KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF AGRICULTURE

DEPARTMENT OF HORTICULTURE

EVALUATION AND SELECTION OF ELEVEN LINES OF HOT PEPPER (*Capsicum frutescens* L.) AT DIFFERENT SPACING FOR SEED YIELD AND QUALITY

BY:

EDWARD BOATENG

APRIL, 2013

EVALUATION AND SELECTION OF ELEVEN LINES OF HOT PEPPER (*Capsicum frutescens* L.) AT DIFFERENT SPACING FOR SEED YIELD AND QUALITY

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

BY:

EDWARD BOATENG

APRIL, 2013

DECLARATION

I hereby declare that this work being submitted is my own original research work and that it has neither in part nor in whole been used for any degree elsewhere. All other works cited are duly acknowledged.

……………………………………. ………………………………

EDWARD BOATENG DATE

(STUDENT)

Certified by:

……………………………………. ………………………………

PROF. (MRS.) N. S. OLYMPIO DATE

(SUPERVISOR)

……………………………….. ……………………………

DR. BEN K.B. BANFUL DATE

(HEAD OF DEPARTMENT)

DEDICATION

To my lovely wife, Regina Boateng,

my daughter, Nana Afia Achiaa Boateng,

my mother, Gifty Owusu and

my pastor, Rev. Isaac Kwabena Agyemang

for their inspiration and guidance.

ACKNOWLEDGEMENTS

I thank the Lord God Almighty for taking me through this programme successfully.

I would like to express my profound gratitude to Prof. (Mrs.) N.S. Olympio, my project supervisor in the Department of Horticulture, Faculty of Agriculture, College of Agriculture and Natural Resources, KNUST, Kumasi, for her diligent guidance, positive criticisms, corrections and effective suggestions at all stages of this project. Mummy, I am extremely grateful to you.

I wish to express my greatest appreciation to Mr. Seth Ekyem Obosu and Mr. K. O. Bonsu both at the Horticulture Section, Crops Research Institute, Kwadaso, Kumasi for their assistance.

I would like to thank the staff at the Seed Pathology section, Crops Research Institute, Fumesua, Kumasi who helped me in the seed health test.

I wish to acknowledge the contribution of Dr. Robert Asuboah of Grains and Legumes Development Board, Kumasi and Mr. M. M. Dawuda, Department of Crop and Soil Science Education, University of Education, Winneba, Mampong-Ashanti for their immense contribution.

I am very grateful to Mr. E. A. Odame, a colleague at the Department of Horticulture, KNUST, for assisting me with the data analysis.

ABSTRACT

An experiment to evaluate and select new lines of hot pepper (*Capsicum frutescens L.)* for seed yield and quality was conducted at the Research fields of the Department of Horticulture, KNUST and the Crops Research Institute, Kwadaso, between May 2007 and November 2008. Eleven lines were multiplied and five best performed lines (ICPN16#3, ICPN16#4, ICPN16#6, ICPN16#7 and ICPN16#9) were selected and further evaluated, using spacing levels of 70cm x 30cm, 70cm x 40cm and 70cm x 50cm. The 5 x 3 factorial experiment was arranged in a randomized complete block design (RCBD). The results showed that, line ICPN16#4 which was a tall variety, produced narrow canopy, more branches, higher fruit yield and was among the lines with high germination percentage and seed vigour. Line ICPN16#9 was a short variety, produced more branches with medium canopy spread and early maturing. The same line gave the highest seed yield but was among those with lower germination percentage and seed vigour. Line ICPN16#3 had the highest percentage plant survival in the field. The widest spacing 70cm x 50cm produced the highest number of branches, wider canopy spread and shorter plants. The medium spacing 70cm x 40cm produced heaviest fruits and 70cm x 30cm produced longest fruits. Fruit and seed yields were highest in 70cm x 30cm spacing followed by 70cm x 40cm and 70cm x 50cm respectively. The interaction of variety and spacing was significant for most of the parameters studied. Line ICPN16#9 planted at 70cm x 40cm spacing was the first to attain 50% flowering in 25 days after transplanting whilst Line ICPN16#9 planted at 70cm x 50cm spacing interaction took 30 days to reach 50% flowering. Percentage plant survival was highest in ICPN16#9 and ICPN16#3 combinations with 70cm x 50cm. Line ICPN16#7 at 70cm x 50cm and 70cm x 40cm spacing produced heaviest fruits but longest fruits were

produced from ICPN16#7 at a spacing of 70cm x 30cm. The line ICPN16#7 at 70cm x 50cm spacing produced the highest number of seeds per fruit. While ICPN16#4 at 70cm x 30cm produced the highest fruit yield per hectare, line ICPN16#9 at 70cm x 30cm produced the highest seed yield per hectare. The highest germination percentage and seed vigour occurred when ICPN16#6 was planted at 70cm x 40cm. The results on seed health revealed the presence of fungal pathogens including *Penicillium, Fusarium solani, Aspergillus flavus, Aspergillus niger, Collectotricum dematium, Rhizopus* and *Fusarium moniliforme* on the seeds of all the lines regardless of the spacing used.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

Seed is an important agriculture input on which the efficacies of other agriculture inputs depend. It is important that seed has the appropriate characteristics that enables it meet the demand of diverse agro-climatic conditions and intensive cropping systems during crop growth. At the same time, sustainable agriculture production and productivity is dependent, to a large extent, on development of new improved crop varieties and an efficient system for timely supply of quality seeds to farmers (Wignell, 1988; Williams *et al*., 1991).

Schippers (2000) mentioned hot pepper to be among the four widely cultivated vegetables in Ghana. Botanically, the crop is known as *Capsicum frutescens* (L.) and it belongs to the family *Solanaceae* (Tindall, 1983). Some other common names are birdseye, red pepper and tabasco pepper (Rice *et al*., 1986).

Hot pepper is widely grown primarily for its fruits and seeds. The seeds contain capsaicin (Messiaen, 1992), which is the main active ingredient and has medicinal uses. Internally, the capsaicin works as a powerful stimulant and carminative and externally as a water-irritant (Onazi *et al*., 1988). The growing plant can repel some insects (Gibbon and Pain, 1985). The mature and immature fruits can be cooked or eaten raw (Boateng, 2006) as vegetable in soups and stews (Tindall, 1983). The dried and powdered hot pepper is used as a spice for seasoning and flavouring (George, 1985; Gibbon and Pain, 1985).

Norman (1992) reporting on the nutritional value of hot pepper stated that mature ripe fruits contains 84% moisture. The author also reported that the approximate value per 100g of fresh edible portion were, energy 46 cal, protein 2.0g, fat 3.0g, total sugar 55g, other carbohydrates 0.3g, vitamin A 1,000 I.U, thiamine 0.10mg, riboflavin 0.10g, niacin, 1.0mg, vitamin C 240mg, calcium 18mg, iron 1.0mg, phosphorus 45mg, potassium 240mg and sodium 9mg (Norman, 1992).

Hot pepper is reported to have originated from Central America, more specifically, Mexico (De Lannoy, 2001). The crop spread into the new world tropics before being introduced into Asia and Africa. Hot pepper is now widely grown throughout the tropics, sub-tropics and the warmer temperature regions of the world (George, 1985).

The pepper plant is a branching perennial herb, which can grow up to 1.5m in height (Tindall, 1983). The stem is woody at the base, and the leaves which are unequal in shape and may be oval or oblong, exhibiting acute apex, 1.5-10cm in length and 0.5-2.5cm wide. The plant bears small flowers, singly or in groups of 2-3, with long pedicels, erect and 1.5-2.5cm in length. The calyx of the 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 instead of a single fruit, which is typical of the sweet pepper plant (Rice *et al.*, 1986). The fruits of some cultivars are small and narrow, up to 2-3cm in length and 7-10mm in diameter. They may be red or yellow when ripe and are extremely pungent (Gibbon and Pain., 1985; Rice *et al.*, 1986).

Grubben and Tahir (2004) have indicated that hot pepper seeds germinate in 6 - 21 days after sowing. Field establishment depends on both the vigour of the cultivar and the irrigation system used (George, 1985). The crop does best on well-drained soil, and the seeds require soil temperature of 18-32^{o}C for good germination (Sinnadurai, 1992). Excessive rainfall and high humidity reduces productivity by affecting flowering and encouraging development of leaf diseases (Rice *et al*., 1986). The crop thrives in hot weather and does not withstand frost. Soils rich in organic matter tend to promote excessive vegetative growth thereby giving poor yields (Sinnadurai, 1992).

Harvesting periods of hot pepper varies from cultivar to cultivar, flowering starts 60-90 days after sowing. Under normal conditions, 40-50% of the flowers set fruits. Fruits begin to mature 4-5 weeks after flowering and can be picked every 5-7 days. The peak harvest period is usually from 4-7 months after sowing (Grubben and Tahir, 2004).

The production of quality seeds depend largely on the use of proper production techniques to achieve high yield, and special methods and precautions are needed to produce seed of high quality, high varietal purity which are free of pests and diseases (van Gastel *et al*., 1996). Despite the high nutritional and economic values of hot pepper, the average yield is still low in West Africa (Grubben and Tahir, 2004) mainly due to lack of genetic information and limited improvement work (Fekadu *et al*., 2008).

Improper use of general agronomic practices, the use of poor quality seed, mostly from farmers own fields and the use of unimproved and low yielding varieties are some of the problems that have necessitated the multiplication of seeds of improved varieties for high yield and quality for sustainable production (AVRDC,1990).

The general agronomic practices in agriculture play major role in producing quality seed for farmers use. According to Williams *et al*. (1991), spacing, which is one of the general agronomic practices in agriculture, has a direct effect on the quality of fruit, varietal purity and the quality of the seeds produced. This is because the type of spacing chosen at a particular planting time can influence the development of diseases and subsequently the yield and quality of seed.

The detail assessment of the lines, therefore, will enable breeders to select high yielding and disease resistant lines which can be multiplied for use by farmers. In addition, the determination of optimum spacing for the selected lines will enable farmers increase their yield.

The project, therefore, sought to evaluate eleven lines of hot pepper (*Capsicum frutescens* L.) for growth, fruit and seed yield, seed quality and to determine the optimum spacing for high seed yield and quality.

CHAPTER TWO

LITERATURE REVIEW

2.1 EFFECTS OF ENVIRONMENTAL FACTORS ON VEGETABLE SEED YIELD

Each crop has its own set of environmental conditions under which it grows most efficiently. Generally, crops are not profitable unless they are adapted to the region in which they are produced. For successful seed production, high seed yield and quality, the plant, before entering the reproductive phase, should have completed sufficient vegetative growth and development to bear as many seeds as possible (van Gastel *et al*., 1996).

According to Karikari and Mathew (1990), the distribution of crops is largely determined by environmental factors such as temperature, relative humidity, light intensity, soil, diseases and pests. Temperature and rainfall are the two main factors that account for the seasonal patterns of different areas. They are natural components which control growth of plants in any specific locality. These variables determined the potential yields and the period of supply of vegetables.

Temperature plays an influential role during plant growth and development. There are three growth temperatures, minimum, maximum, and optimum for each species and variety of plant and for each growth stage, temperature is essential for successful crop growth and seed production (Acheampong, 2007). At sowing time and during transplanting, either high or low temperature particularly in the soil may affect plant stand and establishment. This is because a temperature below the requirement of a crop generally reduces the speed of germination, retards plant growth and increase susceptibility to diseases. However, warm weather, at appropriate time, favours flowering, pollination, seed setting and seed maturity (van Gastel *et al.*, 1996).

Soil temperature can be managed with the sole aim of improving plant growth and development. Raising the soil temperature often improves seed germination and growth (Michael and Donald, 1999). Berke *et al.* (2005) reported that when temperature falls below $15^{o}C$ or exceeds $32^{o}C$ for extended periods, growth, fruit and seed yield are usually reduced. Acheampong (2007) indicated that in Ghana, soil temperatures rarely go below $20^{o}C$. Plants, however, grow poorly when soil temperatures exceed $40^{o}C$ or even $30^{o}C$ in sensitive species (Aiyelaagbe and Fawusi, 1986). Thus it is possible to have crops failing to grow well or produce fruit in Ghana due to high soil temperatures.

Karikari and Mathew (1990) reported that the factor of humidity in vegetable production is closely linked with the rainfall intensity and pattern. High humidity which is prevalent during the rainy season creates conditions which favor fungal diseases on foliage.

Mathai (1998) reported 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 are also affected by relative humidity.

Seed maturation and harvesting in most of the crops require dry weather with low humidity. Dry weather conditions are, however, necessary for seed during ripening and harvesting.

Wet conditions are likely to cause rotting, fungi proliferation and harvesting problems (van Gastel *et al.*, 1996).

Day length and light intensity have a strong influence on plants during the vegetative and reproductive phases. Galanopoulou-Sendouca (1996) reported that light is necessary for photosynthesis, and it is, therefore, required by green plants for the manufacture of food. If photosynthesis is restricted by insufficient light duration and intensity, crop growth and development are hampered (AVRDC, 1990). Cloudy and wet weather do not provide suitable conditions for seed drying (Galanopoulou-Sendouca, 1996).

Pedigo (1996) indicated that poor light penetration can result in poor pollination by insects; fruit shedding occurs, seed development become incomplete and the seeds do not ripe uniformly on all parts of the plant. Similarly, Galanopoulou *et al.* (1980) had earlier reported that inadequate light interception, especially, at the lower parts of the plant may affect seed maturation.

