	227.35	11.97	0.0001
Variety*Spacing	2	5.16	2.58	0.14	0.8734
Variety*Planting	2	124.39	62.20	3.28	0.0500
Spacing*Planting	4	146.64	36.66	1.93	0.1278
Variety*Spacing*Planting	4	58.53	14.63	0.77	0.5520
Error	34	645.67	18.99		
Total	**53**	**2888.45**			

Grand Mean 49.432 CV 8.82

Appendix 4: Factorial Analysis of Variance for Plant Height at First Fork

Source	DF	SS	MS	F	P
Rep	2	2.118	1.059		
Variety	1	535.941	535.941	592.70	0.0000
Spacing	2	1.795	0.898	0.99	0.3811
Planting	2	90.490	45.245	50.04	0.0000
Variety*Spacing	2	0.570	0.285	0.32	0.7318
Variety*Planting	2	28.406	14.203	15.71	0.0000
Spacing*Planting	4	17.888	4.472	4.95	0.0030
Variety*Spacing*Planting	4	1.091	0.273	0.30	0.8749
Error	34	30.744	0.904		
Total	**53**	**709.042**			

	P
	0.0000

Grand Mean 15.936 CV 5.97

Appendix 5: Factorial Analysis of Variance for Branches at 4WAT

Source	**DF**	**SS**	**MS**	**F**	
Rep	2	2.556	1.2779		
Variety	1	67.514	67.5138	86.12	
Spacing	2	0.700	0.3500	0.45	0.6436
Planting	2	43.990	21.9951	28.06	0.0000
Variety*Spacing	2	2.422	1.2109	1.54	0.2280
Variety*Planting	2	11.793	5.8965	7.52	0.0020
Spacing*Planting	4	1.188	0.2970	0.38	0.8221
Variety*Spacing*Planting	4	1.188	0.2969	0.38	0.8222
Error	34	26.655	0.7840		
Total	**53**	**158.006**			

Grand Mean 6.5530 CV 13.51

Appendix 6: Factorial Analysis of Variance for Branches at 8WAT

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	1.544	0.772		
Variety	1	192.176	192.176	392.35	0.0000
Spacing	2	0.284	0.142	0.29	0.7502
Planting	2	33.542	16.771	34.24	0.0000
Variety*Spacing	2	0.333	0.167	0.34	0.7140

Source	DF	SS	MS	F	P
					0.0000
Variety*Planting	2	16.495	8.248	16.84	0.0000
Spacing*Planting	4	0.685	0.171	0.35	0.8426
Variety*Spacing*Planting	4	0.251	0.063	0.13	0.9712
Error	34	16.653	0.490		
Total	**53**	**261.963**			

Grand Mean 7.7831 CV 8.99

Appendix 7: Factorial Analysis of Variance for Canopy Spread at 4WAT

Source	**DF**	**SS**	**MS**	**F**	
Rep	2	14.20	7.102		
Variety	1	350.63	350.625	26.99	
Spacing	2	41.26	20.632	1.59	0.2191
Planting	2	933.27	466.637	35.92	0.0000
Variety*Spacing	2	13.82	6.912	0.53	0.5922
Variety*Planting	2	373.62	186.809	14.38	0.0000
Spacing*Planting	4	99.68	24.921	1.92	0.1299
Variety*Spacing*Planting	4	3.91	0.978	0.08	0.9893
Error	34	441.66	12.990		
Total	**53**	**2272.07**			

Grand Mean 32.107 CV 11.23

Appendix 8: Factorial Analysis of Variance for Canopy Spread at 8WAT

Source	**DF**	**SS**	**MS**	**F**	**P**

					P
					0.0000
Rep	2	23.34	11.672		
Variety	1	150.00	150.000	5.07	0.0309
Spacing	2	0.71	0.353	0.01	0.9881
Planting	2	1053.45	526.726	17.81	0.0000
Variety*Spacing	2	11.32	5.659	0.19	0.8267
Variety*Planting	2	81.52	40.762	1.38	0.2657
Spacing*Planting	4	56.37	14.092	0.48	0.7527
Variety*Spacing*Planting	4	67.41	16.852	0.57	0.6863
Error	34	1005.51	29.574		
Total	53	2449.63			

