EVALUATION OF TOMATO (*SOLANUM LYCOPERSICON L.*) FOR MORPHOLOGICAL ATTRIBUTES AND YIELD UNDER ENVIRODOME GREENHOUSE CONDITIONS

BY

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(AGRONOMY)

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DECLARATION

I, Thomas Anderson, hereby declare that except for the references to other people's work which have been duly cited, this thesis is the result of my original findings and that this thesis has neither in part nor in whole been presented for a degree in Ghana or elsewhere.

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ABSTRACT

Envirodome greenhouse technology has become a widely accepted and profitable system for vegetable production particularly in Ghana. However, plant varieties best suited for the Envirodome have not been fully exploited in Ghana. Thus, an experiment was carried out at the Forest and Horticultural Crops Research Centre (FOHCREC), Okumaing-Kade in Ghana from July 2018 to April 2019 to assess eight different types of tomato for some morphological and yield attributes under Envirodome greenhouse conditions. Six accessions (Tenegru-2010, Tanya, CLN3024A, CLN3212C, FMTT1733E and CLN3900d) from Asia Vegetable Research Development Center (AVRDC) and two varieties (Jaguar F1 and Nkansah HT) locally obtained were used in the study. The six accessions and the two varieties were arranged in a Randomized Complete Block design (RCBD) with three replications. Some morphological descriptors for plant traits and fruit traits were recorded and scored using the AVRDC-GRSU characterization record sheet. Correlation analysis was also performed to know about morphological traits positively correlated with economically important traits. The study revealed that CLN3212C and Jaguar F1 showed the best performance for some morphological attributes such as average fruit weight (size). In terms of yield CLN3212C, Jaguar F1, and Tanya recorded maximum yield of 34.81t/ha, 34.48t/ha and 20.98t/ha respectively. However, in terms of quality, the accession FMTT1733E recorded highest Brix (^{o}5.60) whiles Tanya and Jaguar F1 produced the thickest pericarps measuring 0.80cm and 0.73cm respectively. Longest shelf life averaging 24 days was also obtained by Tanya and Jaguar F1. Farmers who use the Envirodome greenhouse technology and desire high yielding tomato varieties may cultivate CLN3212C, Jaguar F1, and Tanya while those who grow tomato for processing may also cultivate the variety Jaguar F1, and accessions FMTT1733E and Tanya.

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LIST OF ABBREVIATIONS

AC	Anthocyanin coloration
ANOVA	Analysis of Variance
AVRDC	Asia Vegetable Research Development Center
BES	Blossom end shape
CH	Chlorophyll content
cm	Centimeter
ECIF	Exterior color of immature fruit
ECMF	Exterior color of mature fruit
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization Statistical Databases
FD	Fruit diameter
FL	Fruit Length
FOHCREC	Forest and Horticultural Crop Research Centre
FPF	Fifty percent flowering
FSV	Fruit size variation within plant
FY	Fruit yield
g	gram
GRSU	Genetic Resources and Seed Unit

GH	Growth Habit
HT	Heat Tolerant
IGB	Intensity of Greenback
LSD	Least Significant Difference
LT	Leaf type
mm	Millimeter
N.P.K	Nitrogen, Phosphorus and Potassium
NDTM	Number of days to maturity
NFPP	Number of fruits per plant
NFPT	Number of fruits per truss
NL	Number of leaves
NOL	Number of locules
NT	Number of truss
PFS	Predominant fruit shape
PFS	Percentage Fruit set
PH	Plant Height
PJP	Present of Jointless Pedicel
PT	Pericarp thickness
RH	Relative Humidity

AFW	Average fruit weight
SP	Stem Pubescence
t/ha	tonnes per hectare
TSS	Total Soluble Solids
UNESCO	United Nations Educational Scientific and Cultural Organization

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DEDICATION

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CHAPTER ONE

1.0 INTRODUCTION

Tomato (*Solanum lycopersicon* L.), belongs to the family Solanaceae. It is believed to have originated from the Peruvian and Mexican regions. Tomato was thought to be poisonous long before it was considered healthy to eat. It is one of the most accepted vegetables usually grown in the world. Tomato is known as a protective food because of its special nutritive value and also its wide spread production. The cultivation of tomato has multiplied throughout the world occupying an area of 4.6 million ha with an annual production of 128.00 million ton (NHB, 2010).

Tomato is mostly grown in countries such as China, Netherlands, Italy, USA, India, Ghana and Burkina-Faso.

In Ghana, it is an essential ingredient in the diet of many people. It is used in preparing a variety of foods such as soups, sauces, stews, salads and other dishes. In Ghana, tomato is normally used in large quantities as compared to other vegetables (Ellis *et al.,* 1998). The fruit is practically nutritious and contains high amounts of vitamins A and C (AVRDC, 2004). Tomato is the most significant vegetable in the tropics (FAO, 1990; 2003). Universally, it is the second most consumed vegetable after potato (FAOSTAT 2005, Osei *et al.*, 2010).

Tomatoes can be produced across a wide range of soils as long as drainage and the physical soil structure are good. However, it does very well in well-drained sandy loams to loamy soils with optimum pH range of 6.0 - 6.5. In Ghana, highest quality fruits and greatest yields are obtained in the dry season with supplementary water (Osei *et al*., 2010).

Tomato demand in Ghana is very high all year round with local production unable to meet the domestic demand. Some farm yields are as low as 7.5-10 t/ha (Osei *et al*., 2010). This therefore

All available evidence suggests that the variety grown also influence yields. Majority of tomato varieties cultivated in Ghana have not been properly evaluated under the Envirodome greenhouse conditions though they may have been assessed and introduced. This poses challenges such as disease outbreaks, unavailability of seeds, poor adaptability and poor yield among others.

Thus most suitable varieties for different ecozones are yet to be established.

Presently, tomato cultivation in open fields is very common in Ghana. However, these tomatoes in open fields are affected by various abiotic and biotic stresses and thus hinder the production of high quality tomatoes in terms of size, shape, and color. In addition, tomatoes grown in open fields are exposed to diseases and pests compared to tomatoes produced under greenhouse (Rajesh**,** 2017).

Tomato production in greenhouse has become widely accepted and profitable in areas where markets for tomatoes are readily available (Pandey *et al*., 2006). There is a great prospect of year round production by selecting recommended cultivars. Furthermore, growing tomatoes in greenhouse in the tropics allows the farmer to establish the most suitable conditions for each crop stage. This helps the farmer to keep plants in an optimal environment temperature and relative humidity that favors the reduction of the production period.

In addition, growing tomatoes in greenhouse ensures efficient use of production resources such as water and fertilizer. By including techniques such as fertigation, only the appropriate quantities of water and fertilizer are provided to the crops.

The use of greenhouse technology in growing tomato provides and also ensures a greater control of pests, weeds and diseases.

Several greenhouse technologies exist but in Ghana the most commonly greenhouse used by farmers is the Envirodome greenhouse.

Envirodome greenhouses are not simply greenhouses but fully integrated controlled environment growing system specifically designed for climates in West Africa.

There are a number of cultivars that have been evaluated for open field tomato cultivation but only a few have been evaluated under Envirodome greenhouse conditions.

The need, therefore, to evaluate tomato varieties under Envirodome greenhouse conditions to identify their morphological attributes and yield and make recommendations to tomato farmers is very necessary.

Morphological attributes are very helpful for developing varieties and also in the identification of desirable genotypes.

The potential yield of tomato under Envirodome greenhouse conditions has not been fully exploited in Ghana. Before recommending any tomato cultivars suitable for a country, it is relevant to evaluate tomato cultivars giving emphasis to the aspect of growth suitability and yield as the performance of tomato cultivars can vary from place to place. Thus, there is the need to evaluate tomatoes grown under Envirodome greenhouse conditions in Ghana so as to ascertain their growth and yield potential and recommend the cultivars best suited under Envirodome greenhouse conditions for farmers who use Envirodome greenhouses.

The objectives of the studies were:

1. To assess the agro-morphological parameters of different tomato accessions under Envirodome greenhouse condition.

2. To evaluate the yield parameters of different tomato accessions under Envirodome greenhouse conditions.

3. To evaluate the quality parameters of the different tomato accessions.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and domestication of Tomato

Tomato (*Solanum lycopersicon L.*), is believed to have originated from Andean regions which is now part of Bolivia, Colombia, Chile and Peru (Peralta and Spooner, 2007). Although the history of early origins location of tomato domestication has been reported unclearly, there are two hypotheses that have been developed for the actual origin of tomato. The first hypothesis suggests Peru while the second hypothesis suggests Mexico as the places of origin of tomato domestication (Peralta and Spooner, 2007). Though the exact attestation for the time and place of original location of tomato domestication is not present, it is widely assumed that Mexico is the most credible region of domestication. Peru is proposed to be the most credible centre of diversity of tomato wild relatives (Larry and Joanne, 2007). The ancestor of cultivated tomato is believed to be *Solanum lycoperscion cerasiforme*which is spread in Central America (Cox, 2000). Current genetic explorations have shown that the plant 'cerasiforme' is a combination of wild and cultivated tomatoes rather than 'ancestral' to the cultivated tomatoes (Nesbitt and Tanksley, 2002). "The genetic difference present in the wild species has been inspected for precise traits and is being exploited in tomato breeding" (Walter, 1967; Rick and Chetelat, 1995; Larry and Joanne, 2007). New species of tomato are being bred and preserved in various gene banks (Peraltra *et al*., 2005). The estimation of genomes in tomato cultivars contains less than 5% of the genetic variation of their wild relatives (Miller and Tanksley, 1990).

"Domestication of tomato in its center of origin occurred and remained there until its introduction to Europe around the 15th Century where domestication continued over the 18th Century and 19th

centuries" (Sims, 1980). Tomato can thrive well in a wide range of environments and agro-ecological zones; for this reason, it is found and cultivated all over the world as one of the most essential vegetable crops. Tomato was first introduced into the West Africa sub-region by the Portuguese during the period between sixteenth and seventeenth Century and has become one of the most accepted vegetable crops (Norman, 1992; Nkansah *et al*., 2003; Osei *et al*., 2010). Tomato has become one of the vegetable most consumed in Ghana (Schippers, 2000; Osei *et al*., 2010). Its cultivation supplies a key form of employment to many people in Ghana particularly in the Ofinso North, Ada districts and Bolgatanga (Norman 1992).

2.2 Botany of Tomato

2.2.1 Reproductive description

Tomato (*Solanum lycoperscion L*.) plant is mostly self-pollinated (autogamous). However, it may also be cross pollinated (Agong *et al.*, 2001, Shankara *et al*., 2005). Tomato produces a cluster of inflorescences which mostly has an average of six to twelve bisexual flowers with yellow colored petals (Ochar, 2015). It has a bright yellow colored six stamens and anthers and the six stamens and anthers surround the style with an elongated sterile tip (Ochar, 2015). The ovary of tomato is superior with about two to nine locules. The tomato fruit has a fleshy skin and its shape, length and diameter vary depending on cultivar. Mostly, immature tomato has a green color which changes to yellow, orange or red as ripening sets in. Determinate tomato fruit types mature faster than the indeterminate types. Slower ripening rate together with the high leaf to fruit ratio enhance the taste of indeterminate types (Ochar 2015).