Deep, fertile, well drained, light to medium loamy soils are the most suitable for vegetable seed production (Sinnadurai, 1992). Very fertile soil may encourage excessive vegetative growth (Sinnadurai, 1992), and may extends the vegetative phase of the crop and delays flowering and fruiting (Timpo, 2007). Thus, medium soil fertility is preferable for pepper seed production (Sinnadurai, 1992). Many crops are tolerant to a wide range of soil pH which influences mineral availability in the soil for plants use (Acheampong, 2007). Berke *et al.* (2005) also indicated that hot pepper grows best in a loamy or silty loam soil with good water-holding capacity, but can grow on many soil types as long as the soil is well drained and has pH of about 5.5 to 6.8.

Mathai (1998) reported that fruit vegetables grow well in soils with continuous supply of nutrients and moisture. The temperature of a soil greatly affects the physio-chemical and biological processes occurring in the soil.

2.1.1 Diseases of Hot Pepper

Crops are considered healthy when they are capable of carrying out their physiological functions to the best of their genetic potential, under optimal conditions and this can result in high fruit and seed production. Almost all cultivated vegetable crops are subject to disease and pests attack, resulting in severe yield losses (van Gastel *et al.*, 1996).

Fungi are responsible for a greater proportion of plant diseases in Ghana (Clerk, 1974). Plant diseases are any deviation from normal growth or structure of plants that is sufficiently procured and permanent to produce visible symptoms or to impair quality and economic value (Clerk, 1974). Pathogens such as fungi, bacteria and viruses are the cause of most hot pepper diseases (Karikari and Mathew, 1990). Some common hot pepper diseases which occur in the country include damping off, anthracnose, fruit rot, bacterial wilt, pepper veinal mottle virus and leaf curl (Karikari and Mathew, 1990).

Damping off is a fungal disease which is caused by *Pythium spp*. and it affects only seeds and germinated seedlings. It is characterized by seedlings collapsing or seeds failing to germinate after sowing (Clerk, 1974; Norman, 1992).

The anthracnose disease is characterized by lesions which first appear on mature fruits as small, water-soaked, sunken lesions that rapidly expand (AVRDC, 1990). Finally the expanded legions become sunken and the colour range from dark red to light tan. It is caused by fungi, *Collectotrichum spp,* which are spread through infected seeds and debris (Berke *et al*., 2005).

The fruit rot disease is caused by fungi (*Collectotrichum nigrum*) and it is characterized by premature rotting of fruits before they are ready for harvest (Berke *et al*., 2005). Clerk (1974) earlier reported that the fungi may attack the fruits directly or may infect the flowers first and later attack the fruits after they have been formed.

The initial symptom bacterial wilt is wilting of lower leaves, followed by a sudden and permanent wilt of the entire plant without yellowing. High temperature and high soil moisture favour the development of the disease. The pathogen, *Pseudomonas solanacearum*, can survive in soil for a very long time (Olympio, 2007).

According to Lamptey *et al.* (2001), pepper veinal mottle is a very severe viral disease which reduces yield and quality of hot pepper. The disease is characterized by leaf mottling, reduction of leaf size and quite often stunting of infected plants but few varieties are resistant to the virus. It is known to be transmitted by aphid-transmitted potyvirus (AVRDC, 2004).

According to Norman (1992), leaf curl is a very serious disease in the forest zone and a problem in irrigated crops in the drier savannah areas. The symptoms include stunted growth with curled leaves, showing some veinal and interveinal chlorosis. The virus is transmitted by the white fly (Messiaen, 1992; Norman, 1992).

2.1.2 Insect Pests of Hot Pepper

Afun (2007) defined pest as any organism that depends on or whose activities interfere with the natural development of another for its own survival and propagation and while doing so causes, injury or damage to or retards the development of the host organism. With their effect on crops in raising healthy seed crops, Agrawal (1980) indicated that apart from reduction in yield, the quality of seed from diseased and insect damaged plants is invariably poor. Aphids, whitefly and thrips are some vectors of disease pathogens of hot pepper. Afun (2007) stated that pests compete with crops for nutrients, space and light and some of them are also vectors of disease pathogens which reduce yield and quality of produce.

2.2 GROWTH, YIELD AND QUALITY RESPONSE OF VEGETABLE CROPS TO SPACING

It is important to consider spacing because of its effects on crop growth, development and yield. This is necessary, because, as plant population increases per unit area, a point is reached where plants begin to compete for essential growth factors such as nutrients, sunlight and water (Norman, 1992). However, an increase in plant density does not affect the performance of individual plants while the plant density stays below the level at which competition occurs between plants (Acheampong, 2007).

Norman (1992) indicated that spacing of crops varies with the plant, environment and cultural factors. Furthermore, in plant spacing, it is the optimum plant population per unit area which is desired. This is because the optimum plant population produces the greatest net return to the grower. The author also stated that plant density has direct influence on yield and quality of fruits and seeds.

Williams *et al.* (1991) stated that spacing has a direct effect on the quantity, varietal purity and the quality of seed. It was further reported that, wider spacing permit easier entry of pathogens that can cause severe damage in fruits and seeds which can result in low yield and poor quality of seeds (Williams *et al.*,1991).

Pedigo (1996) reported that closer spacing creates a more humid environment that can favour the development of some pathogens whose effects can be detrimental to the production of quality seed. The author further stated that high plant density leads to dense leaf canopy resulting in poor light penetration and aeration at the lower parts of the plant Pedigo (1996). Consequently, this may result in poor pollination by insects, seed deterioration, fruit shedding and incomplete seed development. van Gastel *et al*., (1996) had stated categorically that, wider spacing leads to increased competition between plants and weeds for the essential growth factors and in such situation, plants usually suffer. The authors also indicated that wider spacing promotes the production of numerous lateral branches which delays flowering and seeds do not mature uniformly (van Gastel *et al*., 1996).

Moniruzzaman *et al*. (2007), conducted a field experiment on okra cv. BARI-Dherosh-1 comprising four sowing times and four spacing (60cmx30cm, 60cmx40cm, 60cmx50cm and 60cmx60cm) made the following observations. The closest spacing resulted in taller plants and increase seed yield per hectare but reduced number of mature fruits per plant, number of seeds per fruit, 1000 seed weight and seed yield per plant. However, maximum number of mature fruits per plant was recorded for the widest spacing. Also, the highest number of seeds per fruit, 1000 seed weight and seed yield per plant were recorded in the widest spacing which gave the lowest seed yield per hectare (Moniruzzaman *et al*., 2007).

Lima *et al*. (2003) studied the effect of plant spacing on yield and quality of squash seeds. The number of fruits per plant was lower with lower plant density whiles increasing plant density resulted in higher number of seeds per plant and higher seed yield per hectare. It was observed however that higher 1000 seed weight was obtained with a lower population density (Lima *et al*., 2003).

Oad *et al*. (2002) also conducted an experiment on spacing effect on growth, seed yield and oil content of Safflower and observed that, wider row spacing recorded early days to crop maturity. Seed yield was significantly affected by row and plant densities and the wider spacing increased seed yield. Berke *et al*. (2005) reported that high plant densities lead to weak plants, which are more susceptible to diseases.

2.3 EFFECTS OF CULTURAL FACTORS ON GROWTH AND YIELD OF VEGETABLES

Bonsu *et al*. (2003) reported that young plants whether produced from seeds or through vegetative means require a lot of care particularly during the early stages of growth. Berke *et al.* (2005) also stated that germination and seedling growth varies depending on variety, seed quality and soil moisture.

Onazi *et al.* (1988) reported that seeds should germinate rapidly in order to ensure strong and vigorous seedlings which are an indication of good plant stand and expected higher seed yield. Berke *et al*. (2005) stated that, under good conditions seedlings are ready for transplanting 4 - 5 weeks after sowing. It was further indicated that good seedling has 4 - 5 true leaves, disease-free, stocky and has no flowers. Meanwhile, Xuefeng (1999) in conducting hot pepper varietal trials transplanted 40 days old seedlings in the field after sowing. Earlier, Hung (1996) also in another hot pepper evaluation trial sowed the seeds on October 28 and transplanted on December 12 at 6-7 leaf stage. Thus a period is required to promote efficient selection of vigorous seedlings for transplanting.

Water is essential for the survival and growth of plants. The growth and development of plants is influenced by their internal water balance. Water is involved in essential physiological processes such as photosynthesis and various metabolic reactions (Karikari and Mathew, 1990).

Berke *et al.* (2005) reported that thorough supply of water provides uniform soil moisture, which is essential for optimum fruit and seed yield. Katerji *et al.* (1993) earlier indicated that pepper plants are most sensitive to water stress during flowering and fruit development. Berke *et al.* (2005) concluded that pepper plants are fairly shallow-rooted and have low tolerance to drought or flooding. Fields should therefore be irrigated if there are signs of wilting. It is also known that irrigation is used to overcome the problems caused by variability and unpredictability of rainfall (Karikari and Mathew, 1990).

Agrawal (1980) reported that adequate fertilization results in maximum fruit and seed yields, good seed quality and better expression of plant type which facilitate roguing and thereby helps in maintaining higher genetic purity as well. In addition, adequate supply of nitrogen, phosphorus and potassium promote healthy growth, good root development, good fruiting and seed development, hasten plant maturity, increase crop yield and disease resistance. Nisar *et al*. (2002) also reported that adequate fertilizer application enhances both vegetative and reproductive growth of vegetables.

Berke *et al.* (2005) indicated that the quantity of fertilizer to apply depends on soil fertility, fertilizer frequency rate, soil organic matter, soil mineralization of nitrogen and soil leaching of nitrogen. Therefore, a soil test is recommended to determine the levels of N.P.K, pH and other nutrients. Norman (1992) recommended 250kg/ha NPK and 125kg/ha sulphate of ammonia, Berke *et al*. (2005) recommended fertilizer (NPK) as 180, 22 and 200kg/ha respectively for higher fruit and seed yield of hot pepper.

2.4 SEED QUALITY OF VEGETABLE CROPS

Seed quality is a concept made up of different attributes. These attributes are of different segments of the seed industry. In all cases, the ultimate objective of making a test is to determine the value of seed for sowing (ISTA, 1993). Quality seed can be defined as that of an improved variety, which is true to type, high in varietal and physical purity, has high germination and vigour, free from weed and seed-borne pests, has a low moisture content, uniform, and properly processed for distribution to farmers (van Gastel *et al*., 1996). The main attributes as far as seed quality assessment is concerned are germination, seed vigour and seed health, in that; the viability of seed greatly depends on percent germination, the vigour of a given seed lot and the health status of the seed (Asuboah, 2007).

2.4.1 Seed Testing

The role of germination test in assessing the quality of seed is of outmost importance (ISTA, 1993). This is because seed germination is the main attribute in determining the viability of seed. Loss of seed viability is the final stage in seed deterioration, as reported by Ellis and Roberts (1983) that, ageing can result in a decline in many aspects of seeds potential performance such as the rate of germination. Germination test is also considered important to avoid planting seed of low viability, which may lead to crop failure (ISTA, 1993). Germination capacity indicates the percentage of pure seed that produces normal seedlings, under optimal conditions in the laboratory and, by inference, the field planting value in a favourable environment (ISTA, 1993). Germination capacity, assessed under laboratory conditions are seldom optimal and most seed lots will not attain the predicted germination value due to various field stresses (van Gastel *et al*., 1996). After germination, the seedling must grow vigorously to show its potential in producing quality fruits and seeds (Onazi *et al*., 1988).

2.4.2 Seed Vigour Tests

Seeds must be in the right physiological state to germinate and establish seedlings, perhaps within a limited period when there is a good chance of regeneration (Fenner, 1992). Seed vigour is not a simple measurable property like germination, but rather, a quantitative character controlled by several factors affecting the germinating seed or seedling (van Gastel *et al*., 1996). Contrary to germination, seed vigour demonstrates the capacity of seed lots to produce a good crop stand under adverse field conditions. There are several vigour tests which have been developed to predict field establishment (Ellis, 1992). Seed vigour tests include conductivity test, accelerated ageing test, cold test, tetrazolium test, seedling dry weight and first count in a standard germination test (Asuboah, 2007).Korkmaz *et al*. (2004) reported that the various procedures can be used to detect high and low vigour seed lots and the results can be used to decide whether to keep a particular seed lot for longer period of time or not. Also, seed vigour index has been proposed by Agrawal (1999) as another method that can be used to test the vigour of different seed lots.

2.4.3 Seed Health Tests

Pathogenic attack on vigorous seedling growth can terminate the health of a quality seedling (William *et al.*, 1991). Therefore seed health assessment plays an important supportive role in the overall assessment of a quality seed as losses due to plant diseases occur when less valuable crops are planted. For any disease to develop there should be a susceptible host plant, a causative agent and a favourable environment (Maloy, 1993). Seed health assessment is an important factor in the control of crop disease because the infected seed is less viable, has low germination, reduced vigour and reduced yield (van Gastel *et al*., 1996). Consequently, a healthy seedling grows well, and that enables the plant in its developmental processes, resulting in high yield (Berrie *et al*., 1987).

Neergaard (1977) observed that diseases carried by seeds are known as seed borne diseases and may be caused by pathogenic micro-organisms such as fungi, bacteria, viruses or nematodes. The pathogens are detected and identified in laboratory seed health tests (Mathur and Kongsdale, 2001). Berke *et al*. (2005) described the primary seed-borne fungal pathogens *Fusarium spp., Pythium spp., Rhizoctonia solani* and *Colletotricum spp.* as surface saprophytes. Neergaard (1977) indicated that inspection of dry seed, washing, blotter method, agar plate, growing on test and seedling symptoms are some of the methods approved for seed health testing.

