KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

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QUALITY OF FARMER-SAVED TOMATO (*Lycopersicum esculentum* Mill.) SEEDS AND ITS EFFECT ON FRUIT YIELD IN GHANA

BY

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MAY, 2010

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A THESIS SUBMITTED TO THE DEPARTMENT OF HORTICULTURE, FACULTY OF

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FOR THE AWARD OF A M.Sc. (HONS) DEGREE IN SEED SCIENCE AND TECHNOLOGY

BY

HILLARY MIREKU BORTEY

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DEDICATION

I dedicate this work to my father, Mr. Michael Heneson Botey (Late), my family and my dearest friend Abigail Abena Agbanyo (Miss), who in diverse ways have make this dream a reality.

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 is duly acknowledged.

……. ……

HILLARY MIREKU BORTEY DATE (STUDENT)

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(HEAD OF DEPARTMENT)

ABSTRACT

A field survey was conducted in 2008/2009 cropping season in five agro-ecological zones comprising twenty-nine communities to assess the quality of farmer-saved tomato seeds and its effect on the fruit yield levels in Ghana. Laboratory and field experiment were carried out at the Seed and Pathology laboratories of CSIR-Crops Research Institute, (Fumesua) and Department of Horticulture, KNUST, Kumasi, from 2nd May 2009 to 2nd February 2010. Majority of smallholder farmers in Ghana (52%) saved their own seed for planting. None of the farmers followed proper storage practices for the seeds which were stored under ambient conditions in plastic bins, black polyethylene bags, clay pots, paper bags and pieces of cloth, which were not treated against insect-pests. Except for seed from the forest zone, however, the storage practices had little or no influence on the quality of seeds assessed. The percent pure seed component, vigour and germination were high, ranging from 68.5 to 98%. The study also revealed that none of the seed samples was free from seed-borne pathogenic and saprophytic fungi. The seeds were mainly were infected with eight fungi comprising five pathogenic and three saprophytes, which varied significantly depending on location. The most prevalent seed-borne pathogenic fungi were *Fusarium moniliforme*, *Fusarium oxysporum* and *Curvularia lunata.* Saved seeds from the Transition zone had the highest incidence of pathogenic fungi (56%) while the Guinea savanna zone had the least (20.4%), a situation attributable to the storage structures and practices employed in the different zones. Field studies on performance also revealed a positive but not significant correlation (r = 0.64) between percent seed vigor and fruit yield.

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INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a fruity vegetable, which belongs to a large family of plants known as *Solanaceae*, with the common name, the nightshades. The crop is a perennial, which is usually grown as an annual (Norman, 1992). There are basically two types: (i) Determinate types that produce flowers at almost every internode and ceases growth after flowering. (ii) Indeterminate types that flower at every third internode and continue growing almost indefinitely (Anon. 2000). Tomato is believed to have originated from the Western Coastal Plains of South America, extending from Ecuador to Chile (Yamaguchi, 1983; Harlan, 1992). The crop was introduced in Ghana in the sixteenth or seventeenth century by the Portuguese and has since become the most popular vegetable crop (Norman, 1992; Nkansah *et al.*, 2003). Its versatility in fresh or processed form has played a major role in its rapid and widespread adoption as an important food commodity in Ghana (Norman, 1992; Horna *et al.*, 2006 and Asare-Bediako *et al.*, 2007).

Tomato production in Ghana is mainly a smallholder activity, and its distribution throughout the year is markedly seasonal with a few large scale ventures at designated irrigation sites (FAO, 2005). Commercially, the small-scale production is concentrated in four out of the five agroecological zones, namely Forest, Forest-Savanna Transition, Coastal savanna and Sudan savanna. In the national economy, tomato exports contribute significantly to the foreign exchange portfolio as exemplified by the $437,000 accrued to the country from exports of 4,368 metric tonnes in 2003 (FAO, 2005).

In spite of its intensive cultivation however, the yield of tomato is still low, (about 7.5t/ha) (GIPC, 2005 and Danquah and Fulton, 2007). This has resulted in the importation of fresh tomatoes from neighboring Burkina Faso for about half of the year (Horna *et al*., 2006), a situation attributed to a number of constraints in the production and marketing chain. The quality of seed has been implicated as a probable cause of the low yield (Sinnadurai, 1973 and Horna *et al*., 2006). Presently, about 80-90% of smallholder farmers use their "saved" seeds from previous cultivations (Almekinders *et al.,* 1994; Tripp, 2001 and Danquah *et al.,* 2004). This practice puts the purity of the seeds into doubt since the storage practices employed by these farmers enhance the probability of seeds contamination (Danquah *et al*., 2004). In addition, these seeds could be infected with disease pathogens and therefore may not be regarded as disease-free. Moreover, the viability of the seeds could be compromised as a result of the storage practices employed (Danquah *et al*., 2004). The result is that tomato crop establishment and fruit yield are adversely affected. Shetty (2000) indicated that good crop establishment is directly linked to the quality of seed used. Furthermore, Mew *et al.* (1994) reported that the use of good quality seeds can lead to a yield increase of 5-20%. It is therefore imperative to determine the quality of the farmer-saved seeds and its corresponding yield levels, since these seeds would continue to be the major seed source for small-scale farmers in Ghana for tomato production.

The main objective of the study was to assess the quality of the farmer-saved tomato seeds and its relationship to fruit yield. The specific objectives were: (i) to examine the storage structures and practices employed in the storage of farmer-saved seeds; (ii) to determine the physical purity, germination capacity and vigor of the farmer-saved seeds of tomato varieties grown (iii) to identify the most prevalent disease pathogens (seed health) associated with the farmer-saved tomato seeds and (iv) to determine the effect of the farmer-saved seeds on tomato fruit yield.

2.0 LITERATURE REVIEW

2.1 Sources of seeds to small-holder farmers

Of all farm inputs, high-quality and adapted seeds and planting materials exert the most profound influence on agricultural productivity. A wider appreciation of the importance of quality seeds and their crucial role in agricultural and thus human development cannot be over-emphasized (Cromwell, *et al.,* 1993; Lanteri and Quagliotti, 1997; Scowcroft and Scowcroft, 1998). However, most farmers in Sub-Saharan Africa don't buy seed: they save their own or trade with other farmers. The major reasons assigned to this situation are agronomic and economic viz: the saved variety is the best suited to the local soil and climate and it saves money (Anon., 2001). A survey conducted by Clottey *et al.* (2009) on some tomato farmers in Ghana revealed that some farmers do not realize the economic benefit of investing in good seed, since the fruit prices on the market are the same irrespective of seed quality, thus, making farmer-saved and farmertraded seed to be the dominant source of seed for 80-90% of farmers in Sub-Saharan Africa (Almekinders *et al.,* 1994; Walker, *et al.,* 1997a and Tripp, 2001). Adetumbi and Daniel (2004) also reported that for vegetables, about 60% of vegetable farmers sourced seeds from their previously saved harvests, while about 30% purchased seeds from dealers in a survey conducted in some parts of Nigeria. It is also reported that even in the developed world, specifically, UK, saving seed is widely practiced and may be as high as 40% of crops grown (Anon. 2000).

2.2 Seed Quality

Seed quality is complex to define, but, in simple terms, 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 (Hampton, 2002). 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). If the seed lots possess high genetic purity and high germination percentage and a minimum of inert, weed and other crop seeds and are free from diseases, it is said to have high quality (Copeland and McDonald, 1995; Al-Yahya, 2001; Guberac *et al.*, 2003*;* Šimic *et al*., 2004; Heatherly and Elmore, 2004). This implies that if a seed lot meets the certification standard, it is good quality seed and if it does not meet the certification standards, it is obviously of a lower seed quality (Copeland and McDonald, 1995). Thus, seed quality is rather a broad term, which encompasses several factors: seed health, varietal and physical purity, germination, vigour and size (or weight) (Ellis, 1991).

2.2.1 Seed purity

The purity of a seed lot can be viewed from two angles: genetic and physical. Genetic purity of seeds refers to the trueness to type while physical purity of a seed lot refers to the physical composition of the seed (Anon. 2009). The pure seed component of a seed lot together with seed germination capacity are used to determine the planting value of the seed (Rindels, 1995).

2.2.2 Seed viability

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 and Egli, 1991). Much of seed viability depends upon storage condition (Rindels, 1995). The storage material used and the ensuing storage conditions applied to seeds could reduce viability or render the seed dead (Rindels, 1995). The ideal storage condition for seeds is somewhere cool and dry. For many homeowners a capped jar in the refrigerator serves the purpose (Rindels, 1995). Several environmental factors also affect seed viability during storage. The amount of moisture in the seed is one of the most important factors influencing seed viability during storage. The effect of weather in terms of fluctuating temperature during seed formation and maturity will affect seed viability. Pre-harvest rain may also affect the viability of seed (Anonymous, 2008). The activity of microflora can also 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, which are all environmental factors prevailing during seed storage. Treated seeds or seed storage materials with fungicides can help prolong the storage period (Anon. 2008).

2.2.3 Seed Vigour

The definition and determination of seed vigor has been problematic unlike those for germination and seed size (weight) (Ellis, 1991). Byrum and 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. However, 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. Earlier, 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 furthermore stated that a vigorous seed lot is one that is potentially able to perform well even under environmental conditions which are not optimal for the species.

The importance of a seed vigor 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). Seed vigor precedes loss of viability and therefore seed vigour is as important as seed viability (Caddick, 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).

2.2.4 Seed Germination

Germination of a seed is 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 (AOSA, 1999).

