

**VARIATION IN FLORAL MORPHOLOGY, FRUIT SET AND SEED QUALITY OF  
GARDEN EGG (*SOLANUM AETHIOPICUM* VAR GILO) GERMPLASM IN GHANA.**

**BY**

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN  
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## DECLARATION

I Elijah Kofi Denkyirah, hereby declare that except for references to other people's work which have been cited, this thesis is the result of my own work and that it has neither in part nor in whole been presented elsewhere.

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## ABSTRACT

Two field experiments and a laboratory experiment were conducted at the University of Ghana, Farm, Legon and the Department of Crop Science respectively between June 2012 and May 2013 to determine the variation in floral morphology, fruit set and seed quality of twelve garden egg accessions. A randomized complete block design was used for the field experiments while a completely randomized design was used for the laboratory experiment. Data were collected on vegetative, reproductive, yield and seed characteristics. Results showed that garden egg flowers among the accessions were either solitary (single) or clustered (two or more flowers) with the stigma protruding either above (long styled flower), on the same level (medium styled flower) or below (short styled flower) the anther tips. Variations were observed among and within flowers of the same accessions. Flower number per inflorescence also varied within individual accessions as well as among accessions. Flower drop was very low in the solitary flowering type but was significantly high in the clustered flowering type. The fruit characteristics observed among accessions varied considerably in size, shape, immature fruit colour and fruit surface [characteristics of fruit wall (exocarp)] in both field experiments. Fruit colour (exocarp) among accessions varied from white to green to various combinations of green and white. Significant ( $p < 0.05$ ) differences among accessions were observed for fruit weight, fruit length and diameter. Fruit set from long and medium styled flowers contained a higher number of seeds per fruit compared to fruit set from the short styled flowers. The latter contained about 50% less seeds on average compared to the former. There were significant ( $p < 0.05$ ) differences among accessions for the number of whole seeds per fruit and the germination percentage. Although the 100 seed weight was statistically significant ( $p < 0.05$ ) for the different accessions, those with the mixed type of inflorescence showed no significant differences. Results showed that fruit set in garden

egg was not directly related to the stigma position in relation to the anther tip. However, seed content was positively influenced by the stigma position in relation to the anther tip.



## DEDICATION

This thesis is dedicated to Mr. Emmanuel Asamoah Mpereh, Mrs. Agatha Asante, my lovely daughter Jochebed Essel Quansah and my family.



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## CHAPTER ONE

### 1.0 INTRODUCTION

Garden egg (*Solanum aethiopicum*) Gilo group is a widely cultivated vegetable across most of the African continent and more intensively in West and East Africa (Grubben & Denton, 2004; Norman 1992).

In Ghana, the leaves, shoots and immature fruits of garden egg plant are used as cooked vegetables in stews but sometimes immature fruits may be eaten raw. Some parts of the crop are used as medicine for treating high blood pressure, uterine complaints and tetanus (Grubben & Denton, 2004; Lester & Seck, 2004).

The crop is well-adapted to most areas of crop production in the country. Most of the crop is produced under rain-fed conditions during the rainy season. Minor season production under irrigation also takes place. According to Akinlosotu (1979) the crop can produce fruit yields of about 8 tonnes/ha to 22 tonnes/ha depending on the cultivar. In Ghana, a national average of 8 tonnes/ha was produced under rain-fed conditions in 2005 with a potential of increasing yield up to 18 tonnes/ha (PPMED, 2005)

Garden egg is the main source of income for many families in the rural forest areas and is also consumed almost every day by many families in both the rural and urban parts of Ghana (Owusu-Ansah *et al.*, 2001). According to Gruère *et al.* (2007), the main cultivar groups are Gilo, Kumba, Shum and Aculeatum. The first three are the most important in Africa with Gilo being the most common group in Ghana while the Kumba group produced for their fruit and the Shum group cultivated for their leaves are found more in other countries.

Considerable variability exists in the crop particularly with respect to its morphology (plant growth habit, vigour, hairiness, prickliness, fruit shape, fruit size, fruit colour and yield potential), physiology (flowering behaviour and water use) and biochemical properties (fruit bitterness and glycoalkaloid content) (Daunay *et al.*, 1991; Collonier *et al.*, 2001; Gisbert *et al.*, 2006; Osei *et al.*, 2010; Chinedu *et al.*, 2011). The fruit shape, fruit size, fruit colour and taste are the most obvious characters that vary among cultivars (Frery *et al.*, 2007).

Choice of garden egg variety depends on usage (Gyiele, 1999). In Nigeria, the varieties with green immature fruit colour are preferred as fruits whiles in Ghana varieties with cream or white immature fruit colour are preferred for use as vegetable (Hornal *et al.*, 2007).

*Solanum aethiopicum* flowers are borne either solitarily or in clusters of two or more. Flower drop is very low in the solitary flowering type whereas flower drop may be as high as 80% in the clustered flowering type due to low pollination, the genetic architecture and pattern of inheritance of inflorescence (Som & Maity, 1986; Pradeepa, 2002). Early studies showed that inflorescence of *Solanum* species varied from 2-5 flowers per inflorescence. It has also been reported that flowers developed at the onset are larger than subsequent ones which tend to have short styles (Murtasow *et al.*, 1971 and Prasad & Prakash, 1968).

Mohideen *et al.* (1977) reported that fruit set rates are higher for long-styled flowers as compared to short-styled flowers in eggplant. However, Chadha & Saimbhi (1977) reported that, the fruiting habit in a cultivar is not directly related to the length of style in eggplant.

The work of Badea *et al.* (1996) and Ofosu-Budu (1984) revealed that the seed content of garden egg fruit varies with fruit size and it is higher in large fruits. However, there is no relation between the number of seeds per fruit and fruit length.

A distinct feature in garden egg germplasm in Ghana that usually goes unnoticed is the floral morphology and pattern.

While several studies have investigated the relationship between floral morphology and fruit set in eggplant, research in garden eggs is very limited. Therefore this study was carried out to ascertain the inflorescence type and the role of the position of the stigma in relation to anthers as well as the type of inflorescence in garden eggs on flower abortion, yield and yield components. The genetic variability identified among the accessions will serve as a guide in the selection of garden egg species for breeding purposes.

The specific objectives were to:

- a. assess variability in floral morphology and abortion between and within 12 garden egg accessions in Ghana.
- b. determine association between the stigma position and fruit set.
- c. determine association between the flower type and seed content and viability.

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 Botany of crop or flowering

Garden egg (*Solanum aethiopicum* Gilo group) possibly originated in tropical Africa as a result of the domestication of *Solanum anguivi* and *Solanum distichum*. It is believed to be cultivated abundantly and more intensively in West and East Africa (Norman, 1992; Grubben & Denton, 2004). It comprises four groups: Gilo, Shum, Kumba and Acculeatum (Lester & Niakan, 1986).

*Solanum aethiopicum* is a shrub that may either be an annual or perennial herb. It can grow up to about 200 cm tall, much-branched with a root system extending both vertically and laterally. The branches and leaves may at times have prickles and stallet hairs. The flowers are bisexual with regular (4-10) merous, 2-15 mm long pedicel, white but sometimes pale purple in colour (PROTA, 2004). The flowers are single or arranged in cluster of two or more flowers with the stigma protruding either above (long styled flower), on the same level (medium styled flower) or below (short styled flower) anther tips. The long and medium styled flowers are characterized by a well developed nodule, good pollen absorption capacity as well as a permissible tissue rich in polysaccharide, protein and other nutrient. The position of the stigma in relation to anther tips in long styled flowers favours cross pollination. The short styled flowers are characterized by a small, reduced gynoecium which is often infertile, a relatively small stigma with undeveloped papillae as well as a spatial separation of anther pores and a low sugar content which prevents pollen germination hence results in pollen drop (Passam & Bolmatis, 1997; Chen, 2001; Sekara & Bieniasz, 2008). Short styled flowers are however less exposed to sun, wind and rain and may remain receptive for long hours. Stamens are inserted near the base of the corolla tube and

alternate with corolla lobe filaments which are short and thick. Inflorescence is lateral, racemose cyme (5-12) flowers with peduncle often short or absent and the rachis short or too long. The fruit is a globose to depressed globose, ellipsoid, ovoid or fusiform berry (1-6) cm long, smooth to grooved, red or orange in colour (Handique & Sarma, 1995; Chen, 2001; Diggle & Miller, 2004; Lester & Seck, 2004; PROTA, 2004).

## **2.2 Growing conditions**

According to Lester & Seck (2004) *Solanum aethiopicum* Gilo Group grows well in sandy, loamy and heavy clay soils and requires fairly deep and well-drained soils with pH of about 5.5-6.8 and day and night temperatures of about 25°C–35°C and 20°C –27°C respectively.

## **2.3 Utilization**

The leaves, shoots and immature fruits of garden eggplant are used as cooked vegetables in stews and sometimes eaten raw. Garden egg fruit has a low content of Vitamin C but is valued locally for its high iron content (Macha, 2005; Gruère *et al.*, 2007). The vegetable plays an important role in traditional foods of Africa and has been reported to have the potential to improve the nutrition, boost food security, foster rural development and sustainable landcare.