2.5 SEED QUALITY AS INFLUENCED BY HOT PEPPER VARIETY

2.5.1 Flowering and Fruiting

Nisar *et al.* (2002) stated that days to flowering may be enhanced or delayed due to availability of nutrients, soil condition and climatic factors prevailing during the growing period of the crop. The authors conducted research on the influence of various levels of nitrogen and phosphorus on the growth and yield of Chilli and concluded that maximum days of flowering and delay in fruiting were as a result of high doses of nitrogen which enhanced vegetative growth. Shivastava (1996) worked on the effect of fertilizer levels and spacing on flowering, fruit set and yield of sweet pepper (*Capsicum anuum* var. *grossum* L.) cv. Hybrid Bharat and reported that first flowering and 50% flowering were delayed by 4-6 days in plants which received the highest rate of fertilizers.

Aboagye and Bennett-Lartey (2003) conducted research on the evaluation of agro-morphological diversity in pepper landraces collected from Ghana and reported that days to 50% flowering ranged from 65 to 124 days. Jackson (2006) has reported that newly released varieties CRI-Shito Adope and CRI-Mako Ntoos took 60 days and 63 days to flower respectively.

2.5.2 Yield

Clerk (1974) stated that lower rate of phosphorus causes poor fruit formation and lower yields. Such poorly nourished plants are also less able to withstand drought and other severe environmental conditions. According to Berke *et al*. (2005), hot pepper yields vary widely depending on cultural practices and season. Hung (1996) also reported that in general, the yield of hot pepper is higher during the dry season than during the wet season because of less disease occurrence during dry season. Bonsu *et al.* (2003) indicated that multiple fruit number per axil is more desirable since number of fruits per plant becomes high and yield increases. In the work on the morphological characterization of hot pepper germplasm in Ghana, accession PBC 717 recorded a range of 7-14 pedicels per axil (Bonsu *et al.*, 2003). This accession was described as a good genetic material that could be used to increase fruit number per axil and therefore increase yield and ease of harvesting. Nisar *et al*., (2002) observed high fruit yield, due to high nitrogen and phosphorus rates, and it was explained that the nitrogen promoted vegetative growth due to increased branches leading to more fruits and higher yield. Jackson (2006) reported that fruit yields of CRI-Shito Adope and CRI-Mako Ntoos were 30t/ha and 35t/ha respectively.

2.5.3 Fruit Quality

Berke *et al*. (2005) reported that consumer preference for pepper fruits are considered according to the shape, colour and degree of pungency. Quality fruit should exhibit characters such as thick pericarp, firm mesocarp, higher aroma and higher pungency when freshly picked, higher number of seeds and well developed placenta (AVRDC, 2004). Bonsu *et al*. (2003) and AVRDC, (2004) also mentioned pepper fruit shape as conical, campanulate, elongate, blocky and round. Xuefeng (1999) and Bonsu *et al.* (2003) reported unripe stage colour as green, light green, dark green and cream with ripe fruit exhibiting red or yellow colours. Bonsu *et al*. (2003) further observed that dark green fruit colour at the unripe stage is a character very much desired in the export trade. This could therefore be used to develop materials to suit the export market in Ghana. Fruit shape and fruit colour have direct relationship with pepper fruit uses. For example, "Super-hot" large elongated red fruit is good for processing whiles thin elongated fruits with lower pungency are good for seasoning as they dry faster (AVRDC, 2004).

2.5.4 Diseases and Pests

Lamptey *et al.* (2001) stated that vegetable crops are generally susceptible to a host of diseases. Diseases affect yields both in quality and quantity and the most important are those caused by viruses. In a survey conducted countrywide, it was observed that virus infection was very severe on pepper, okra and egg plant and moderately severe on tomato (Lamptey *et al.*, 2001). The authors further reported that few lines of pepper and eggplant were observed to be resistant to viruses, and these could be useful materials for breeding purposes. In a preliminary evaluation of 20 hot pepper varieties, Hau (1989) indicated that all the varieties were susceptible to viral disease. Anh (1996) evaluated six cultivars of hot pepper and concluded that cultivars CA 169 and CA 101 were resistant to most diseases. Khanh (1997) also evaluated 12 AVRDC hot peppers and reported that cultivar CA 169 had good resistance to diseases such as virus, wilt and anthracnose and pests such as mites, worms and aphids.

2.6 SEEDBORNE PATHOGENS OF VEGETABLE CROPS

Liwayway (1993) has reported that seeds for storage should be free from injury, surface infestation by microbes or insect infestation. Hasmi (1989) mentioned that, among seedborne mycoflora, *Fusarium moniliforme* caused 6 to 8% loss in germination of pepper seeds. Grover and Bansal (1970) stated that pepper seed infected with *Collectotrichum spp.* often has poor germination or viability. Berke *et al*. (2005) have mentioned the primary seedborne fungal pathogens (Fusarium *spp, Pythium spp, Rhizoctonia solani* and *Collectotrichum spp*) as saprophytes. Meanwhile, Neergaard (1977) stated that saprophytes may lower the quality of seeds by causing discoloration which may seriously depreciate the commercial value of seeds.

CHAPTER THREE

MATERIALS AND METHODS

3.1 LOCATION OF EXPERIMENT

The evaluation and selection of 11 lines of hot pepper for seed yield and quality was carried out on the experimental plots of the Department of Horticulture, Faculty of Agriculture, KNUST and Crops Research Institute, Kwadaso in the forest zone of Ghana, from May 2007 to November 2008.

3.2 PHASE I: MULTIPLICATION STAGE AND SELECTION

Breeder seeds of eleven hot pepper lines were collected from the Department of Horticulture for the evaluation. The soil at the Department of Horticulture is sandy loam in structure and well drained with moderately good water holding capacity (Ablor, 1972). The seeds were sown and nursed on separate nursery beds. The seedlings were transplanted to the field at four weeks old. The lines were planted in separate rows which were 1m apart. Spacing within rows for each line was 60cm. Each row was 24m long and had forty plants without replications. The total land area used for the multiplication trial was 24mx10m. Mosquito proof nylon mesh was used to cover the plants during the period under cultivation to prevent insect vectors which could transmit viral diseases. Data on growth and yield parameters such as plant height, canopy spread, number of branches, number of fruits per plant and number of seeds per fruit were collected from ten plants selected using random numbers in each line. Five lines which were found to have produced taller plants, wider canopy, more branches, more fruits, longer fruits and higher seed yield were selected for further study at different spacing.

3.3 PHASE II: EVALUATION OF LINES

The phase II experiment was conducted at the experimental field of the Crops Research Institute, Kwadaso-Kumasi. The six month experiment was started from May, 2008 and completed in November, 2008.

3.4 LAND PREPARATION OF EXPERIMENTAL PLOT

The land was ploughed and harrowed to ensure adequate moisture retention in the soil, reduced erosion and modify the soil temperature. The field was demarcated, lined and pegged before seedlings were transplanting.

3.4.1 Experimental Area and Layout

A total land area of 52.5m x 11.4m was used for the experiment and this was sub-divided into four blocks from which soil samples were taken for laboratory analysis for nutrient levels. Each block was further divided into fifteen plots, each measuring 3m x 2.1m. The blocks were 1m apart whiles a path of 0.5m wide was allowed between the plots. There were fifteen treatments (i.e. 5 lines and 3 spacing) which were replicated four times to give a total of 60 plots. Each plot was labeled for easy identification of the treatments.

3.5 EXPERIMENTAL DESIGN AND TREATMENTS

The 5x3 factorial experiment was arranged in a Randomized Complete Block Design (RCBD) with 4 replications. There were 5 different pepper lines and 3 different spacings resulting in 15 treatment combinations. The treatments were randomly assigned to the plots in each block. The choice of spacing (70cmx30cm, 70cmx40cm and 70cmx50cm) was based on recommendations by some authors; 80cmx40cm (Grubben and Tahir, 2004), 90cmx90cm (Norman, 1992), 90cmx60cm (George, 1985; Tindall, 1983), and 75-90cmx45-60cm (Yamaguchi, 1983).

3.6 AGRONOMIC PRACTICES

3.6.1 Weed Control

Weeds were controlled mainly by hand hoeing two weeks after transplanting and continued at three weeks interval to ensure good weed control throughout the growing period.

3.6.2 Irrigation

The experiment was conducted during the major rainfall season. However, supplementary irrigation was done on three occasions whenever there was no rain for about a week. Watering was carried out using sprinklers.

3.6.3 Fertilizer Application

NPK (15:15:15) compound fertilizer was applied at the rate of 5g/plant two weeks after transplanting. This was followed by the application of sulphate of ammonia at the same rate four weeks after transplanting.

3.6.4 Insect Pests and Disease Control

A broad spectrum insecticide, PAWA 2.5EC, with active ingredient of 25g lamba-cyhalothrin per litre was used to control insect pests such as aphids (*Aphis gossypii*), whitefly (*Bemisia tabaci*), thrips (*Scirtothrips dorsalis H*) and leafminers (*Agromyza spp*). Spraying was done using hand propelled CP15 Knapsack sprayer with recommended rate of 35ml/15L water, at all the critical stages of growth and development.

Fungicide (Topsin-M), with active ingredient of 70% thiophanate-methyl was used to control fungal diseases. Spraying was done using hand propelled CP15 Knapsack sprayer with recommended rate of 210g/15L water, at all the critical stages. In all there were three spraying regimes for the control of pests and diseases. The sprayings were done at pre-flowering, at fruit set and fruit development stages.

3.6.5 Harvesting of Fruits

Ten plants randomly selected within the two inner rows of each plot were tagged for data collection. Manual harvesting of fresh fruits started 90 days after transplanting and was continued at weekly interval. The tagged plants were harvested throughout the reproductive period.

3.7 PARAMETERS STUDIED

3.7.1 Vegetative Growth:

3.7.1.1 Plant height

Plant height was taken at 2^{nd}, 4^{th} and 8^{th} weeks after transplanting using a meter rule. The measurements were taken from the soil level to the apex of the plant. Weekly mean figures of ten plants were taken per plot.

3.7.1.2 Canopy spread

Canopy spread was taken at 4^{th} and 8^{th} weeks after transplanting at two perpendicular distances across the widest positions and the mean figures were recorded.

3.7.1.3 Number of branches

The total number of branches on the tagged plants from each plot was counted at the 4^{th} and 8^{th} weeks after transplanting and the mean figures were calculated and recorded.

3.7.2 Reproductive Growth

The reproductive growth parameters studied included the number of days to 50% flowering, fruit set and first fruit harvest. These were obtained by observing visually and counting the number of days from transplanting to visible flower opening, fruit set and first fruit harvest.

3.7.2.1 Assessment of disease incidence

Pepper veinal mottled virus (PVMV) disease was the main disease for assessment on the plants. Visual observation as the plant grew during all the developmental stages of the plant was carried out and the disease score on all affected plants on each plot was recorded. A severity scale rated 1-5 (Lamptey, 2008) was used for the assessment. The scale was described as follows; 1 - Apparently no symptom, 2 - Slightly severe, 3-Moderately severe, 4-Severe, 5-Very severe. The data collected was used to determine mean severity of leaf damage.

3.7.2.2 Fruit assessment

Mean fruit length

A measuring tape and a pair of divider were used to determine the length of ten randomly selected fruits from the tagged plants in each plot and the mean fruit length recorded.

Number of fruits per plant

This was obtained after the numbers of fruits harvested from sampled plants were counted for each plot.

Mean single fruit weight

This was determined by weighing ten randomly harvested fruits from the tagged plants in each plot using a sensitive electronic scale and dividing the weight by ten.

Fruit yield per hectare

The fruit yield was computed by the formular:

$$Yf = P \times F \times Wf$$

Where: Yf = fruit yield

P = number of plants per hectare

F = number of fruits per plant

Wf = mean weight per fruit

Source: AVRDC (1990).

3.7.2.3 Seed yield assessment

Mean Number of Seeds per fruit

Ten fruits were randomly selected from the tagged plants in each plot within the harvesting period. A sharp knife was used to divide each fruit and the seeds were removed, counted and the result computed per fruit from the ten.

Mean seed yield per hectare

This was determined from ten fruits per plant and then extrapolated to hectare.

1000 seed weight

The extracted seeds from ten fruits in each plot were dried under sun for three days and the weight of 100 seeds determined using an electronic balance. The weight for each 100 seeds was multiplied by 10 for 1000 seed weight.

3.7.2.4 Seed quality assessment

Germination Test and Seed Vigour

Fifteen seed pans filled with sieved fine river sand from River Dwahyen (Kwadaso, Kumasi) were assembled for each block. Seeds used for the test were sun dried. One hundred seeds for each treatment were sown into the filled seed pans at a depth of about 5mm. Three weeks period was used for the germination test and seed vigour. For seed germination, the number of seeds which germinated were recorded and calculated on percentage basis. For seed vigour, the first seedlings count which germinated seven days after sowing were used (Lima *et al*., 2003). These tests were replicated twice.

Seed Health Test

Blotter test method was carried out for the seed health test. Four hundred seeds for each treatment were plated on well water-soaked blotters (3/petridish) using a pair of calipers. Seeds were incubated for 7 days in an incubation room at $20^{o}C \underline{+} 1\text{-}2^{o}C$ 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 presence of fungi. Compound microscope was used to identify all fungi based on their spores (fruiting bodies) as described by Mathur and Kongsdale (2001).