Seed germination could also be referred to as the ability of a seed, when planted under normal sowing conditions, to give a normal seedling (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 sufficiently long period that even weak seeds are coaxed or provided every opportunity to be considered germinable (Byrum and Copeland, 1995). Therefore, the germination percentage is the sum of strong and weak seedlings (Byrum and Copeland, 1995). Germination is the most important function of a seed as it is an indicator of its viability and growth (Barua *et al.,* 2009).

2.2.5 Seed Health

Seed health refers to the presence or absence of disease-causing organisms such as fungi, nematodes, bacteria, viruses and insects, and also to the status of seeds in a seed lot (Mathur and Kosgdal, 2003). Seed health status is also affected by the presence of non disease-causing contaminants in the particular seed lot (Mew and Gonzales, 2002). 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 and Gonzales, 2002). When seeds are used for sowing, seed-borne pathogens may cause disease or death of plants resulting in crop loss (Morre and Tymowski, 2005).

2.3 Quality of Farmer-saved seeds in Ghana

Most authors are of the view that farmer-saved seeds are generally substandard in terms of vigor and health (Katiyar and Vaish, 1998; Praveen *et al.,* 2001). As regards physical purity however, some good results of farmer-saved rice seeds have been obtained (Haque *et al*., 2007).

The physical purity of farmer-saved seeds could be as high as 96.1% to 99.1% for the pure seed component (Haque *et al.,* 2007). Similarly, Mekbib (2008) also observed good results for physical purity of farmer-saved sorghum seed, although the standard varietal purity level was not met due to varietal mixture. Generally, the kind of storage practices employed could render farmer-saved seeds genetically impure through the possibility of seeds mixture (Danquah *et al.,* 2004; Hemanth *et al.,* 2007).

In terms of seed health, Hemanth *et al.* (2007) in their study of paddy, sorghum and cowpea revealed that farmer's saved seeds were of poor health status, in view of the fact that the seeds were infected with 28 different genera of fungi. The storage structure was implicated as a major factor responsible for the prevalence of the seed mycoflora (Hemanth *et al.*, 2007). In Ghana, about 25% of farmers attributed poor field germination of cowpea to poor seed quality (Walker *et al.*, 1997a). Similarly, the poor field germination of rice was attributed to the quality of farmersaved seeds (Haque *et al.*, 2007).

2.4 Influence of Seed Quality on crop growth and yield

Seed lot certification is an important requirement in the seed industry because of the effects of seed quality on crop yield (Singh and Maheshwari, 2001; Kumar *et al.,* 2004). High quality seed enhances the raising of healthy plants and establishment of optimal plant population in the field (Doijoe, 1988). The three major aspects of seed quality, (seed germination, vigour and size) have both direct and indirect influences on crop yield (Ellis, 1991). The indirect effects include percentage emergence and time from sowing to emergence, which can influence plant population, spatial arrangement and crop duration (Ellis, 1991). In this regard, reductions in yield could be directly related to low seed vigour if plant population fell below a critical level (TeKrony and Egli,

1991). Thus when seed quality is low and the resulting plant density falls below a threshold level, yield would be reduced (Basra, 1995). The direct effects on subsequent plant performance are however more difficult to discern (Ellis, 1991). On the contrary, TeKrony and Egli (1991) reported that seed viability and vigour have direct effects on the performance of seeds planted to regenerate a crop. Consequently, positive correlation has been found between seed vigor and yield for onions (Harrison, 1966), lettuce (Smith *et al*. 1973), cauliflower (FinchSavage and McKee, 1990), peas and tomato (Basra, 1995).

2.5 Seed-borne diseases and crop yield

Seed-borne diseases cause enormous losses to our crop (Fakir *et al.*, 2002). Seed-borne fungi in particular are of considerable importance due to their influence on the overall health, germination and final crop stand in the field (Agarwal, 1981). The infected seeds may fail to germinate, or transmit disease from seed to seedling and/or from seedling to growing plant (Fakir *et al.*, 2002). The presence of disease pathogens on seeds is also one of the causes of low seed viability (Bewley and Black, 1994; Elias *et al.*, 2004). According to Anjorin and Mohammed (2009), the effects of fungi on seeds include poor germination, less vigorous seedlings and low yield. However, the effect of seed-borne pathogen on seed and seedling production can go unnoticed until extreme germination failures have occurred in deed beds (Epners, 1964).

2.5.1 Seed-borne diseases of tomato and their effects on growth and yield

There are numerous reports on seed-borne fungi of tomato (Neergaard, 1977; Suryanarayana, 1978; Richardson, 1979). *Fusarium oxysporum* is reported to be one of the most pathogenic as it can cause a 65% reduction in germination. Also *Phoma destructiva* can reduce tomato germination percentage by 58% (Bankole, 1996). Other fungal pathogens of tomatoes include: *Alternaria solani, Curvularia lunata, Fusarium moniliforme, Cladosporum sp.*etc (Bankole, 1996). Mehrota and Agarwal (2003) reported that these fungi could retard seed germination through softening and necrosis of tissues. They have also been found to be associated with seed viability, wilting of plants and stem flaccidity. *Fusarium oxysporum* causes foot and root rot and wilt of tomato while *Alternaria solani* causes early blight of tomato (Sherf and Macnab, 1986). Conversely, storage fungi such as *Aspergillus flavus* and *Apergillus niger* are not pathogenic to tomatoes (Kulik, 1973; Harman and Pfleger, 1974; Bankole, 1996) and therefore have no effect on germination of tomato seeds. However, they are associated with damaged seeds and Agarwal and Sinclair (1995) regard these fungi as "storage fungi" that can be involved in deterioration during storage.

Studies have shown that the pathogenicity of isolates from these species ranges from highly virulent to non-pathogenicity, therefore the level of contamination by these fungal species do not always correspond to development of seed-borne diseases (Padwuk, 1978; Graham and Linderman, 1983 and Axelrood *et al.*, 1995). Moreover, damping-off disease caused by *Fusarium oxysporum* and *Fusarium moniliforme* in several studies has been shown to increase greatly following heat stress (Haug and Kuhlman, 1990 and Axelrood *et al.*, 1995).

3.0 MATERIALS AND METHODS

3.1 Study Approaches

The study approaches comprised (i) field survey and (ii) laboratory and field experiments. The field survey was conducted in 2008/2009 cropping season to find out the sources of seeds available to tomato farmers and the storage practices employed by these farmers in Ghana. Questionnaires were administered randomly to tomato farmers in five (5) agro-ecological zones of Ghana to identify the main source of seeds, storage structure and practices, bio-data of farmers and constraints facing them in tomato production. The laboratory and field experiments were carried out to assess the quality and yield performance of the farmer-saved tomato seeds.

3.2 Field survey

A field survey was conducted from 2nd May to 2nd July, 2009 in tomato-growing areas using a structured questionnaire to gather information from tomato growers. In all 29 communities in 16 districts, covering five agro-ecological zones comprised the study areas. These were Offinso, Agogo and Bibiani for the Forest zone; Ga-West, Dangbe-East and Dangbe-West in the Coastal savanna zone; Wenchi, Techiman and Akumadan in the Forest-Savanna Transition zone; WestMamprusi, Zabzugu/Tatale, and Yendi in the Guinea savanna zone; Talensi/Namdam, Bolgatanga, Navrongo and Kassena/Nankani in the Sudan savanna zone. Information gathered included names of varieties grown, source (s) of seeds, seed storage practices, storage packaging material, production constraints as well as the bio-data of growers (educational background, gender and age, APPENDIX I). A total of one hundred farmers were randomly selected and interviewed in the study areas.

Statistical Package for Social Sciences (SPSS) was used in the analysis of the data obtained from the survey and results were expressed as percentages.

3.2.1 Seed Sample Collection Procedure

A total of fifty farmer-saved seed samples, each weighing 68g were collected from fifty farmers randomly selected from twenty-nine communities in five agro-ecological zones of Ghana. The agro-ecological zones were Forest, Forest-Transitional, Coastal savanna, Guinea and Sudan savanna zones. These seeds were previously stored in various storage structures comprising plastic bottles/tins, polyethylene bags, clay pots, piece of cloth and paper bags. The seeds were re-packaged in brown envelopes (20mm x 15mm), labeled, sealed, and put in a High Density Polyethylene bag (HDPE-90mm x 60mm) and kept under refrigeration with temperature range of 5°C-10°C and Relative humidity of 50-55%.

3.3 Field and Laboratory Experiments

3.3.1 Experimental Locations

Seed health test was conducted at the Seed Pathology Laboratory of CSIR-Crops Research Institute, (Fumesua). On the other hand, seed purity, germination, and vigour tests were carried out at the Seed Laboratory of CSIR-Crops Research Institute (Kwadaso). At the Department of Horticulture, KNUST, field experiments on crop performance were carried out. The site is characterized by a bi-modal rainfall distribution with peaks in June and September. The first and second growing seasons typically last from late March to mid-July and from mid-August to the

end of November, respectively, separated by a short dry spell of about four weeks in July. The major dry season starts in mid-November and lasts to the end of February or mid-March. Average annual rainfall ranges from 1000mm to 1500mm. The soil belongs to the oxisols and typically represented by sandy loam. Rainfall, temperature and humidity data during the period of the experiment are presented in Appendix II. The entire experimental period was from 13th July, 2009 to 20th February, 2010.

3.3.2 Seed Quality Analysis (Laboratory experiments)

Seed quality analysis included seed purity, health, germination and vigour tests.