2.2.2 Vegetative description

Tomato (*Solanum lycoperscion L*.) belongs to the S*olanaceae* family (Peralter and Spooner, 2007). It is short-term perennial herb but mostly cultivated as annual vegetable crop. Tomato is a dicotyledonous crop and has a tap root system which mostly grows to a length of about 50cm (Akinfasoye, 2011). The glandular stems of tomato plant normally grow to about 2 to 4 m high (Shankara *et al*., 2005). Tomato has a compound leaf which comprises of ovate to oblong leaflets spirally arranged along the hairy weak wooden stem by the petiole (Ochar, 2015). Usually, tomato is classified as determinate, semi-determinate and indeterminate according to their growth habits. Determinate types of tomato cease to grow further at about 1.5 m high when flower clusters form at the terminal growing point. The determinate tomato unlike the indeterminate tomato does not require staking since it is self-supporting. Cultivation of the determinate type of the tomato normally requires less labor and therefore makes the determinate type of tomato suitable for commercial production. Indeterminate type of tomato on the other hand continue to grow even after they have flowered though their growth might cease after flowering when they are cultivated under tropical conditions (Shankara *et al*., 2005).

2.3 Classification by fruit type

Commonly cultivated tomato types include the plum (Roma), cherry and the shared table varieties (Jensen and Schock 2009). However, Van *et al*. (2004), classified tomato cultivars based on: Growth habit: indeterminate, semi -determinate or determinate (bushy); Fruit size: small round (cherry tomato, < 30 g; medium-large round (120-150 g), beefsteak and ribbed (> 200 g); Fruit shape: round, heart-shaped, pear-shaped, plum-shaped, elongated or flat; Colour of ripe fruit: red, pink, orange or yellow; Utilization: for fresh market or processing (Oduor, 2016).Some varieties of tomato cultivated in Ghana are Roma VF, Wosowoso, Nkansah Heat Tolerant, Anna, Mongal, Jaguar, Pectomech, Laurano 70 and Tropimech. Petomech variety is mostly appropriate for processing (Robinson and Kolavalli, 2010).

2.4. Classification by growth type

Reader (2003) and Jansen and Shock (2009), reported that, the growth habit of tomato can either be determinate or indeterminate. They describe determinate tomato plant as tomato which will grow a certain quantity of foliage and then future growth is directed towards fruit production. They also describe the indeterminate tomato growth type to be those that are generally viny and continue to grow new stems and leaves throughout the growing season, along with fruit setting on a continuing basis.

2.5 Nutritional and health benefits of tomato

Tomato fruit is consumed and valued throughout the world by consumers and processors because it contains many essential nutrients such as vitamins, minerals and antioxidant which have been reported very important to the health of humans (Reddy *et al*., 2013). Tomato contains a rich source of vitamin C, beta-carotene, folate, lycopene, potassium and flavonoids (Wilcox *et al*., 2003). Its chemical composition such as β-carotone, vitamins (A and C) and potassium determines tomato's significant nutritional quality. WHO (2003) reported that diet containing essential phytochemical components aid or help to avoid about 90% Type II diabetes and these phytochemicals are mostly present in fruits of which tomato is one of them. Consumption of tomato reduce the risk of about 80% of diseases associated with cardiovascular-related conditions since tomato contains a good source of organic acids and other metabolites such as lycopene, phenolics acids caroteniods and flavonoids which function as antioxidants (Mertenz-Talcott *et al*., 2003). In addition, flavonoids which are essential components of tomato play a major role in the reduction of cancer-related diseases by suppressing the excretion of certain molecules from cells that causes cancer (Yu and Sacco, 2005). The antioxidants in tomato have also been reported to protect cells in humans from oxidants that cause cancer mainly in the stomach (Hounsome *et al*., 2006).

2.6 Economic Importance of tomato

Tomato (*Solanum lycoperscion L.*) is considered universally as the second most paid vegetables after potato (FAOSTAT, 2005). USDA (2005), tomato is ranked as the third most economically important vegetable "(with a farm value of $2.062 billion) following potato ($2.564 billion) and lettuce ($2.064 billion)". Tomato can normally be processed into many varieties of forms such as sauces, paste, juices and soup although it can be consumed as a raw vegetable. The total harvested area of tomato in the U.S in the year 2013 was estimated to be about 430,000ha (130,000ha fresh market and 300,000ha processed tomatoes) and the total farm value was recorded to be about $3.00 billion ($1.6 billion fresh market and $1.4 billion processing (USDA 2013). Tomato also constitute to an essential balanced diet (Wilcox, et al., 2003). Tomato in Ghana plays a very important part in the food of humans (Beecher, 1998; Osei et al., 2008) and is consumed in different ways.

2.7 Adaptability of tomato production Ghana

The production of tomato (Solanum lycoperscion l.) in Ghana is relatively higher than other vegetable crops with an annual total production of about 350,000 tonnes, corresponding to about 38% of its production (Osei *et al*., 2010). In Ghana, tomato is mainly grown in the Eastern, Ashanti, Greater Accra, Upper East and Brong Ahafo regions (Yeboah, 2011). Low production of tomato can be attributed to factors such as abiotic stress which mostly comprises of drought, excessive heat, and poor or declining soil fertility. Biotic stress which causes low production of tomato in Ghana can be attributed to pests and diseases. To increase production of tomato, there is the need to develop and introduce new varieties that will be adaptable to a particular environment. Only few of the new tomato varieties are adaptable in Ghana (Yeboah, 2011).

2.8. Tomato characterization and its importance in improving crop

Usually, every plant breeder ultimately aims at developing crop varieties that are high yielding and of high quality. Such cultivars should be able to withstand disease and pest and also cope with harsh environmental conditions. Annual increase in demand by consumers for high quality tomato products has led to the need to constantly collect, characterize and evaluate tomato genotypes (Oduor, 2016). Characterization and documentation of tomato genotypes is therefore essential for tomato breeders.

Agro-morphological evaluation entails the identification and recording of evident characters of plants alongside height, leaf type, leaf colour, hairiness and floral features (Godia, 2014; Nwosu et al., 2014). The employment of morphological data is one of the most significant methods in estimating genetic differences in a crop. The use of agro-morphological data is uncomplicated, less expensive and brief and hence used as diagnostic tool in evaluating the performance of different genotypes under definite growing environments (Hoogendijk and Williams, 2001).

Agro-morphological evaluation in crops provides direction to the choice of parents in hybridization breeding. Descriptors developed by the International Board for Plant Genetic Resource (IBPGR) are often used as guide during such data recordings (Ibitoye et al., 2009).

Characterization and evaluation of plants in the most accurate, fast and consistent reliable manner is significant in crop improvement programs.

Phenotypic characterization of plants is often the technique employed to evaluate a range of study of agro-morphological traits (Bajrachaya *et al*., 2006). It is often based on recording and describing phenotypic and agronomic characteristics that encompasses the leaf, floral parts and the yield and yield components.

2.9 Constraint of Tomato Production in Ghana

Some major constraints of tomato production in Ghana are pests and diseases (Singh *et al*., 2014) and marketing of tomato produce (KHCP, 2011). Maerere *et al*. (2006), biotic and abiotic factors are some of the factors leading to low yields and increased cost of production of tomato. The main pests that attack tomato in Ghana are nematodes, whiteflies, mites, thrips, leaf miners, African bollworm and aphids (KARI, 2005; Waiganjo *et al*., 2006). In addition, diseases such as early and late blight, powdery mildew, yellow leaf curl virus, tobacco mosaic virus, bacterial spot, Fusarium wilt and septoria leaf spot are some of the common diseases encountered during tomato production in Ghana. However, there is an estimation of two hundred tomato diseases (Jones, 2008). To control these pests and diseases of tomato mentioned above, farmers often use pesticides and fungicides and other chemicals. The excessive use of chemicals poses health threats to consumers and also pollutes the environment (Waiganjo et al., 2006).

Biotic stress such as heat, drought and salinity adversely affect plant growth and developments and may cause losses in agricultural production (Mittler and Blumwald, 2010). Tomato is one of the vegetable crops prone to water stress especially during its flowering and fruit formation stage (Nuruddi, 2001). Therefore, providing the right amount of water to tomato plant is very important for its growth and economic production particularly in a greenhouse.

2.10 Greenhouse technologies in Ghana and its benefits in tomato production

A Greenhouse is a dome or square like structure that allows a farmer to grow crops especially vegetables including tomato, sweet pepper, strawberry, broccoli etc. in a controlled environment ("Seth J. Bokpe's Ghana Newsreel", 2019).

Greenhouse technology has been posed to be cost-effective in addressing issues related to tomato cultivation in Ghana.

A variety of levels of greenhouse technologies are available but in fact, greenhouses are usually the same and have similar benefits. Elings *et al*. (2005) outlined some factors to consider when choosing a greenhouse. Elings *et. al*. (2005) reported that in cool areas, a low tunnel greenhouse will be ideal for crop growth and in hotter climates a high-roof greenhouse will be suitable.

In addition, Elings *et al*., (2005) reported that a metal structure greenhouse structure is preferred as compared to a wooden structured greenhouse. This is because metals are stronger and more durable than wood.

Furthermore, Elings *et al*., (2005) also reported that either netting or polythene or both can be used as a cover for a greenhouse. However, using net as a cover can provide shade and also protect the crops grown in the greenhouse from insect. A major drawback in using net as a cover is that, it does not protect the greenhouse from rainfall. Polythene provides shade and also protects insects but it is expensive.

Finally, Elings *et al*., (2005) reported that one must consider how to regulate the climate in the greenhouse. The climate in the greenhouse can be regulated by using ventilation opens. Farmers can however have the choice to create fixed or movable vents on the top or sides of the greenhouse.

Several greenhouse technology levels are available in Ghana. These are the high technology level greenhouses, medium technology level greenhouses and the low technology level greenhouses. Most farmers in Ghana prefer the medium technology level and the low technology level greenhouses because of their financial standings.

The medium technology level greenhouses come with several options and are more solid and last longer. An example of a medium technology level greenhouse in Ghana is the EnviroDome greenhouse. These greenhouses are equipped to block pests from entering the greenhouse and can cope with high temperatures. This is because the top of the greenhouse has fixed or movable openings.

Cultivating tomato in greenhouse has the potential of achieving maximize yield on the same piece of land as compared to open field tomato cultivation. Nordey *et al*., (2017) reported that greenhouses maximize production of vegetables outside regular production seasons, this allows sales during months in which supply is low. In Ghana, tomato production in the rainy season is tedious as crops are destroyed from intense rainfall. During the rainy season, high yield of tomato cultivation can only be possible in greenhouses.