3.8 STATISTICAL ANALYSIS OF DATA

Data on vegetative, reproductive and yield parameters were analyzed using Analysis of Variance and differences among treatments were separated by least significant difference (LSD) at 5% level of significance for interpretation of the results (Steel and Torrie, 1980). The Genstat computer package version 9.1 was used for the analysis. Data on seed health parameters were summarized per treatment and presented in tables.

CHAPTER FOUR

RESULTS

4.1 FIELD OBSERVATIONS

There were good plant stand and establishment of seedlings after transplanting. There was a favourable weather conditions during the growing periods of the plants. Data collected during the multiplication phase are presented in Table 4.1.1.

Data collected on the effects of variety and spacing on vegetative growth, reproductive growth, plant survival, fresh fruit yield, yield and quality of seeds are presented in Tables 4.2.1 - 4.8.2. The results are on the main treatment effects of variety, spacing and the interaction effects (variety x spacing) of the various parameters. Means separation which were statistically significantly different are shown in the tables.

4.1.1 Multiplication and Selection Results

Morphological variations were observed among the lines evaluated (Table 4.1.1). The results indicated the need for careful selection of promising parent lines for breeding purposes. The five lines which performed better in terms of plant survival and other parameters including plant height, canopy spread, number of branches, total number of fruits, fruit length and number of seeds per fruit were ICPN 16#4, ICPN 16#7, ICPN 16#9, ICPN 16#3 and ICPN 16#6. However, seedlings from line ICPN 16#8 died off soon after transplanting as a result of unidentified cause but no pathological assessment was conducted.

Table 4.1.1: Characteristics of the Initial Elite Hot Pepper Lines Tested

LINES	Plant height at flowering (cm)	Canopy spread at flowering (cm)	Number of branches	Fruit length (cm)	Total number of fruits per plant	Number of seeds per fruit
Birds eye	33.9	37.7	6.3	4.75	78	58.8
ICPN 16#1	26.9	33.7	8.0	7.6	16	76.6
ICPN 16#2	35.2	53.0	12.6	6.8	16	68.6
ICPN 16#3	46.2	60.7	17.7	12.12	105	93.8
ICPN 16#4	52.0	68.3	20.6	10.32	365	111.4
ICPN 16#5	38.0	52.0	9.1	8.15	49	81.9
ICPN 16#6	38.8	75.9	17.5	11.84	193	113.7
ICPN 16#7	37.0	56.3	16.4	18.0	156	128.0
ICPN 16#9	39.8	61.4	20.0	11.52	194	106.1
ICPN 16#10	25.0	52.3	10.0	7.7	13	77.3

4.2 EFFECT OF VARIETY AND SPACING ON VEGETATIVE GROWTH OF THE SELECTED HOT PEPPER LINES

4.2.1 Plant Height at 2 Weeks after Transplanting

At 2 weeks after transplanting, ICPN16#4 plants were significantly ($P<0.05$) taller than the other lines (Table 4.2.1). Mean plant height of ICPN16#4 plants was 42.6cm. ICPN16#9 produced the shortest plants (33.0cm) but was not significantly different from ICPN16#6. For spacing, data collected show no significant difference among treatments.

The interaction of variety and spacing on plant height at 2 weeks after transplanting was statistically significant as shown in Table 4.2.1. Variety and spacing combinations which gave the tallest (44.4cm) and shortest (32.5cm) plants were ICPN16#4 combined with 70cm x 30cm and ICPN16#9 combined with 70cm x 50cm respectively.

Table 4.2.1: Effect of Variety and Spacing on Plant Height (cm) at 2 weeks after Transplanting of the selected Hot Pepper Lines

	Spacing (cm)			
Variety	**70 x 30**	**70 x 40**	**70 x 50**	**Variety mean**
ICPN16#3	39.1	43.9	35.8	**39.6**
ICPN16#4	44.4	42.9	40.8	**42.6**
ICPN16#6	40.6	35.5	36.8	**37.5**
ICPN16#7	40.1	40.1	43.9	**41.4**
ICPN16#9	33.5	32.7	32.5	**33.0**
Spacing mean	**39.6**	**39.1**	**38.1**	
CV (%)	15.28			

Lsd $_{(0.05)}$ Variety = 4.8 Spacing = 3.5 Variety x Spacing = 8.3

4.2.2 Plant Height at 4 Weeks after Transplanting

Significant differences (P<0.05) were shown on plant height at 4 weeks after transplanting among the lines (Table 4.2.2). The ICPN16#4 plants were significantly (P<0.05) taller than the ICPN16#9 but were not different from the other lines. Spacing results did not show any significant differences among the lines with respect to plant height at 4 weeks after planting.

The interaction effect was statistically significant (P<0.05) since for example 70cm x 40cm spacing which gave the tallest plants when interacted with ICPN16#4 and ICPN16#3 also produced the shortest plants when interacted with ICPN16#9.

Table 4.2.2: Effect of variety and spacing on plant height (cm) at 4 weeks after Transplanting of the selected Hot Pepper Lines

Variety	Spacing (cm) 70 x 30	70 x 40	70 x 50	Variety mean
ICPN16#3	48.2	52.3	43.1	**48.0**
ICPN16#4	51.8	52.8	51.8	**52.0**
ICPN16#6	50.5	45.7	50.0	**48.7**
ICPN16#7	47.7	45.2	52.3	**48.5**
ICPN16#9	40.6	41.4	40.6	**40.8**
Spacing Mean	**47.7**	**47.4**	**47.4**	
CV (%) 14.88				
Lsd $_{(0.05)}$	**Variety=5.8**	**Spacing=4.3**	**Variety x Spacing=9.9**	

4.2.3 Plant Height at 8 Weeks after Transplanting

Significant differences (P<0.05) in plant height occurred among the lines (Table 4.2.3). Line ICPN16#4 produced significantly taller plants than ICPN16#7 and ICPN16#9 lines but it was similar to ICPN16#3 and ICPN16#6 lines. Spacing did not affect (P>0.05) plant height at 8 weeks after transplanting.

The interaction effect was statistically significant (P<0.05). Line ICPN16#3 planted at 70cm x 40cm spacing produced significantly taller plants whilst ICPN16#7 at the same spacing of 70cm x 40cm spacing produced significantly shorter plants (Table 4.2.3).

Table 4.2.3: Effect of variety and spacing on plant height (cm) at 8 weeks after transplanting of the selected Hot Pepper Lines

	Spacing (cm)			
Variety	**70 x 30**	**70 x 40**	**70 x 50**	**Variety mean**
ICPN16#3	68.0	75.6	60.9	**68.3**
ICPN16#4	69.5	71.6	72.1	**71.1**
ICPN16#6	67.3	62.7	65.7	**65.2**
ICPN16#7	61.9	55.8	68.3	**61.9**
ICPN16#9	58.9	61.2	55.8	**58.6**
Spacing Mean	**65.2**	**65.5**	**64.5**	
CV (%) 13.95				

Lsd $_{(0.05)}$ Variety=7.3 Spacing=5.5 Variety x Spacing=12.9

4.2.4 Canopy Spread at 4 Weeks after Transplanting

At four weeks after transplanting, canopy spread varied significantly (P<0.05) among the lines. Lines ICPN16#7 and ICPN16#3 had wider canopy spreads of 59.4cm and 59.1cm respectively than the other lines (Table 4.2.4).

The 70cm x 50cm spacing produced significantly (P<0.05) wider canopy spread than 70cm x 40cm and 70cm x 30cm spacing (Table 4.2.4).

The interaction effect between variety and spacing was significant (P<0.05). Line ICPN16#7 plants which were spaced at 70cm x 50cm produced the widest canopy spread (69.0cm).

Table 4.2.4: Effect of Variety and Spacing on Canopy Spread (cm) at 4 weeks after Transplanting of the selected Hot Pepper Lines

	Spacing (cm)			
Variety	**70 x 30**	**70 x 40**	**70 x 50**	**Variety mean**
ICPN16#3	54.8	61.2	61.2	**59.1**
ICPN16#4	51.8	47.2	49.2	**49.5**
ICPN16#6	50.5	44.1	55.3	**50.0**
ICPN16#7	56.3	52.8	69.0	**59.4**
ICPN16#9	53.0	58.4	58.4	**56.6**
Spacing Mean	**53.3**	**52.8**	**58.6**	
CV (%) 16.06				
Lsd $_{(0.05)}$ Variety = 7.1	**Spacing = 5.5**	**Variety x Spacing=12.4**		

4.2.5 Canopy Spread at 8 Weeks after Transplanting

At eight weeks after transplanting, canopy spread showed no significant (P>0.05) differences among lines. Spacing did not also affect canopy spread at 8 weeks after transplanting. Interaction effect between variety and spacing was not also significant at 8 weeks after transplanting (Table 4.2.5).

Table 4.2.5: Effect of Variety and Spacing on Canopy Spread (cm) at 8 weeks after Transplanting of the selected Hot Pepper Lines

	Spacing (cm)			
Variety	**70 x 30**	**70 x 40**	**70 x 50**	**Variety mean**
ICPN16#3	61.4	69.3	65.2	**65.2**
ICPN16#4	58.6	54.1	60.1	**57.6**
ICPN16#6	55.8	52.8	64.2	**57.6**
ICPN16#7	64.7	58.6	74.6	**66.0**
ICPN16#9	63.2	66.2	66.0	**65.2**
Spacing Mean	**60.7**	**60.1**	**66.0**	
CV (%) 16.98				
Lsd $_{(0.05)}$ Variety=8.6	**Spacing=6.6**	**Variety x Spacing=14.9**		

4.2.6 Number of Branches at 4 Weeks after Transplanting

The number of branches produced by the lines was not significantly different (Table 4.2.6). Spacing did not also affect number of branches produced by the lines.

The interaction between variety and spacing was significant (P<0.05) as shown in Table 4.2.6. Line ICPN16#3 at 70cm x 40cm spacing produced the highest number of branches of 27.8 whilst ICPN16#7 at 70cm x 40cm gave the least number of 16.2.

Table 4.2.6: Effect of variety and spacing on number of branches at 4 weeks after transplanting of the selected Hot Pepper Lines

	Spacing (cm)			
Variety	**70 x 30**	**70 x 40**	**70 x 50**	**Variety mean**
ICPN16#3	22.8	27.8	21.0	**23.9**
ICPN16#4	18.9	20.1	26.4	**21.8**
ICPN16#6	19.5	16.8	23.5	**19.9**
ICPN16#7	19.4	16.2	27.6	**21.1**
ICPN16#9	21.5	25.9	21.2	**22.9**
Spacing Mean	**20.4**	**21.4**	**23.9**	
CV (%) 25.19				

Lsd $_{(0.05)}$ Variety=4.5 Spacing=3.5 Variety x Spacing=7.8

4.2.7 Number of Branches at 8 Weeks after Transplanting

The highest and lowest numbers of branches were produced by ICPN16#9 and ICPN16#6 respectively as shown in Table 4.2.7. The highest number of branches (36.5) produced by ICPN16#9 did not differ significantly (P>0.05) from that of ICPN16#7(36.3). The number of branches produced by ICPN16#3 and ICPN16#4 were not significantly different. With respect to spacing, differences among treatments were not significant (Table 4.2.7).

The interaction between variety and spacing was significant as shown in Table 4.2.7. Line ICPN16#7 plants spaced at 70cm x 50cm gave the highest number of branches whilst ICPN16#6 at 70cm x 40cm spacing gave the least number of branches.

Table 4.2.7: Effect of variety and spacing on number of branches at 8 weeks after transplanting of the selected Hot Pepper Lines

Variety	Spacing (cm) 70 x 30	70 x 40	70 x 50	Variety mean
ICPN16#3	31.1	39.6	33.8	**34.8**
ICPN16#4	29.7	29.8	33.8	**31.1**
ICPN16#6	29.3	26.2	29.2	**28.2**
ICPN16#7	35.5	29.9	43.5	**36.3**
ICPN16#9	35.9	37.5	36.2	**36.5**
Spacing Mean	**32.3**	**32.6**	**35.3**	
CV (%) 24.56				

Lsd $_{(0.05)}$ Variety=6.7 Spacing=5.2 Variety x Spacing=11.7

4.3 EFFECT OF VARIETY AND SPACING ON REPRODUCTIVE GROWTH OF THE SELECTED HOT PEPPER LINES

4.3.1 Days To 50% Flower Opening

Days to 50% flowering was significantly (P<0.05) different among lines with ICPN16#4 and ICPN16#9 taking fewer days (27.6/27.5) than ICPN16#6 (29.5).

Plants spaced at 70cm x 50cm took significantly (P<0.05) longer period (29.4 days) to attained 50% flowering whiles lines planted at 70cm x 40cm spacing took fewer days (27 days) to attain 50% flowering.

Interaction between variety and spacing was significant (Table 4.3.1). Line ICPN16#9 at 70cm x 50cm took 30.5 days to attained 50% flowering whilst line ICPN16#9 at 70cm x 40cm spacing took 25.5 days.

Table 4.3.1: Effect of Variety and Spacing on Days to 50% Flower Opening of the selected Hot Pepper Lines

Variety	spacing (cm) 70 x 30	70 x 40	70 x 50	Variety mean
ICPN16#3	29.0	28.5	28.0	**28.5**
ICPN16#4	28.7	25.7	28.5	**27.6**
ICPN16#6	28.7	29.7	30.0	**29.5**
ICPN16#7	27.7	29.5	30.2	**29.1**
ICPN16#9	26.5	25.5	30.5	**27.5**
Spacing Mean	**28.1**	**27.8**	**29.4**	
CV (%) 7.44				
Lsd $_{(0.05)}$ Variety=1.7	**Spacing=1.3**	**VarietyXSpacing=3.0**		

4.3.2 First Fruit Set

Table 4.3.2 shows that the days to first fruit set was significantly (P<0.05) different among the lines. Lines ICPN16#7 and ICPN16#3 took more days (29.8) than ICPN16#9 (26.8 days). Spacing did not significantly affect days to first fruit set.