According to Chinedu *et al.* (2011), garden egg is very important as a traditional folklore medicine which is used to treat certain ailments and is also beneficial to patients suffering from anemia because of its rich iron content. In addition, some parts of the crop are used as medicine for treating high blood pressure, uterine complaints and tetanus (Igwe *et al.*, 2003; Grubben & Denton, 2004; Lester & Seck, 2004; Hornal *et al.*, 2007; Okon *et al.*, 2010). Garden egg offered

as a gift is a sign of blessing and fruitfulness in many cultures in sub-Saharan African (Chinedu *et al.*, 2011).

## **2.4 Production and use in Ghana**

Garden egg is one of the most important vegetable crops produced by farmers in Ghana and represents the main source of income for many rural households in the forest zone of the country (Norman, 1992; Danquah-Jones, 2000; Owusu Ansah *et al.*, 2001; Grubben & Denton, 2004).

According to Asenso-Okyere *et al.* (2000) about 4,305 families are actively involved in the production of vegetable crops such as garden eggs in Ghana. Over 97% of total production of garden egg in Ghana occupies less than 1 ha of land. Sixty percent of this total produce is sold out at the market.

Annual production over the years has continued to decline in spite of several programme interventions by district officers of the Ministry of Food and Agriculture. Increasing cost of farm inputs and the low soil fertility have been cited as challenges. Crop production is largely rain-fed, and traditional technology of production continues to dominate the sector with peasant farmers using simple tools such as hoe and cutlass. The average land holding per farmer is relatively low and is about 0.5 ha (MLGRD, 2006).

The work of Daunay *et al.* (2001) on the production of garden egg revealed that it is grown as a commercial crop for domestic consumption and also for export. In 1997, approximately 750 metric tons of garden egg fruits were exported from Ghana and this constituted about 5% of the total production at that time (Danquah-Jones, 2000). However, according to Hernal *et al.* (2007)

a very small share of the total national production of garden egg fruits around 30,000 metric tonnes is exported to Europe.

In the Greater Accra, Volta and Brong-Ahafo Regions, garden egg yields and prices are both comparatively higher than in the other regions of Ghana with producers earning higher returns on their investments (Gruère *et al.*, 2007).

## **2.5 Harvesting and Yield**

In Ghana, fruits of garden egg are normally harvested before the first sign of ripening and the best prices are offered for larger fruits. Some cultivars may however be harvested when the colour of the fruit changes to orange. Blay (1991) reported however that in some other countries, small tender fruits are preferred. Fruits of garden eggs need to be harvested regularly and carefully using a knife, since the stems are hard, woody and quite brittle. The fruit colour of garden egg also serves as an indicator of its freshness. The study of Olympio and Schippers (1995), Lester & Seck (2004) and PROTA (2004) revealed that garden egg has a potential yield of about 225 tonnes/ha. A plant may produce about 500 g to 800 kg weight of fruits, depending on the cultivar and growing conditions. The preferred weight for fruits of the Gilo group ranges from about 30-40 g. Garden egg cultivated without irrigation may yield about 5-8 tonnes/ha while those cultivated under irrigation may yield about 12-20 tonnes/ha. Improved cultivars grown under favourable conditions may yield about 50-80 tonnes/ha.

According to Norman (1992) the local eggplant can give an average yield of about 35-40 fruits per plant weighing between 0.9-1 kg per plant with fruit size decreasing as fruit number increases. When fruits are left on the plant for a long period they change colour from pure white

to creamy white or pale yellow, becoming less palatable. Ripe fruits also have lower market value than “green” fruits; moreover, they also hamper the development of new fruits (Blay, 1991; Lester & Seck, 2004). There are many different sizes and shapes of garden egg. The shape of the fruit varies from elongated to round and fruits may have ridges or present a smooth appearance (Gisbert *et al.*, 2006; Osei *et al.*, 2010; Chinedu *et al.*, 2011).

## **2.6 Genetic variation in garden egg**

*Solanum aethiopicum* is a herbaceous shrub with hairy hermaphroditic flowers which are borne either in singles or in clusters. The crop can either be self or cross pollinated. The fruits colour ranges from light to dark green, white or blackish with taste varying from sweet to bitter depending on the saponin content of the cultivar. The fruit shape may be round or oval with smooth, grooved or ribbed surfaces (Cebula *et al.*, 2007). At full maturity, the fruits turn red or reddish-orange due to increasing carotene content.

### **2.6.1 Variation in agronomic traits**

Blay (1978) reported that, the agronomic attributes of garden egg like branching habit, time of flowering, time of fruit maturity and fruit yield vary broadly across cultivars. The fruit shape, immature fruit colour, fruit size, diameter of corolla, petiole length, leaf blade and taste also vary considerably. Some characteristics such as prickliness, hairiness, leaf colour and inflorescence structure have been attributed to simply inherited dominant genes, although only a few attributes of the plant have been investigated (Lester *et al.*, 1987).

### **2.6.2 Variations in qualitative variables**

Grubben & Denton (2004) reported that, domesticated and wild relatives of garden egg have important breeding traits that are yet to be explored. In the field, garden egg shows a higher drought and heat tolerance than tomato and conventional eggplant.

Susceptibility of garden eggs to pest and disease is low. Taste is also an important quality attribute sought after by consumers and quite often is related to the shape. Garden egg can have blunt, sweet or bitter taste, with round types tending to be more bitter than elongated types. Although this is a genotype-specific characteristic, certain agricultural practices have been reported to influence the taste of the fruits. Often cultivars that are green when immature tend to be bitter at harvest.

Garden egg germplasm in Ghana expresses a considerable amount of diversity but little research has been done to evaluate the factors that determine and affect this diversity. No real strategy has been put in place to conserve the diversity of garden egg (Grubben & Denton, 2004; Daunay *et al.*, 2006).

### **2.7 Relationship between floral morphology and fruit set**

Genotype and environmental factors influence the course of flowering and the flower morphology, especially the style length which determines the effectiveness of fruit setting. Eggplant is a partly self-incompatible species which needs cross-fertilization for greater fruit set (Amoako & Yeboah-Gyan, 1991). Swarup (1995) observed that in hot humid climate, cross-pollination up to 20% may occur due mainly to heterostyly. The amount of cross pollination in eggplant is estimated between 0 and 46%, but cross pollination at distances of 50 m or more does

not occur. The flower remains open for 2-5 days without closing at night and anthesis and pollen release occur in the mornings. These are however influenced by environmental factors such as the day length, temperature, and relative humidity. Pollen viability is retained for 8-10 days at a temperature of 20°C -22°C with a relative humidity of 50%-55% (Chen, 2001).

Nagasawa *et al.* (2001) reported that in eggplant, fertilization is completed within 3 days after pollination. Gene expression occurs within 3 days after anthesis and it is induced by stimuli of both pollen tube elongation and fertilization. In addition, they observed that ovaries of unpollinated flowers began to senesce 3 days after anthesis, although half of them had the potential to set fruit.

The variation in style length and its position with regards to the stamen has been widely evaluated in eggplant. Long styled flowers where the stigma may be above the stamen or may be on the same level as the stamen often occur in higher numbers than short-styled flowers in which the stigma is below the stamen. Sometimes a flower with the stigma at the same level as the stamen is defined as medium styled (Passam & Bolamti, 1997; Nagasawa *et al.*, 2001).

Krishnamurthi & Subramaniam (1954) have described four types of flowers in eggplant: (a) long styled with large ovary, (b) medium styled with medium ovary, (c) pseudo short styled with rudimentary ovary, and (d) true-short-styled with very rudimentary ovary. Pseudo and short styled flowers fail to set fruits whereas long and medium styled flowers produce fruits. Studies by Chen (2001) revealed that fruit set rates are higher for long styled flowers compared with short styled flowers as in long styled flowers, the stigma may project beyond the anthers and this favoured cross-pollination.

Several other studies done on fruit set in relation to stigma position have also showed that fruit set is high where the stigma is above or on the same level with anther tips while short styled stigmas do not set fruits at all (Passam & Bolamtis, 1997).

According to Popova (1961) and Mohideen *et al.* (1977) the percentage fruit set is high in long styled flowers. However, Chadha & Saimbhi (1977) reported that fruiting habit in a cultivar is not directly related to the stigma position in relation to the anther tips or style length.

Nothmann *et al.* (1983) also reported that stylar heteromorphism affected fruit set more than the position of the flower in the cluster of eggplant. Passam & Bolmatis (1997) added that the proximity of the stigma to the anther pores at anthesis influences fruit set, fruit size and seed content, but not seed quality of eggplant. They reported that fruit weight and seed formation were maximal in flowers with the stigma at maturity situated close to the anther pores (stigma above anther tips).

According to Sekara & Bieniasz (2008), pollination efficiency was greatest for long and medium styled flowers in a range of 38.8% - 50.8% while pollination efficiency for the short styled flowers ranged only between 17.3% - 30.2%. They further stated that, during fruit set, the efficiency of the long and medium styled flowers were much higher as compared to the short styled ones. However, in the subsequent planting, significant differences in fruit setting between the investigated types of flowers were not observed.