3.3.2.1 Purity Analysis

Seed samples collected from farmers were taken through a purity test. The seed was separated into three categories according with the procedures of ISTA (2007) as follows: (a) pure seed (b) other seeds and (c) inert matter. The various components were weighed after separation. Data gathered were averaged for each sample and percentages calculated accordingly by weight of the sample being tested. All seed samples were tested for purity.

3.3.2.2 Seed Health Test

The seed health test was done using the Blotter Method (Marthur and Kolgsdal, (2003). Four hundred seeds were randomly taken from the pure seed component of each sample for the health test. Three pieces of filter paper were soaked in distilled water and placed at the bottom of a 9cm petri dish. Twenty-five (25) seeds were plated in each petri dish.

Sixteen plates were used for each sample. The seeds in petri dishes were incubated at 20 ± 2°C under alternating cycles of 12 hours near ultraviolet (NUV) light and darkness for 7 days. After incubation the seeds were examined under Stereobinocular microscope to record the incidence of different seed- borne fungi. For proper identification, slides were prepared from the fungal colony and observed under Compound microscope. The results were presented as percent incidence for identified pathogens.

3.3.2.3 Germination Test

Germination test was conducted in fine sand (1 litre of sand: 160mls of water). Plastic trays (30 x 25cm) were used for the test. Fifty seeds were sown in five rows with 10 seeds per row in each plastic tray. For each sample, four trays were used for testing 400 seeds. Germinated seeds were counted and recorded at 5 and 14 days after sowing. After the 14 days, seedlings were classified into normal seedlings and abnormal seedlings. Percentage germination was calculated as:

$$\% \text{ Germination} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds}} \times 100$$

3.3.2.4 Vigour (Speed of Germination)

The vigor was measured as the percentage of the seeds that had germinated by the 5th day of incubation. Data gathered were averaged for each sample. All seeds were tested for vigour (speed of germination).

3.3.3 Field experiment

3.3.3.1 Nursery Preparation

Seeds were sown on raised beds on 14th August, 2009 by drilling. Palm branches were mounted over the beds to protect the seeds from direct rain and irradiation impact. The palm branches were however, removed after seedlings emerged. Watering and weed control were carried out as and when necessary. Percentage Seedling emergence was determined 5 days after sowing.

3.3.3.2 Land Preparation and Soil analysis

The land was ploughed and harrowed two times to obtain a fine tilth for planting. Prior to the preparation of the land, soil samples were randomly collected from the area marked out for planting at a depth of 0-30cm and analyzed for per cent organic matter, organic carbon, total Nitrogen, Potassium, Calcium, Magnesium (cmol/kg), available Phosphorus and pH at the Soil Science Laboratory, Crop and Soil Science Department of the Faculty of Agriculture, KNUST.

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3.3.3.3 Field Experiments Layout

The experimental design was a Randomized Complete Block Design with five (5) treatments replicated three times. Each plot measured 1.8m x 6m with 1m between blocks and plots. The experiment covered a total land area of 123.4m^2. Seedlings were transplanted onto the field at a spacing of 90cm x 60cm, giving 20 plants per plot and a total plant population of 200 plants.

3.3.3.4 Agronomic Practices

Seedlings were transplanted 27 days after sowing (DAS) on 10th September 2009. Replacement of dead seedlings as a result of transplanting shocks was carried out one week after transplanting. The field was irrigated as and when necessary since the rainfall pattern was erratic. Regular hoeing to control weeds as well as to aerate the soil was done. NPK (15-15-15) was applied two weeks after transplanting (WAP) at a rate of 250kg/ha on 24th September, 2009. Sulphate of ammonia was applied four weeks after transplanting as a side dressing at a rate of 125kg/ha on 8th October 2009. A systemic and contact insecticide, Cymethoate Super EC (a.i. 36g cypermethrin and 400g dimethoate per litre) was sprayed at an application rate of 1.0 litre/ha to control Fruit borer (*Helicoverpa armigera*), which were boring into the fruits. Additionally, a broad spectrum fungicide, Foko -"No Weapon", W.P. (a.i. Mancozeb 800g/kg) was sprayed against fungal diseases at an application rate of 4.0g/litre of water.

3.3.3.5 Field Data Collected:

Ten plants were randomly selected, tagged and staked two weeks after transplanting from each plot and the following data were collected.

- **Days to 50% flowering**

  The number of days for each sample to attain 50% flowering was recorded from date of sowing to when 50% of plants of each plot had reached anthesis.

- **Plant height at flowering.**

  Plant height was measured from soil level to the tip, at first appearance of inflorescence and recorded and the mean height at flowering for each sample was determined.

- **Girth of plant at flowering**

  The girth of each plant was measured six weeks after transplanting (WAT).

- **Number of flowers per truss**

  The number of flowers per truss was counted and the mean determined.

- **Number of flowers per plant**

  The number of flowers per plant was counted up to the top bud of the plant and recorded.

- **Number of fruits per truss**

  The mean number of fruits per truss were counted. This was also used to determine the percentage flower abortions and fruit set.

- **Days to fruit set**

  The number of days taken from sowing to time of first fruit appearance was noted.

- **Number and weight of fruit per plant**

  The number of fruits harvested per plant was counted and weighed.

- **Number and weight of marketable fruit per sample**

  The total number of fruits harvested per sample was sorted out into marketable fruits and unmarketable fruits and weighed.

- **Field yield per hectare**

  The mean yield per plant (kg/plant) was used to calculate the yield per hectare (t/ha).

3.3.4 Laboratory Data Collected

- **Number and weight of seed per fruit**

  The mean number of seeds per fruit was determined by extracting seeds from ten fruits, air dried, counted and weighed and their means calculated.

- **Seed yield per hectare**

  The weight of seeds per fruit and the average number of fruits per plant was used to compute seed yield/ha using the plant population.

- **1000 seed weight**

  One hundred (100) seeds was counted, weighed and multiplied by 10 to obtain the 1000 seed weight for each sample.

Collected data from both field and laboratory experiments were analysed using the analysis of variance (ANOVA). Least Significant Difference (LSD) was used to determine the difference among the treatments at P = 0.05.

4.0 RESULTS

4.1 Bio-data of tomato farmers in Ghana

84 per cent of the farmers were between the aged from 30 years and above while 16 per cent were between 20 – 29 years. Males formed 77 per cent of farmers while 23 per cent were females (Table 4.1).

Table 4.1 Age and Gender Distribution

Age	Percent	Gender	Percent
20 – 29	16	Male	77
30 – 39	42	Female	23 40
and above	42		

4.1.2 Educational background of tomato farmers

Forty-five per cent of farmers had secondary education, thirty-seven per cent had received basic education (primary/junior high school), seventeen per cent of the farmers had no education and only one per cent had education beyond the secondary level (Figure 4.1).

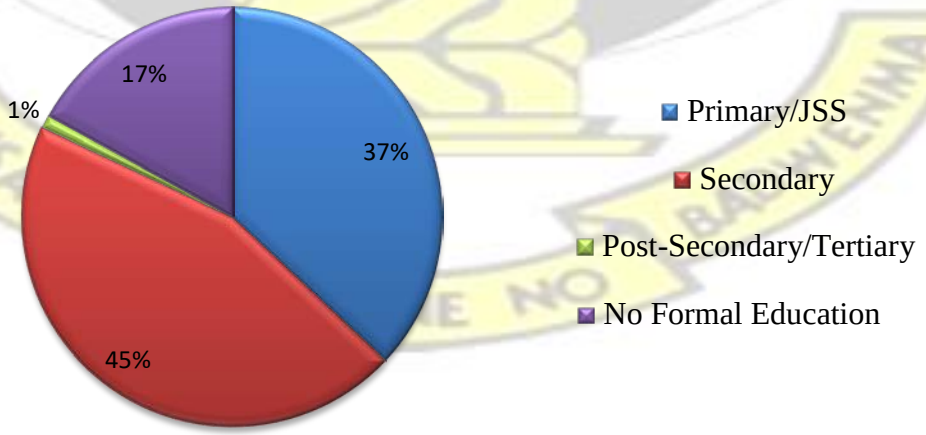

Figure 4.1: Education background of tomato farmers

4.2 Source of Seeds to Smallholder Tomato Farmers

Fifty-two per cent of farmers saved their own seeds for planting in the following year while twenty-eight per cent of them obtained seeds from the local market. Fifteen per cent of farmers purchased seeds from agro-stores while four and one per cent obtained seeds from friends and NGOs, respectively (Figure 4.2).