Another benefit of using greenhouse is that, it can alleviate the impact of climate change through the protection of tomatoes grown in the greenhouse against high solar radiation (Nordey, 2017). This is very important in the tropics where solar radiations are very high since too much of the solar radiation will lead to decrease in tomato yield.

Panwar *et al*. (2014) reported that, production of crops under greenhouse conditions produced better quality fruit produce as compared to open field cultivation. The better quality of crop produce is obtained as a result of the farmer having total control over the growing conditions. High quality fruits produce are usually sold at higher prices which intend maximizes the profit of the farmer.

2.11 EnviroDome Greenhouse Systems

The EnviroDome greenhouses are not simply greenhouses but are fully integrated controlled environment growing system specifically designed for climates in West Africa. It has properties for light transmission, insect protection with nets, thermal screening and ventilation system using special chimneys and can be manually operated. The use of the Envirodome greenhouse system reduces insect pests, spraying of insecticides and residual levels of harmful chemicals in vegetable produce.

2.12 Greenhouse Factors

Air- temperatures, relative humidity (RH), light, carbon dioxide and diseases and insects are the main factors in greenhouse. Good management of these factors in the greenhouse leads to high tomato yield and quality and prevent tomato plant stress.

Greenhouse uses the sun as a free light energy source. The challenge therefore is to control other factors like temperature and carbon dioxide to be able to produce high yielding tomatoes under appropriate environmental conditions (Hanan, 1998; Bot, 2003). High or low intensity of light can stress crops grown under greenhouse conditions which have specific requirement of light (Peet, 1999).

Rylski *et al*. (1994) reported that, low light intensity leads to puffy fruits and blotchy ripening in tomato. Smillie *et al*. (1999) also reported that the formation of green shoulder in tomato fruit is positively related to the degree of shading during the fruit development.

Air temperatures influence fruit color, taste and shape. Low air temperatures produce fruits which are less juicy with mealy taste. Gross, (1991), reported that high temperatures above 30 degrees inhibit normal fruit ripening and development of lycopene. Peet (1992), also reported that, high day and night temperatures can cause cracking of tomato fruits.

Adams *et al*. (2001a), reported that high temperatures led to the formation of small parthenocarpic tomato fruits, poor fruit set and cracks under controlled environment. However, tomato tolerant to high temperatures is genotype dependent (Abdul-Baki and Stommel, 1995; Sato*etal*., 2000).

Humidity is one of the most important factors in the greenhouse. Humidity influences water status of greenhouse tomato and also affects all the processes associated with transpiration and ion translocation. Humidity is one of the difficult environmental factors to control in a greenhouse. To maintain humidity in a greenhouse efficiently, one must open the vents of the greenhouse slightly; this allows the water vapour to escape as heat. Low humidity in greenhouse has been reported by several researchers to reduce the average fruit weight of tomato (Bakker,1990a; Holder and Cockshull,1990).

2.13 Agro-morphological Parameters

2.13.1 Plant Height

Plant height is one of the most significant components of plant species' ecological strategy. It is essential to species' carbon gain strategy. This is because; plant height is one of the most important determinants of the plant's ability to compete for light (Falster & Westoby 2003). Plant height is among characters with high heritability (Veershetty, 2004, Mohanty, 2003, Singh *et al*., 2000). The height of tomato plant categorizes them into two different growth habits. These are determinate and indeterminate type of tomato. Determinate tomato plant type can reach a height of about 100-120centimeters. Determinate types have a comparatively concentrated fruit set and lasts only two or three weeks and the fruit ripen much faster than those of indeterminate types (Naika *et al*., 2005).

Indeterminate tomato plant on the other hand produces either one or two stems which continue to grow on and on till they stop by terminating their growing points. Indeterminate tomato usually has smaller fruits and attains maturity late. They bear fruits over a long period and are usually suitable to staking and pruning, both in open field and greenhouse.

Dudi and Sanwal (2004) evaluated 150 F1 hybrids of tomato under Haryana conditions and reported that the maximum plant height of 156.cm in HTH-18 and the minimum plant height of 53.8cm in Rupali.

Ganesan (2001) studied the performance of different tomato cultivars under both greenhouse and open field conditions and reported that the highest plant height was recorded by the cultivar Pusa Ruby (211 and 146 cm) in both green house and field conditions.

Islam et al. (2012) studied the Genetic variability and trait relationship in eleven (11) cherry tomato inbred lines assembled from AVRDC and he reported that, the cultivars, CLN15558A had the tallest plant height (154cm) followed by CLN1558B (131 cm) and CLN1555B (129 cm).

Wahundeniya et al. (2013) evaluated fifteen tomato varieties for growth and yield performance under controlled environment conditions and reported that, among the fifteen varieties the maximum plant height of (185 cm) was recorded by variety Alambra F1 while the minimum plant height of (93 cm) was recorded by variety Red Boy.

Hussain *et al*., (2014) evaluated the yield potential of some exotic and local cultivars grown for summer production and reported the maximum plant height of 126.5 cm in Samarzano and the minimum plant height of 61.6cm in Nadir.

Bhati V. (2017) evaluated tomato genotypes for growth, yield and quality traits under foothills condition of Nagaland, India and reported the maximum plant height of 64.75cm in the genotype TODVAR-8 and the minimum plant height of 50.07 in the genotype TODVAR-7.

2.13.2 Number of fruits per plant and single fruit weight

Kumar et al., (2006) reported that the number of fruits per plant ranges from 27.33 to 64.67. Also, Upadhyay et al., (2005) reported that the number of fruits per plant can range between 14 to 65.

Mohanty B.K (2002) experiment conducted in Orrisa reported the maximum number of fruits per plant in Rasika (38.92) and minimum in Pusa Ruby (16.45). Sheferaw Nesgea (2001) observed the maximum number of fruits per plant in Pusa Ruby (24.48) and a minimum in Arka Abha (11.15).

Bhati V. (2017) recorded the maximum number of fruits per plant of 34.01 in the genotype TODVAR-8 and the minimum number of fruits per plant of 16.58 in TODVAR-6.

Different researchers have reported different single fruit weight as follows 36.33 to 71.07grams (Veershetty,2004), 16.13 to 95.7 grams (Joshi et al.2004), 29.83 to 92.67grams (Mohanty,2003). There is significant genetic variation for these traits in tomatoes. This is very important because the success of crop improvement depends on the magnitude of genetic variability.

2.13.3 Number of days to Maturity

Harvesting of tomato must be done very timely. This is very important so as to avoid post-harvest losses. Because of the juicy nature of tomatoes, they are mostly prone to post harvest losses. Rice et al. (1990) reported that Tomato fruit have about 93% water. The high-water content of the tomato fruit enhances favorable conditions for microbes which can cause damage to the fruit. Tomato fruits do not ripe at the same time and it is usually advisable to harvest at different times.

Naika *et al*. (2005), reported that, first harvest of tomato can be done from forty-five (45) to fifty-five (55) days after flowering, or ninety (90) to one hundred and twenty (120) days after sowing.

2.13.4 Days to 50 per cent flowering

Sanwal and Dudi (2004) evaluated 150 hybrids of tomato and recorded the minimum days to 50% flowering of 22.3 days in the hybrid HTH-18 and a maximum of 30.3 days in Rashmi.

2.13.5 Number of trusses per plant and Number of fruits per plant

Tomato number of trusses per plant differs among varieties. Nyirongo, (1995) reported that the number of trusses per plant ranges from six (6) to nine (9).

Marimbe, (1995) also reported that the number of trusses per plant ranges from six (6) to eight (8).

Singh *et al*., (2000) reported (4.40) as the mean number of fruit per plant. Also, Joshi *et al*., (2004) reported 3.50 fruit as mean number of fruit per truss.

Prashanth, (2003) reported 4.47 fruits as the mean number of fruits per truss.

The number of trusses and fruit number per truss influence the yield of tomato. Using pruning to regulate the number of trusses and fruits per truss significantly affects the quality and yield of fruit in some tomato cultivars. Six trusses of tomato have been reported to give the highest yield and best quality. This is because, photosynthesis becomes enough for the development of tomato fruit. On the other hand, when less than six trusses were left per plant, the fruit size was large but the total plant yield was low. Artur, (1995) reported that, keeping the appropriate number of trusses per plant is important in the production of high-quality tomato fruit and the number of fruits per truss can be more than six. Read and Fieldhouse (1970), observed that high yield in tomato is as a results of more flowers per cluster, greater number of fruits set per cluster and thus more fruit per plant.

2.13.6 Quality Parameters of tomato

Processors and consumers often desire a particular tomato fruit quality characteristic. Producers must aim at producing these fruits in order to make profits from their sale of produce. Some of the quality traits of tomato that producers and consumers often look out for are appearance or shape, taste, firmness, texture and aroma (Carli *et al*., 2009; Rocha et al 2012). Tomato quality parameters can be verified by both physical and chemical characteristics of the fruit (Aoun *et al*., 2013). These traits are due to many components which are quality determinant traits (Ochar, 2015). Sugars, total soluble solids, acidity, lycopene, β-carotene, phenolic acids and flavonoids are among these quality components.

Islam et al. (2012) studied the genetic variability of eleven inbred lines of cherry tomato and reported that line CH155 (5.7%) has the highest total soluble solids followed by CLN1555A (4.9%).

IIic and Milenkovic (2010) conducted an experiment on the influence of photo-selective shade nets on quality of tomatoes grown under plastic tunnels and field conditions and reported that the TSS content of tomatoes grown in open field (5.42^0 brix) was greater than tomatoes grown in protected environment (5.10^0).

2.14 Yield and Yield Parameters

Several factors such as weather, soil, agronomic practice and the choice of cultivar interact to influence yield of crops. In general, some of the above-mentioned factors can be modified or altered whiles other cannot be altered or modified. However, the choice of cultivar has a significant role on crop yield. Over the years, the yield potential of some crops has increased because of the revelation of factors that influence yield. These factors are referred to as yield components. Some of the yield components include the mean fruit weight, fruit number per truss, and number of trusses per plant.

Hazarika and Phookan (2005) studied twenty-seven tomato cultivars under polyhouse conditions and recorded higher yield per plant of 1.76 kg with the cultivar Yash followed by Arka Ahuti with 1.31 kg yield per plant.

Kacjan *et al*., (2005) studied the influence of different climatic conditions on fruit yield and quality of ten determinate tomato cultivars and reported highest marketable yield of 4.05kg per plant.

Kumar *et al*., (2007) evaluated 42 tomato genotypes under green house and open field conditions and reported that genotypes COTH1, CLN14665 and CLN1352A are suitable under greenhouse conditions based on yield per plant.

Islam et al. (2012) reported the maximum fruit yield per plant of 1.89 kg in CLN1555A followed by CLN1555C with a yield per plant of 1.82 kg among the 11 inbred lines of cherry tomatoes studied. Also Singh et al., (2013) studied the performance of different tomato hybrids under greenhouse conditions in 2008 to 2009 and 2009 to 2010 at Hissar and reported that Avinash-23 recorded maximum yield per plant of 2.90 kg followed by Richa with a yield of2.88 kg.