According to Kowalska (2003), eggplant produces a high number of flowers with a long pistil than with medium and short pistils. The production of short styled flowers with small and highly reduced gynoecium, often infertile may account for functional andromonoecy (the production of staminate and hermaphroditic flowers) which is widespread in the genus *Solanum* (Solomon, 1986; Diggle & Miller, 2004).

The study of Rylski *et al.* (1984) in eggplant revealed that pistils with a style length of less than 0.5 cm tend to be smaller than medium or long styled ones and carry relatively small stigmas with undeveloped papillae and a low sugar content that prevented pollen germination thereby resulting in pollen drop. Passam & Bolamtis (1997) found that in eggplant, flowers of style length < 0.5 cm had significantly smaller ovaries which failed to set fruits.

Sekara & Bieniasz (2008) however reported that self-pollination is prevented in short styled flowers because of the spatial separation of terminal pores with the stigma turned downward hence pollination facilitated mainly by insects will result in setting fruits.

## **2.8 Seed number and quality as affected by flower structure**

Stigma position is a key aspect of flower morphology that may influence pollination success and seed production. Identification of the functional and adaptive significance of variation in flower morphology is fundamental to our understanding of the processes that shape patterns of seed quality (Campbell, 1991; Johnston, 1991; Schemske & Agren, 1995; Galen & Cuba, 2001; Aigner, 2004).

The position of the stigma within the flower is a key aspect of flower morphology, which influences the efficiency of pollen transfer (Campbell *et al.*, 1996; Cresswell, 2000; Nishihiro *et al.*, 2000) and the likelihood of within flower self-pollination (Karron *et al.*, 1997; Motten & Stone, 2000; Elle & Hare, 2002; Medrano *et al.*, 2005).

Cesaro *et al.* (2004) reported that less is known about the association between stigma position and duration of stigma receptivity and pollen–pistil interactions. However, a stigma concealed

inside a corolla tube is less exposed to sun, wind, and rain and may therefore remain receptive for longer than a stigma protruding out of the corolla.

Sekara & Bieniasz (2008) reported that fruits set from the long and medium styled flowers in eggplant contained a comparably high number of seeds (371 seeds per fruit) while fruits set from the short-styled flowers contained about 50% less seed (179 seeds per fruit) on the average.

## **2.9 Seed Quality**

Seed quality is regarded as the degree or standard of excellence in certain characters or attributes that will determine the performance of the seed when sown or stored. In practice, the expression “seed quality” is used loosely to reflect the overall value of seed for its intended purpose; the performance of seed must measure up to the expectations of the end user of that seed (Hampton, 2002).

Seed lot is said to be of a high quality if it possess high genetic purity and high germination percentage and a minimum of inert, weed and other crop seeds and is free from diseases (Copeland & McDonald, 1995; Guberac *et al.*, 2003; Heatherly & Elmore, 2004; Šimic *et al.*, 2004).

According to Copeland & McDonald (1995) if a seed lot meets the certification standard, it is said to be a good quality seed and if it does not meet the certification standards, it is obviously of a lower seed quality. Thus seed quality encompasses several factors including seed health, varietal and physical purity, germination, vigour and size or weight. Seed processing is done to

ensure the highest seed quality as in physiological maturity stage before storage (Agrawal, 1996).

### **2.9.1 Seed purity and viability**

The purity of a seed lot is related to its genetic and physical qualities. Genetic purity of seeds refers to the trueness to type while physical purity refers to the physical composition of the seed (Anon. 2009). The pure seed component of a seed lot together with the seed germination capacity is used to determine the planting value of the seed (Rindels, 1995).

The viability of a seed is the seed's capability to germinate and develop or produce a new plant (Rindels, 1995). Seed viability and vigor directly affect the performance of seeds planted to regenerate the crop in terms of total emergence and rate of emergence (Tekrony & Egli, 1991).

Much of seed viability depends upon storage condition. The storage material used and the ensuing storage conditions applied to seeds could reduce viability or kill the seed. Also several other environmental factors affect seed viability during storage; the amount of moisture in the seed is one of the most important factors. The effect of weather in terms of fluctuating temperature during seed formation and maturity, pre-harvest rain and the activity of micro flora all lead to damage resulting in loss of viability. This is because the activity of all these organisms is controlled by relative humidity, temperature and moisture content of the seed during seed storage. Treating seeds or seed storage materials with fungicides can help prolong the storage period (Rindels, 1995; Anon. 2008).

### **2.9.2 Seed vigour**

Byrum & Copeland (1995) defined seed vigour as the sum of those properties that determine the activity and performance of seed lots of acceptable germination in a wide range of environments. According to ISTA (2007), seed vigour is the sum of those properties of the seed that determine the potential level of activity and performance of the seed or seed lot during germination and seedling emergence.

Delouche (1974) indicated that seed vigour is a concept describing several characteristics associated with rate and uniformity of seed germination and emergence as well as seedling growth. He further stated that a vigorous seed lot is one that has the potential to perform well even under environmental conditions which are not optimal for the species.

The importance of a seed vigour test is to provide information about the planting value of seed lots in a wide range of environments and also on the storage potential of the seed (ISTA, 2007). Seeds with low vigour will show stunted growth and abnormalities in the developing shoot and root system and subsequently affect crop establishment (Caddick, 2007).

### **2.9.3. Seed germination**

AOSA (1999) defines seed germination as the emergence and development from the seed embryo of those essential structures which for the kind of seed in question are indicative of the ability to produce a normal plant under favourable conditions. Seed germination could also be referred to as the ability of a seed to give rise to normal seedlings under normal growing conditions (McDonald, 1980).

The standard germination test is designed to provide a first and a final count. The purpose of the first count is basically to determine the strong seedlings (vigour) that have germinated and the final count is to provide a sufficient period for weak seeds to germinate. Therefore, the germination percentage is the sum of strong and weak seedlings and is the most important function of a seed as it is an indicator of its viability and growth (Byrum & Copeland, 1995).

#### **2.9.4. Seed health**

Mathur & Kongsdal (2003) explained seed health as the presence or absence of disease-causing organisms such as fungi, nematodes, bacteria, viruses and insects in a seed lot. Seed health status is affected by the presence of non disease-causing contaminants in the particular seed lot. These contaminants include weed seeds that compete with the target seed for nutrients, other seeds, plant parts other than the target seeds, soil particles and insect eggs that can degrade the quality of the seed lot (Mew & Gonzales, 2002).

## CHAPTER THREE

### 3.0 MATERIALS AND METHODS

#### **3.1 Experiment 1: Assessment of floral morphology and flower abortion in 12 garden egg accessions.**

##### **3.1.1 Experimental site**

The experiment was conducted at the University of Ghana Farm, Legon between June 2012 and November 2012. The soil type on the farm is classified as the Adenta series, a savannah Acrisol (FAO/UNESCO, 1999). According to USDA classification the soil is 150 cm deep, moderately well-drained and occurring on the middle slope of Legon hill where it is gentle to medium (2% - 3%).

The soil profile consist of about 23 cm dark brown to reddish brown sandy clay loam topsoil slightly sticky with a weak, fine granular structure with few to common fine, medium root distribution and below this is about 17 cm thick yellowish red sandy clay containing few fine roots and few fine quartz and ironstone concretions (Brammer, 1967).

##### **3.1.2 Climatic condition during the experimental period**

During the experimental period, minimum and maximum temperatures ranged from 23.1-24.6°C and 28.8-32.4°C, rainfall distribution ranged between 173.2-1115 mm while relative humidity ranged between 69-89%.

**Table 1: Mean monthly temperature (°C), rainfall (mm) and relative humidity (%).**

Month	Temperature (°C)		Rainfall (mm)	Relative humidity (%)	
	Minimum	Maximum		Minimum	Maximum
June	23.7	30.3	173.2	78	89
July	23.1	28.8	20.9	68	86
August	22.4	28.2	11.5	67	86
September	23.2	30.0	42.5	67	86
October	23.8	31.2	88.3	67	89
November	24.6	32.4	14.0	63	88

**Source: Ghana Meteorological Agency, Mompasem, Legon, 2012.**

### 3.1.3 Experimental treatments

Twelve accessions of garden eggs were used for the study. Seeds were obtained from the Department of Crop Science of the College of Agriculture and Consumer Sciences, University of Ghana, Legon. The accessions used were; ACC1R1P2, ACC4R1P2, ACC5R2P2, ACC6R1P3, ACC8R2P3, GH4156A, GH4921B, GH4927B, GH4993B, GH4993C, GH4993F, LEGON 1.

### 3.1.4 Nursery practices

Seed trays were filled with well decomposed substrate comprising saw dust, rice husk and cow dung in the ratio 2:2:1 by volume. The seeds were covered lightly with soil and watered. Seeds of the twelve garden egg accessions were sown orderly by placing three seeds in each cell of the seed trays and labelled. Seedlings were thinned out to two in each cell a week after emergence.

A compound fertilizer N.P.K (20-20-20) was applied at the rate of 3.3 g/l of water to the seedlings once a week to promote vigorous growth in the nursery.

“Cabendazim” containing bendazium (50WP) was applied at 20 g/15l of water to control fungal diseases. Seedlings were watered and control of weeds was done regularly. Seedlings were transplanted to the field four weeks after emergence.