Interaction between variety and spacing was significant. Line ICPN16#6 at 70cm x 40cm spacing took 30.7 days to set fruit whilst line ICPN16#9 at 70cmx40cm took shorter days of 25.2 to set fruits.

Table 4.3.2: Effect of variety and spacing on days to first fruit set of the selected Hot Pepper Lines

Variety	Spacing (cm)			Variety mean
	70 x 30	70 x 40	70 x 50	
ICPN16#3	29.5	29.5	30.5	**29.8**
ICPN16#4	29.5	25.7	30.5	**28.6**
ICPN16#6	27.0	30.7	26.2	**28.0**
ICPN16#7	30.5	30.0	29.0	**29.8**
ICPN16#9	27.5	25.2	27.7	**26.8**
Spacing Mean	**28.8**	**28.2**	**28.8**	
CV (%) 12.22				

Lsd $_{(0.05)}$ Variety=2.8 Spacing=2.2 Variety x Spacing=4.9

4.3.3 First Fruit Harvest

Line ICPN16#7 took longer days (70.1) to ripe than the other lines with respect to days to first fruit harvest (Table 4.3.3). There were however no significant differences among the lines. Spacing did not also influence days to first fruit harvest.

There was significant interaction effect as shown in Table 4.3.3. Line ICPN16#7 at 70cm x 40cm spacing took more days (73.2) to ripe whilst ICPN16#6 at 70cm x 50cm spacing took (63.0days).

Table 4.3.3: Effect of variety and spacing on days to first fruit harvest of the selected Hot Pepper Lines

Variety	Spacing (cm) 70 x 30	70 x 40	70 x 50	Variety mean
ICPN16#3	65.5	67.0	70.2	**67.6**
ICPN16#4	68.0	67.0	70.0	**68.3**
ICPN16#6	71.5	70.7	63.0	**68.4**
ICPN16#7	69.0	73.2	68.2	**70.1**
ICPN16#9	66.5	63.7	67.0	**65.7**
Spacing Mean	**68.1**	**68.3**	**67.7**	
CV (%) 7.89				

Lsd $_{(0.05)}$ Variety=4.4 Spacing=3.4 Variety x Spacing=7.6

4.4. EFFECT OF VARIETY AND SPACING ON PLANT SURVIVAL AT FIRST FRUIT HARVEST STAGE OF THE SELECTED HOT PEPPER LINES

4.4.1 Plant Survival

Table 4.4.1 shows that a significantly (P<0.05) higher number of plants survived in lines ICPN16#9 (79.9%) and ICPN16#3 (79.8%) than ICPN16#6 (70.5%). No differences were recorded between ICPN16#7 and ICPN16#4. For spacing, values obtained did not differ statistically.

There was significant interaction effect among the treatments. Lines ICPN16#9 at 70cm x 50cm and ICPN16#3 at 70cm x 50cm had higher plant survival (82.1%) whilst ICPN16#6 at 70cm x 30cm had the least value (68.1%).

Table 4.4.1: Effect of variety and spacing on percentage plant survival at first fruit harvest stage of the selected Hot Pepper Lines

Variety	Spacing (cm)			Variety mean
	70 x 30	**70 x 40**	**70 x 50**	
ICPN16#3	80.1	77.3	82.1	**79.8**
ICPN16#4	75.5	72.6	69.6	**72.6**
ICPN16#6	68.1	70.3	73.2	**70.5**
ICPN16#7	75.0	74.2	81.2	**76.8**
ICPN16#9	77.2	80.4	82.1	**79.9**
Spacing Mean	**75.2**	**75.0**	**77.6**	
CV (%) 12.57				

Lsd $_{(0.05)}$ Variety=7.8 Spacing=6.0 Variety x Spacing=13.6

4.4.2 Disease Severity Of Pepper Veinal Mottle Virus

Variety, spacing and their interaction did not influence the severity of pepper veinal mottle virus disease on the lines evaluated (Table 4.4.2). Generally, the severity of the disease was low across the lines.

Table 4.4.2: Effect of variety and spacing on severity of pepper veinal mottle virus disease of the selected Hot Pepper Lines

Variety	Spacing (cm)			Variety Mean
	70 x 30	70 x 40	70 x 50	
ICPN16#3	1.15	1.05	1.10	**1.1**
ICPN16#4	1.00	1.05	1.00	**1.0**
ICPN16#6	1.02	1.02	1.00	**1.0**
ICPN16#7	1.02	1.02	1.00	**1.0**
ICPN16#9	1.02	1.00	1.00	**1.0**
Spacing Mean	**1.00**	**1.00**	**1.00**	
CV (%) 6.21				

Lsd $_{(0.05)}$ Variety=0.05 Spacing=0.04 Variety x Spacing=0.09

4.5. EFFECT OF VARIETY AND SPACING ON COMPONENTS OF FRUIT YIELD OF THE SELECTED HOT PEPPER LINES

4.5.1 Fruit length

There were significant ($P<0.05$) differences among the lines with respect to mean fruit length (Table 4.5.1). While ICPN16#7 produced the longest fruits (17.8cm), the shortest fruits (13.0cm) were produced by ICPN16#4. Significant differences were not found in fruit length produced by ICPN16#9, ICPN16#3 and ICPN16#4.

There were significant differences among the spacing treatments with respect to mean fruit length. Plants at 70cm x 30cm spacing produced the longest fruits (15.6cm) while those spaced at 70cm x 50cm recorded the shortest length (14.5cm). However, mean fruit length from 70cm x 40cm and 70cm x 50cm spacing was not significantly different.

Interaction between variety and spacing was significant as shown in Table 4.5.1. Significant interaction effect occurred between ICPN16#7 at 70cm x 40cm and ICPN16#4 at 70cm x 40cm.

Table 4.5.1: Effect of variety and spacing on fruit length (cm) of the selected Hot Pepper Lines

Variety	Spacing (cm)			Variety mean
	70 x 30	**70 x 40**	**70 x 50**	
ICPN16#3	14.9	13.7	12.6	13.7
ICPN16#4	13.6	12.5	12.9	13.0
ICPN16#6	16.8	16.5	16.1	16.5
ICPN16#7	18.2	17.8	17.5	17.8
ICPN16#9	14.4	13.8	13.6	13.9
Spacing Mean	15.6	14.9	14.5	
CV (%) 7.58				

Lsd $_{(0.05)}$ Variety=0.9 Spacing=0.7 VarietyXSpacing=1.6

4.5.2 Mean Weight per Fruit

There were significant (P<0.05) differences among the lines with respect to mean fruit weight (Table 4.5.2). While line ICPN16#7 produced heaviest fruits (7.9g), while line ICPN16#9 gave the least fruit weight (4.2g). Significant differences were not found among fruit weight produced by ICPN16#3, ICPN16#6, ICPN16#4 and ICPN16#9.

There were significant differences among the spacing treatments with respect to mean fruit weight. Plants at 70cm x 40cm spacing produced fruits with the highest mean weight (5.6g) while fruits with the least mean weight (4.9g) were recorded from 70cm x 50cm.

Interaction effect of variety and spacing was significant as shown in Table 4.5.2. Line ICPN16#7 at 70cm x 50cm spacing gave the highest mean fruit weight (8.3g) while ICPN16#4 and ICPN16#6 at 70cm x 50cm spacing gave the least mean fruit weight (3.4g).

Table 4.5.2: Effect of variety and spacing on fruit weight (g) of the selected Hot Pepper Lines

	Spacing (cm)			
Variety	**70 x 30**	**70 x 40**	**70 x 50**	**Variety mean**
ICPN16#3	5.6	4.7	4.9	**5.1**
ICPN16#4	4.4	5.2	3.4	**4.3**
ICPN16#6	6.2	5.4	3.4	**5.0**
ICPN16#7	7.3	8.1	8.3	**7.9**
ICPN16#9	3.6	4.6	4.4	**4.2**
Spacing Mean	**5.4**	**5.6**	**4.9**	
CV (%) 20.53				

Lsd $_{(0.05)}$ Variety=0.9 Spacing=0.7 VarietyXSpacing=1.5

4.5.3 Number of Fruits per Plant

Table 4.5.3 shows that a significantly (P<0.05) higher number of fruits per plant was produced by lines ICPN16#4 (44.0) and ICPN16#9 (42.0). No differences were recorded among ICPN16#6, ICPN16#3 and ICPN16# 7. Spacing did not affect number of fruits per plant.

Interaction between variety and spacing significantly affected number of fruits per plant. The combination with highest number (49.3) of fruits per plant was line ICPN16#4 at 70cm x 50cm spacing whilst the least (21.6) was line ICPN16#3 at 70cm x 30cm spacing.

Table 4.5.3: Effect of variety and spacing on number of fruits per plant of the selected Hot Pepper Lines

	Spacing (cm)			
Variety	**70 x 30**	**70 x 40**	**70 x 50**	**Variety mean**
ICPN16#3	21.6	34.7	26.4	**27.6**
ICPN16#4	44.7	38.1	49.3	**44.0**
ICPN16#6	26.7	26.5	40.2	**31.1**
ICPN16#7	22.8	21.7	27.1	**23.9**
ICPN16#9	43.8	46.6	35.6	**42.0**
Spacing Mean	**31.9**	**33.5**	**35.7**	
CV (%) 29.88				

Lsd $_{(0.05)}$ Variety=8.3 Spacing=6.4 Variety x Spacing=14.3

4.5.4 Fruit yield per hectare

Significant differences were recorded among the lines as shown in Table 4.5.4. The yield obtained from line ICPN16#4 (10.2t/ha) was significantly ($P<0.05$) higher than the yields produced by ICPN16#6 and ICPN16#3 but similar to lines ICPN16#7 and ICPN16#9.

There was significant spacing effect on yield (Table 4.5.4). The closest spacing (70cm x 30cm) gave significantly higher yield than the other spacing. The 70cm x 40cm spacing also gave significantly higher yield than the 70cm x 50cm spacing.

The interaction between variety and spacing was significant as shown in Table 4.5.4. Line ICPN16#4 plants spaced at 70cm x 30cm gave the highest fruit yield (12.9t/ha) while line ICPN16#6 planted at 70cm x 50cm spacing produced the lowest yield (5.7t/ha).

Table 4.5.4: Effect of variety and spacing on fruit yield (tons) per hectare of the selected Hot Pepper Lines

Variety	Spacing (cm)			Variety mean
	70 x 30	**70 x 40**	**70 x 50**	
ICPN16#3	8.6	8.1	5.7	**7.5**
ICPN16#4	12.9	10.1	7.5	**10.2**
ICPN16#6	11.3	7.2	5.7	**8.1**
ICPN16#7	11.6	8.7	10.1	**10.1**
ICPN16#9	11.0	10.7	6.6	**9.4**
Spacing Mean	**11.1**	**9.0**	**7.1**	
CV (%) 27.76				

Lsd $_{(0.05)}$ Variety=2.0 Spacing=1.6 Variety x Spacing=3.6

4.6 EFFECT OF VARIETY AND SPACING ON COMPONENTS OF SEED YIELD OF THE SELECTED HOT PEPPER LINES

4.6.1 Number of Seeds per Fruit

There were significant ($P<0.05$) differences among the lines with respect to number of seeds per fruit as shown in Table 4.6.1. Line ICPN16#7 gave significantly higher number of seeds (108.5) per fruit as compared to the lowest number of seeds produced by ICPN16#4 (83.0). The values recorded by lines ICPN16#9 and ICPN16#4 was not significantly different. There was no significant spacing effect on number of seeds per fruit.

Interaction between variety and spacing was significant. The combination which recorded the highest number of seeds per fruit was ICPN16#7 at 70cm x 50cm while the lowest was line ICPN16#4 at 70cm x 50cm and line ICPN16#4 at 70cm x 40cm as shown in Table 4.6.1.

Table 4.6.1: Effect of variety and spacing on number of seeds per fruit of the selected Hot Pepper Lines

	spacing (cm)			
Variety	**70 x 30**	**70 x 40**	**70 x 50**	**Variety mean**
ICPN16#3	99.1	81.5	89.0	**89.9**
ICPN16#4	87.3	80.8	80.8	**83.0**
ICPN16#6	94.1	103.2	99.6	**99.0**
ICPN16#7	96.7	106.3	121.1	**108.0**
ICPN16#9	81.0	88.4	86.2	**85.2**
Spacing Mean	**91.6**	**92.0**	**95.3**	
CV (%) 16.48				

Lsd $_{(0.05)}$ Variety=12.6 Spacing=9.7 Variety x Spacing=21.88

4.6.2 1000 Seed Weight

There were significant differences among the lines as shown in Table 4.6.2. The highest 1000 seed weight (4.5g) was produced by ICPN16#3 and ICPN16#4 which were significantly higher than that of ICPN16#9 but similar to ICPN16#6 and ICPN16#7. Spacing did not affect 1000 seed weight.

Interaction between variety and spacing was significant (Table 4.6.2). Line ICPN16#3 at 70cm x 30cm gave the highest 1000 seed weight (5.0g) while ICPN16#9 at 70cm x 40cm produced the least weight (2.5g).