Pandey et al., (2006) compared four tomato varieties under polyhouse conditions of Nepal and reported that NSITH-162 produced the highest marketable fruit yield (89.05 t ha^{-1}) and Avinash-2 produced the lowest yield (51.98 t ha^{-1}).

Prema *et al*., (2011) reported the highest fruit yield of 75.55 t ha^{-1} in Podland Pink followed by Tomy Toe with a fruit yield of 59.91 t $ha^{-1.}$ An additional field investigation by Chapagain *et al*.,

(2011) assessed the performance of tomato varieties under plastic house for two successive years from 2009 to 2010 in Nepal. The highest marketable yield was recorded from All Rounder (86.6 t ha^{-1}) followed by Srijana (80.8 t ha^{-1}).

2.15 Correlation

The use of correlation analysis is important in statistical analysis. Correlation is the measure of association between two variables. Correlation can either be negative or positive. Negative and positive correlation coefficients are very significant in plant breeding since they show the strength of association between two traits under study. The relationship of plants traits can be used for selection which can be used to improve plant yield.

The importance of correlation has been reported by (Rogler, 1954, Kneebone, 1956).Rogler and Kneebone used cereals crops to demonstrate that positive relationship exist between seed size and seedling vigor and reported that, the selection for large seeded grass species will result in strain with superior ability to establish.

Researchers have reported positive correlation in tomato component traits with fruit yield and reported that; plant height have a positive correlation with fruit yield per plant (Joshi *et al*.,2004, Prashanth, 2003). Fruits per truss also have a positive correlation with fruit yield per plant (Singh et al.,2004). Number of fruits per plant also have a positive correlation fruit yield per plant (Haydar *et al*.,2007, Kumar et al.,2006, Prashanth 2003. Average fruit weight with fruit yield per plant (Prashanth,2003, Joshi *et al*.,2004).

A number of components are associated with yield since yield is a complex entity. Yield is the ultimate concern of every plant breeder in the world. Changes in yield must be associated with changes in one or more characters (Graffius,1964). Not all changes in the components need however, be expressed by changes in yield. This is as a result of varying degrees of positive and negative correlation between yield and its components and among components themselves (Rani *et al*., 2008).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Location

The experiment was conducted under Envirodome greenhouse growing conditions at the University of Ghana Forest and Horticultural Crops Research Centre (FOHCREC), Okumaning-Kade in the Eastern Region of Ghana. FOHCREC-Kade is located in the Denkyembour District and form part of the forest agro-ecological zone of Ghana (Ofosu-Budu, 2003; Nkansah *et al*., 2007). The geographical study area is located between latitude 60, 0854'N and longitude 0^0, 5400'W at about 114 m above sea level. Mostly, soils found in these areas are Haplic Acrisol (FAO/UNESCO, 1990). The mean annual rainfall varies between 150mm-200mm and has a bimodal rainfall pattern of two peaks that occurs around June to July and September to October. The mean annual temperature also ranges from 25-38 ^oC (Ofosu-Budu, 2003).

3.2 Experimental Materials

Eight (8) different tomatoes were evaluated for their morphological attributes, yield and fruit quality traits. The sources of the experimental materials and type are shown in Table 3.1

Table 3.1 Tomato accessions used for the study

Number	Accession name and varieties	Source	Salient features
1.	Tengeru-2010	AVRDC	Intermediate resistance to pest like nematode and Bacteria wilt.
2.	Tanya	AVRDC	Suitable for growing in tropical lowland conditions and resistance to Fusarium wilt
3.	CLN3024A	AVRDC	Moderate heat tolerant variety and resistant to Bacteria wilt
4.	CLN3212C	AVRDC	Resistance to Tomato Leaf Curl and early maturing
5.	FMTT1733E	AVRDC	Resistant to bacteria wilt and good heat tolerant variety
6.	CLN3900D	AVRDC	Semi-determinate and round fruit shape
7.	Jaguar F1	AGRISEED	Determinate plant and early maturing
8.	Nkansah Heat Tolerant (HT)	FOHCHREC	Determinate tomato, early maturing and tolerant to high temperature

3.3 Nursery and Nursery Management Practices

Seedlings of all the **eight (8)** different tomatoes were raised under greenhouse conditions. Plastic seed trays consisting of **32** cells filled with soil as growth medium were used to raise the seedlings. The seed trays were washed, and the growth media were sterilized with sodium hypochlorite solution to control microbial and fungal infection. Watering of seedlings was done daily (as and when necessary) following germination using watering can.

Seedlings were sprayed with fungicide, Mancozep 80 WP (Mancozeb dithiocarbonate) at a rate of 10g per litre of water to prevent fungal infection. The spraying was then repeated on the 12 and 17 days.

When seedlings were seven (7) days old, the fungicide, Mancozep 80 WP (Mancozeb dithiocarbonate) at 10 g per litre of water was sprayed on seedlings to control fungal infection especially damping off. This was repeated at days 12 and 17 before the healthy and uniform seedlings were transplanted to the experimental site when they were **twenty-one (21)** day old. The seedlings were supplied with N.P.K (19:19:19) nutrient solution. The nutrient solution was prepared using 1g/litre N.P.K (19:19:19) at a concentration of 0.5% in order for seedlings to get good rooting as well as growth.

3.4 Experimental Design and Field Layout

The **eight** (8) tomato accessions were arranged in a Randomized Complete Block Design (RCBD) with three replications. The seedlings were transplanted at a spacing of 30 cm x 40 cm. Seedlings were transplanted in two drip rows of five plants each. Data were collected from 6 tagged plants in the middle rows. The climatic conditions (mean monthly temperature and relative humidity under the greenhouse were recorded. (Table 3.2 and Table 3.3)

Table 3.2 Climatic data in the Envirodome greenhouse

	Temperature (^oC)		Relative Humidity (%)	
Month	**Maximum**	**Minimum**	**Maximum**	**Minimum**
July 2018	29.39	23.59	79.3	62.9
August2018	31.54	24.71	78.9	61.4
September 2018	31.03	25.03	79.9	65.5
October 2018	32.47	24.64	79.4	66.8
November 2018	32.63	30.55	79.7	69.1

Source: *FOHCREC, Okumaning - Kade.*

3.5 Preparation of experimental site

Beds which had earlier been used to cultivate tomato was removed and replaced with fresh soil medium. Soil sample from the greenhouse was collected and analyzed for physical and chemical composition. Crops were planted on raised beds of approximately 21.5 m length, 0.3 m width and 0.2 m high. The planting area of the greenhouse area was 20 m x 10 m and consisted of a total of **eight (8)** beds each of which was made up of 2 rows. The entire greenhouse environment was sterilized using hot water treatment. The water was boiled to 100ºC and was sprayed at the corners, ceilings, floors, nets and crevices of the greenhouse. The entire greenhouse was also sprayed with Topcop (active ingredient: Copper Sulphate Tribasic) and cuprofix to prevent fungi and soil borne diseases.

Table 3.3 Physicochemical properties of soil in the Envirodome greenhouse

S/N	Property	Value
1.	Sand (%)	42.44
2.	Silt (%)	28.90
3.	Clay (%)	26.50
4.	Texture	Sandy clay loam
5.	pH	5.10
6.	Total Nitrogen (%)	0.15
7.	Available Phosphorus	10.18
8.	Available Potassium	0.55
9.	Organic Carbon	1.52
10.	Electrical conductivity	0.60

3.6 Transplanting

Twenty-one-day old healthy seedlings of each tomato accession were transplanted on to the experimental site. Almost all the transplanted seedlings had about 4-6 leaves and their average plant height ranges 9-13cm. Before transplanting, seedlings were watered before they were removed from their seed trays to the field. Watering was carried out immediately after transplanting to prevent stress of seedlings.

3.7 Cultural Practices

3.7.1 Fertigation

3.7.1.1 Polyfeed (NPK 19:19:19) was used in fertigation.

Watering of crops was done daily both in the morning and later in the evening depending on the temperature in the Envirodome greenhouse. 1-liter amount of water and 6grams of (NPK 19:19:19) was supplied to each crop per plant. This was applied every two weeks as recommended to boost the crop growth vegetatively. The polyfeed (NPK 19:19:19) was applied to crops until the crops reached their reproductive or flowering stage.

3.7.1.2 Fertigation with Calcium Nitrate

13 grams of calcium Nitrate was mixed in 1liter of water and was applied to the crops once every week. This is very important to prevent blossom end rot disease.

3.7.1.3 Fertigation with Potassium Nitrate

2 kilograms of Potassium Nitrate was mixed in 1 liter of water and was applied to the crops once every week. This was done after the first truss has flowered till the crops have been harvested. This is very important to help in flower formation and fruit setting.

3.7.2 Trellising

Trellis system was used to train the crops in the greenhouse. This was done with a twine (rope). Crops were trellised 15days after transplanting. This is important to provide support for the plant, help the plant grow erect and also to produce clean fruits.

3.7.3 Weeding and Pruning

Weeds were uprooted with the hand regularly when they appear from the soil as and when necessary. Pruning was carried out according to good greenhouse pruning practices.

3.7.4 Pesticide application

3.7.4.1 Akape (Anty Ataa) 250ml bottle

A systemic broad-spectrum insecticide Akape (active ingredient is MIDACLOPRID 200g/L.) was used to prevent aphid, white fly, caterpillar, thrips, leaf miner or mealy bug. 30ml of Akape was mixed in 15L of water and was applied to crops every 2weeks.

3.7.4.2 Top Cop with Sulphur (1 Litre)
150-300mls of Top cop (active ingredient: Copper Sulphate Tribasic) with Sulphur was put in a Knapsack sprayer and was sprayed on crops when any whitefly was detected on the tomato fruit. This was repeated every two weeks but was stopped when the fruits had attained ripening.

3.7.5 Plant hormone application
Tomatone plant hormone was sprayed on flowers whenever they appear. This was to facilitate pollination in the Envirodome.

3.7.6 Harvesting
Tomato fruits were handpicked after they had reached full maturity. It took barely three months for the tomato to reach full maturity. Harvesting was carried out three times at an interval of 6 days.

3.8 PARAMETERS RECORDED

3.8.1 Qualitative data collected

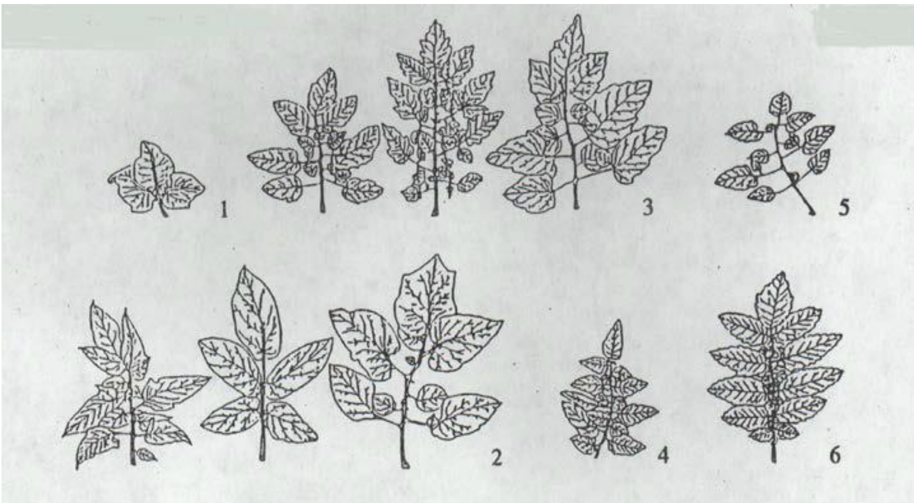
Scoring of the qualitative data was done using the AVRDC-GRSU characterization record sheet.