### **3.1.5 Field establishment and experimental design**

The experimental field was ploughed, harrowed, lined and pegged prior to transplanting. A Randomized Complete Block Design (RCBD) was used. Each accession was represented by two rows of seven plants with three replications. Rows were spaced 80 cm apart and plants within rows were spaced 80 cm apart. Records were taken on the five middle plants for each treatment row per replicate.

### **3.1.6 Cultural practices**

A starter solution, 100 ml of compound fertilizer N.P.K (15-15-15) was applied to each plant four days after transplanting to harden the seedlings. A compound fertilizer N.P.K (15-15-15) was applied at a rate of 250 kg/ha two weeks after transplanting to each plant by side placement. At the eighth week, sulphate of ammonia was applied at a rate of 125 kg/ha at fruit set. Watering was done twice a day and control of weeds was done regularly.

Pests were controlled by alternating the application of two different insecticides namely “Levo” a botanical insecticide containing prosuler oxamatrine 2.4SL applied at a rate of 5 ml/15l of water and “Cydim Super” containing cypermethrin and dimethoate applied at 35 ml/15l of water

as and when necessary. Harvesting was done with a sharp knife when fruits reached physiological maturity.

### **3.1.7 Data collection**

Data collection was grouped into vegetative, reproductive and yield characteristics. Five record plants per each accession were used;

#### **3.1.7.1 Vegetative characteristics:**

- *Plant height (cm) at 2 weekly intervals*

The height of each record plant was taken from the stem at soil level to the growing tip of the shoot using a meter rule.

- *Number of leaves per plant at 2 weekly intervals*

The total number of leaves per plant was counted separately for each record plant and averaged.

- *Canopy diameter (cm) at maturity*

The diameter of the canopy at maturity of record plants for each treatment was measured using a meter rule.

- *Number of primary branches per plant at maturity*

The number of primary branches on record plants was counted at plant maturity.

#### **3.1.7.2 Reproductive characteristics**

Data recording commenced when 50% of plants reached the stage of flowering for each of the accessions.

- *Days to flowering*

Days to flowering from seedling emergence to time of first flower opening.

- ***Type of inflorescence***

The type of inflorescence of each record plant was observed with the naked eye and data recorded as follows: single, cluster or mixed type of inflorescence.

- ***Stigma position in relation to anther tips at full anthesis (below/same level/above)***

The magnifying lens was used to identify the position of stigma in relation to anther tips at the time of flower opening and data recorded as follows: long, medium or short styled flowers.

- ***Number of flower(s) per inflorescence***

The number of flowers per inflorescence per plant counted over the experimental period.

- ***Number of flowers dropped***

The number of flowers shed from each plant at the end of the experimental period.

- ***Number of flowers that developed into matured fruits***

The number of tagged flowers that developed into matured fruit per plant at the end of the experimental period.

### **3.1.7.3 Yield characteristics**

- ***Days to fruit formation***

Days to fruit formation covered the period from seedling emergence to time of first fruit formation.

- ***Days to first harvest***

Days to first fruit covering the period of harvest from seedling emergence to time of first fruit harvest.

- ***Number of days to maturity***

Days from seedling emergence to time of formation of the first physiologically mature fruit.

- ***Number of fruits per plant***

The total number of mature fruits per plant was counted at each harvest and the mean computed.

- ***Fruit weight (g)***

The total number of fruits per plot per harvest was weighed and the mean computed.

- ***Fruit length (cm)***

The lengths of five mature fruits per record plant were measured from the base of the fruit stalk to the apex of the fruits using vernier caliper and the mean calculated.

- ***Fruit diameter (cm)***

The diameters of five mature fruits per record plant were measured at the middle portion of the fruits using vernier caliper and the mean calculated.

- ***Fruit yield per plant (g)***

Sum of mature fruits per plant at each harvest beginning from first harvest to the last harvest was computed to obtain the total yield per plant.

- ***Fruit yield (ton/ha)***

$$\text{Yield (tonne/ha)} = \frac{\text{Area of a hectare} \times \text{yield per plot}}{\text{Area of plot} \times 1000}$$

### **3.1.8 Data analysis**

Data collected were subjected to analysis of variance (ANOVA) using Genstat 15<sup>th</sup> edition. Means were separated using Least Significant Difference (LSD) where significant differences existed. Data transformation prior to statistical analysis was done where necessary using log/square root/arc sine transformation.

### 3.2 Experiment 2: Assessment of floral morphology in relation to fruit set for garden egg accessions with mixed type inflorescence.

#### 3.2.1 Experimental site

The experiment was conducted at the University of Ghana Farm, Legon between November 2012 and May 2013.

#### 3.2.2 Climatic condition during the experimental period

During the experimental period, minimum and maximum temperatures ranged from 5.7 and 25.4°C and 32.2-34.8°C, rainfall distribution ranged between 19.2 and 63.5 mm while relative humidity ranged between 88 and 92%.

**Table 2: Mean monthly temperature (°C), rainfall (mm) and relative humidity (%).**

Month	Temperature (o C)		Rainfall (mm)	Relative humidity	
	Minimum	Maximum		Minimum	Maximum
December	24.5	32.2	63.5	88	94
January	24.2	33.9	-	89	89
February	25.4	33.5	-	92	92
March	5.7	34.3	19.2	91	91
April	25.0	33.8	58.5	88	88

**Source: Ghana Meteorological Agency, Mompasem, Legon, 2012/2013.**

### **3.2.3 Experimental treatments**

Accessions of mixed type inflorescence with same number of flowers per inflorescence relating to the different types of stigma position in relation to anther tips from Experiment 1 were selected. These accessions were; ACC1R1P2 (Short styled flower), ACC8R2P3 (Long/Medium styled flower), GH4993C (Long styled flower) were used for Experiment 2.

### **3.2.4 Nursery practices**

The nursery practices carried out were same as described in section 3.1.4 of Experiment 1.

### **3.2.5 Field and experimental design**

Field preparation was done as described in Section 3.1.5. For each accession in this experiment, there were 2 rows of five plants with 4 replications.

### **3.2.6 Cultural practices**

The cultural practices undertaken in this experiment were same as described in Section 3.1.6 of Experiment 1.

### **3.2.7 Data collection**

Data collection was same as described in Section 3.1.7 of Experiment 1. The proportion of stigma position in relation to anther tips (P) was recorded in addition. This was calculated using the formula below:

$$P = \frac{\text{Number of 'n' styled flowers per plant}}{\text{Total number of flowers per plant}} \times 100$$

Where 'n' is either: short, medium or long styled-flower.

### **3.2.8 Data analysis**

Data collected were subjected to analysis of variance (ANOVA) using Genstat 15<sup>th</sup> edition. Means were separated using Least Significant Difference (LSD) where significant differences existed. Data transformation prior to statistical analysis was done where necessary using log/square root/arc sine transformation.

### **3.3 Experiment 3: Assessment of seed content and viability among garden egg accessions.**

The study was carried out at the Physiology laboratory, Crop Science Department of the College of Agriculture and Consumer Science, University of Ghana, Legon. Garden egg seeds extracted from the accessions in both Experiment 1 and 2 were used. Each treatment was replicated three times for both Experiment 1 and 2. A Completely Randomized Design (CRD) was used.

#### **3.3.1 Seed extraction and drying**

Five ripened fruits harvested from each record plant were used for the study. Fruits were allowed to ripen fully to ensure complete seed development and maturity. The harvested fruits were stored for four days after harvest until they became soft ensuring full maturity. Seeds were extracted by crushing fruits gently to avoid destruction of seeds and squeezed by hand to get fruit pulp mass which was collected in plastic containers. The separated seeds settling at the base of the mix were collected manually from the fermenting pulp mass by decanting the liquid. After extraction, seeds were washed thoroughly with clean water to remove the mucilaginous pulp materials. More water was added to the container having pulp and seed mass. It was stirred thoroughly and drained out to separate out seed from pulp mass. The process was repeated until

cleaned seeds were obtained. After washing, the seeds were sun dried until constant dry weight was obtained.

### **3.3.2. Preparation of tetrazolium (TTC) staining solution**

The recommended tetrazolium derivative, 2, 3, 5 triphenyl tetrazolium chloride powder was obtained from Crop Science Department, University of Ghana, Legon and made into solution for further tests.

A 0.1% tetrazolium staining solution was prepared by weighing 0.1 gram of 2, 3, 5 triphenyl tetrazolium chloride using the electronic scale. The 0.1 gram of tetrazolium powder was dissolved in a small quantity of distilled water in a beaker and then transferred into a 100 ml conical flask. Distilled water was then added to the solution in the 100 ml conical flask to make it up to the 100 ml mark. The prepared TTC solution was stored in a brown coloured bottle and kept in a cool dark place to prevent deterioration from light.

### **3.3.3 Viability test of garden egg seeds**

Tetrazolium chloride test is a biochemical test which differentiates live tissues from dead tissues of seed embryos on the basis of dehydrogenase enzyme activity (respiration enzymes). Upon seed hydration, the activity of dehydrogenase enzymes increases, resulting in the release of hydrogen ions which reduce the colourless tetrazolium salt solution (2, 3, 5-triphenyltetrazolium chloride) into a chemical red compound called formazan. Formazan stains living cells with a red colour while dead cells remain colourless. The viability of seeds is interpreted according to the staining pattern of the embryo and the intensity of the colouration (Patil *et al.*, 2009).