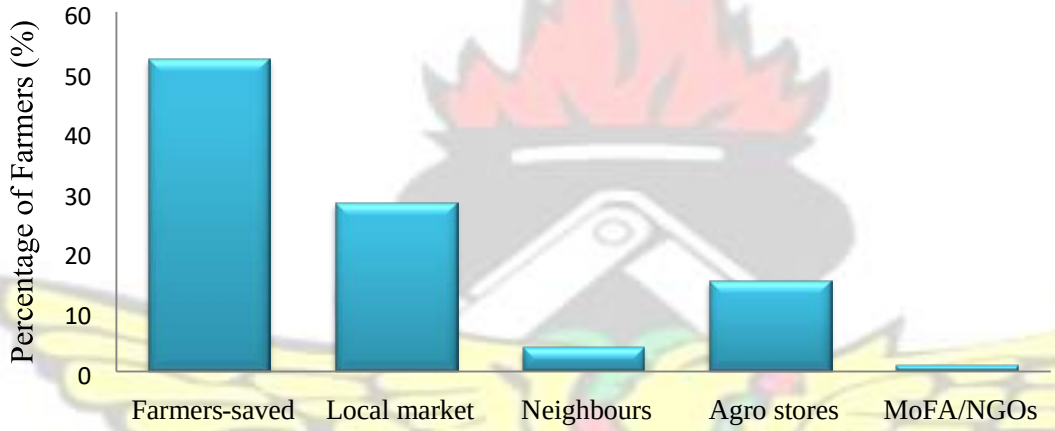

Figure 4.2: Sources of Seeds to Smallholder Farmers in Ghana

4.2.1 Farmers' knowledge on varieties cultivated

Majority of the farmers (52%) did not know the names of the varieties they cultivated, while twenty-eight per cent of them were not sure of the varieties they were planting. Only 20 per cent of farmers had knowledge of the varieties they cultivated (Figure 4.3). Some of the varieties mentioned were "Power", "Akoma", "Rasta", Petomech, "Dogobum" and "Italy".

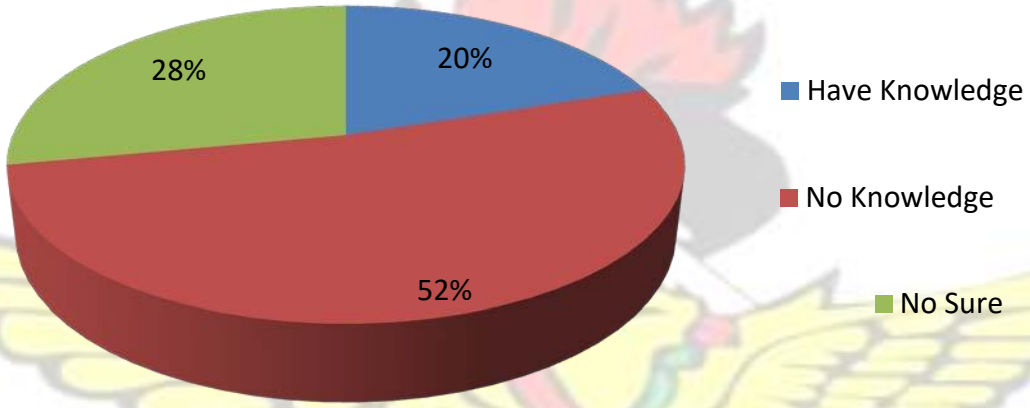

Figure 4.3: Percent Farmers on knowledge of varieties cultivated

4.2.2 Quantity of Seeds used per 0.4ha

Thirty-one per cent of farmers used 136g of seeds per 0.4ha, while twenty-five percent each of farmers used 68g and 204g or more per 0.4ha. Nineteen per cent of these farmers also used at least 170g of seeds per 0.4ha (Table 4.2).

Table 4.2: Quantity of Seeds used per 0.4ha

Quantity (g/0.4ha)	Frequency	Percent
68	25	25.0
136	31	31.0
170	19	19.0
204 and Above	25	25.0
Total	100	100.0

4.2.3 Cost of Farmer-saved Tomato seeds/68g in Ghana

The cost per 68g of tomato seeds ranged from Gh. ¢ 5.00 – Gh. ¢ 15.00 in the Transition; Gh. ¢ 5.00 – Gh. ¢ 10.00 in the Forest zone and Gh. ¢ 1.00 – Gh. ¢ 4.00 in both Guinea and Sudan savanna zones (Table 4.3).

Table 4.3: Cost of Farmer-saved Tomato seeds/68g in Ghana

Zone	Cost (GH. ¢)
Forest	5.00 -10.00
Transition	5.00 – 15.00
Coastal	5.00 -10.00
Guinea	1.00 – 4.00
Sudan	1.00 – 4.00

Exchange Rate: GH. ¢1.00 = 1.43 USD

4.3 Storage Practices employed by tomato farmers in Ghana

4.3.1 Storage materials used by tomato farmers

Majority of tomato farmers in Ghana (49%) used a piece of cloth to store their seeds until the next planting season (Table 4.4). Twenty-nine percent of the farmers also used Plastic bottles/bowls to store their seeds. Others used newspapers/paper bags (12%) and polyethylene bags (10%) for storing their seeds while only 5% used clay pots.

Table 4.4: Storage materials used by tomato farmers

Storage materials	Frequency	Percent
Piece of Cloth	49	49.0
Paper bags/Newspapers	12	12.0
Black polyethylene bags	10	10.0
Clay pots	5	5.0
Plastic Bottles/Bowls	29	29.0

4.3.2 Storage condition under which seeds are stored

All farmers (100%) stored their seeds under ambient conditions with none storing their seeds under cold storage conditions (Table 4.5).

Table 4.5: Storage condition under which seeds are stored

Storage condition	Frequency	Percent
Ambient (room)	100	100.0
Cold storage (refrigeration)	0	0.0

4.3.3 Agro zone versus Major Storage material

Majority of farmers (70.0%) in the Forest zone used plastic bowls for storing their seeds while in the Transition zone, 50.0% stored their seeds in black polyethylene. In the Coastal savanna zone, 60.0% of the farmers used newspaper/paper bags. Fifty per cent of tomato farmers in the Guinea and Sudan savanna zones used pieces of cloth and clay pots, respectively, to store seeds (Table 4.6)

Table 4.6: Agro zone versus Major Storage material

	Storage material					
Agro-eco zone	Plastic bowls	Newspaper/ paper bags	Clay pots	Pieces of cloth	Black Polybag	Total
Forest	70.0%	10.0%	0%	20.0%	0%	100.0%
Transition	0%	20.0%	0%	30.0%	50.0%	100.0%
Coastal	30.0%	60.0%	0%	10.0%	0%	100.0%
Guinea zone	30.0%	20.0%	0%	50.0%	0%	100.0%

Sudan zone	20.0%	10.0%	50.0%	20.0%	0%	100.0%

4.3.4 Frequency of Cropping versus Duration of Storing Seeds

Tomato farmers in Ghana cropped once to four times in a cropping season. The duration of storing their seeds ranged from 2 to 10 months before planting (Table 4.7). Tomato farmers who cropped once in a growing season stored their seeds for at least 9-10 months while farmers who cropped twice (94.4%) in a cropping season stored seeds for 6-7 months. Those who cropped three and four times (100%) stored their seeds for 3 to 5 months and 2 months, respectively.

Table 4.7: Frequency of Cropping versus Duration of Storing Seeds

	Duration of storage before sowing (Months)				
Frequency of Cropping	9-10	6-7	3-5	2	Total
Once	100.0%	0%	0%	0%	100.0%
Twice	5.6%	94.4%	0%	0%	100.0%
Three times	0%	0%	100.0%	0%	100.0%
Four times	0%	0%	0%	100.0%	100.0%

4.4 Farmers' determination of germination potential prior to seed sowing

Majority of farmers (81%) did not test their seeds before sowing while only 19 per cent conducted germination test (Figure 4.4). Reasons assigned for not conducting a germination test included lack of technical know-how and the faith in the ability of their seeds to germinate when sown.

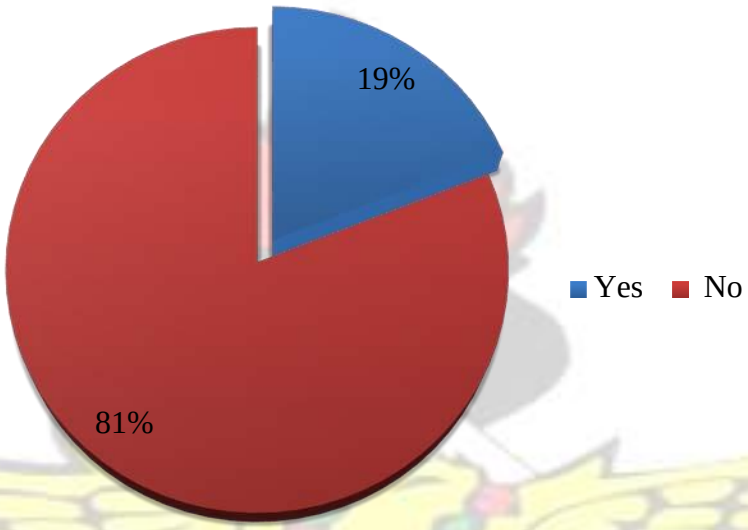

Figure 4.4: Percent determination of germination potential prior to seed sowing

4.5 Seed Quality Assessment

4.5.1 Purity Analysis of Farmer-saved tomato seeds in Ghana

Results of the three seed quality components, namely, pure seed, other crop seed and inert matter are presented in Table 4.8. The significantly highest percentage of pure seed (95.2%) was found from samples collected from the Forest zone. There was however, no significant difference in the percent pure seed between the other agro-zones. The least percentage pure seed was found in the Transition zone samples. The highest percentage of inert matter (25.1%) was found in seed samples from the Transition zone, significantly greater than the least from the Forest zone.

Table 4.8: Purity of Farmer-saved tomato seeds in Ghana Agro zone

	Pure seed (%)	Other crop seed (%)	Inert matter (5%)
Forest	95.2	0.15	4.6
Transition	74.9	0.00	25.1
Coastal	82.2	0.00	17.5
Guinea	79.0	5.55	15.5
Sudan	80.9	0.00	19.1
Mean	82.4	1.14	16.3
LSD (5%)	12.77	0.41	12.82
CV (%)	5.6	13.2	7.4

4.5.2 Seed Vigour and Germination tests of Farmer-saved tomato seeds

There were significant differences in percent seed vigor as well as percent seed germination. The highest percent seed vigor was from the Transition zone seeds, significantly better than the seeds from the Coastal and Forest zones. The least percent vigor was from the Forest zone seeds. Similarly, the highest percent germination was from the Transition zone, significantly better than the seeds from the Forest and Guinea savanna zones (Table 4.9).