Table 4.6.2: Effect of variety and spacing on 1000 seed weight (g) of the selected Hot Pepper Lines

Variety	Spacing (cm)			Variety mean
	70 x 30	**70 x 40**	**70 x 50**	
ICPN16#3	5.0	4.2	4.2	**4.5**
ICPN16#4	4.2	5.0	4.2	**4.5**
ICPN16#6	4.7	4.2	4.2	**4.4**
ICPN16#7	4.2	4.5	3.7	**4.1**
ICPN16#9	3.5	2.5	3.2	**3.1**
Spacing Mean	**4.3**	**4.1**	**3.9**	
CV (%) 18.93				

Lsd $_{(0.05)}$ Variety=0.6 Spacing=0.4 Variety x Spacing=1.11

4.6.3 Seed Yield per Hectare

There were significant differences among the lines. Line ICPN16#9 gave the highest seed yield (1179.5g/ha) whilst ICPN16#3 had the least yield (715.6g/ha).

There were significant differences among the spacing treatments. The highest seed yield (1146.7g/ha) was produced from the closer spacing of 70cm x 30cm while the lowest yield (855.1g/ha) was obtained from the 70cm x 40cm spacing. The differences between the 70cm x 50cm and 70cm x 40cm spacing were not significant.

Interaction between variety and spacing was significant as shown in Table 4.6.3. The combination of ICPN16#9 and 70cm x 30cm gave the highest seed yield (1563.7g/ha) whilst ICPN16#3 and 70cm x 50cm recorded the lowest yield (515.6g/ha).

Table 4.6.3: Effect of variety and spacing on seed yield (g) per hectare of the selected Hot Pepper Lines

Variety	**Spacing (cm)**			**Variety mean**
	70 x 30	**70 x 40**	**70 x 50**	
ICPN16#3	809.3	822.0	515.6	**715.6**
ICPN16#4	1358.2	724.4	1148.1	**1076.9**
ICPN16#6	924.0	818.7	971.0	**904.6**
ICPN16#7	1078.5	800.4	780.8	**886.6**
ICPN16#9	1563.7	1109.8	865.0	**1179.5**
Spacing Mean	**1146.7**	**855.1**	**856.1**	
CV (%) 30.88				

Lsd $_{(0.05)}$ Variety=242.4 Spacing=187.7 Variety x Spacing=419.7

4.7 EFFECT OF VARIETY AND SPACING ON QUALITY OF SEED OF THE SELECTED HOT PEPPER LINES

4.7.1 Germination Percentage

There were significant differences among the lines with respect to germination percentage as shown in Table 4.7.1. Line ICPN16#6 had the highest percentage germination (87.1%) whilst ICPN16#7 gave the least (65.0%). Germination of seeds from ICPN16#6 did not differ significantly compared to ICPN16#3 and ICPN16#4. Spacing did not affect the germination of seeds.

Table 4.7.1 indicates significant interaction between variety and spacing. The highest (96.5%) germination occurred in line ICPN16#6 at 70cm x 40cm spacing whilst the least (50.5%) was recorded in ICPN16#9 at70cm x 40cm spacing.

Table 4.7.1: Effect of variety and spacing on germination percentage of the selected Hot Pepper Lines

	Spacing (cm)			
Variety	**70 x 30**	**70 x 40**	**70 x 50**	**Variety mean**
ICPN16#3	89.0	86.2	83.5	**86.2**
ICPN16#4	76.5	78.2	81.7	**78.8**
ICPN16#6	78.5	96.5	86.5	**87.2**
ICPN16#7	65.5	56.2	73.2	**65.0**
ICPN16#9	64.2	50.5	81.0	**65.2**
Spacing Mean	**74.7**	**73.5**	**81.2**	
CV (%) 20.48				

Lsd $_{(0.05)}$ Variety=12.9 Spacing=9.9 Variety x Spacing=22.35

4.7.2 Seed Vigour

Seed vigour significantly differs among the lines as shown in Table 4.7.2. The highest value (87.0%) was recorded by ICPN16#6 and the lowest (65.0%) recorded by ICPN16#7. There were no significant difference between ICPN16#9 and ICPN16#7. Spacing did not affect seed vigour.

Interaction between variety and spacing was significant. Line ICPN16#6 at 70cm x 40cm gave the highest seed vigour value but the lowest value occurred in ICPN16#9 at 70cm x 40cm spacing.

Table 4.7.2: Effect of variety and spacing on seed vigour (%) of the selected Hot Pepper Lines

	Spacing (cm)			
Variety	**70 x 30**	**70 x 40**	**70 x 50**	**Variety mean**
ICPN16#3	86.5	86.0	82.5	**85.0**
ICPN16#4	74.7	78.2	81.7	**78.2**
ICPN16#6	78.0	96.5	86.5	**87.0**
ICPN16#7	65.5	56.2	73.2	**65.0**
ICPN16#9	63.7	50.5	81.0	**65.1**
Spacing Mean	**73.7**	**73.5**	**81.0**	
CV (%) 20.74				

Lsd $_{(0.05)}$ Variety=12.9 Spacing=10.0 Variety x Spacing=22.51

4.8 Seed Health

4.8.1 Incidence of fungal pathogens

A total of seven fungal pathogen species including *Penicillium, Fusarium solani, Aspergillus flavus, Aspergillus niger, Collectotricum dematium, Rhizopus* and *Fusarium moniliforme* were found on the seeds (Table 4.8.1).

Table 4.8.1: Variety and spacing effect on incidence of fungal pathogens on seeds of selected Hot Pepper Lines

Treatments	Pathogens						
	Penicillium	*Fusarium solani*	*Aspergillus flavus*	*Aspergillus niger*	*Collectotricum dematium*	*Rhizopus*	*Fusarium moniliforme*
ICPN16#3 at 70cmx30cm	√	√	√	X	√	X	√
ICPN16#3 at 70cmx40cm	√	√	√	√	√	√	√
ICPN16#3 at 70cmx50cm	√	√	√	√	√	√	X
ICPN16#4 at 70cmx30cm	√	√	√	√	√	√	X
ICPN16#4 at 70cmx40cm	√	√	√	X	√	X	√
ICPN16#4 at 70cmx50cm	√	√	√	√	√	√	√
ICPN16#6 at 70cmx30cm	√	√	√	√	√	√	X
ICPN16#6 at 70cmx40cm	√	√	√	√	√	√	X
ICPN16#6 at 70cmx50cm	√	√	√	√	√	√	X
ICPN16#7 at 70cmx30cm	√	√	√	√	√	√	√
ICPN16#7 at 70cmx40cm	√	√	√	X	√	√	√
ICPN16#7 at 70cmx50cm	√	√	√	√	√	√	√
ICPN16#9 at 70cmx30cm	√	√	√	√	√	√	√
ICPN16#9 at 70cmx40cm	√	√	√	√	√	√	√
ICPN16#9 at 70cmx50cm	√	√	√	√	X	√	X

Note: √ (pathogen present) X (pathogen not present)

4.8.2 Frequency of fungal pathogens

Penicillium and *Aspergillus flavus* dominated and were present abundantly. *Collectotricum dematium* was present in considerable number. *Aspergillus niger and Fusarium moniliforme* were the least occurred pathogens (Table 4.8.2).

Table 4.8.2: Variety and spacing effect on frequency of fungal pathogens on selected Hot pepper Lines

Treatments	Pathogens						
	Penicillium	*Fusarium solani*	*Aspergillus flavus*	*Aspergillus niger*	*Collectotricum dematium*	*Rhizopus*	*Fusarium moniliforme*
ICPN16#3 at 70cmx30cm	160	10	137	0	26	0	2
ICPN16#3 at 70cmx40cm	120	1	112	1	3	2	1
ICPN16#3 at 70cmx50cm	137	2	80	1	2	1	0
ICPN16#4 at 70cmx30cm	122	8	141	2	9	1	0
ICPN16#4 at 70cmx40cm	74	1	266	0	11	0	1
ICPN16#4 at 70cmx50cm	169	5	163	2	2	1	5
ICPN16#6 at 70cmx30cm	64	1	286	2	56	2	0
ICPN16#6 at 70cmx40cm	97	5	164	1	8	1	0
ICPN16#6 at 70cmx50cm	114	6	207	2	20	3	0
ICPN16#7 at 70cmx30cm	113	26	62	1	30	1	1
ICPN16#7 at 70cmx40cm	151	2	20	0	12	1	1
ICPN16#7 at 70cmx50cm	120	4	125	1	11	3	3
ICPN16#9 at 70cmx30cm	165	2	150	1	15	2	1
ICPN16#9 at 70cmx40cm	157	18	80	3	29	4	1
ICPN16#9 at 70cmx50cm	123	3	46	1	0	1	0

CHAPTER FIVE

DISCUSSION

5.1 VARIETY AND SPACING EFFECT ON VEGETATIVE GROWTH OF HOT PEPPER

There were variation in plant height among the varieties and this could be attributed to differences in their genetic make-up. Plant height is one of the criteria used in recommending a variety for release as reported by Decoteau and Graham (1994) that, the height of the plant may influence fruit position with respect to the ground. The ultimate height reached by the lines depended greatly on their growth characters (Tindall, 1983). The heights recorded by all the lines at 8th week (Table 4.2.3) were far below the 1.5m reported by Tindall (1983) and this is desirable because taller plants could lodge easily which can result in mechanical damage.

Decoteau and Graham (1994) in their study indicated that, as in-row plant spacing increased, plant height increased. The results of the present study showed similar trend as the closest spacing gave the tallest plants throughout the assessment. This is because with closer spacing, there are a greater number of plants per unit area competing for available sunlight, nutrients and water (AVRDC, 1990). The combined effects of ICPN16#4 and all the spacing levels produced the highest plant height and this can be attributed to their inherent genetic trait. For this study, the increased plant density did not affect the performance of the individual plants, probably; there was limited competition among the plants for sunlight, soil moisture and nutrients (Norman, 1992).

Generally, the differences observed in branching of pepper plants might have been due to genetic variations among the lines. Thus branch formation could be variety dependent and this could be the reason why ICPN16#9 and ICPN16#7 produced more branches at 8 weeks after transplanting. The other varieties varied in number of branches which is an indication of their varietal differences. Line ICPN16#6 recorded the least number of branches 8 weeks after transplanting probably because it was genetically developed to produce fewer branches.

The widest spacing was consistent in producing more branches. The increase in number of branches per plant under medium and wider spacing noticed in this study was mainly attributed to its better plant growth and development (Anilkumar, 2004) due to less competition for nutrients, space, light and moisture (Norman, 1992).

The stretch to which plant canopy can reach may be due to their genetic character or space available for the growing plants (Seleshi, 2011). In this experiment, line ICPN16#7 gave the widest canopy spread while ICPN16#4 had the least spread. The canopy variation may determine the yielding potential of the crop, since, varieties with wider canopy could produce more fruits than varieties with narrow canopy due to increased number of secondary and tertiary branches which are the locations for fruit bud formation (Seleshi, 2011). The widest spacing 70cm x 50cm gave the widest spread because the plants had the opportunity of utilizing abundant supply of essential growth factors, as reported by (AVRDC, 1990) that, the closer the plants are to each other, the more they shade each other resulting in lesser effective leaf area exposed to sunlight. The combined effects of ICPN16#7 and 70cm x

50cm which gave the widest canopy spread goes in line with the findings of Lima *et al*. (2003) who reported that an ideal population density is necessary for optimized leaf index, so that the maximum useful radiation for photosynthesis would be intercepted.

5.2 VARIETY AND SPACING EFFECT ON REPRODUCTIVE GROWTH OF HOT PEPPER

The fewer number of days taken to attain 50% flowering by ICPN16#9 could be due to the genetic make-up which is an indication of earliness. The combined effects of the widest spacing and all the lines resulted in longer days to attain 50% flowering (Table 4.3.1) probably due to the utilization of the abundant nutrients, moisture, space and sunlight for vegetative growth. The result of this study is in contrast with the results of Deonton and Vakinde (1993) who reported mean days to 50% flowering of 94.5.

Line ICPN16#9 took 26.8 days after transplanting to set a fruit which is an indication of a desirable trait for selection and release of a variety. The same line recorded the least number of days (65.7) to produce first ripe fruits. The variations in days to first fruit set and first fruit harvest could be due to the genetic make-up of the lines. The interaction of ICPN16#9 and all the spacing levels took fewer days to set fruits and produced ripe fruits which is a sign of earliness. Meanwhile, all the lines mature in less than 80 days after transplanting and can be considered as early maturing varieties.

5.3 VARIETY AND SPACING EFFECT ON FRUIT YIELD

In general the interaction of spacing by varieties had relatively better effect on the number of fruits per plant as it has been observed. The relative earliness in flowering and maturity could also have enabled the varieties to produce more fruits per plant, which contributed to higher productivity of the varieties per unit area. The recorded variations of varieties in fruit yield components might be due to variation in plant height, as well as formation of more branches that increased the potential of fruit bearing buds and also leaf area that maximizes photosynthetic capacity and assimilate partitioning to the fruits. This result is further consolidated by the findings of Sam-Aggrey and Bereke-Tsehai (2005) who reported positive impact of vegetative growth on yield and yield components of hot pepper. Bosland and Votava (2000) also pointed out that primary and secondary branches were locations of fruit buds and thus foundations of new fruit bud development in bell peppers. This report is in conformity with the present result, consolidating the role of branches in determining pepper total yield.