Garden egg seeds were placed on moistened filter paper in petri dishes for several hours; this was to allow seeds imbibe water. The imbibed seeds were then cut deeply with a razor blade to expose the embryo to the staining solution. Prepared 100 seeds of each garden egg accession were introduced into petri dishes lined with filter paper and then few drops of TTC staining solution was applied onto the filter paper to cover the seeds. Viable seeds stained red while non viable seeds were not stained.

### **3.3.4 Data collection**

#### **3.3.4.1 Seed characteristics**

- *Number of seed per fruit*

Seeds from the first five fruits per record plant were extracted, counted and the mean calculated

- *Seed colour per fruit*

Seed lots were prepared taking into consideration seed coat colors of fresh seeds with the naked eye. Seed samples of prepared seed lots (1 – brown, 2 – light brown, 3 – dark yellow, and 4 – light yellow) were given.

- *100 seed weight (g)*

Hundred seeds were counted per fruit and weighed using the electronic balance.

- *Number of damaged seeds per fruit*

The number of damaged seeds of record fruits was record.

- *Number of whole seeds per fruit*

The number of whole seeds of record fruits was recorded.

- *Percentage damaged seeds per fruit*

$$= \frac{\text{Number of damaged seeds per fruit}}{\text{Number of seeds per fruit}} \times 100$$

- *Germination percentage*

The number of viable seeds were counted and expressed as percentage.

$$= \frac{\text{Viable seeds}}{\text{Total number of seeds/petri dish}} \times 100$$

### **3.3.5 Data analysis**

Data collected were subjected to analysis of variance (ANOVA) using Genstat 15<sup>th</sup> edition. Means were separated using Least Significant Difference (LSD) where significant differences existed. Data transformation prior to statistical analysis was done where necessary using log/square root/arc sine transformation.

## CHAPTER FOUR

### 4.0 RESULTS

#### **4.1 Experiment 1: Assessment of floral morphology and flower abortion in 12 garden egg accessions.**

##### **4.1.1 Vegetative characteristics of garden egg accessions**

There were no significant differences in plant height at 2 and 4 WAT among the garden egg accessions. Plant height ranged from 6.4 cm (GH4993B) to 9.6 cm (ACC8R2P3) at 2WAT while at 4 WAT plant height ranged from 17.7 cm (GH4993B) to 24.5 cm (GH4927B). At 6WAT however, there were significant ( $p<0.05$ ) differences in plant height among the garden egg accessions with accession GH4927B increasing significantly in plant height (Table 3). There was a significant ( $p<0.05$ ) difference in the number of leaves per plant at 2 WAT among accessions, with accession GH4993C recording the highest number of leaves per plant. By 4 WAT differences in the number of leaves per plant were no longer significant. However at 6 WAT, significant ( $p<0.05$ ) differences in the number of leaves per plant among the accessions were observed again. Accession ACC5R2P2 produced the highest number of leaves per plant and this differed significantly from all the other accessions. The least number of leaves per plant was observed for accession GH4927B (Table 4).

**Table 3: Plant height of twelve garden egg accessions at two weekly intervals**

Accession	2 WAT*	4WAT	6 WAT
ACC4R1P2	7.2	21.4	32.5
GH4156A	7.0	20.9	33.5
GH4927B	8.2	24.5	46.8
LEGON 1	7.1	21.7	33.7
ACC5R2P2	6.6	22.3	31.4
GH4921B	7.2	21.3	32.4
GH4993B	6.4	17.7	25.8
GH4993F	8.0	17.8	29.3
ACC1R1P2	7.8	20.9	33.9
ACC6R1P3	8.7	18.8	31.1
ACC8R2P3	9.6	22.9	35.3
GH4993C	9.3	23.9	38.1
LSD (p<0.05)	NS*	NS	6.41

**WAT\*:** Weeks after transplanting

**NS\*:** Not significant

**Table 4: Number of leaves of twelve garden egg accessions at two weekly intervals**

Accession	2 WAT	4WAT	6 WAT
ACC4R1P2	6	24	65
GH4156A	7	26	64
GH4927B	6	24	48
LEGON 1	5.	26	64
ACC5R2P2	8	37	87
GH4921B	8	29	64
GH4993B	6	26	62
GH4993F	6	26	62
ACC1R1P2	8	27	74
ACC6R1P3	8	26	66
ACC8R2P3	8	32	73
GH4993C	9	31	69
LSD (p<0.05)	2	NS	17

Primary branches and canopy size (cm) ranged from 5 branches for accession ACC1R1P2 to 8 branches for accessions GH4156A, GH4993B, ACC6R1P3 and canopy size of 83.6 cm for accession ACC6R1P3 to 103.7 cm for accession ACC4R1P2. There were significant ( $p < 0.05$ ) differences in the number of primary branches and canopy size among garden egg accessions (Table 5)

**Table 5: Number of primary branches and mean canopy size of twelve garden egg accessions**

Accession	Primary branches	Canopy size (cm)
ACC4R1P2	6	103.7
GH4156A	8	84.4
GH4927B	7	87.1
LEGON 1	7	88.1
ACC5R2P2	7	87.6
GH4921B	6	94.3
GH4993B	8	91.7
GH4993F	7	84.9
ACC1R1P2	5	93.9
ACC6R1P3	8	83.6
ACC8R2P3	7	91.1
GH4993C	7	90.5
LSD ( $p < 0.05$ )	1	8.45

#### **4.1.2 Variation in floral characteristics of garden egg accessions**

Accessions ACC4R1P2, GH4156A, GH4927B and LEGON 1 produced a single type of inflorescence, representing 33.3% of the inflorescence types studied. The rest of the accessions produced clusters or mixed type of inflorescence (Table 6). Four accessions produced single flowers only while the rest had only clusters or both clusters and single flowers together on plants. There were no variability in stigma position in relation to anther tip within the accessions except for the following two accessions, GH4921B and ACC8R2P3. For these the stigma position in relation to anther tip was either long styled, short styled or medium styled (Appendix 1). Accessions were therefore grouped into three based on the type of inflorescence, that is single, cluster or mixed (Table 6).

**Table 6: Type of inflorescence, number of flower (s) per inflorescence, stigma position in relation to anther tips in twelve garden egg accessions**

<b>Accession</b>	<b>* Type of inflorescence</b>	<b>Number of flower(s) per inflorescence</b>	<b>Stigma position in relation to anther tips</b>
ACC4R1P2	Single	1	Long styled flower
GH4156A	Single	1	Long styled flower
GH4927B	Single	1	Long styled flower
LEGON 1	Single	1	Long styled flower
ACC5R2P2	Cluster	≥ 5	Long styled flower
GH4921B	Cluster	2 – 4	Long styled/Short styled flower
GH4993B	Cluster	≥ 5	Long styled flower
GH4993F	Cluster	2 – 3	Long styled flower
ACC1R1P2	Mixed	1 – 2	Short styled flower
ACC6R1P3	Mixed	1-3	Long styled flower
ACC8R2P3	Mixed	1 – 2	Long styled/Medium styled flower
GH4993C	Mixed	1 – 2	Long styled flower

**\*Mixed:** Cluster and Single inflorescence      **Long styled flower:** Stigma is above anther tips

**Medium styled flower:** Stigma and anther positions are at the same level

**Short styled flower:** Stigma is below anther tips

There were no significant differences in the average number of flowers per plant among garden egg accessions (Table 7), with accessions ACC4R1P2 and GH4927B recording 13 flowers per plant and GH4156A and LEGON 1 producing 12 flowers per plant. The average number of flowers aborted per plant ranged from 1 flower for accessions GH4927B and LEGON 1 to 3 flowers for accession GH4156A. More flowers were observed to have aborted in accession GH4156A, which subsequently resulted in low number of flowers developing into fruits per plant in that accession. The differences in the average number of flowers aborted per plant as well as average flowers developed into fruits per plant were statistically significant ( $p < 0.05$ ) (Table 7).

**Table 7: Total number of flowers, number of flowers aborted and number of flowers developed into fruits per plant for single flowers.**

<b>Accession</b>	<b>Number of flowers plant<sup>-1</sup></b>	<b>Number of flowers aborted plant<sup>-1</sup></b>	<b>Number of flowers developed into fruits plant<sup>-1</sup></b>
ACC4R1P2	13	2	11
GH4156A	12	3	9
GH4927B	13	1	12
LEGON 1	12	1	11
LSD ( $p < 0.05$ )	NS	1	1

There were significant ( $p < 0.05$ ) differences in the average number of flowers per plant, the average number of flowers aborted per plant and the average number of flowers developed into fruits among garden egg accessions (Table 8). Accessions ACC5R1P2 and GH4993B recorded the highest number of flowers per plant. Average number of flowers per plant ranged from 11 for accession GH4921B and GH4993F to 12 for accession ACC5R2P2 and GH4993B. Accession ACC5R2P2 recorded the least number of flowers aborted per plant (3 flowers) and also recorded the highest number of flowers developing fruits per plant (9 fruits) while accession GH4921B recorded the highest number of flowers aborted per plant (9 flowers) and also recorded the least number of flowers developed into fruits per plant (3 fruits).