Table 4.9: Percentage Seed Vigour and Germination of Farmer-saved tomato seeds

Agro zone	Vigour (%)	Germination (%)
Forest	68.5	68.8
Transition	94.0	98.0
Coastal	82.0	93.0
Guinea	92.0	92.3
Sudan	90.5	95.8
Grand Mean	85.5	89.5
LSD (5%)	8.9	5.2
CV (%)	6.8	3.8

4.5.3 Health Status of Farmer-saved tomato seeds

A total of eight fungi comprising five pathogens and three saprophytes were found to be associated with the farmer-saved tomato seeds collected from the five agro-ecological zones of Ghana (Table 4.10). The fungi were *Alternaria solani, Aspergillus niger, Aspergillus flavus, Curvularia lunata, Cladosporum spp., Fusarium oxysporum, Fusarium moniliforme, and Penicillium spp.* Among the pathogenic fungi, the highest percent incidence of *Fusarium moniliforme* (22.6%) was recorded in the Transition zone, followed by *Curvularia lunata* (19.5%) and *Alternaria solani* (6.4%) significantly higher than samples from the Forest, Guinea and Sudan savanna zones. On the other hand, *Fusarium oxysporum*, another major seed-borne fungus of tomato was highest (21.17%) in seeds from the Sudan savanna zone, significantly higher than samples from the other four zones.

Curvularia lunata recorded the highest percent incidence (19.5%) in the Transition zone, which differed significantly from samples in the Forest, Coastal, Sudan and Guinea savanna zones. Seed samples from the Transition zone recorded the highest percent incidence of pathogenic fungi (56%) while the Guinea savanna zone recorded the least (20.4%).The saprophytic fungi; *Aspergillus flavus, Aspergillus niger* and *Penicillium sp*. recorded high percent incidence in seeds from the Coastal savanna zone (83%, 34% and 18.9%) respectively, which differed significantly between samples from the various agro-zones.

Table 4.10: ***Pathogenic and Saprophytic fungi infecting farmer-saved tomato seeds***

	Percent incidence of							
Zone	*F. moniliforme*	*F. oxysporum*	*Cladosporum spp.*	*Curvularia lunata*	*Alt. solani*	*Aspergillus flavus*	*Aspergillus niger*	*Penicillium spp.*
Forest	2.43	1.47	0.45	17.83	0.47	35.0	3.97	-
Transition	22.6	6.5	1.0	19.5	6.4	9.40	1.53	5.5
Coastal	21.70	4.43	11.83	11.33	0.07	83.3	34.7	18.9
Guinea	12.3	0.97	0.5	5.0	1.47	63.0	8.96	4.0
Sudan	2.0	21.17	0.06	5.0	1.47	39.0	4.33	1.0
Mean	12.20	8.91	2.8	11.72	1.97	45.95	10.69	5.89
LSD (5%)	2.4	0.23	0.3	0.28	1.41	1.69	0.54	0.16
CV (%)	0.56	1.4	5.4	1.3	3.8	2.7	1.5	1.5

4.6 Crop performance studies

4.6.1 Selected soil chemical properties of the study location

Results of the soil analysis indicated a good amount of organic matter in the top soil (Table 4.11). The soil was slightly acidic with pH 5.7 to 5.9. The exchangeable cations (Ca, K and Mg) were higher in the top-soil (0-15cm) and reduced down the sub-soil (15-30cm) except for Magnesium, which increased. Similarly, N and P were higher at 0-15cm than 15-30cm. **Table 4.11: Selected soil chemical properties of the study location**

Sample (cm)	% Org. Matter (O.M)	% Total Nitrogen (N)	Exchangeable Cations cmol/kg or me/100g			Avail. P	pH
			Calcium (Ca)	Potassium (K)	Magnesium (Mg)		
0-15	2.11	0.18	5.13	0.76	1.27	130.93	5.9
15-30	1.61	0.15	4.53	0.48	1.40	123.74	5.7

4.6.2 Growth of farmer-saved tomato seeds

4.6.2.1 Plant height at flowering and Girth at 6 Weeks after transplanting

There were significant differences in plant height at flowering and girth of plant at 6 weeks after transplanting (Table 4.12). Samples from the transition zone recorded the highest (40.5 cm) plant height at flowering significantly higher than samples from the other four zones. The shortest plants (33.0cm) were samples from the Sudan savanna zone.

However, samples from the forest zone recorded the widest plant girth of 3.7 cm significantly wider than samples from the other four agro-ecological zones. Samples from the Guinea savanna zone recorded the narrowest plant girth (2.7cm).

Table 4.12: Plant height at flowering and Girth at 6 Weeks after transplanting

Zone	Plant Height at Flowering (cm)	Girth of Plant (6 WAP) (cm)
Forest	36.5	3.7
Transition	40.5	3.1
Coastal	32.8	3.1
Guinea	33.6	2.7
Sudan	33.0	2.8
LSD (5%)	2.3	0.38
CV (%)	2.4	4.5

4.6.2.2 Days to 50% flowering and fruit set of samples

Samples from the various agro ecological zones took 40 to 46 days from sowing to flower (Table 4.13). There were significant differences in days to 50% flowering as well as days to fruit set. The first to flower were samples from the Forest zone (40 days), significantly earlier than samples from the other zones. The last to flower were samples from the Coastal savanna zone.

Days to fruit set also ranged from 48 to 51 days.

Similarly, samples from the Forest zone were the first to set fruit (48 days), significantly earlier than samples from Transition, Coastal, Guinea and Sudan savanna zones.

Table 4.13 Days to 50% flowering and fruit set of samples

Agro-zone	Days to 50% flowering	Days to fruit set

Forest	40	48
Transition	44	51
Coastal	46	51
Guinea	45	50
Sudan	44	51
Mean	44	50
LSD (5%)	1.64	1.6
CV (%)	1.3	1.3

4.6.2.3 Number of flowers per truss, Flowers per plant and Fruits per truss

There were significant differences in the number of flowers per truss, number of flowers per plant as well as the number of fruits per truss between plants from the agro-zones (Table 4.14). Plants from the Forest zone recorded the highest number of flowers per truss, significantly more than plants from the Transition, Coastal and Sudan zones.

Similarly, the number of fruits per truss was highest in the Forest zone, significantly greater than plants from the Transition and Coastal zones.

Table 4.14: Number of flowers per truss, Flowers per plant & Fruits per truss

Sample from	No. of Flowers/truss	No. of flowers/plant	No. of fruits/truss

Forest	5.2	21.0	4.2
Transition	4.2	23.7	3.2
Coastal	4.0	22.7	3.2
Guinea	4.5	21.4	3.8
Sudan	4.4	21.3	3.5
Mean	4.5	22.0	3.6
LSD (5%)	0.8	1.6	0.8
CV (%)	6.5	2.5	8.2

4.6.2.4 Number and Weight of Fruits per plant per plot

There were significant differences in the number and weight of fruits per plant between plants from the agro-zones (Table 4.15). The number of fruits per plant ranged from 12.0 to 23.8. The highest number of fruits was recorded in the Sudan savanna zones, significantly higher than samples from the Forest, Coastal and Guinea savanna zones. The least number of fruits per plant was obtained from the Forest zone.

Table 4.15: Number and Weight of Fruits per plant plot

Samples from	No. of Fruits per plant	Weight of fruits per plant (kg/plot)
Forest	12.0	0.60

Transition	22.1	1.0
Coastal	16.0	0.85
Guinea	19.3	0.95
Sudan	23.8	1.35
Mean	18.63	0.95
LSD (5%)	4.2	0.3
CV (%)	8.1	11.8

4.6.2.5 Number of Marketable tomato fruit per plot

There were significant differences in number of marketable fruit between plants from the agrozones. Samples from Sudan savanna zone produced the highest number of marketable fruits (370.5), followed by samples from the Transition zone (321.5). The least number (177.5) of marketable fruits was recorded for samples in the Forest zone as shown in Table 4.16.

Table 4.16 Number of Marketable tomato fruit per plot

Agro-zone	Number of marketable fruits per plot

Forest	177.5
Transition	321.5
Coastal	180.5
Guinea	244
Sudan	370.5
Mean	258.8
LSD (5%)	31.5
CV (%)	4.4

4.6.2.6 Marketable tomato fruit yield per hectare (t/ha)

Significant differences were observed in the fruit yield (t/ha) between plants tomato plants from the various agro-zones (Table 4.17). Plants from the Sudan savanna zone gave the highest yield of 19.5 t/ha, significantly higher than plants from the other four agro-zones. The lowest yield was recorded by samples from the Forest zone (10.3 t/ha).

Table 4.17 Marketable tomato fruit yield per hectare (t/ha)

Agro-zone	Marketable fruit yield (t/ha)
Forest	10.3

Transition	15.6
Coastal	10.5
Guinea	12.3
Sudan	19.5
Mean	13.6
LSD (5%)	0.4
CV (%)	0.9

4.6.2.7 Relationship between % seed vigour and fruit yield of tomatoes (t/ha)

There was a positive but not significant relationship (r = 0.64) between the percentage seed vigor and tomato fruit yield (Figure 4.5).