5.4 VARIETY AND SPACING EFFECT ON SEED YIELD

The lines showed significant differences. Since the same cultural practices were applied to the plants, the differences found may be due to their genetic make-up. Line ICPN16#7 recorded the highest (108.0) number of seeds per fruit whilst ICPN16#4 gave the least number (83.0) of seeds per fruit. This result is in line with Lemma (1998), who pointed out that seed number per fruit is one factor that determines fruit size. Lemma (1998) observed a linear increase in individual fruit size and weight with seed number. The widest spacing (70cm x 50cm) gave the highest value because the pepper plants exhibited high vegetative growth due to effects of spacing , gained high leaf area, increased photosynthetic capacity and assimilate partitioning that resulted in large fruit size and hence in greater seed number per fruit and large fruit size. Alan and Eser (2007) have also pointed out that pepper fruit size and fruit set positively correlated with seed number.

The variation in 1000 seed weight might be attributed to the genetic make-up of varieties and the spacing effect. Because fruits with higher seed weight can be considered as those receiving higher percentage of assimilates which also indicate that a good combination of number of seeds and seed weight per fruit could improve fruit quality which make it an important economic part of the crop as reported by Bosland and Votava (2000). The highest seed weight (4.5g) from lines ICPN16#3 and ICPN16#4 were significantly different from the value recorded by ICPN16#9 (3.1g). This probably was as a result of their genetic make-up. This result is in line with George (1985) who reported that 1000 seed weight of hot pepper seeds as 3.5g and an indication of good seed vigour as reported by Powell and Mattews (1995).

There were significant differences among lines for seed yield. Line ICPN16#9 gave the highest seed yield while ICPN16#3 recorded the least yield. This may be due to their genetic make-up. Spacing treatments recorded significant differences among them with the closest spacing (70cm x 30cm) showing higher weights (1146.7g) with 70cm x 40cm giving least weights (855.1g). The highest seed yield in the closest spacing might be due to increased plant population which gave more seeds per unit area.

5.5 SEED QUALITY AS AFFECTED BY VARIETY AND SPACING

After one month of seed storage, germination percentage showed significant differences among the lines. From the results, higher germination was recorded by line ICPN16#6 than those recorded by ICPN16#9 and ICPN16#7. The reason may be due to their genetic make-up as well as their larger seed sizes (van Gastel *et al*, 1996). From the experiment, there was a favourable environmental condition as the fruits mature and were harvested during the drier months of the year when relative humidity was low. Moisture is the greatest single cause of loss of seed viability that is why Asiedu and Powell (1998) reported that seeds stored in tropical environment where both relative humidity and temperature values are high during most of the year, will deteriorate faster resulting in low germination. Ellis *et al.* (1983) reported that ageing can lead to a decline in many aspects of seeds potential performance including the rate of germination. The one month storage period was short and perhaps there was no loss of seed viability which could have contributed to low germination recorded by ICPN16#7 and ICPN16#9.

Powell and Mattews (1995) stated that seed vigour is affected by genotype, seed size, seed density, the incidence of seed borne pathogens and ageing. The differences in seed vigour may be attributed to their genetic make-up. According to van Gastel and Bishaw (1993), seed size is the common difference among seeds and generally varies from one plant to another. Variation from plant to plant which results from genetic difference and other factors contributes to a wide range of seed sizes within a seed lot. In general, there is a positive correlation between seed size and seed vigour as larger seed tends to produce more vigorous seedlings (van Gastel *et al.*, 1996).

5.6 DISEASES, PLANT SURVIVAL AND SEED HEALTH

Lamptey *et al*. (2001) reported that vegetable crops are generally susceptible to a number of diseases. Diseases affect yields and quality of produce and the most important are those caused by viruses. Virus infection often results in leaf mottling and distortion, reduction of leaf size and quite often stunting of infected plants (Lamptey *et al*., 2001). In this experiment, pepper veinal mottle virus disease occurrence was assessed. Crop growth stages of the various varieties were assessed between two weeks after transplanting and harvesting. Score for virus damage was mainly on the foliage. Thus, a disease rating for each plant was based on the percentage of leaves that showed symptom. Generally all five lines were found to be resistant to the mosaic virus disease as indicated by Lamptey *et al*. (2001). Thus, the lines showed strong potential for use in breeding pepper lines that will be resistant to the disease.

Field establishment depends on the vigour of the cultivar, the type of cultural practices used and the prevailing environmental conditions (van Gastel *et al.*, 1996). In this experiment, all the varieties recorded higher percentages of survival. Lines ICPN16#9 and ICPN16#3 produced plants that survived better. Wider spacing 70cm x 50cm promoted plant survival. Combinations of 70cm x 50cm between ICPN16#3 and ICPN16#9 gave the highest plant survival.

Regarding seed health, a seed health test was conducted to identify the presence or absence of fungi. This is because good seeds should be free from any contaminants in order for them to achieve high germination percentage. The results revealed the presence of both storage and seed borne pathogens which include *Penicillium, Fusarium solani, Aspergillus flavus, Aspergillus niger, Collectotricum dematium, Rizopus* and *Fusarium moniliforme. Collectotricum spp* and *Fusarium spp* are known to cause diseases in pepper (Grover and Bansal, 1970). The results suggested low occurrence of these seed borne pathogens. Seed health is an important factor in the control of plant disease since infected seed is less viable, has low germination, reduced vigour and reduced yield (van Gastel *et al.*, 1996).

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 SUMMARY AND CONCLUSION

Hot pepper (*Capsicum frutescens L*.) is one of the most important vegetable crops grown for fresh market use and processing worldwide. The crop is also an important cash crop in the forest, transitional and savannah zones of Ghana. Even though farmers have cultivated the available varieties year after year which have been well adapted, yields are still low. The experiment was set up to evaluate and select varieties that are high yielding for farmers to increase yield on sustainable basis. Breeder seeds of eleven lines of hot pepper were multiplied at the experimental field of Department of Horticulture, KNUST. Five promising lines including ICPN16#3, ICPN16#4, ICPN16#6, ICPN16#7 and ICPN16#9 was studied for their seed yield and quality at the experimental field of the Crops Research Institutes, Kwadaso-Kumasi in the Forest Zone of Ghana.

The experiments were conducted from May 2007 to November 2008. The experiment was a 5 x 3 factorial in a randomized complete block design with 4 replications. The five hot pepper lines include ICPN16#3, ICPN16#4, ICPN16#6, ICPN16#7 and ICPN16#9. The three spacing levels were 70cm x 30cm, 70cm x 40cm and 70cm x 50cm which gave 69,841, 50,793 and 44,444 plants per hectare respectively. Data was collected on vegetative and reproductive growth parameters, fruit and seed yield, and seed quality.

The results of the study revealed that variety and spacing had significant interaction effect on most of the parameters studied.

Line ICPN16#4 which was a tall line produced narrow canopy with more branches whilst ICPN16#9 which was a short line produced more branches with medium canopy spread. Line ICPN16#9 was early maturing and it flowered in 19 days after transplanting and was also the first to set fruits in 26 days after transplanting. Lines ICPN16#9 and ICPN16#3 had the highest percentage plant survival. Line ICPN16#4 produced the highest fruit yield/ha whilst ICPN16#9 gave the highest seed yield. ICPN16#4 was among the varieties with high percentage germination and seedling vigour whilst ICPN16#9 was among those with the lowest percentage germination and seedling vigour.

Plants which were spaced at 70cm × 50cm produced the widest canopy spread. The 70cm × 40cm and 70cm × 30cm resulted in early flowering. The 70cm × 40cm spacing produced heavier fruits and the 70cm×30cm gave longer fruits. Fruit and seed yields were highest in 70cm × 30cm followed by 70cm × 40cm and 70cm × 50cm respectively. Spacing did not affect percentage germination and seedling vigour.

For interaction between variety and spacing, ICPN16#9 at 70cm × 40cm was the first to attained 50% flowering in 25 days after transplanting whilst ICPN16#9 at 70cm × 50cm interactions took 30 days to attain 50% flowering.

Percentage plant survival was highest in ICPN16#9 and ICPN16#3 at 70cm × 50cm.

ICPN16 # 7 at 70cm × 50cm and ICPN16 # 7 at 70cm × 40cm produced heavier fruits but longer fruits were produced by line ICPN16 # 7 at 70cm × 30cm. Line ICPN16 # 7 at 70cm × 50cm also produced the highest number of seeds per fruit probably due to the heaviest fruits produced which confirms positive impact of fruit weight on seed yield. ICPN16#4 at 70cm × 30cm produced the highest fruit yield/ha as a result of increased plant population.

The highest germination percentage and seedling vigour occurred in ICPN16#6 at 70cm × 40cm spacing.

6.2 RECOMMENDATIONS

Line ICPN16#6 should be planted at 70cm × 50cm for earliness whilst line ICPN16#9 should be planted at 70cm × 50cm and ICPN16#3 at 70cm × 50cm to promote plant survival.

For increased fruit yield, line ICPN16#4 should be planted at 70cm × 30cm whilst ICPN16#9 should be planted at 70cm × 30cm spacing to obtain higher seed yield.

For increased fruit and seed yields, 70cm × 30cm spacing is recommended.

For fruit production, ICPN16#4 is recommended whilst ICPN16#9 is recommended for seed production in the Ashanti Region.

REFERENCES

Ablor, F.S. (1972). Report on the detailed soil survey of the Horticulture farm, Faculty of Agriculture, KNUST, Kumasi, Ghana. Pp 24

Aboagye, L.M. and S.O. Bennett-Lartey (2003). Evaluation of Agro-Morphological Diversity in the Landraces of four vegetable genera Collected in Ghana. *Ghana Journal of Horticulture*, volume 3, pp 70-78.

Acheampong, P. (2007). Influence of planting Time and Spacing on Growth, Yield, Fruit and Seed Quality of Okra (*Hibiscus esculentus* L.) Cultivar KNUST selection line 1A103 in the Forest Ecological Zone of Ghana. MSc. Degree thesis submitted to the School of Graduate Studies, KNUST; Kumasi, Ghana. Pp 10-15.

Afun, J.V.K. (2007). Pest Management. Compiled Lecture Notes. Department of Crop Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Unpublished.

Agrawal, R.L. (1980). *Seed Technology*. Mohan Premlani, Oxford & IBH Publishing Co., 66 Janpath, New Delhi, pp 58-59

Agrawal, B.L. (1999). *Seed Technology* (3rd edition). Oxford and IBH Publishing Co. pvt., Ltd. New Delhi, India. p 829.

Aiyelaagbe, I.O.O. and Fawusi, M.O.A. (1986). *Growth and Yield Response of Pepper to Mulching.* Biotronics 15, 25-29.

Alan, O. and Eser, B. (2007). Pepper Seed Yield and Quality in Relation to Fruit Position on the Mother Plant. *Pakistan Journal of Biological Sciences* 10 (23):4251-4255.

Anh, N.H. (1996). Chilli Pepper Evaluation Trial. Asian Regional Center-Asian Vegetable Research and Development Center (AVRDC), Annual Report. pp.3

Anilkumar, A. (2004). Standardization of Seed Production Techniques in Fenugreek (*Trigonella foenum graecum* L.). M.Sc (Agri) Thesis, University of Agricultural Sciences, Dharwad (India).

Asiedu, E. A. and Powell, A.A. (1998). Comparison of storage potential of cultivars of cowpea (*Vigna unguilata*) differing in seed coat pigmentation. Seed Science and Technology, 26,211-221.

Asuboah, R. (2007). Lecture Notes on Special Topics in Seed Science and Technology. Department of Horticulture, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST). Kumasi. Unpublished

AVRDC (1990). Vegetable production training manual. Asian Vegetable Research and Development Center (AVRDC). Shanhua, Tainan. Pp 55-56.

AVRDC (2004). Asian Vegetable Research and Development Center (AVRDC). Fact Sheet; Pepper Mottle Virus. Asian Vegetable Research and Development Center (AVRDC) Publication.

Berke, T. L.L. Black, N. S. Talekar, J.F. Wang, P.Gniffke, S.K. Green, T.C. Wang and R. Morri (2005). Suggested Cultural Practices for Chilli Pepper – International Cooperators' Guide. Asian Vegetable Research and Development Center (AVRDC). pub # 05-620.

Berrie, G.K., Berrie, A. and Eze, J. M. O. (1987). *Tropical Plant Science*. Longman Group UK Ltd. Pp 167.

Boateng, P.Y. (2006). Personal Communication. Department of Horticulture, KNUST.

Bonsu, K. O., Owusu, E. O., Nkansah, G. O., Oppong-Konadu, E. and Adu-Dapaah, H. (2003). Morphological Characterisation of Hot Pepper (Capsicum Spp.) Germplasm in Ghana. *Ghana Journal of Horticulture*; Volume 2. pp 17-23.

Bosland, P.W. and Votava, E.J. (2000). Peppers, Vegetables and Spices Capsicum. CABI Publishing. New York. Pp 198.

Clerk G.C. (1974). *Crops and their diseases in Ghana*. Ghana Publishing Corporation. Pp. 11, 32-84

Deonton, L. and Vakinde, M.J. (1993). Variation among Landraces of Peppers in Nigeria. *Capsicum and Eggplant Newsletter*, 12: 13-24.

Decoteau, R.D. and Graham, H.A (1994). Plant Spatial Arrangement Affects Growth, Yield and Pod Distribution of Cayenne Peppers. *Hort Science* 29 (3): 149-151

De Lannoy, G. (2001). Hot pepper (*Capsicum frutescens* L.). In: *Crop production in Tropical Africa*. Romain, H. R. (Editor). Directorate General for International Cooperation, Brussels, Belgium. Pp 1540.