Growth Habit: The growth habits of the various accessions were observed when their first truss has ripened and was scored as Dwarf (1), Determinate (2), Semi-determinate (3) and Indeterminate (4).

Anthocyanin Coloration of hypocotyls: This was observed when the seedling primary leaves are fully opened and the terminal bud was around 5mm on ten randomly selected seedlings of each accession and was scored as Absent (0), Present (1) and Mixture (x).

Stem Pubescence: the stem pubescence of the various accessions was observed on ten randomly selected seedlings and scored as Absent (0), weak (3), medium (5) and strong (7).

Leaf type: The leaf type of the various accessions was observed and scored as Dwarf (1), Potato leaf type (2), Standard (3), Peruvianum (4), Pimpinellifolium (5), Hirsutum (6) and other (7)



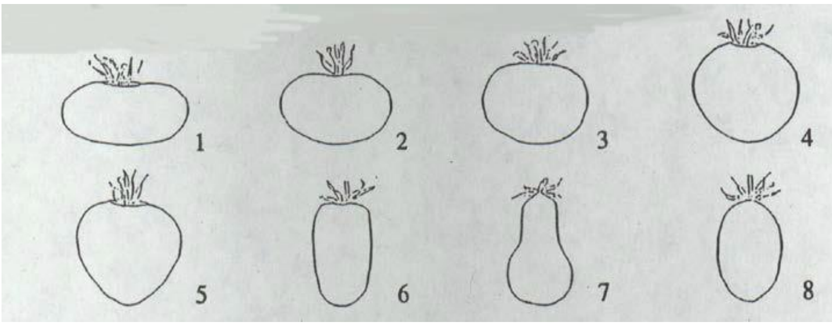
Anthocyanin coloration of leaf veins: The anthocyanin coloration of the leaf veins of ten randomly selected plants from each of the various accessions were observed and scored as Absent (0), Present (1) and Mixture (1).

Inflorescence type: The inflorescence type of the various accessions was observed on the 2nd and 3rd truss for all the various accessions at their reproductive stage and was recorded as Generally uniparious (1), Generally multiparious (2) and Both (3).

Style type: the style type of the flowers of the various accessions were observed and recorded as Inserted (1), Same as level as stamen, Slightly inserted, Highly inserted (7) and Mixture (X).

Fruit size variation within plant: The fruit sizes on the plant of the various accessions were observed when the fruit has ripened and was scored as Uniform (1), Slight (3), Medium (5), and High (7).

Predominant fruit shape: The predominant fruit shape of the various accessions were observed in ten randomly selected fruits from each of the accessions after their fruits turn color and was scored as 1 = Flattened 2 = Slightly flattened 3 = Round 4 = High-round 5 = Heart shaped 6 = Lengthened cylindrical 7 = Pear-shaped 8 = Plum shaped X = Mixture



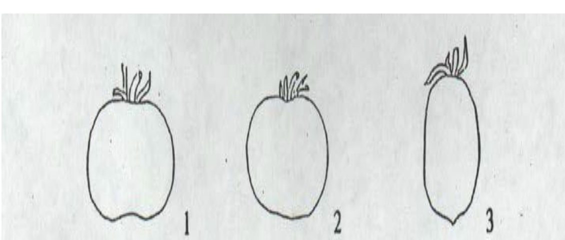
Exterior color of immature fruit: The exterior colors of immature fruits of the various accessions were observed on five fruits each from the various accession and was scored as 3 = Light 5 = Medium 7 = Dark 9 = Very dark X = Mixture

Intensity of greenback: The fruit shoulders of ten randomly ripened fruits of each accession were observed and scored as 0 = None 3 = Slight 5 = Medium 7 = Strong X = Mixture

Puffiness: Five randomly selected fruits of each accession were cut opened and observed for presence of cavity or puffiness and were recorded as 0=Absent, 3=Slight, 5= Medium, 7=Severe and X=Mixture

Presence of jointless pedicel: the pedicel of the various accessions was observed after their fruit have set and was scored as 0 = Absent 1 = Present X = Mixture

Blossom end shape: Five randomly selected fruits of each hybrid were observed for its blossom end shape and grouped in to. 1 =Indented 2 =Flat 3= Pointed X =Mixture



Exterior color of mature fruit: Five fruits were harvested at maturity from five plants from each accession and observed the colour under constant white light and grouped into1 = Green 2 = Yellow 3 = Orange 4 = Red 5 = Pink 6 = Orange-red 7 = Orange-yellow X = Mixture

3.8.2 Quantitative data

Mean plant height: Six tagged plants from the middle row were measured from the soil to the tip of the shoot. This was recorded at thirty (30) days after transplanting using a meter rule.

Mean stem girth: Six tagged plants from the middle row were measured using a vernier caliper around the base of the plant. This was recorded at thirty (30) days after transplanting.

Mean number of leaves per plant: The leaves of six tagged plants were counted and recorded at thirty (30) days after transplanting.

Mean chlorophyll content (CC): The Chlorophyll content (nm) of six tagged plant was recorded at thirty (30) days after transplanting using a chlorophyll meter.

Mean number of days to 50 % flowering: The number of days from transplanting to 50% flowering of six tagged plants per accession was counted and recorded.

Mean number of days to fruit maturity: This was determined by counting the number of days from transplanting until 50 % of the tagged plants had at least one fruit ripened (at breaker stage)

Mean number of trusses per plant: The number of trusses of six tagged plants were counted and recorded.

Mean number of flowers per truss: The number of flowers per truss was counted for 10 trusses on each of the tagged plants and the mean number determined

Mean number of fruits per truss: The number of fruits per truss was counted for each of the six tagged plants and the mean number per truss determined.

Mean fruit set percentage: Fruit set percentage was determined by dividing the number of fruits by the number of flowers per cluster and the mean computed and expressed in percentage.

Mean number of fruits per plant: Number of fruits per plant was determined by counting the number of harvested fruits from each of the six recorded plants and the mean number determined.

Mean individual fruit weight per plant: Average fruit weight was determined as total weight (g) of fruits harvested from tagged plants divided by the total number of fruits harvested from tagged plants

Mean fruit weight per plant: Mean fruit weight (g) per plant was determined by weighing the harvested fruits from the six tagged plants using an electronic balance and the mean determined

Mean fruit yield per hectare: The mean fruit weight for each of the six record plants was used to calculate yield per hectare. This was expressed as:

$$\text{Yield/hectare} = \left(\frac{\text{Fruit yield per plot}}{\text{Plot size}}\right) \times 10{,}000\text{m}^2$$

3.8.3 Fruit physical and quality traits

Fruit samples were collected separately from the experiments conducted during the peak period of harvest when the fruits were fully ripe and were in their mature stage. Composite samples of 10 fruits were taken from the selected tagged plants from all the three (3) replications to determine fruit physical and quality characters. Fruit physical characters were scored shortly after harvest while composite samples of fruits from replications were carried to the laboratory for chemical trait analysis.

3.8.4 Tomato fruit physical characteristics

Mean fruit length: Fruit length (cm) was recorded at harvest from ten fruits per each tomato accession, from the stem end (pedicel attachment) to the blossom end (apex) using meter rule and the mean determined.

Mean fruit diameter (FD): Fruit diameter (cm) was recorded at harvest from ten fruits at the largest diameter of cross-sectional fruits to one decimal place using Vernier caliper and the mean determined.

Mean pericarp thickness: This was determined by making a transverse cut through 10 randomly selected fruits per each tomato accession and the thickness of the pericarp measured using Vernier caliper at four cardinal points and their mean determined.

Mean number of locules: This was determined by counting the number of locules from 10 randomly dissected fruits of each tomato accession per replication and their mean determined.

Shelf life: Ten healthy ripe tomato of each of the accessions were handpicked and stored at room temperature. The number of days taken to rotting was recorded.

3.8.5 Tomato fruit quality characteristics

3.8.5.1 Determination of pH and total soluble solids (TSS)

Sample preparations of **ten (10)** fruits per each tomato accession per replication were selected separately from each experimental location. The fruits were washed thoroughly with distilled water, cut open and mashed using a blender. Mashed samples were then used to determine each of the fruit quality traits.

Determination of pH

Sample of juice extracted from mashed fruits per each tomato accession was poured into separate beaker and a digital pH meter (JENWAY 3520) was used for the pH readings. The readings were taken in triplicates and the averages for each replication were worked out.

Determination of total soluble solids content (TSS)

The total soluble solids content was determined by placing a thin film of blended tomato sample on a DIGITAL BENCH MODEL refractometer (HANNA Instruments HI 96801 0- 85) and the total soluble solids content scored in % Brix units (percentage solids). In each case, measurements were taken in triplicates for each sample by recording the readings on the prism scale. Before each sample test was carried out, the prism plate was cleaned with distilled water and wiped dry with soft tissue. The activity was done in triplicates per genotype per replication and the mean value of the total soluble solids content computed.

3.9. Statistical analysis

The data collected on different accessions of tomato were tabulated and analyze for variances. Fisher's Least Significant Difference, LSD was used to separate means that differed significantly based on parameters gathered following the procedure described by Gomez and Gomez 1984. GENSTAT statistical software (12th edition) was used for the data analysis.

CHAPTER FOUR

4.0. RESULTS

4.1 Plant Morphological parameters (Qualitative)

4.1.1Growth habit

The accessions CLN3024A, FMTT1733E, CLN3212C were observed to show an indeterminate growth habit while CLN3900D showed a semi-determinate growth habit and Tanya, Jaguar F1, Tengeru-2010 and Nkansah HT showed a determinate growth habit as presented in Table 4.1

4.1.2 Anthocyanin coloration of hypocotyls

It was observed that all the accessions showed no coloration of hypocotyls as presented in Table

4.1.3 Stem Pubescence

Table 4.1 shows that all the various accessions have a weak stem pubescence.

4.1.4 Leaf type

The leaf type for the various accessions is presented in Table 4.1. All the accessions have a standard tomato leaf type.

4.1.5 Anthocyanin Coloration of leaf veins

The results for anthocyanin coloration of leaf veins are presented in Table 4.1. The results show that anthocyanin coloration of leaf veins was absent in all the accessions.