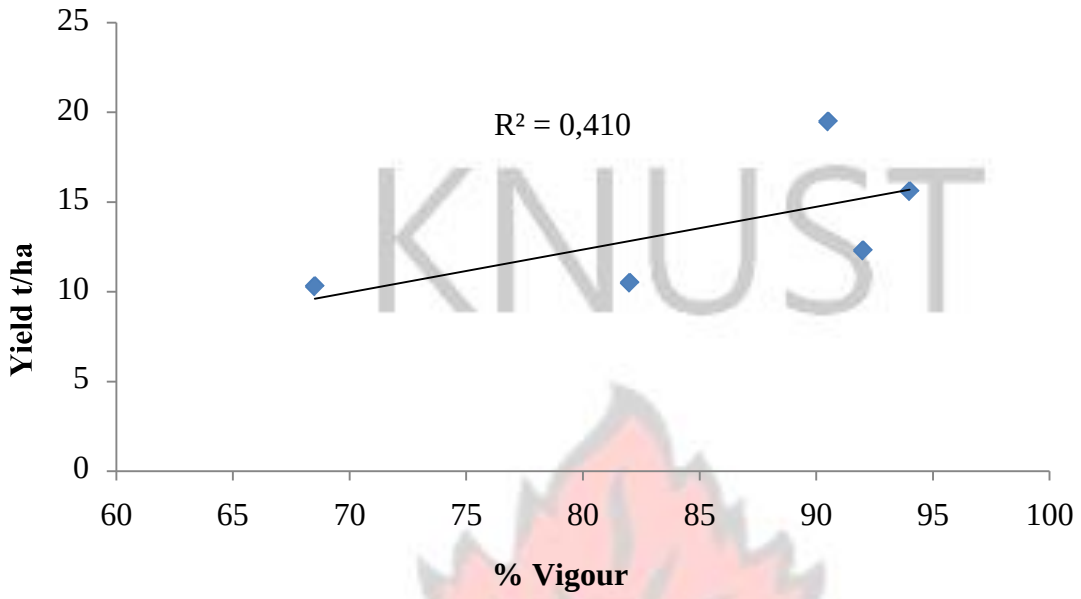

Figure 4.5 Relationship between % seed vigor and fruit yield

4.6.2.8 Number of seeds per fruit, 1000 seed weight and seed yield of farmer-saved tomato

There were significant differences observed in the number of seeds per fruit, 1000 seed weight (g) and seed yield per ha (kg) between samples from the various agro-zones (Table 4.18). Samples from the Transition zone recorded the highest number of seeds per fruit (273.6), significantly higher than samples from the other four agro-zones. The least number of seeds per fruit (125.1) was recorded in samples from the Coastal savanna zone. For the 1000 seed weight, seeds from the Forest zone were significantly heavier than seeds from the Transition, Coastal, Guinea and Sudan savanna zones.

The lowest 1000 seed weight was recorded for samples from the Transition zone but the Transition zone recorded the highest seed yield of 23kg/ha, significantly higher than samples from the Forest, Coastal savanna, Guinea and Sudan savanna zones.

Table 4.18: Seed yield of farmer-saved tomato (kg/ha)

Sample from per fruit	No. of Seeds per fruit (g)	Weight of seeds	1000 seed wt (g)	Seed yield per ha (kg)
Forest	163.3	1.15	10.0	21.7
Transition	273.7	1.24	8.6	23
Coastal	125.1	0.97	9.1	18
Guinea	176.7	1.17	9.4	21.8
Sudan	147.4	1.0	8.8	19.6
Mean	177.2	1.12	9.21	20.8
LSD (5%)	7.2	0.07	0.2	0.65 CV
(%)	1.5	2.4	0.9	1.1

5.0 DISCUSSION

5.1 Bio-data of Tomato farmers in Ghana

Majority of the farmers were in their youthful age (20-30 years) and are in their energetic and productive years. If the poor image of persons involved in agriculture needs to be changed and the young people are the ideal catalysts for such change given their greater willingness to adopt new ideas, concepts and technology which are all critical to changing the way agriculture is perceived and practiced. When all the other necessary material resources such as high quality seeds and supplementary inputs are made available to these young farmers, tomato production in Ghana has the potential of expanding.

The high percentage (77%) of farmers being males with only 23% being females as revealed from the survey may be because, in Ghana, tomato production is known to attract more men than women (Clottey *et al.,* 2009). The reason assigned to this situation could be that, tomato production is more capital intensive and it is known that men have more access to financial capital than women. As reported by Mamudu *et al.* (2009), about 44 per cent of the credit portfolios of Rural Banks in Ghana go to women while the remaining 56 per cent goes to men. Moreover, tomato production is regarded as a risky venture and women appeared not to be ready to take so much risk for fear of incurring debts (Clottey *et al.,* 2009). Additionally, according to the Ghana Living Standard Survey (1991/92), about 830, 000 household are engaged in harvesting and marketing of tomatoes, especially women. This implies that women are most likely to be associated with marketing (wholesaling and retailing) of farm produce than production.

The literacy rate of farmers in Ghana is believed to be generally low. However, the survey findings indicated that 37% of tomato farmers interviewed had at least basic education (primary/junior high

school) while 47% had received secondary education and only 17% had no formal education. A similar trend was observed by Kyofah-Boamah (2002). However, a survey conducted by Asare-Bediako *et al.* (2007) in the northern part of the country reported a high illiteracy rate of 60% among farmers interviewed. This situation however, may substantiate the notion of disparity in education and development within the country. At the national level, illiteracy rate is about 38.0 per cent (33.1% males and 44.5% females) compared with 72.3 per cent in the Northern regions of the country (Akolongo and van Klinken, 2008). These findings may therefore validate the reason why most smallholder farmers especially in the northern part of the country find difficulty in adopting new farming practices and technologies but rather often use wrong dosages of chemicals, wrong application rates, unimproved seeds as also reported by Bull (1989).

5.2 Source of seeds available to tomato farmers in Ghana

Majority of the farmers (52%) sourced their seeds from previously saved harvests while 28% obtained seeds from the local market and 15% purchased seeds from the agro-stores. It must however, be noted that seeds obtained from the local markets are most often 'farmer-saved'. This implies that farmer-saved seeds could be as high as 81% of the seeds available to tomato farmers in Ghana. This finding lends support to that of Asare-Bediako *et al.* (2007). Adetumbi and Daniel (2004) also reported that for vegetables, about 60% of farmers sourced seeds from their previously saved harvests, while about 30% purchased seeds from dealers in a survey conducted in Nigeria. In Sub-Saharan Africa, it is established that most farmers do not buy seed: they save their own or trade with other farmers (Almekinders *et al.,* 1994; Anon. 2001). Thus, farmersaved seed continues to be the dominant source of seeds for about 80-90% of farmers in SubSaharan Africa (Almekinders *et al.,* 1994 and Tripp, 2001).

The reason for the over-reliance on saved seeds may be for agronomic and economic reasons namely the saved variety is the best suited to the local soil and climate and it saves money (Anon. 2001). Kumar *et al.* (2004) also attributed small land holdings as revealed from the survey (0.2 to 1.2 ha) and lack of inputs as reasons that could force farmers to use their own saved seeds. A survey conducted by Clottey *et al.* (2009) on some tomato farmers in Ghana also revealed that some farmers do not see the economic benefit in investing in good quality seed, because the fruit prices on the market are the same irrespective of the variety or seed quality used. It must however, be noted that seeds obtained from the local market or farmers' own are most likely impure (Danquah *et al.,* 2004) as confirmed in the study. Majority of farmers (52%) do not even know the names of the varieties they cultivate and thus bulk all the seeds available to them as planting material. Moreover, these seeds could also be infected with disease pathogens which may contribute to the poor crop establishment and subsequently lower yields (Danquah *et al.,* 2004), since the productivity of a crop is directly linked to quality of the seed used (Shetty, 2000).

5.2.1 Cost and Quantity of Farmer-saved Seeds used by farmers

About 31% of tomato farmers in Ghana use 68g of seeds per 0.4ha at a cost, ranging from Gh. ¢ 5.00 – Gh. ¢ 10.00 per 68g. Surprisingly, this same quantity of seed is sold between Gh. ¢1.00 - ¢ 4.00 in the northern part (Sudan and Guinea savanna zones) of the country. This according to the farmers is still expensive. Most of Ghana's population especially, smallholder farmers are

extremely poor; living on less than one dollar ($ 1.00) a day especially in the northern parts of the country (Anon. 2009). This is confirmed by the reports that poverty in Ghana is evident in two sectors: agriculture and the informal sector, with the agricultural sector being the worse affected (National Policy Group, 2005).

Although most farmers know that seeds of improved varieties are of high quality in terms of viability, purity, health and good yield yet find the prices quite exorbitant. This perceived high cost of seeds could also be the reason why farmers do not purchase certified seeds, since they want to save money (Anon. 2001). Moreover, farmers do not realize the importance of buying seeds of improved varieties because there are no premium prices for their produce irrespective of the quality of seed used (Clottey *et al.*, 2009). The quantity of seeds used by farmers per 0.4ha of land, which ranges from 68g to 204g is on the high side. However, since only 19% of farmers (Figure 4.4) test their seeds to assess their germination potential prior to sowing, they increase the sowing rate just to compensate for seeds that may fail to germinate or survive after transplanting. Conversely, using this technique may imply that farmers are likely to spend more on seeds and increase their cost of production (Anon. 2008).