Grand Mean 40.971 CV 13.27

Appendix 9: Factorial Analysis of Variance for Stem Girth at 4WAT

Source	DF	SS	MS	F	P
Rep	2	1.6711	0.8356		
Variety	1	0.1700	0.1700	0.31	0.5841
Spacing	2	0.0282	0.0141	0.03	0.9750
Planting	2	11.9177	5.9589	10.71	0.0002
Variety*Spacing	2	0.7730	0.3865	0.69	0.5063
Variety*Planting	2	54.3511	27.1756	48.82	0.0000
Spacing*Planting	4	0.6787	0.1697	0.30	0.8727
Variety*Spacing*Planting	4	1.2634	0.3158	0.57	0.6879
Error	34	18.9242	0.5566		
Total	**53**	**89.7776**			

Grand Mean 5.7269 CV 13.03

Appendix 10: Factorial Analysis of Variance for Stem Girth at 8WAT

Source	DF	SS	MS	F	P
Rep	2	0.598	0.2992		
Variety	1	39.732	39.7323	39.04	0.0000
Spacing	2	0.346	0.1728	0.17	0.8445
Planting	2	0.706	0.3532	0.35	0.7093
Variety*Spacing	2	0.462	0.2311	0.23	0.7981
Variety*Planting	2	22.925	11.4623	11.26	0.0002
Spacing*Planting	4	0.686	0.1715	0.17	0.9529
Variety*Spacing*Planting	4	1.663	0.4157	0.41	0.8013
Error	34	34.604	1.0178		
Total	**53**	**101.722**			

Grand Mean 7.6081 CV 13.26

Appendix 11: Factorial Analysis of Variance for Days to 50% flowering

Source	DF	SS	MS	F	P
Rep	2	53.59	26.80		
Variety	1	1451.85	1451.85	167.67	0.0000
Spacing	2	0.48	0.24	0.03	0.9726
Planting	2	227.37	113.69	13.13	0.0001
Variety*Spacing	2	12.04	6.02	0.70	0.5060
Variety*Planting	2	23.15	11.57	1.34	0.2762
Spacing*Planting	4	36.19	9.05	1.04	0.3987
Variety*Spacing*Planting	4	15.30	3.82	0.44	0.7776
Error	34	294.41	8.66		
Total	**53**	**2114.37**			

Grand Mean 35.259 CV 8.35

Appendix 12: Factorial Analysis of Variance for Days to 50% Fruit Set

Source	DF	SS	MS	F	P
Rep	2	26.70	13.35		
Variety	1	3520.30	3520.30	377.22	0.0000
Spacing	2	3.59	1.80	0.19	0.8258
Planting	2	114.37	57.19	6.13	0.0053
Variety*Spacing	2	8.04	4.02	0.43	0.6536
Variety*Planting	2	49.93	24.96	2.67	0.0834
Spacing*Planting	4	62.30	15.57	1.67	0.1799
Variety*Spacing*Planting	4	13.41	3.35	0.36	0.8358
Error	34	317.30	9.33		

Total	**53**	**4115.93**			
Grand Mean 42.037	CV	7.27			

Appendix 13: Factorial Analysis of Variance for Mean Flower Drop

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	87.957	43.979		
Variety	1	34.560	34.560	4.26	0.0466
Spacing	2	21.380	10.690	1.32	0.2807
Planting	2	266.413	133.206	16.44	0.0000
Variety*Spacing	2	11.206	5.603	0.69	0.5078
Variety*Planting	2	25.159	12.579	1.55	0.2264
Spacing*Planting	4	50.545	12.636	1.56	0.2075
Variety*Spacing*Planting	4	20.803	5.201	0.64	0.6364
Error	34	275.516	8.103		
Total	**53**	**793.539**			
Grand Mean 13.803 CV	20.62				

Appendix 14: Factorial Analysis of Variance for Mean Fruit Number

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	5.03	2.516		
Variety	1	469.23	469.227	10.67	0.0025
Spacing	2	75.28	37.640	0.86	0.4340
Planting	2	800.05	400.024	9.09	0.0007
Variety*Spacing	2	33.72	16.860	0.38	0.6846
Variety*Planting	2	598.77	299.384	6.81	0.0033
Spacing*Planting	4	58.83	14.707	0.33	0.8529
Variety*Spacing*Planting	4	134.33	33.582	0.76	0.5565
Error	34	1495.81	43.994		

Total	**53**	**3671.04**			

Grand Mean 28.073 CV 23.63

Appendix 15: Factorial Analysis of Variance for Fruit Weight per Plant

Source	DF	SS	MS	F	P
Rep	2	169.9	84.94		
Variety	1	1058.5	1058.50	5.64	0.0234
Spacing	2	478.4	239.22	1.27	0.2927
Planting	2	9672.5	4836.24	25.76	0.0000
Variety*Spacing	2	283.7	141.83	0.76	0.4775
Variety*Planting	2	5760.3	2880.14	15.34	0.0000
Spacing*Planting	4	438.5	109.64	0.58	0.6764
Variety*Spacing*Planting	4	422.6	105.65	0.56	0.6913
Error	34	6383.2	187.74		
Total	**53**	**24667.6**			