Table 4.1 Morphological descriptor for Growth habit, Stem pubescence, leaf type, Anthocyanin coloration of stem and leaf (Plant trait) of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accession	GH	AC of stem	SP	LT	AC of leaf veins
CLN3900D	Semi-determinate	Absent	Weak	Standard	Absent
Nkansah HT	Determinate	Absent	Weak	Standard	Absent
Tengeru-2010	Determinate	Absent	Weak	Standard	Absent
CLN3212C	Indeterminate	Absent	Weak	Standard	Absent
Tanya	Determinate	Absent	Weak	Standard	Absent
FMTT1733E	Indeterminate	Absent	Weak	Standard	Absent
Jaguar F1	Determinate	Absent	Weak	Standard	Absent
CLN3024A	Indeterminate	Absent	Weak	Standard	Absent

GH- Growth Habit, AC- Anthocyanin coloration, SP- Stem Pubescence, LT- Leaf type

4.1.6 Inflorescence type

Table 4.2 shows that the inflorescence type for the various accessions are all generally uniparous.

4.1.7 Fruit size variation within plant

The data for fruit size variation within plant of the various accessions are presented in Table 4.2.

The results show that the fruit size variation within the plant of all the accessions were uniform.

4.1.8 Intensity of greenback

The data pertaining to the intensity of greenback are presented in Table 4.2. The results show that greenback was absent in all the accessions.

4.1.9 Exterior color of immature fruit

Table 4.2 shows that all the accessions have a light exterior immature fruit color.

4.1.10 Puffiness

Table 4.2 shows the results for the puffiness of the various accessions. Puffiness was absent in all the various accessions but was observed to be slight in the accession Tanya.

Table 4.2 Morphological descriptors for inflorescence type, fruit size variation, intensity of greenback, exterior color of immature fruit and Puffiness of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accession	Inflorescence type	FSV	IGB	ECIF	Puffiness
CLN3900D	Generally uniparous	Uniform	None	Light	Absent
Nkansah HT	Generally uniparous	Uniform	None	Light	Absent
Tengeru-2010	Generally uniparous	Uniform	None	Light	Absent
CLN3212C	Generally uniparous	Uniform	None	Light	Absent
Tanya	Generally uniparous	Uniform	None	Light	Slight
FMTT1733E	Generally uniparous	Uniform	None	Light	Absent
Jaguar F1	Generally uniparous	Uniform	None	Light	Absent
CLN3024A	Generally uniparous	Uniform	None	Light	Absent

FSV- Fruit size variation within plant, IGB- Intensity of greenback, ECIF- Exterior color of immature fruit.

4.1.11 Blossom end shape

Table 4.3 shows the blossom end shape of the various accessions. It was observed that the blossom end shape of CLN3900D and Jaguar F1 were pointed whiles Tengeru-2010, Nkansah HT, Tanya, CLN3024A, FMTT1733E and CLN3212C all had a mixture blossom end shape.

4.1.12 Presence of Jointless Pedicel

The results for the presence of jointless pedicel of the various accessions are presented in Table 4.3. It was observed that there was presence of jointless pedicel in all the accessions except Tanya.

4.1.13 Predominant Fruit shape

The results of the predominant fruit shape are presented in Table 4.3. Jaguar F1, CLN3900D and Tanya were heart shaped, Nkansah HT have a plum shaped, FMTT1733E and Tengeru-2010 have a round shape, CLN3212C have a high-round shape and CLN3024A had a Mixture of fruit shape

4.1.14 Exterior color of mature fruit

The exterior colors of mature fruit for the various accessions are presented in Table 4.3. All the accessions have red color expect the accession Tanya which has an orange-red color.

Table 4.3. Morphological descriptors for Blossom end shape, Presence of jointless pedicel, Predominant fruit shape and Exterior color of mature fruit of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accession	BES	PJP	PFS	ECMF
CLN3900D	Pointed	Present	Heart Shaped	Red
Nkansah HT	Mixture	Present	Plum Shaped	Red
Tengeru-2010	Mixture	Present	Round Shaped	Red
CLN3212C	Mixture	Present	High-round shaped	Red
Tanya	Mixture	Absent	Heart Shaped	Orange-Red
FMTT1733E	Mixture	Present	Round Shaped	Red
Jaguar F1	Pointed	Present	Heart Shaped	Red
CLN3024A	Mixture	Present	Mixture	Red

BES-Blossom end shape, PJP-Presence of jointless pedicel, PFS- Predominant fruit shape, EMCF-Exterior color of mature fruit

4.2 Mean performance of tomato accessions for agro-morphological traits (Quantitative)

4.2.1 Mean Plant Height (cm)

Plant height differed significantly among the various accessions as presented in Table 4.4. The maximum plant height of 96.5cm was recorded by the accession CLN3024A whiles the minimum plant height of 65.0cm was recorded by the accession CLN3900D.

4.2.2 Mean Chlorophyll

From Table 4.3, there was significant difference in chlorophyll content among the various accessions. The maximum chlorophyll content of 35.3 was recorded by the accession CLN3212C while the minimum chlorophyll 22.1 content was recorded by the accession CLN3900D.

4.2.3 Mean number of leaves

There was no significant difference in number of leaves among the various accessions as presented in Table 4.4. The highest number of leaves 36.0 was observed in the accession Jaguar while the lowest number of leaves 30.0 was observed in the accession Tengeru-2010.

Table 4.4 Mean Plant height, chlorophyll and number of leaves of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accession	Plant height(cm)	Chlorophyll(nm)	Number of leaves
CLN3900D	65.0a	22.1a	32.0
Nkansah HT	71.9ab	26.3ab	35.0
Tengeru-2010	74.8ab	26.7ab	30.0
CLN3212C	80.8bc	35.3d	33.0
Tanya	81.6bc	24.1a	32.0
FMTT1733E	88.8cd	23.5a	32.0
Jaguar F1	91.1cd	29.4bc	36.0
CLN3024A	96.5d	32.4cd	32.0
Mean	81.3	27.52	32.92
LSD (0.05)	11.55	5.20	3.96NS

Means followed by the same letter within the same column are not significantly different at 5% level of significance

4.2.4 Mean Stem Girth (mm)

There were no significant differences among the various accessions as presented in Table 4.4. The minimum mean stem girth of 0.43mm was recorded by the accession CLN3900D and the maximum mean stem girth of 0.53mm was recorded by the accessions Tanya and CLN3024A.

4.2.5 Mean root length

There were no significant differences in root length among the various accessions as presented in Table 4.5. The minimum root length of 13.7cm was recorded by FMTT1733E and the maximum root length of 19.2cm was recorded by the accession Tengeru-2010

4.2.6 Mean number of days to 50% flowering

Table 4.5 shows that the minimum number of days to 50% flowering of 22.3 was observed in Nkansah HT and the maximum number of days to 50% flowering of 35.0 was observed in Tengeru-2010.

Table 4.5 Mean stem girth, root length and number of days to 50% flowering of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accession	Stem girth(mm)	Root length (cm)	Number of days to 50% flowering
CLN3900D	0.43	18.0	29.3c
Nkansah HT	0.50	14.4	22.3e
Tengeru-2010	0.50	19.2	35.0a
CLN3212C	0.50	16.1	27.6c
Tanya	0.53	18.5	25.3d
FMTT1733E	0.50	13.7	28.3c
Jaguar F1	0.50	15.7	24.3d
CLN3024A	0.53	15.0	32.6b
Mean	0.50	16.3	28.12
LSD(0.05)	0.06NS	4.32NS	1.86

Means followed by the same letter within the same column are not significantly different at 5% level of significance NS – Not significant

4.2.7 Mean number of flowers per truss

There were no significant differences in the number of flowers per plant in the various accessions as presented in Table 4.6. The highest number of flowers per truss of 7.0 was recorded by the accessions CLN3024A, Jaguar F1 and Tanya and the minimum number of flowers per truss 6.0

was recorded by the accessions Tengeru-2010, Nkansah HT, CLN3900D, FMTT1733E and CLN3212C.

4.2.8 Mean number of fruits per truss

There were significant differences in the number of fruits per truss among the accessions as presented in Table 4.6. The maximum number of fruits per truss of 5.0 was recorded by Nkansah HT and the minimum number of fruit per truss of 1.0 was recorded by Tengeru-2010.

4.2.9 Mean number of primary branches

There were significant differences in the number of primary branches among the accessions as presented in Table 4.6. The highest number of primary branches of 4.0 was recorded by Jaguar F1 while the Nkansah HT, Tanya, Tengeru-2010, CLN3900D, CLN3212C, FMTT1733E, and CLN3024A recorded the lowest number of primary branches of 3.0.

Table 4.6 Mean number of flowers per truss, number of fruits per truss and number of branches of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accession	Number of flowers per truss	Number of fruits per truss	Number of branches
CLN3900D	6.0	3.0b	3a
Nkansah HT	6.0	5.0b	3a
Tengeru-2010	6.0	1.0a	3a
CLN3212C	6.0	4.0c	3a
Tanya	7.0	4.0c	3a
FMTT1733E	6.0	3.0b	3a
Jaguar F1	7.0	4.0c	4b
CLN3024A	7.0	3.0b	3a
Mean	6.50	3.417	3.25
LSD (0.05)	1.26 NS	0.84	0.62

Means followed by the same letter within the same column are not significantly different at 5% level of significance. NS- No Significance difference

4.2.10 Mean percentage fruit set

The mean values for percentage fruit set presented in Table 4.7 shows that there was significant difference in the percentage fruit set. The highest mean percentage fruit set of 68.3% was recorded by the accession Nkansah HT whiles the lowest mean percentage fruit set of 24.7% was recorded by the accession Tengeru-2010.

4.2.11 Number of truss per plant

The mean values of number of truss per plant presented in Table 4.7 shows significant differences among the various accessions. The lowest mean value of number of truss of 6.0 was recorded by the accession Tengeru-2010 while the highest mean value of number of truss per plant of 21.0 was recorded by the accession Nkansah HT.

4.2.12 Number of days to maturity

Table 4.7 shows that there were significant differences among the mean values of number of days to maturity. The number of days to maturity ranges from 58-76days. Nkansah HT recorded the least number of days to maturity while the highest number of days to maturity was recorded by the accession Tengeru-2010.

Table 4.7. Mean percentage fruit set, number of truss per plant and Number of days to maturity of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accession	Percentage fruit set	Number of truss per plant	Number of days to maturity
CLN3900D	47.7b	10.0b	65a
Nkansah HT	68.3c	21.03	58a
Tengeru-2010	24.7a	6.0a	76e
CLN3212C	63.3bc	17.0d	68d
Tanya	54.0bc	18.0d	65c
FMETT1733E	47.7b	9.0b	64bc
Jaguar F1	61.7bc	20.0e	63b
CLN3024A	52.3bc	13.0c	67d
Mean	52.5	14.38	65.71
LSD(0.05)	19.54	16.2	1.18

Means followed by the same letter within the same column are not significantly different at 5% level of significance

4.2.13 Mean number of fruits per plant

The mean values of number of fruits per plant are presented in Table 4.8. The lowest mean value of 3.0 was recorded by Tengeru-2010 while the highest mean value of 28.0 was recorded by the accession Nkansah HT.