5.3 Seed storage practices of tomato farmers in Ghana

From the survey, none of the farmers followed proper storage practices to save their seeds. Farmers saved their seeds in black polyethylene bags, pieces of cloth, plastic bins, paper bags/newspaper and Clay pots, which were not treated with any pesticides and kept under ambient conditions. Barua *et al.* (2009) reported that the storage techniques employed by farmers in storing their seeds have significant influence on seed germination. From the study, seeds stored in Plastic bins/bowls

in the Forest zone recorded the lowest percentage germination. This could be attributed to the fact that the seeds stored in plastic bowls were perhaps not tightly covered to prevent increase in moisture content of the seeds and this can reduce its germination capacity and overall viability, since the moisture content of a seed affects seed viability during storage (Rindels, 1995). However, the highest percentage germination was observed in samples from the Transition zone, which were stored in polyethylene bags. This storage material can prevent or reduce the influence of external factors like moisture on the seed. The findings are consistent with that of Barua *et al.* (2009), although in his study, seeds stored in cloth recorded the lowest percentage germination followed by plastic bins/tins. It must however, be noted that seed deterioration is a natural phenomenon and that the life span of seeds decreases with the passing of time irrespective of the storage structure used (Harrington, 1972). Further, the storage practices employed by the farmers perhaps rendered the seeds genetically impure as evident from the field studies that seed samples from the same source showed significant variation in morphology, especially fruit shape characteristics (APPENDIX III). Seed health studies also revealed high percent incidence of seed-borne fungi, especially storage fungi.

5.4 Seed Quality of Farmer-saved tomato seeds in Ghana

The present study revealed that farmer-saved tomato seeds grown in Ghana have high physical purity, although varietal purity was compromised as a result of the storage practices employed by the farmers and the sources from where farmers obtained their seeds for planting. Other crop seed was virtually absent in most samples collected but inert matter was recorded in all the samples. The absence of other crop seeds observed in samples collected could be because majority of the

farmers practiced mono cropping, especially during the minor season; with few inter crops. The percentage germination and vigor of the farmer-saved seeds collected from the various ecological zones were also high ranging from 68.69% to 98%. This could be attributed to the fact that most of the tomato farmers extracted seeds from the red ripe fruits and also applied the fermentation technique for extracting the seeds (APPENDIX IV). According to Baruah *et al.* (1996) and Doijoe, (1988), the best germination is obtained from seeds extracted from red ripe tomato fruits. Das and Baruah (1997), comparing manual extraction of seeds from fruit pulp with fermentation technique revealed that the highest percentage germination and vigour were recorded for seeds extracted using the fermentation technique.

The seed samples from both the Sudan savanna and Transition zones did not only give maximum percentage vigor (90.0% and 94%) and germination (95.8% and 98.0%) respectively, but also gave the highest yield. This result also confirms the positive relationship (r = 0.64) that was observed between percentage seed vigor and fruit yield. These findings lend support to the report that high quality seed (in terms of vigor and germination) have some positive influence on yield (Harrison, 1966; TeKrony and Egli, 1991). High quality seed helps in raising healthy plants and in the establishment of optimal plant population in the field (Doijoe, 1988).

Additionally, crops harvested during early reproductive growth, such as tomato, can show positive relationship between seed vigor and yield (Basra, 1995).

Most authors are of the view that farmer-saved seeds are generally substandard (Katiyar and Vaish, 1998; Praveen Kumar *et al.,* 2001). On the contrary, the study revealed comparatively high physical purity, vigor and germination which corroborates with other reports by (Walker *et al.* (1997a), Haque *et al*. (2007) and Mekbid (2008). On seed health studies, the present study revealed that none of the seed samples was free from seed-borne pathogen and saprophytic fungi being

infected with eight fungi, comprising five pathogenic and three saprophytic fungi. However, variations were observed in the abundance of fungi depending on the agro zones. Variation in prevalence of the individual fungi with respect to location is consistent with the findings of Kulik (1973), Harma and Pfleger (1974), Bankole (1996) and Nutsugah, *et al*. (2004).

On tomato, *Fusarium oxysporum* causes foot and root rot and wilt of tomato (Sherf and Macnab, 1986) while *Alternaria solani* causes early blight of tomato (Sherf and Macnab, 1986). However, the disease symptoms of these fungi were not observed on the field when infected seeds were sown. This could be attributed to the fact that good agricultural practices (GAP) such as timely weed control, application of the right pesticide at the correct rate, good sanitation among others, which contribute to raising a healthy plant, were followed. This implies that when farmers follow good agricultural practices, even sowing infected seeds may not lead to disease development that can cause economic loss on the field and subsequently give reasonable yields. Moreover, several studies have indicated, the pathogenicity of isolates within these fungal species identified ranges from highly virulent to non-pathogenic, therefore the level of seed contamination by these species do not always correspond to development of seed-borne diseases (Padwuk, 1978; Graham and Linderman, 1983 and Axelrood *et al.,* 1995).

Additionally, the climatic conditions (Appendix I) during the cropping period may not have favoured the growth, development and spread of these fungi pathogens. For instance, Dampingoff disease caused by *Fusarium oxysporum* and *Fusarium moniliforme* has been shown in several studies to increase greatly following heat stress (Haug and Kuhlman, 1980 and Axelrood *et al.,* 1995). Farmers can also reduce the incidence of these diseases when they crop during the dry season provided irrigation facilities are available. The storage fungi, *Aspergillus flavus* and *Aspergillus niger,* recorded the highest percent incidence, but had no effect on germination of the

tomato seeds, since they are not pathogenic to tomato (Kulik, 1973; Harman and Pfleger, 1974 and Bankole, 1996) but are known to be involved in deterioration of seeds during storage (Mittal and Wang, 1993; Agarwal and Sinclair, 1997). The presence of certain fungi on seeds is often significant because it may indicate problems with the quality of the seed lot due to improper handling and storage of seeds (Michelle and Fraedrich, 2009).

5.5 Performance of Farmer-saved tomato seeds on the field.

Vegetative and reproductive growth showed significant differences among all the samples collected from the various ecological zones. The tomato germplasm were collected from varied agro-ecological zones of Ghana; Forest zone, Transition, Coastal savanna, Guinea and Sudan savanna zones. Thus, these tomato samples may have developed traits adaptable to peculiar environments in which they have lived, hence their varied field performance.

Generally, qualitative and quantitative traits are less variable due to environmental conditions ((Aboagye and Bennett-Lartey, 2004). However, the present results revealed some differences in both qualitative and quantitative traits evaluated.

This demonstrates that not all qualitative and quantitative characters may express similarly irrespective of the environmental conditions. The variation in morphological differences may also imply that there is some level of genetic diversity existing among the cultivated varieties of tomatoes grown in Ghana. This according to Rick and Hole (1990) may be as a result of evolutionary changes, since farmers have been recycling these materials for years.

Samples took 40 to 47 days to flower, with samples from the Forest zone being the first to flower. Generally, early flowering is detrimental for the overall productivity of fruit per plant, since the

source to sink ratio will be limited for effective photosynthesis (Aboagye *et al.,* 1994). This could be the reason why samples from the Forest zone recorded the lowest number of fruits per plant and least yield of 10.3 t/ha. However, early maturing cultivars would be ideal for production in areas prone to water stress or short duration of rainfall to obtain desirable yields. Moreover, there were significant differences in the number of flowers per truss and number of fruits per truss among some samples studied. The results thus, revealed a flower abortion of about 20% for all samples. The percentage flower abortion could be attributed to the short dry spell of drought and high temperatures experienced at flower bud formation. According to Wudiri and Hendeson (1985), the average number of flowers that develops into fruits decreases with decreasing water supply.

The number and weight of marketable fruits per plant and fruit yield per hectare showed significant differences between samples studied. Samples which had the least number of fruits recorded the lowest weight. Samples from the Sudan savanna zones which recorded the highest number of fruits per plant also had the highest weight and overall yield per hectare (19.5 t/ha). In addition to the number of fruits per plant, the size of fruit as well as the number of locules could also account for the highest weight recorded for the samples from the Sudan savanna zone.

Samples from this zone were bigger (7 cm in diameter) and recorded the highest average number (8) of locules per fruit. Studies have shown that there is a strong positive correlation between fruit weight and number of locules (Markovic *et al.,* 1996).

The differences in yield could be attributed to several factors. The study indicated a positive relationship between percentage seed vigor and fruit yield. From the results, samples which recorded the highest percentage germination of 98% and 95.8% also gave the highest fruit yields of 15.6 and 19.5 t/ha. This result also confirms the positive correlation (r =0.64) that was observed between percentage seed vigour and fruit yield. Conversely, the Forest zone which gave the

minimum percent seed vigor (68.5%), gave the lowest fruit yield, 10.3t/ha. These findings lend support to the report that high quality seed (in terms of vigor and germination) have some positive influence on yield (Harrison, 1966; TeKrony and Egli, 1991). High quality seed helps in raising healthy plant and establishment of optimal plant population in the field (Doijoe, 1988). Crops harvested during vegetative growth or early reproductive growth, such as tomato, can show positive correlation between seed vigor and yield as confirmed by Harrison (1966) for onions, Smith *et al*. (1973) for lettuce and Finch-Savage & McKee (1990) for cauliflower and peas and tomato (Basra, 1995).

The differences in yield could also be due to morphological differences as reported by Nsowah (1969) and Norman (1992). All samples were the indeterminate type and thus had a growth habit of spreading their leaves wide for light interception for the production of photosynthate. Norman (1992) also reported that the yield of tomato depends on other factors such as spacing, type of cultivar, whether plants were staked, location, the quality of seed etc.