**Table 8: Total number of flowers, number of flowers aborted and number of flowers developed into fruits per plant for clustered flowers.**

Accession	Number of flowers plant <sup>-1</sup>	Number of flowers aborted plant <sup>-1</sup>	Number of flowers developed into fruits plant <sup>-1</sup>
ACC5R2P2	12	3	9
GH4921B	11	7	4
GH4993B	12	9	3
GH4993F	11	7	4
LSD ( $p < 0.05$ )	1	3	2

Significant ( $p < 0.05$ ) differences were observed in the number of flowers produced per plant among garden egg accessions (Table 9). Accession ACC8R2P3 recorded the highest number of flowers produced per plant (9 flowers) while accession ACC6R1P3 recorded the lowest number of flowers produced per plant (5 flowers). Flower drop among accessions was not significantly different (Table 9). However, significant ( $p < 0.05$ ) differences were observed in the number of flowers developing into fruits per plant among the accessions. This was attributed either to the differences in number of flowers produced per plant or was genetically inherent. The number of flowers developing fruits per plant ranged from four fruits for accession ACC6R1P2 to eight fruits for accession ACC8R2P3.

**Table 9: Total number of flowers, number of flower aborted and number of flowers developed into fruits per plant for mixed flowers.**

Accession	Number of flowers plant <sup>-1</sup>	Number of flowers aborted plant <sup>-1</sup>	Number of flowers developed into fruits plant <sup>-1</sup>
ACC1R1P2	7	1	6
ACC6R1P3	5	1	4
ACC8R2P3	9	1	8
GH4993C	8	1	7
LSD ( $p < 0.05$ )	3	NS	4

Days to 50% flowering ranged from 67 days to 71 days among the accessions (Table 10). There were significant ( $p < 0.05$ ) differences in days to flowering, days to fruit set and days to first harvest (Table 10). Accessions ACC4R1P2, LEGON 1 and ACC5R2P2 flowered significantly earlier (67 days) than accessions GH4927B, GH4921, GH4993B, and ACC6R1P3 (71 days). Days to fruit set and days to first harvest ranged from 81 days (Accessions ACC4R1P2, LEGON 1 and ACC5R2P2), 86 days (Accession ACC6R1P3), 100 days (LEGON 1) to 105 days (Accessions GH4993B and ACC6R1P3) (Table 10). Accessions which flowered early also set fruits early and were also harvested early compared to those that came later. Thus significant ( $p < 0.05$ ) differences in the number of days to fruit set among accessions were observed. However, in spite of a significant ( $p < 0.05$ ) difference in the number of days to fruit set between accession GH4993B (85 days) and ACC6R1P3 (86 days) the number of days to first fruit harvest recorded no significant differences.

**Table 10: Number of days to flowering, days to fruit set and days to first harvest of twelve garden egg accessions.**

<b>Accession</b>	<b>Days to flowering</b>	<b>Days to fruit set</b>	<b>Days to first harvest</b>
ACC4R1P2	67	81	101
GH4156A	69	83	103
GH4927B	71	85	104
LEGON 1	67	81	100
ACC5R2P2	67	81	101
GH4921B	71	85	104
GH4993B	71	85	105
GH4993F	69	83	102
ACC1R1P2	69	83	103
ACC6R1P3	71	86	105
ACC8R2P3	69	82	102
GH4993C	69	83	103
LSD (p<0.05)	1	1	2

#### 4.1.3 Yield characteristics of garden egg accessions

There were significance ( $p < 0.05$ ) differences among garden egg accessions for fruit yield and yield components. Fruit size measurement comprised fruit weight, fruit length and fruit diameter. Accession ACC5R2P2 had the highest number of fruits (92) with Accession ACC8R2P3 recording the least (16) (Table 11). There was a significant ( $p < 0.05$ ) difference in the number of fruits per plant among accessions but accessions GH4993C, GH4156A, GH4927B, GH4921B and ACC1R1P2 did not differ significantly from each other with regards to fruit number per plant. Fruit yield per plant (g) and fruit yield (tonne/ha) showed no statistically significant differences (Table 11) among the accessions. Fruit weight, fruit length and fruit diameter differed significantly ( $p < 0.05$ ) among the accessions (Table 12). Fruit weight per plant ranged from 6.9 g for accession ACC5R2P2 to 64.6 g for LEGON 1. Fruit length and fruit diameter ranged from 2.15-6.51cm, with Accession GH4921B recording the highest fruit length (Table 12).

**Table 11: Mean number of fruits, fruit yield plant<sup>-1</sup> and fruit yield hectare<sup>-1</sup> of garden egg accessions**

Accession	Number of fruits plant <sup>-1</sup>	Fruit yield plant <sup>-1</sup>	Fruit yield hectare <sup>-1</sup>
ACC4R1P2	25	826.0	19.3
GH4156A	24	808.0	18.9
GH4927B	23	1174.0	27.5
LEGON 1	27	1326.0	31.0
ACC5R2P2	92	1455.0	34.0
GH4921B	24	752.0	17.6
GH4993B	25	858.0	20.1
GH4993F	20	651.0	15.2
ACC1R1P2	24	683.0	16.0
ACC6R1P3	20	748.0	17.5
ACC8R2P3	16	447.0	10.5
GH4993C	24	645.0	15.1
LSD (p<0.05)	2	287.50	6.72

**Table 12: Mean fruit length (cm), fruit diameter (cm) and fruit weight (g) of garden egg accessions**

<b>Accession</b>	<b>Fruit weight (g)</b>	<b>Fruit length (cm)</b>	<b>Fruit diameter (cm)</b>
ACC4R1P2	40.2	6.2	4.2
GH4156A	36.7	3.8	6.1
GH4927B	58.4	4.6	4.7
LEGON 1	64.6	5.6	5.2
ACC5R2P2	6.9	2.2	2.3
GH4921B	35.4	6.5	5.4
GH4993B	30.1	5.4	4.0
GH4993F	42.9	3.9	5.3
ACC1R1P2	45.6	3.6	5.5
ACC6R1P3	39.2	6.1	5.7
ACC8R2P3	22.3	2.9	4.1
GH4993C	42.9	5.4	5.3
LSD (p<0.05)	1.42	0.23	1.27

#### 4.1.4 Variation in fruit characteristics

Fruit shape was variable with 41.7% of the fruits being longer than broad, 33.3% of the fruits being as long as broad and 25% of the fruits being broader than long. 50% of the fruits were smooth, 16.7% of the fruits were slightly grooved and 33.3% of the fruits were grooved (Table 13). Fruit shape, fruit surface and immature fruit colour varied among accessions (Table 14). Immature fruit colour ranged from white, light green to stripes while fruit surfaces were mostly smooth.

**Table 13: Frequency distribution of qualitative variable descriptor for garden egg accessions**

<b>Descriptor and classes</b>	<b>0</b>	<b>3</b>	<b>5</b>
Fruit shape	41.7	33.3	25
Fruit surface	50	16.7	33.3

Fruit shape: 0= longer than broad; 3= as long as broad; 5= broader than long.

Fruit surface: 0= smooth; 3= slightly grooved; 5= grooved.

**Table 14: Qualitative fruit characteristics of individual garden egg accession**

<b>Accession</b>	<b>Fruit shape</b>	<b>Immature fruit colour</b>	<b>Fruit surface</b>
ACC4R1P2	Longer than broad	White	Smooth
LEGON 1	Longer than broad	White	Smooth
GH4921B	Longer than broad	Light green	Smooth
GH4993F	Longer than broad	White + green stripes	Slightly grooved
ACC6R1P3	Longer than broad	White	Grooved
GH4156A	Broader than long	White + green stripes	Grooved
ACC1R1P2	Broader than long	White + green stripes	Grooved
ACC8R2P3	Broader than long	Green	Smooth
GH4927B	As long as broad	White + green stripes	Grooved
ACC5R2P2	As long as broad	White + green stripes	Smooth
GH4993B	As Long as broad	White + green marks	Slightly grooved
GH4993C	As long as broad	White	Smooth

#### **4.1.5 Seed characteristics of garden egg accessions**

Seed colour recorded was uniformly light yellow for all garden egg accessions using the garden egg descriptor. There were significant ( $p < 0.05$ ) differences in the number of seeds per fruit and number of whole seeds per fruit (Table 15). Accession ACC4R1P2 had the most number of seeds per fruit (740 seeds) as well as the number of whole seeds per fruit (710 seeds) while accession ACC1R1P2 had the least number of seeds per fruit (175 seeds) as well as the least number of whole seeds (150 seeds). Percentage damaged seeds ranged from 2-14% but differences among accessions were not statistically significant (Table 15).