4.2.14 Mean individual fruit weight

The mean values of individual fruit weight per tomato as presented in Table 4.8 shows significant difference. The lowest mean value of average fruit weight per tomato of 24.3g was recorded by the variety Nkansah HT and the highest mean value of single fruit weight per tomato of 121.7g was recorded by the variety Jaguar F1.

4.2.15 Mean fruit weight per plant

The mean values of the total fruit weight per plant are presented in Table 4.8. There were significant differences among the various accessions. The highest mean value of total fruit weight per plant of 2088g was recorded by the accession CLN3212C followed by the variety Jaguar F1 (2069g) and the lowest mean value of total fruit weight per plant of 95.0g was recorded by the accession Tengeru-2010.

Table 4.8 Mean number of fruits per plant, individual fruit weight and fruit weight per plant of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accession	Number of fruits per plant	Individual fruit weight(g)	Fruit weight per plant (g)
CLN3900D	9.0d	81.9bc	737.0d
Nkansah HT	28.0e	24.3e	680c
Tengeru-2010	3.0a	31.7a	95.0a
CLN3212C	20.0d	104.4cd	2088h
Tanya	16.0cd	78.7bc	1259f
FMTT1733E	5.0ab	62.4b	312b
Jaguar F1	17.0cd	121.7d	2069g
CLN3024A	15.c	61.7b	926e
Mean	13.96	70.9	1021.03
LSD(0.05)	4.53	25.8	3.45

Means followed by the same letter within the same column are not significantly different at 5% level of significance

4.2.16 Mean fruit yield per hectare (t/ha)

The mean values of total fruit yield per hectare are presented in Table 4.9. There were significant differences among the accessions. The highest yield per hectare 34.81t/ha was recorded by the accession CLN3212C followed by the variety Jaguar F1 (34.48t/ha) whiles the lowest mean value of 1.58 t/ha was recorded by the accession Tengeru-2010.

Table 4.9 Mean fruit yield per hectare (t/ha) of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accession	fruit yield per hectare (t/ha)
CLN3900D	12.29d
Nkansah HT	11.35c
Tengeru-2010	1.58a
CLN3212C	34.81h
Tanya	20.98f
FMTT1733E	5.17b
Jaguar F1	34.48g
CLN3024A	15.49e
Mean	17.02
LSD(0.05)	0.0089

Means followed by the same letter within the same column are not significantly different at 5% level of significance

4.3 Mean performance for quality parameters of tomato accessions

4.3.1 Mean pH value of tomato accessions

The mean values of pH of the tomato accessions presented in Table 4.10. shows that there were significant differences among the tomato accessions. The lowest mean value of pH of 3.9 was recorded by the accession CLN3212C and the highest mean pH value of 4.1 was recorded by the variety Jaguar F1.

4.3.2 Mean number of locules per fruit

The accessions differed significantly for the number of locules per fruit. This is presented in Table.

4.10. The highest mean number of locules per fruit of 6.0 was recorded by the accession FMTT1733E and the lowest mean number of locules of 2.0 was recorded by the accessions Tanya and Nkansah HT.

4.3.3 Mean Total soluble solids content (TSS) (°Brix)

The results of Total soluble solids (TSS) are presented in Table 4.10. There was significant difference in the mean Total soluble solids content among the tomato accessions. The highest TSS (°Brix) of 5.60 was recorded by the accession FMTT1733E and the lowest TSS (°Brix) of 3.80 was recorded by the accession Tengeru-2010.

Table 4.10 Mean pH, number of locules and Total soluble solids (TSS) of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accession	pH	Number of locules	Total soluble solids (°Brix)
CLN3900D	4.0 b	3.0 b	4.97bc
Nkansah HT	4.0 b	2.0 a	4.03ef
Tengeru-2010	4.0 b	3.0 b	3.80f
CLN3212C	3.9 a	6.0 d	4.57cd
Tanya	4.0 b	2.0 a	5.20ab
FMTT1733E	4.0 b	6.0 d	5.60a
Jaguar F1	4.1 c	5.0 c	4.63cd
CLN3024A	4.0 b	3.0 b	4.47de
Mean	4.03	3.79	4.66
LSD(0.05)	0.09	0.86	0.4992

Means followed by the same letter within the same column are not significantly different at 5% level of significance

4.3.4 Mean fruit length (cm)

Table 4.11 shows that there were significant differences in mean fruit length among the tomato accessions. The lowest fruit length of 6.07cm was recorded by Nkansah HT and the highest fruit length of 10.37cm was recorded by Jaguar F1.

4.3.5 Mean pericarp thickness

Pericarp thickness varied significantly among all the tomato accessions as presented in Table 4.11. It varied between 0.40cm and 0.80cm. The mean pericarp thickness was 0.57cm and the highest mean pericarp thickness of 0.80cm was obtained by the accession Tanya while the lowest mean pericarp thickness of 0.40cm were recorded by the accessions Tengeru-2010 and Nkansah HT.

4.3.6 Mean fruit diameter

The fruit diameter differed significantly among the different tomato accessions. The result is presented in Table 4.11. The maximum mean value of fruit diameter of 5.77cm was obtained by the variety Jaguar F1 and the minimum mean value of fruit diameter 3.23cm was obtained by the variety Nkansah HT.

Table 4.11 Mean fruit length, pericarp thickness and fruit diameter of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accession	Fruit length(cm)	Pericarp thickness(cm)	Fruit diameter(cm)
CLN3900D	7.93b	0.67ab	5.50ab
Nkansah HT	6.07d	0.40d	3.23d
Tengeru-2010	6.37cd	0.40d	4.23c
CLN3212C	7.87b	0.50cd	5.50ab
Tanya	8.53b	0.80a	4.87bc
FMTT1733E	7.63bc	0.47cd	4.90abc
Jaguar F1	10.73a	0.73a	5.77a
CLN3024A	7.40bcd	0.57bc	4.17c
Mean	7.77	0.57	4.71
LSD(0.05)	1.379	0.163	0.886

Means followed by the same letter within the same column are not significantly different at 5% level of significance

4.3.7. Shelf life

Significant difference in shelf life was observed under room temperature as presented in Table 4.12. The shelf life ranges between 11 to 24.6 days. The longest shelf life (24.6 days) was recorded by the accession Tanya followed by the variety Jaguar F1 (24 days) and least was recorded by the accession Tengeru-2010 (11.6 days).

Table 4.12 Shelf life of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

Accessions	shelf life (days)
CLN3900D	21.6d
Nkansah HT	12.3a
Tengeru-2010	11.6
CLN3212C	15.3b
Tanya	24.6e
FMTT1733E	13.3a
Jaguar F1	24.0e
CLN3024A	18.0c
Mean	17.62
LSD (0.05)	1.76

Means followed by the same letter within the same column are not significantly different at 5% level of significance

Table 4.13 Correlation table for some morphological trait, fruit quality and yield of eight tomato accessions grown at FOHCREC, Kade under environdome greenhouse conditions

	PH	CH	NL	FPF	NT	NFPT	PFS	pH	Brix	FL	FD	PT	NOL	NFPP	SFW	FY	NDTM
PH																	
CH	0.36																
NL	0.16	0.26															
FPF	0.06	0.11	-0.57*														
NT	0.06	0.29	0.63**	-0.83*													
NFPT	0.14	0.16	0.58**	-0.83*	0.88**												
PFS	0.20	0.25	0.47	-0.66*	0.77**	0.92**											
pH	0.80	-0.12	0.27	-0.28	0.31	0.22	-0.03										
Brix	0.32	-0.31	-0.09	-0.18	-0.80	0.08	0.15	-0.05									
FL	0.34	-0.03	0.37	-0.29	0.26	0.12	0.07	0.50*	0.39								
FD	0.16	-0.02	0.08	-0.08	0.00	-0.15	-0.09	0.23	0.35	0.82**							
PT	0.21	-0.16	0.23	0.23	0.27	0.18	0.10	0.51*	0.38	0.73**	0.54**						
NOL	0.35	0.22	0.09	0.09	-0.13	-0.02	0.10	-0.10	0.40	0.36	0.57**	-0.08					
NFPP	0.00	0.33	0.52**	0.52**	0.88**	0.83**	0.72**	0.09	-0.23	-0.03	-0.26	0.03	-0.22				
SFW	0.31	0.24	0.26	0.26	0.27	0.20	0.28	0.29	0.48*	0.79**	0.78	0.60**	0.56**	0.05			
FY	-0.04	0.02	0.53**	0.53	0.53**	0.55**	0.49*	0.41	0.02	0.48*	0.25	0.31	0.25	0.41*	0.53**		
NDTM	0.00	0.18	-0.50*	-0.50*	-0.70*	-0.84*	0.69*	-0.32	-0.29	-0.16	0.12	-0.18	0.02	-0.628	-0.09	-0.51*	

** = significant at P < 0.05 (r >*0.404*), ** = significant at P < 0.01 (r > 0.515), PH=Plant Height, CH=Chlorophyll, NL= Number of leaves, FPF= number of days to fifty percent flowering, NT=Number of truss per plant, NFTPT=Number of fruit per truss, PFS= Percentage fruit set, FL=fruit length, FD=fruit diameter, PT=pericarp thickness, NOL=Number of locules, NFPP=number of fruit per plant, SFW=Single fruit weight, FY=fruit yield(tons/ha) and NDTM=number of days to maturity.*

4.3.8. Correlation of tomato traits of the accessions

Fruit yield (tons/ha) for the accessions showed significant positive correlations with number of leaves (r=0.53**), number of trusses per plant (r=0.53**), number of fruits per truss (r=0.55**), percentage fruit set (r=0.49*), pH (r=0.41), fruit length (r=0.48*), number of fruit per plant (r=0.41*) and single fruit weight (r=0.53**). On the other hand, a significant negative correlation was observed between fruit yield (ton/ha) with number of days to 50% flowering (r= -0.59*)

Single fruit weight correlated positively with brix (r=0.48*), fruit length (r=0.79), fruit diameter (0.78**), pericarp thickness (0.6**) and number of locules (r=0.56**). The number of days to maturity also showed a positive association with number of days to 50% flowering.

The following traits also showed a significant positive correlation; number of truss per plant with number of leaves (r=0.63**); number of fruits per truss with number of leaves (r=0.58**) and number of trusses per plant (0.88**); percentage fruit set with number of leaves (r=0.47*), no of truss (r=0.77**) and number of fruit per truss (r=0.92**); fruit length with pH (r=0.50*), fruit diameter with fruit length (0.82**), pericarp thickness with pH (r=0.51*), fruit length (r=0.73**) and fruit diameter (r=0.54**); number of locules with fruit diameter (r=0.57**); number of fruits per plant with number of leaves (r=0.52**), number of trusses (r=0.88**), number of fruit per truss (r=0.83) and percentage fruit set (r=0.72).