Grand Mean 64.569 CV 21.22

Appendix 16: Factorial Analysis of Variance for Fruit Yield/ ha

Source	DF	SS	MS	F	P
Rep	2	0.3800	0.1900		
Variety	1	2.6979	2.6979	5.91	0.0205
Spacing	2	1.4211	0.7106	1.56	0.2258
PDate	2	21.6336	10.8168	23.68	0.0000
Variety*Spacing	2	1.0725	0.5362	1.17	0.3214
Variety*PDate	2	13.5367	6.7684	14.81	0.0000
Spacing*PDate	4	2.3367	0.5842	1.28	0.2976
Variety*Spacing*PDate	4	1.1769	0.2942	0.64	0.6349
Error	34	15.5334	0.4569		
Total	**53**	**59.7889**			

Grand Mean 3.1028 CV 21.78

Appendix 17: Factorial Analysis of Variance for Number of Seeds per Fruit

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	34.92	17.46		
Variety	1	2358.84	2358.84	57.65	0.0000
Spacing	2	173.33	86.66	2.12	0.1359
Planting	2	637.52	318.76	7.79	0.0016
Variety*Spacing	2	172.43	86.22	2.11	0.1372
Variety*Planting	2	495.16	247.58	6.05	0.0057
Spacing*Planting	4	387.20	96.80	2.37	0.0723
Variety*Spacing*Planting	4	162.48	40.62	0.99	0.4248
Error	34	1391.24	40.92		
Total	**53**	**5813.13**			

Grand Mean 66.809 CV 9.57

Appendix 18: Factorial Analysis of Variance for Mean Seed Weight per Fruit

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	0.00746	0.00373		
Variety	1	0.07223	0.07223	18.99	0.0001
Spacing	2	0.00281	0.00141	0.37	0.6939
Planting	2	0.04599	0.02299	6.04	0.0057
Variety*Spacing	2	0.01156	0.00578	1.52	0.2333
Variety*Planting	2	0.05117	0.02558	6.72	0.0035
Spacing*Planting	4	0.01084	0.00271	0.71	0.5891
Variety*Spacing*Planting	4	0.04391	0.01098	2.89	0.0369
Error	34	0.12936	0.00380		
Total	53	0.37534			

Grand Mean 0.3348 CV 18.43

Appendix 19: Factorial Analysis of Variance for 1000 Seed Weight

Source	DF	SS	MS	F	P
Rep	2	0.2478	0.12389		
Variety	1	3.9474	3.94741	19.36	0.0001
Spacing	2	0.4311	0.21556	1.06	0.3586
Planting	2	5.3344	2.66722	13.08	0.0001
Variety*Spacing	2	0.0370	0.01852	0.09	0.9134
Variety*Planting	2	0.0915	0.04574	0.22	0.8002
Spacing*Planting	4	0.1944	0.04861	0.24	0.9146
Variety*Spacing*Planting	4	0.1641	0.04102	0.20	0.9360
Error	34	6.9322	0.20389		
Total	53	17.3800			

Grand Mean 4.7667 CV 9.47

Appendix 20: Factorial Analysis of Variance for Seedling Vigour

Source	DF	SS	MS	F	P
Rep	2	139.11	69.556		
Variety	1	0.02	0.019	0.00	0.9888
Spacing	2	338.19	169.097	1.83	0.1757
Planting	2	1509.08	754.542	8.17	0.0013
Variety*Spacing	2	49.06	24.532	0.27	0.7683
Variety*Planting	2	1106.79	553.394	5.99	0.0059
Spacing*Planting	4	147.64	36.910	0.40	0.8075
Variety*Spacing*Planting	4	362.55	90.637	0.98	0.4306
Error	34	3139.89	92.350		
Total	**53**	**6792.33**			

Grand Mean 80.056 CV 12.00

Appendix 21: Factorial Analysis of Variance for Germination Rate

Source	DF	SS	MS	F	P
Rep	2	65.36	32.681		
Variety	1	28.89	28.894	0.48	0.4939
Spacing	2	96.58	48.292	0.80	0.4579
Planting	2	497.19	248.597	4.12	0.0251
Variety*Spacing	2	78.45	39.227	0.65	0.5288
Variety*Planting	2	98.23	49.116	0.81	0.4519
Spacing*Planting	4	160.22	40.056	0.66	0.6220
Variety*Spacing*Planting	4	279.46	69.866	1.16	0.3471
Error	34	2053.97	60.411		
Total	**53**	**3358.38**			