**Table 15: Quantitative seed characteristics of garden egg accessions**

Accession	Number of seeds fruit <sup>-1</sup>	Number of whole seeds fruit <sup>-1</sup>	Number of damage seeds fruit <sup>-1</sup>	% damage seeds fruit <sup>-1</sup>
ACC4R1P2	740	710	30	4.1
GH4156A	514	503	11	2.1
GH4927B	665	637	28	4.2
LEGON 1	306	295	11	3.6
ACC5R2P2	409	380	29	7.1
GH4921B	255	245	10	3.9
GH4993B	515	507	8	1.6
GH4993F	300	267	33	11.0
ACC1R1P2	175	150	25	14.3
ACC6R1P3	295	267	28	9.5
ACC8R2P3	335	320	15	4.5
GH4993C	321	297	24	7.5
LSD (p<0.05)	12	37	NS	NS

100 seed weight (g) and percentage germination ranged from 0.1 g to 0.3 g and 75.7% for to 90.7% respectively (Table 16). There were significance ( $p < 0.05$ ) differences in 100 seed weight (g) and germination percentage among garden egg accessions (Table 16). ACC4R1P2 recorded the highest germination % while ACC1R1P2 recorded the least.

**Table 16: Seed weight (g) and Germination %**

<b>Accession</b>	<b>100 - seed weight(g)</b>	<b>Germination %</b>
ACC4R1P2	0.2	92
GH4156A	0.2	88
GH4927B	0.2	87
LEGON 1	0.2	88
ACC5R2P2	0.1	85
GH4921B	0.2	88
GH4993B	0.1	82
GH4993F	0.2	87
ACC1R1P2	0.1	77
ACC6R1P3	0.3	91
ACC8R2P3	0.2	86
GH4993C	0.2	88
LSD ( $p < 0.05$ )	0.01	2.80

## 4.2 Experiment 2 : Assessment of floral morphology in relation to fruit set for garden egg accessions with mixed type inflorescence.

### 4.2.1 Vegetative characteristics of 3 garden egg accessions.

There was no significant difference in plant height at 2, 4 and 6 WAT among the garden egg accessions (Table 17). At 2 WAT and 6WAT the plant height ranged from 9.7cm for accession ACC1R1P2 to 12.3cm for accession GH4993C and 38.6cm for accession ACC1R1P2 to 46.7cm for accession GH4993C respectively (Table 17).

There were no significant differences in the number of leaves per plant at 2, 4 and 6 WAT among the garden egg accessions (Table 18). At 6 WAT the number of leaves ranged from 71 for accession GH4993C to 74 for accession ACC1R2P3 (Table 18).

**Table 17: Plant height of three garden egg accessions at two weekly intervals**

<b>Accession</b>	<b>2 WAT</b>	<b>4 WAT</b>	<b>6 WAT</b>
ACC1R1P2	9.7	23.7	38.6
ACC8R2P3	12.3	28.6	43.7
GH4993C	11.6	28.5	46.7
LSD (p<0.05)	NS	NS	NS

**Table 18: Number of leaves of three garden egg accessions at two weekly intervals**

Accession	2 WAT	4 WAT	6 WAT
ACC1R1P2	9	31	74
ACC8R2P3	10	37	73
GH4993C	10	35	71
LSD (p<0.05)	NS	NS	NS

Primary branches and canopy size (cm) ranged from 6 branches for accessions ACC1R1P2 and ACC8R2P3 to 7 branches for accession GH4993C and canopy size of 91.1cm for accession ACC8R2P3 to 95.5cm for accession ACC1R1P2. Significant (p<0.05) differences were observed in the number of primary branches among accessions but the canopy size was not significantly different (Table 19). Accession ACC1R1P2 recorded the highest canopy size while accession ACC8R2P3 recorded the least.

**Table 19: Number of primary branches and mean canopy size of garden egg accessions**

Accession	Primay branches	Canopy size
ACC1R1P2	6	95.5
ACC8R2P3	6	91.1
GH4993C	7	91.5
LSD (p<0.05)	1	NS

#### 4.2.2 Variation in floral characteristics of garden egg accessions

The type of inflorescence and number of flowers per inflorescence were not different among accessions but the stigma position in relation to anther tips varied considerably among the accessions (Table 20). Stigma position in relation to anther tips varied in the following proportion: 20% of the number of flowers per plant were long styled flowers while 80% of the number of flowers per plant were medium styled flowers for accession ACC8R2P3, 100% of the number of flowers per plant were short styled flowers for accession ACC1R1P2 and 100% of the number of flowers per plant were long styled flowers for accession GH4993C (Table 20).

**Table 20: Type of inflorescence, number of flower (s) per inflorescence, stigma position in relation to anther tips and proportion of stigma position in relation to anther tips (%) in three garden egg accessions**

Accession	Type of inflorescence	Number of flower(s) per inflorescence	Stigma position in relation to anther tips	Proportion of stigma position in relation to anther tips (%)
ACC1R1P2	Mixed	1 – 2	Short styled flower	100
ACC8R2P3	Mixed	1 – 2	Long/Medium styled flower	20/80
GH4993C	Mixed	1 – 2	Long styled flower	100

There were no significant differences in the average number of flowers, average number of flowers aborted as well as the average number of flowers developed into fruits for both single and 2 flowers among the accessions. No significant differences in the reproductive characteristics among the 3 accessions observed with regards to the floral number, flower abortion and flowers developing into fruit (Table 21).

**Table 21: Total number of flowers, number of flower aborted and number of flowers developed into fruits per plant for mixed flowers**

Treatment	Number of flowers plant <sup>-1</sup>		Number of flowers aborted plant <sup>-1</sup>		Number of flowers developed into fruits plant <sup>-1</sup>	
	Single flower	2 flowers	Single flower	2 flowers	Single flower	2 flowers
ACC1R1P2	14	6	1	1	13	5
ACC8R2P3	14	6	1	1	13	5
GH4993C	15	7	1	1	14	6
LSD (p<0.05)	NS	NS	NS	NS	NS	NS

Days to flowering, days to fruit set and days to first harvest were not significantly different among accessions (Table 22). The number of days to flowering ranged from 71 days for accessions ACC8R2P3 and GH4993C and 72 days for accession ACC1R1P2. The number of days to fruit set was 84 days for all accessions. However, the number of days to first harvest ranged from 104 days for accession ACC8R2P3 and 105 days for accessions ACC1R1P2 and GH4993C.

**Table 22: Number of days to flowering, days to fruit set and days to first harvest of 3 garden egg accessions**

Accession	Days to flowering	Days to fruit set	Days to first harvest
ACC1R1P2	72	84	105
ACC8R2P3	71	84	104
GH4993C	71	84	105
LSD (p<0.05)	NS	NS	NS

#### 4.2.3 Yield characteristics of garden egg accessions

The number of fruits/plant was significantly ( $p<0.05$ ) different among the accessions (Table 23). Accessions ACC1R1P2 and GH4993C recorded the highest number of fruits/plant (27 fruits) each while accession ACC8R2P3 recorded the least number of fruits/plant (16 fruits). Significant differences were not observed in fruit yield/plant (g) and fruit yield (tonne/ha) among the garden egg accessions (Table 18). Accession ACC1R1P2 recorded the highest fruit yield/plant and fruit yield (tonne/ha) of 673.0 g and 76.1 tonne/ha while accession ACC8R2P3 recorded the least fruit yield/plant (g) and fruit yield (tonne/ha) of 477.0 g and 53.9 tonne/ha. However, significant

differences ( $p < 0.05$ ) were observed in the fruit weight (g), fruit length (cm) and fruit diameter (cm) among the accessions (Table 24). The fruit weight (g), fruit length (cm) and fruit diameter (cm) ranged from 23.0 g for accession ACC8R2P to 46.8 g for accession ACC1R1P2, 3.0 cm for accession ACC8R2P3 to 5.5 cm for accession GH4993C and 4.2 cm for accession ACC8R2P3 to 5.5 cm for accession ACC1R1P2 (Table 24).

**Table 23: Mean number of fruits, fruit yield plant<sup>-1</sup> and fruit yield hectare<sup>-1</sup> of garden egg accessions**

Accession	Number of fruits plant	Fruit yield/plant (g)	Fruit yield (tonne/ha)
ACC1R1P2	27	673.0	76.1
ACC8R2P3	16	477.0	53.9
GH4993C	27	644.0	72.7
LSD ( $p < 0.05$ )	3	NS	NS

**Table 24: Mean fruit length (cm), fruit diameter (cm) and fruit weight (g) of garden egg accessions**

Accession	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)
ACC1R1P2	46.8	3.7	5.5
ACC8R2P3	23.0	3.0	4.2
GH4993C	34.2	5.5	4.4
LSD ( $p < 0.05$ )	1.76	0.07	0.08

Fruit shape, immature fruit colour and fruit surface varied among the garden egg accessions (Table 25). Fruit shape for accessions ACC1R1P2 and ACC8R2P3 was broader than long as compared to accession GH4993C which was as long as broad. Immature fruit colour ranged from white to green with or without stripes. Accession ACC1R1P2 had a grooved fruit surface while accessions ACC8R2P3 and GH44993C both had a smooth fruit surfaces.