Ellis, R.H. (1992). Seed and seedling vigor in relation of crop growth and yield. *Plant Growth Regul*. 11: 249-255.

Ellis, R.H. and Roberts, D.A (1983). The quantification of ageing and survival in orthodox seeds. *Seed Science and Technology* 9.Pp 373-409.

Fekadu, M., Lemma, D., Harjit, S., Chemeda, F. and Roland, S. (2008). Genetic Components and Heritability of Yield and Yield Related Traits in Hot Pepper. *Research Journal of Agriculture and Biological Sciences*, 4(6): 803-809.

Fenner, M. (1992) *SEED: The Ecology of Regeneration in Plant Communities,* CAB International, Redwood Books, Trowbridge. Pp 193.

Galanopoulou-Sendouca, S. (1996). Abiotic Stresses on Seed Production: *In Seed Science and Technology*. *Proceedings of a Train-the-Trainer Workshop*, 24th April to 9th May 1993, Human, Jordan. 1 CARDA, Aleppo, Syria pp 243-251

Galanopoulou-Sendouca, S., Sficas, A.G., Fotiadis, N.A., Gagianas, A.K. and Gerakis, P.A. (1980). Effect of population density, planting date and genotype on plant growth and development of cotton. *Agron J. 72*

George, R.A.T. (1985). *Vegetable Seed Production*. John Wiley and Sons, Inc. 605. 3rd Avenue. New York, NY 10158. Longman Group Ltd. pp 208

Gibbon, D. and Pain, A. (1985). *Crops of the Drier Regions of the Tropics*. Longman Group UK Ltd. pp. 138

Grubben, G.J.H. and Tahir, I. M. E. (2004). *Capsicum Annum* L. In: *Plant Resources of Tropical Africa 2*: *Vegetables*. Grubben, G.J.H. and Denton, O.A. (Editors). PROTOA Foundation, Wageningan, Netherlands, Laiden, Netherlands/CTA, Wageningan, Netherlands. Pp. 154-163.

Grover, R. K. and Bansal, R.D. (1970). Seed-borne nature of Collectotrichum capsici in Chilli Seeds and its control by seed dressing fungicides. *Indian Phytopath*. 23:664-668

Hasmi, M. H. (1989). Seed-borne mycoflora of Capsicum anuum L. *Pakistan Journal of Botany*. 21: 302-308

Hau, T.V. (1989). Preliminary Education 20 Hot Pepper varieties. Asian Regional Center – AVRDC Publication.

Hung, T.N. (1996). Hot Pepper varietal trial. Asian Regional Center – AVRDC Publication.

ISTA (1993). *International Rules for Seed Testing*, International Seed Testing Association, Zurich, Switzerland. Pp 9.

Jackson, I. F. (2006). Quality Seed Development and Varietal Releases in Ghana: The 1st Step in Agricultural Productivity. WASNET NEWS 16. pp 15-16.

Karikari, S. K. and I. P. Mathew (1990). *Horticulture; Principles and Practices*. Macmillan Education Ltd. pp 27-33

Katerji, M., Mastrolilli, M., Handy, A., (1993). Effects of water stress at different growth stages on pepper yield. *Acta Horticulturae*. 335:165-171.

Khanh, L. T. (1997). Hot Pepper Evaluation Trial. Asian Regional Center – Asian Vegetable Research and Development Center (AVRDC). AVRDC Publication

Korkmaz, A., N. Ozbay and B. Eser (2004). Assessment of Vigour Characteristics of processing tomato cultivars by using various Vigor tests. *Asian Journal of Plant Sciences* 3 (2); 181-186.

Lamptey, J. N.L. (2008). Personal Communication, Crops Research Institute, Fumesua-Kumasi.

Lamptey, J.N.L., Anno-Nyako, F.O. and Olympio, N.S. (2001), Survey of various diseases on some major vegetable crops in some ecological zones of Ghana. *Ghana Jnl agric. Sci*. NARS edu No.1, 145-154.

Lemma, D. (1998). Seed Production Guideline for Tomatoes, Onion and Hot pepper. Institute of Agricultural Research, Addis Ababa, Ethiopia. Pp 11-27.

Lima, M. S., Cardoso, A. I. I. and Verdial, M. F. (2003). Plant Spacing and Pollen Quantity on Yield and Quality of Squash Seeds. *Horticultura Brasileira*, v. 21, n. 3, p. 443-447.

Liwayway, M. E. (1993). The Preservation of Pepper and Eggplant germplasm. *Capsicum and Eggplant Newsletter*, 12: 13-24. Invited Paper.

Maloy, O. C. (1993). *Plant Diseases Control: Principles and Practice*. John Wiley & Sons, Inc. Pp 23-27.

Mathai, P.J. (1998). *Vegetable Growing in Zambia*. Zambia Seed Co. Ltd., Lusaka, Zambia 12-17, 108-112.

Mathur, S.B. and O. Kongsdale. (2001). *Common Laboratory Seed Health Testing Methods for Detecting Fungi*. Danish Government Institute of Seed Pathology for Developing Countries Copenhagen. Denmark

Messiaen, C.M., (1992). *The Tropical Vegetable Garden*. The Macmillan Press Ltd. pp 234.

Michael, J.S. and Donald, N.M. (1999). *Soils.* 4th edition Prentice Hall, Inc. Upper Saddle Review, New Jersey, 07.458 USA pp 101.

Moniruzzaman, M., Uddin, M. Z. and Choudhury, A.K. (2007). Response of Okra Seed Crop to Sowing Time and Plant Spacing in South Eastern Hilly Region of Bangladesh. Bangladesh J. Agril. Res. 32(3): 393-402

Neergaard, P. (1977). *Seed Pathology* Vol.1. Revised edition. Macmillan Press London, pp 715-754.

Nisar, N., M. Irfan, J. Khan, G. Nabi, Muhammed and N. Badshah. (2002). Influence of various levels of nitrogen and phosphorus on the growth and yield of Chilli. *Asian Journal of Plant Sciences.* Volume 1(5):599-601.

Norman, J.C. (1992). *Tropical Vegetable Crops*. Arthur H. Stockwell Ltd., Devon, Great Britain. pp 13-30, 78-103

Oad, F. C., Samo, M. A., Qayyum, S. M. and Oad, N.L. (2002). Inter and Intra Row Spacing Effect on the Growth, Seed Yield and Oil Content of Safflower. *Asian Journal of Plant Sciences,* Volume 1 Number 1, 18-19.

Olympio, N. S. (2007). Seed pathology. Compiled Lecture Notes. Department of Horticulture, KNUST, Kumasi, Ghana. Unpublished

Onazi, O.C., Yayock, J.Y, Lombin, G., and Owonubi, J.T. (1988). *Crop Science and Production in warm Climates*. Macmillan Publishers Ltd. London Basingstoke pp 80

Pedigo, L. P. (1996). *Entomology and Pest Management*. Prentice-Hall Inc., USA. Pp 348-349

Powell, A. and Mathews, S. (1995). Seed Vigour and its measurements. In: *Techniques In Seed Science and Technology*. 2nd Edn. South Asian Publishers. New Delhi. Pp 98

Rice, R. P., Rice, L.W. and Tindall, H. D. (1986). *Fruits and Vegetable Production in Africa*. The Macmillan Press Ltd. London. Pp.230-231.

Sam-Aggrey, W.G. and Bereke-Tsehai, T. (2005). Proceeding of the 1st Horticultural Workshop. 20-22 February. IAR. Addis Ababa. Pp 212.

Schippers, R. R. (2000). *African Indigenous Vegetables. An overview of the cultivated species*. The University of Greenwich, UK and the ACP-EU Technical Centre for Agricultural and Rural Co-operation (2000). A CAB International. Pp. 103-114.

Seleshi, D. (2011). Evaluation of Elite Hot Pepper Varieties (*Capsicum species*) for Growth, Dry pod yield and Quality under Jimma condition, South West Ethiopia. M.sc. Thesis. Jimma University College of Agriculture and Veterinary Medicine. Pp 26-30.

Shivastava, A. K. (1996). Effect of Fertilizer Levels and Spacing on Flowering, Fruit set and yield of sweet pepper (*Capsicum annum* var. *grossum L*.) cv. Hybrid Bharat. *Adv. Pl. Sci.*, 9:171-175.

Sinnadurai, S. (1992). *Vegetable Cultivation*. Asempa Publishers. Accra. Pp 127-129

Steel, R. G. D. and Torrie, J. H. (1980). *Principles and procedures of Statistics*. McGraw Hill book Co. Inc, New York, U.S.A. pp 33-35

Timpo, G. M. (2007). Physiology of Horticultural Crops. Compiled Lecture Notes. Department of Horticulture, KNUST, Kumasi, Ghana. Unpublished

Tindall, H. D. (1983). *Vegetables in the Tropics*. Macmillan Education Ltd. Hampshire. pp 352-354

van Gastel, A. J. G. V., Pagnotta, M.A. and Porceddu, E. (1996). *Seed Science and Technology*. ICARDA, Aleppo, Syria. Pp 289-295

van Gastel, A. J. G. and Bishaw, Z. (1993). Components of Seed quality. In: *Seed Science and Technology, the proceedings of a Train-the-Trainers Workshop* 24 April-9 May 1993, Amman, Jordan. ICARDA Publication. Pp 289-296

Wignell, A.O. (1988). Report on the status of the development of the FAO "Quality Declared Seed" System. In: *Seed Production in and for Mediterranean Countries* edited by A. J. G. van Gastel and J. D. Hopkins, pp 106-121.

Williams, C.N., Uzo, J.O and Peregrine, W.T.H. (1991). *Vegetable Production in the Tropics*. Intermediate Tropical Agric. Series. Longman group U.K Ltd, pp.26 – 48

Xuefeng, L. (1999). Evaluation of Sweet and Hot Peppers in Kamphaengsaen. Asian Regional Center – AVRDC Report: ARC Training Report. AVRDC Publication.

Yamaguchi, M. (1983). *World Vegetables: Principles, production and nutritive values*. Van Nostrand Reinhold, New York, pp 305-306.S

APPENDICES

Appendix 1: Soil Analysis

Multiplication and selection site:

Soil sample analysis showing the nitrogen, phosphorus, potassium, pH and organic matter levels before the experiment. The results classified the soil as moderately acidic with moderate nitrogen, phosphorus, calcium and organic matter.

Appendix 1 Physical and chemical properties of soil prior to cropping

Horizon	**Chemical properties**				
	pH	**Nitrogen%**	**Phosphorus (ppm) (Blay-1)**	**Potassium cmol/kg**	**Organic matter%**
Top soil (0-15cm)	5.6	0.10	15	0.39	1.3
Sub soil (15-30cm)	6.0	0.07	13	0.23	1.2

Evaluation site:

The experimental soil can be described as acidic with low organic matter and low nitrogen. The results indicated moderate levels of phosphorus and potassium as well as exchangeable cations.

Appendix 2 Physical and chemical properties of soil prior to cropping

Block	Horizon (cm)	Chemical Properties								
		pH	Organic matter%	Total nitrogen%	Exchangeable cations me/100g				Available-Bray's	
					Ca	Mg	K	Na	ppm P	Ppm K
1	0-20 20-40	4.60 5.15	1.05 1.19	0.14 0.12	1.34 1.87	0.53 0.80	0.27 0.20	0.09 0.11	11.93 28.33	73.65 113.83
2	0-20 20-40	5.15 4.90	1.02 0.95	0.10 0.08	2.40 1.60	0.53 0.27	0.16 0.12	0.08 0.06	51.30 30.27	87.04 80.35
3	0-20 20-40	5.17 4.82	0.95 1.19	0.08 0.11	2.14 2.40	0.80 0.27	0.18 0.13	0.08 0.06	33.80 24.98	107.13 77.00
4	0-20 20-40	5.10 5.28	1.12 1.02	0.12 0.10	2.14 1.07	0.13 0.53	0.14 0.13	0.07 0.08	49.02 52.19	133.91 150.65

Source: Soil Research Institute

Analytical Services Division, Kumasi

Appendix 3 Climatological data for the year 2007

Months	Elements				
	Temperature(°C)		Relative humidity (%)		Rainfall (mm)
	max	min	0900	1500	
January	34.0	16.5	60	34	8.5
February	34.5	22.4	83	49	65.5
March	35.2	22.6	89	49	76.7
April	34.0	21.8	83	58	189.9
May	32.9	22.2	84	62	84.3
June	31.6	22.6	81	65	244.2
July	29.6	22.1	86	72	374.0
August	29.9	22.0	89	75	127.3
September	30.2	21.5	90	71	539.8
October	30.9	21.9	86	67	237.6
November	31.4	22.2	83	62	48.6
December	32.1	19.9	80	51	2.9

Source: Ghana Meteorological Department, KNUST, 2007

Appendix 4 Climatological data for the year 2008

Months	Elements				
	Temperature(°C)		Relative humidity (%)		Rainfall (mm)
	max	min	0900	1500	
January	33.3	19.2	48	32	0.0
February	34.6	21.7	79	41	61.7
March	34.2	22.0	81	53	134.1
April	33.3	22.9	83	59	117.1
May	33.0	22.8	82	59	185.8
June	31.4	22.5	85	64	179.8
July	28.8	22.3	80	65	45.0
August	29.5	20.8	88	69	114.5
September	30.0	21.3	87	68	148.9
October	31.3	21.6	85	62	95.8
November	32.7	22.2	84	55	30.7
December	32.0	21.1	84	53	47.5

Source: Ghana Meteorological Department, Kumasi, 2008