Grand Mean 86.917 CV 8.94

Appendix 22: Factorial Analysis of Variance for Disease Severity (yellowing)

Source	DF	SS	MS	F	P
Rep	2	2.4649	1.23245		
Variety	1	0.0719	0.07187	0.31	0.5826
Spacing	2	0.1064	0.05321	0.23	0.7973
Planting	2	8.0855	4.04277	17.33	0.0000
Variety*Spacing	2	0.3094	0.15472	0.66	0.5218
Variety*Planting	2	4.5384	2.26920	9.72	0.0005
Spacing*Planting	4	0.4191	0.10478	0.45	0.7723
Variety*Spacing*Planting	4	0.3014	0.07534	0.32	0.8607
Error	34	7.9338	0.23335		
Total	**53**	**24.2309**			

Grand Mean 2.6439 CV 18.27

Appendix 23: Factorial Analysis of Variance for Disease Severity (Leaf curl)

Source	DF	SS	MS	F	P
Rep	2	0.00714	0.00357		
Variety	1	0.01909	0.01909	8.48	0.0063
Spacing	2	0.00272	0.00136	0.60	0.5522
Planting	2	2.43338	1.21669	540.66	0.0000
Variety*Spacing	2	0.00511	0.00256	1.14	0.3330
Variety*Planting	2	0.04983	0.02491	11.07	0.0002
Spacing*Planting	4	0.00791	0.00198	0.88	0.4867
Variety*Spacing*Planting	4	0.00746	0.00186	0.83	0.5163
Error	34	0.07651	0.00225		
Total	**53**	**2.60916**			

Grand Mean 1.2984 CV 3.65

Appendix 24: Variety, planting date and spacing effect on occurrence of fungal pathogens on two chilli varieties.

			Pathogens					
Variety	**Planting Date**	**Spacing Distance (cm)**	**Aspergillus flavus**	**Aspergillus tamarii**	**Aspergillus niger**	**Collectotrichum graminicola**	**Curvularia lunata**	**Rhizopus**
Legon-18	PD-1	60 x 30	56	256	0	162	54	26
Legon-18	PD-1	70 x 30	42	44	18	108	44 6	0
Legon-18	PD-1	80 x 30	32	0	0	10	44	0
Legon-18	PD-2	60 x 30	16	158	8	122	12 0	38
Legon-18	PD-2	70 x 30	20	48	11	112	26	0
Legon-18	PD-2	80 x 30	8	46	0	56	36	0
Legon-18	PD-3	60 x 30	0	136	0	112	0	0
Legon-18	PD-3	70 x 30	14	114	0	64		0
Legon-18	PD-3	80 x 30	12	56	0	4	70	0
							42	
Shito Adope	PD-1	60 x 30	68	124	0	282	26	106
Shito Adope	PD-1	70 x 30	58	104 84	0	178	50	42 0
Shito Adope	PD-1	80 x 30	58	134	0	142	28	28
Shito Adope	PD-2	60 x 30	44 4	24	0	140	16	0
Shito Adope	PD-2	70 x 30	22	30	0	96	14	0
Shito Adope	PD-2	80 x 30	0	118	0	67	18	38
Shito Adope	PD-3	60 x 30	8	94	0	103	50	0
Shito Adope	PD-3	70 x 30	38	68	10	39		0
Shito Adope	PD-3	80 x 30			0	36		

Appendix 25: Results from soil analyses of soil samples from the experimental sites at Kwadaso

Locations	PH 1:1 H20	% Org. C	% Total N	Org. M %	Exchangeable Cations (cmol/kg) Ca	Mg	K	Na	T.E.B	Exc. Acidity (Al,$^{+}$ H^{+})	E.C.E.C Me/100g	Base Sat. %	Available-Bray's ppm P	ppm K
Site 1*	6.21	0.89	0.13	1.54	2.87	0.6	0.12	0.17	3.65	0.18	3.75	97.32	78.37	31.58
Site 2*	5.82	1.01	0.13	1.73	1.74	0.7	0.22	0.12	2.75	0.30	3.52	89.63	81.09	48.17

***Site 1** = Plot cultivated with Shito Adope**; Site 2 =** Plot cultivated with Legon-18

Courtesy: Soil Science Laboratory, Soil Research Institute (SRI), Kwadaso