**Table 25: Qualitative fruit characteristics of the garden egg accessions**

<b>Accession</b>	<b>Fruit shape</b>	<b>Immature fruit colour</b>	<b>Fruit surface</b>
ACC1R1P2	Broader than long	White + green stripes	Grooved
ACC8R2P3	Broader than long	Green	Smooth
GH4993C	As long as broad	White	Smooth

#### **4.2.4 Seed characteristics of garden egg accessions**

The number of seeds per fruit and number of whole seeds per fruit were significantly ( $p < 0.05$ ) different among the accessions (Table 26). The number of seeds per fruit ranged from 319 to 743 seeds where as the number of whole seeds per fruit ranged from 303 to 728 seeds (Table 26). The number of damaged seeds per fruit was not significantly different among the garden egg accessions (Table 26). Percentage damaged seeds per fruit was significantly ( $p < 0.05$ ) different among the accessions. Accession with the stigma position below anther tips (ACC1R1P2) had the highest percentage damaged seeds per fruit (9.6 %) and the accession with stigma position same as anther tips (ACC8R2P3) had the lowest percentage damaged seeds per fruit (4.1 %) (Table 26).

**Table 26: Quantitative seed characteristics of garden egg accessions**

<b>Accession</b>	<b>Number of seeds per fruit</b>	<b>Number of whole seeds per fruit</b>	<b>Number of damaged seeds per fruit</b>	<b>% damaged seeds per fruit</b>
ACC1R1P2	178	161	17	9.6
ACC8R2P3	338	324	14	4.1
GH4993C	327	311	16	4.9
LSD (p<0.05)	20	27	NS	0.02

Significant differences were not observed in 100 seed weight (g) among the accessions (Table 27). Significant (p<0.05) differences were however observed in the germination percentage among the garden egg accessions (Table 27). Accession ACC1R1P2 recorded the least germination percentage of 77% while accession GH4993C recorded the highest germination percentage of 88%.

**Table 27: Seed weight (g) and Germination %**

<b>Accession</b>	<b>100 - seed weight (g)</b>	<b>Germination %</b>
ACC1R1P2	0.2	77
ACC8R2P3	0.2	87
GH4993C	0.2	88
LSD (p<0.05)	NS	2.71

## CHAPTER FIVE

### 5.0 DISCUSSION

#### 5.1 Assessing floral morphology and flower abortion among garden egg accessions

Results from the studies revealed wide morphological diversity among the garden egg accessions. Vegetative, reproductive and yield characteristics varied considerably among the accessions. Using the inflorescence, the garden egg accessions were grouped as single, clustered or mixed. Similar groupings were reported by Furini & Wunder (2004). Earlier studies by Som & Maity (1986); Hepper (1987) and Pradeepa (2002) reported inflorescence single, clustered and mixed type flowers as was observed in this study. The current results also confirm the work of Prakash (1968), Murtasow (1971) and Singh *et al.* (2004) in which the number of flowers per inflorescence varied from 2 to 4 and from 3 to 5 with number of flowers per inflorescence varying within individual plants as well as between accessions. In Experiment one, it was observed that the largest group of accessions had one or two flowered inflorescence in the total population regardless of the type of inflorescence. This was attributed to the genetic architecture and pattern of inheritance of inflorescence type. Nagasawa *et al.* (2001) and Kowalska (2003) reported that the position of the stigma in relation to anther tips varied within cultivars and even within flowers of the same cultivar. This assertion is supported by the results of the studies where the stigma position in relation to anther tips varied within accessions. The stigma position in relation to anther tips were either above, below or on the same level. The observed phenomenon is explained in studies by Peter & Singh (1973) to be due to the presence of the additive gene action which controls the number of stigma position in relation to anther tips in eggplant. Data clearly showed that the clustered type of inflorescence had a high rate of flower

abortion resulting in lower number of flowers developing into fruits per plant as compared to the single and mixed type of inflorescence. These observations are in agreement with Marcelis *et al.* (2004) who reported that flower drop is very low in the solitary flowering type whereas flower drop may be as high as 80% in clustered flowering type as a result of environmental stress such as heat, drought, and low light conditions or failure of pollination/fertilization which are important factors that may induce abscission and are also yield limiting factors (Guilioni *et al.*, 1997; Goldschmidt, 1999; Halbrecq *et al.*, 2005; Berjano *et al.*, 2006) . Observation in the variation in flower abortion could be related to the differences in the vegetative growth rate or the source sink balance of the plant because when the total sink strength is high due to the many growing flowers and are not able to compete for assimilates with the fast-growing flowers they then abort (Marcelis *et al.*, 2004; Wubs *et al.*, 2009).

## **5.2 Effect of stigma position on fruit characteristics**

According to Cebula *et al.* (2007) the fruit shape of garden egg is round, elongate-round or oval with smooth or grooved surface. Similar observations were also made by Daunay *et al.* (2006) in *Solanum aethiopicum* Gilo group which typically have fruits of size ranging from 2-8 cm and are oval shaped, depressed, spherical to ellipsoid. The results of this experiment where the fruit characteristics observed among accessions varied considerably in size, shape, immature fruit colour and fruit surface confirms observations made in previous studies. Most fruits with single fruit colour such as white, green and light green were smooth while fruits with combination of colours such as green and white were grooved. Fruit colour among accessions varied from white to green to various combinations of green and white (Lester *et al.*, 1990; Blay, 1991).

The assertion by Passam & Bolamti (1997) that fruit set is high where the stigma is above or on the same level with anther tips and that short styled flowers do not set fruits at all is contrary to the results of this study. Also ACC1R1P2 (stigma below anther tips) produced a significantly higher number of fruits compared to the accessions with long and medium styled flowers (ACC4R1P2, GH4156A, GH4927B, GH4921B, GH4993B, GH4993C). The differences may be explained by studies conducted by Chadha & Saimbhi (1977) where the fruiting habit or fruit set in a cultivar is not directly related to the stigma position in relation to the anther tip. Fruit weight, fruit length and fruit diameter were significantly different among accessions. Moreover, the fruit length and fruit diameter influence the fruit shape and size. These findings are in agreement with Nsawah (1969), Blay (1978), Hitomi *et al.* (1998), Gisbert *et al.* (2006), Osei *et al.* (2010) and Chinedu *et al.* (2011) who all observed significant variation in the fruit weight, fruit length and fruit diameter among garden egg accessions studied.

### **5.3 Effect of type of inflorescence on seed characteristics**

Fruit set from long and medium styled flowers in the study (ACC4R1P2, GH4156A, GH4927B, LEGON 1, ACC5R2P2, GH4921B, GH4993B, GH4993F, ACC6R1P3, ACC8R2P3 and GH4993C) contained a higher number of seeds per fruit than fruit set from the short styled flower (ACC1R1P2). The latter contained about 50% less seed on average compared to the former. These observations were similar to the study of Sekara & Bieniasz (2008) which revealed that fruit set from long and medium styled flowers of eggplant contained a comparatively higher number of seeds than the short styled flowers. This phenomenon could be due to the morphological characteristics of short styled flowers which are characterized by a small sized stigma, spatial separation of anther pores and stigma, low number of pollen tubes and

fertilized ovules which significantly result in a low pollination and fruit set efficiency. Such fruits produce significantly low number of seeds per fruit (Passam & Bolamti, 1997 and Sekara & Bieniasz, 2008). The number of whole seeds per fruit as well as the germination percentage was significantly lower for short styled flowers than for long and medium styled flowers. This observation in the low number of whole seeds per fruit may be due to poor pollination in short styled flowers which eventually result in poor fertilization and poor seed formation. The number of damaged seeds per fruit and the % damaged seeds per fruit were not significantly different among the garden egg accessions in Experiment 1. However, in Experiment 2 differences were statistically significant. Accession ACC1R1P2 with short styled flowers recorded the highest % damaged seeds per fruit as compared to the accessions (ACC4R1P2, GH4156A, GH4927B, LEGON 1, ACC5R2P2, GH4921B, GH4993B, GH4993F, ACC6R1P3, ACC8R2P3 and GH4993C) with long and medium styled flowers. Sekara & Bieniasz (2008) have reported that pollination in eggplant flowers with short style may be difficult because of the small size of the stigma and separation of anther pores. Significant differences were observed in 100 seed weight (g) among the accessions in Experiment 1. However, significant differences were not observed among the accessions in Experiment 2.

## CHAPTER SIX

### 6.0 CONCLUSION AND RECOMMENDATION

#### 6.1 Conclusion

The following conclusions were drawn from the study:

Flowers were either borne in clusters or single among garden egg accessions. The type of inflorescence and number of flowers per inflorescence varied considerably within as well as among garden egg accessions. The stigma position in relation to anther tips was either above, on the same level or below anther tips and also varied among accessions as well as in different flowers of the same accession. Flower abortion was lower in the solitary flowering type than in the clustered flowering type. The stigma position in relation to anther tips did not influence the fruit set and yield in accessions.

Fruit length and fruit diameter varied considerably among accessions. Immature fruit colour which influences consumer preference to a large extent varied from white to green with some accessions having white and green stripes or patches. Fruit surfaces were either grooved or smooth, single coloured fruits were mostly smooth whilst fruits with colour combinations were grooved. Fruit set from long and medium styled flowers contained significantly higher number of seeds than fruit set from short styled flowers. Long and medium styled flowers had a significantly higher 100 seed weight (g) and germination percentage than short styled flowers.

## 6.2 Recommendation

- There is the need to investigate the effect of flower, fruit abortion as well as seed quality of clustered inflorescence in relation to the plant architecture.
- Factors responsible for flower abortion such as competition for plant resources, water stress, temperature effects, planting times or planting densities may need to be investigated to ascertain their influence on the different garden egg accessions.

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