Although it is reported that, the average yield of tomato in Ghana is low, about 7.5 t/ha (Danquah and Fulton, 2007), with high quality seed, which is free from disease pathogens and of high viability, higher yields could be realized.

6.0 CONCLUSION AND RECOMMENDATION

A field survey was conducted in the 2008/2009 cropping season in five agro-ecological zones of Ghana to identify the sources of seeds available to smallholder tomato farmers and the storage practices employed in storing the seeds. Laboratory and field experiments were carried out to assess the quality and its effect on the fruit yield levels of the farmer-saved seeds.

The study revealed that the majority of smallholder tomato farmers (52%) in Ghana saved their own seeds for planting. None of the farmers followed proper storage practices to save their seeds as farmers saved their seeds in plastic bowls/bins, black polyethylene bags, clay pots, paper bags/newspapers and pieces of cloth, which were not treated against insect-pests. Seeds were also kept under ambient conditions. However, except for samples from the Forest zone, the storage

practices had little influence on the quality (percent pure seed, vigor and germination) of the seeds. The physical purity of farmer-saved tomato seeds was high, with a percent pure seed component ranging from 74.9 to 95%. The study also revealed that none of the samples collected was free from seed-borne and saprophytic fungi and were infected with eight. However, the abundance of different fungi on seeds varied depending on the location of the sample collected. The most prevalent seed-borne fungi of farmer-saved tomato seeds in Ghana were *Fusarium moniliforme, Fusarium oxysporum* and *Curvularia lunata* and the saprophytic fungi were *Aspergillus flavus* and *Aspergillus niger* and *Penicillium spp.* The crop performance studies indicated a positive correlation between percentage vigor and fruit yield of tomatoes. Marketable fruit yield of tomatoes was relatively high, ranging from 10.3 tonnes/ha to 19.5 tonnes/ha. This implies that high quality seed, which is physically pure, of high vigour, viable and free from disease pathogens has positive influence on fruit yield of tomatoes.

Thus, if farmers are educated to take proper measures to keep their saved seed to maintain good health, purity and viability until planting, yield can certainly enhanced.

I recommend that further studies is necessary to determine the varietal or genetic purity of farmer-saved tomato seeds grown in Ghana to help make available to farmers pure tomato seeds which are locally adaptable.

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APPENDIX I: WEATHER DATA DURING THE EXPERIMENTAL PERIOD

TEMPERATURE (^{0}C)

	2008		2009	
MONTH	**MAX.**	**MIN.**	**MAX.**	**MIN.**
JAN.	33.3	19.2	33.5	20.3
FEB.	34.6	21.7	33.8	22.5
MAR.	34.2	22.0	33.5	22.7
APR.	33.3	22.9	33.4	22.5
MAY	33.0	22.8	33.0	22.7
JUNE	31.4	22.5	31.7	22.1
JULY	28.8	22.3	29.6	21.4
AUG.	29.5	20.8	28.6	21.7
SEPT.	30.0	21.3	30.0	21.9
OCT.	31.3	21.6	31.1	22.1
NOV.	32.7	22.2	31.8	22.4
DEC.	32.0	21.1	32.9	23.1

RELATIVE HUMIDITY (%)

	2008		2009	
MONTH	**0900**	**1500**	**0900**	**1500**
JAN	48	32	70	38
FEB	79	41	85	53
MAR	81	53	81	58
APR	83	59	84	60
MAY	82	59	81	60
JUNE	85	64	87	66
JULY	80	65	88	72
AUG	88	69	90	74
SEPT	87	68	88	69
OCT	85	62	88	65
NOV	84	55	85	61
DEC	84	53	84	55

RAINFALL (mm)

MONTH	2008	2009
JAN	0.0	0.0
FEB	61.7	114.9
MAR	134.1	162.9
APR	117.1	123.9
MAY	185.8	99.0
JUNE	179.8	365.9
JULY	45.0	226.1
AUG	114.5	19.0
SEPT	148.9	59.7
OCT	95.8	201.7
NOV	30.7	40.4
DEC	47.5	30.0

APPENDIX II: QUESTIONNAIRE

1. Region/ Area/Zone: …….
2. Name of Town/Village: …….
3. Age of farmer: a. 10-19 ( ) b. 20-29 ( ) c. 30-39 ( ) d. Above 40
4. Sex: Male ( ) Female: ( ) 5. Educational Background:
   a. Primary ( ) b. Secondary ( ) c. Post-Secondary /Tertiary ( )
   d. No Formal Education ( )

6. How long have you been farming? A. 1-3 yrs ( ) B. 4-6yrs ( ) C. 7-10yrs. ( ) D. Above 10 yrs. ( )

7. Size of farm (acres) for a season: ……..

8. How many times do you farm in a year? A. Once ( ) B. Twice ( )

C. Other (s). Specify. ……..

9. When do you plant (nursery to harvest time)? …….

10. Type of farming. A. Inter ( ) B. Mono/Sole ( ) C. Subsistence ( )

11. Cropping pattern. A. Rotation ( ) B. Bush fallow ( ) C. Continuous cropping ( )

SEED QUALITY ASSESSMENT

12. What do you use to plant? A. Seed: Yes ( ) No ( ) B. Seedlings: Yes ( ) No ( )

13. What is you source (s) of Seeds/Seedlings?

a. Own farm (farmer-saved) ( )
b. Local market ( )
c. Neighbour (Relatives) ( )
d. Agro-Stores ( )
e. Other (s) Specify …….

13. If seeds, how do you store your seeds before planting the following season?

a. In cloth ( ) b. paper bags ( ) c. black poly bags ( ) d. plastic/bowl ( )

d. others ……..

I4. If own farm saved, which of the fruits do you select for seeds?

a. Unmarketable fruits ( ) *damaged, cracked, other defects
b. Those left after harvest ( )
c. Marketable fruits ( ) *no defects
d. Other (s), Specify ( )

15. What specific criteria do you use? A. Size ( ) B. Colour ( ) C. Age (maturity) ( )
D. Other, specify: ……If Colour, what stage ……..

16. How do you extract or process your fruits to get the seeds:

a. Fermentation technique ( )

b. Manual extraction (Cut and extract from pulp) ( ) c. Other (s), Specify,……

17. Quantity of seeds used for an acre: …….(Cup/tin)

18. How much does it cost? ……

19. Do you readily get enough seeds for your farm? Yes ( ) No ( )

20. If no, what do you do? …….

21. Do you test your seeds for germination potential before they are sown? Yes ( ) No ( )

22. If no, what do you do if some fail to germinate? ……

23. Do you treat your seeds before sowing? Yes ( ) No ( )

24. If yes, with what and against what? ……

25. If no, do you encounter any pest or disease problems?

a. At Seedling stage (Nursery): ……

b. Before flowering: …….

c. Fruiting stage: ……

FRUIT QUALITY ASSESSMENT

26. Type of varieties cultivated

a. Local var. ( ), Eg……
b. Exotic var. ( ), Eg. ……

27. How many varieties have you cultivated since you started farming?

a. One ( ) b. two ( ) c. three ( ) d. more than three ( )

28. What is/are the cause (s) for the change in the varieties cultivated?

a. ……
…….

b. ……
……..

29. What is your estimated yield from farm in a season (per acre) ……..

30. What is your market outlet? A. Local market ( ) B. Processing factory ( ) C. Other (s),

Specify, …….

31. How long are produce/fruits able to store. A. 0-3 days ( ) B. 4-6 days ( )

C. Above 7 days ( )

32. Any additional peculiar problem (s)? ……

……

APPENDIX III

APPENDIX IV: Some output of Farmer survey

Farm sizes cultivated by tomato farmers in Ghana

Size of farm (acre)	Frequency	Percent
1/2	19	19.0
1	10	10.0
2	53	53.0
<3 & >2	18	18.0

Method of seed extraction

Method of seed extraction	Frequency	Percent
Fermentation	87	87
Manual extraction	13	13
Total	100	100

Types of cultivars grown

Types of cultivars grown	Frequency	Percent
Local	80	80.0
Exotic	20	20.0
Total	100	100.0

Do farmers treat their seeds before sowing

Respondent	Frequency	Percent
Yes	4	4.0
No	96	96.0
Total	100	100.0

Types of Pesticides Used by Farmers

Pesticide	Frequency	Percent (%)
Poison (Karate)	38	38
Diathane	42	42
Cymathoate	3	3
Ridomil	4	4
Cocide	6	6
Furadan	4	4
Botanicals	3	3

Pests farmers normally encounter

Pest	Frequency	Percent (%)
Nematode	15	15
Caterpillar	42	42
Whitefly	21	21
Aphids	15	15
Other insects	7	7

Diseases

Disease	Frequency	Percent (%)
Damping off	45	45
Wilt	15	15
Leaf Curl	14	14
Blight	17	17
Fruit	9	9

PLATES FROM RESEARCH

Plate 1: Some Villages Surveyed

Plate 2: Seed Health Test at CSIR-CRI (Fumesua) Seed Pathology Laboratory

Plate 3: Germination Test of Farmer-saved Tomato seeds at CRI-Kwadaso Seed Science Lab.

Plate 4: Flowers on truss and Flower after fertilization

Plate 5: Fruits of plant

Plate 6: Different shapes of fruits obtained from a seed sample (depicting varietal impurity)

Plate 7: Harvested fruits