No correlations were observed in number of days to maturity with plant height and number of trusses per plant and fruit diameter.

CHAPTER FIVE

5.0 DISCUSSION

5.1. Morphological Parameters

5.1.1 Plant traits (qualitative)

The current study reveals that the growth habits of three of the accessions were indeterminate while four were determinate and one was semi-determinate. This finding is in agreement with Reader (2003) and Jansen and Shock (2009), who reported that, the growth habit of tomato can either be determinate or indeterminate. Plant growth habits are clearly visible characters and hence can be utilized for identification of a particular cultivar.

The study also reveals that, there was absence of anthocyanin coloration of hypocotyls and leaf veins in all the eight accessions. Hypocotyls coloration and leaf veins could also be used to differentiate tomato cultivars at seedling stage. However, no variations in coloration of hypocotyls were reported in this study. This finding is not in agreement with Yesmin*et al*., (2014), who reported wider variation in hypocotyls coloration and leaf veins coloration.

The type of leaf in all the accessions was observed to be a standard tomato leaf type. This trait is also significant in the identification and grouping of tomato cultivars. This finding is not in agreement with the findings of Bhattarai *et al*., (2018) who reported three different tomato leaf types (standard, peruvianum, and potato). The differences may be due to the type of genotypes used for the study.

The study also reveals that there were also no variations in the inflorescence type and style type of all the accessions as all the accessions showed a generally uniparous inflorescence type and an inserted style type. Similar observations were made by Yesmin *et al*., (2014) and Vishwanath*etal.*, (2014) in cultivated tomato. The position of the style is an important trait which influences pollination in a particular cultivar and time of pollination best suited for a particular cultivar.

5.1.2 Plant trait (quantitative)

The present study revealed significant differences in plant height, chlorophyll content, number of days to 50% flowering, number of trusses per plant, number of fruits per truss, percentage fruit set, number of days to maturity and number of branches.

Plant height is one of the most significant components of plant species' ecological strategy.

The highest plant height was observed in the accession CLN3024A (96.5cm) followed by the variety Jaguar F1 (91.0cm) while the least plant height was recorded by the accession CLN3900D. This finding do not agree with Wahundeniya *et al*., (2013) who evaluated fifteen tomato varieties for growth and yield performance under controlled environment conditions and reported the maximum plant height of (185 cm). This variation may be due to different genotypes used for the study and different environmental conditions present in the greenhouse condition.

The highest chlorophyll content was recorded by the accession CLN3212C (35.3nm). The relationships between chlorophyll content and Nitrogen content in plant leaves have been reported by several authors (Sexton and Carol, 2002; Wang *et al.*, 2004).

Fontes, (2001) reported that, chlorophyll contents in plants leaves can be used as a substitute measure of plant nitrogen status. This finding is useful for breeders who are interested in developing nitrogen use efficiency crops.

The earliest accession to attain 50% flowering was Nkansah HT (22.3 days) followed by Jaguar F1 (24.3 days). Days to 50% flowering gives a good indication of the earliness of a particular variety. This finding is in agreement with Sanwal and Dudi (2004) who evaluated 150 hybrids of tomato and recorded the minimum days to 50% flowering of 22.3 days in the hybrid HTH-18 and a maximum of 30.3 days in Rashmi. The first variety to reach maturity was Nkansah HT (58days) followed by the variety Jaguar F1 (63days). This may be due to their ability to flower early.

Percentage fruit set is a significant trait for increasing productivity of tomato in terms of fruit yield. It also serves as a vital indicator of the resistance of a particular cultivar to the immediate environmental conditions mostly temperature (Singh *et al*., 2014). Singh *et al.,* (2014), reported that, a higher percentage fruit set is essential to achieve high fruit yield. In the presence study, high percentage fruit set was recorded by the variety Nkansah HT (68.3%) followed by CLN3212C (63.3%) while the least percentage fruit set was recorded by the accession Tengeru-2010 (24.7%). From the studies, though Nkansah HT recorded the highest percentage fruit set (68.3%) it did not obtain the highest fruit yield. However, the accession CLN3212C which obtained the second highest percentage fruit set (63.3%) recorded the highest fruit yield. This may be due to the average fruit weight of CLN3212C (104.4g) which is relatively higher than Nkansah HT (24.3g). This finding though in agreement with Singh *et al*., (2014) also reveals that not only percentage fruit set is essential to achieve high fruit yield but also a high individual fruit weight.

Earlier findings reported minimum and maximum values of percentage fruit set as 50.33% and 84.09 % (Singh, 2014), 72.84 % and 86.21 % (Sharma *et al*., 2011) and 83.1 and 93.9 % (Pandey *et al*., 2006). The variation recorded by different authors may be due to different genotypes used for the studies.

The number of trusses and fruit number per truss influence the yield of tomato. The present study reveals significant differences among the accessions in number of trusses and fruit number per truss. The maximum number of truss was recorded by the accession Nkansah HT (21.0), followed by Jaguar F1 (20.0) while the least was recorded by Tengeru-2010 (6.0). This finding is in agreement with Artur, (1995) who reported that, the number of truss per plant can be more than six.

5.1.3. Fruit trait

Fruit traits are one of the most promising descriptors features which can be used to differentiate cultivars (Natarajan *et al*., 1994; Patel *et al*., 2001; Arvindkumar *et al*., 2003). The shape and size of tomato is not only relevant to consumers but also relevant for transportation purposes. The shape of tomato fruit can easily be visualized by the naked eye and can clearly be used in the identification of a particular tomato cultivar during inspection on the field.

The present study revealed wide variation in the fruit shape among the various tomato accessions. Three of the accessions were heart shaped while two of the accessions were round shaped. Plum shaped was observed in one genotype while one accession showed a mixture of shapes and one accession was observed to be high-round. Similar observations were also reported by Bhattarai *et al.,* (2018) who also observed diverse fruit shape such as flattened, slightly flattened, cylindrical, rounded, high-rounded, and heart-shaped.

Pointed blossom end shapes were observed in two accessions while the remaining accessions showed a mixture (pointed, flat and indented) blossom end shape. This finding is in agreement with Maria *et al.,* (2014) who observed and reported variations in Spanish local tomato varieties.

The blossom end shape trait of tomato is stable and is not influenced by biotic or abiotic stresses and is more useful in differentiating tomato cultivars. There was variation in color of the immature tomato accession as one accession produced a dark-green color. The variation observed could be due to genetic variation of the various accessions and environmental factors. Similar observation was made by Bhattarai *et al.,* (2018) who observed greenish-white, green, light green, dark green, green and dark color fruits at immature stage in ninety-one tomato genotypes.

5.1.4. Fruit Yield

Fruit yield is a significant trait when recommending a suitable cultivar. Fruit yield is a very complex trait which is influenced by several yield components. In the current study, considering the mean fruit yield per hectare (tons/ha) of the various tomatoes under study, CLN3212C (34.81t/ha), Jaguar F1 (34.48t/ha) and Tanya (20.98t/ha) showed superior performance in terms of fruit yield.

The single fruit weight was highest in the accession Jaguar F1 (121.7g) followed by the accession CLN3212C which had a single fruit weight of 104.4g while the accession Nkansah HT had the least single fruit weight of 24.3g. The present study revealed that variety Jaguar F1 and the accession CLN3212C comparatively recorded a smaller number of fruits per plant than Nkansah HT which recorded the highest number of fruits per plant (28.0). This may be as a result of higher assimilates available for CLN3212C and Jaguar F1 which lead to an increase in fruit weights as a result of the inverse relationship existing between fruit weight and number of fruits per plant. These findings have also been reported by Supe *et al.*, (1989).

Yield per plant among the accessions varied differently and this may be attributed to the significantly varied number of fruits per plant and single fruit weight. The highest yield per hectare was recorded by the accession CLN3212C (34.81t/ha). This finding is not in agreement with Pandey *et al*., (2006) who reported the highest yield of 89.05t/ha in the variety NSITH-162 under polyhouse conditions of Nepal. This variation may be due to differences in genotypes used for the study as well as environmental conditions under the polyhouse.

5.1.5. Fruit quality parameters

The quality parameters in tomato focus on traits for fresh market and processing. The tomato cultivars developed for fresh market and processing should have certain quality characteristics. Tomato fruits for the fresh market should be firm and have a longer shelf life, it must have a good red color development with an acceptable flavor.

Tomatoes grown for export should have fruits that are firm and smooth enough to withstand spoilage during transportation. Tomato cultivar for processing purpose must also have good color and should be firm. Tomato is one of the most important vegetables which rank first among processed vegetables in the world.

In the processing industry of tomato, the major factors considered are high total soluble solids (TSS) and low acidity.

5.1.6. Total soluble solids content

Tomato for the processing industries should contain between fifty and sixty-five percent (50 - 65 %) of total soluble solids content (TSS) which are mainly sugars (glucose and fructose). Higher amounts of TSS have been reported to correlate with higher recovery product yield (Manashi, 2011; Emami *et al.*, 2013; Singh *et al.*, 2014). For processing, tomato should have a range of TSS between 4 to 8 ^{0}Brix. The present study reveals a wide variation for TSS content among the various accessions which ranges from 3.80 ^{0}Brix (Tengeru-2010) to 5.60 ^{0}Brix (FMTT1733E). A related range of Brix was also reported by Islam et al. (2012) who studied the genetic variability of eleven inbred lines of cherry tomato. Since the accessions FMTT1733E and Tanya recorded higher brix of 5.60 and 5.20 respectively, they can be suitable for the processing industry.

5.1.7 Fruit pH

The fruit pH and TSS are desirable indices used as assessment of related quality traits of tomato in the processing industry (Agong *et al.*, 2001). Aoun *et al.* (2013) reported that acidity of fruit affects flavor when the pH value is low. The growth of pathogens like *Bacillus coagulans* in tomato products are reduced when pH value less than 4.1 (Majid, 2007). pH values less than 4.49 are appropriate in terms of fruit sourness (Aoun *et al.*, 2013).

Caliman *et al*., (2010) reported that for a tomato cultivar to be used for processing, it should have a pH value lower than 4.5. Findings from the current study revealed that pH value among the accession’s ranges from 4.1 -3.9. The pH values obtain from this study suggests that most of the accessions could be suitable for processing.

5.1.8. Number of locules

The current study revealed that, the number of locules ranges from 2.0-6.0. The accessions FMTT1733E and CLN3212C recorded the highest number of locules (6.0). Fruits with higher number of locules were oblate or round in shape. This finding is in agreement with the findings of Kamimura *et al.,* (1985) who reported that the number of locules in oblate fruit is significantly higher than those in the elongated fruit group. Padda *et al*., (1971) also reported that, fruits which have higher locules have more juice content.

5.1.9. Pericarp thickness and shelf life

The study reveals higher pericarp thickness in the accession of Tanya (0.80cm), followed by the variety Jaguar F1 (0.73cm) while the least pericarp thickness was observed in Nkansah HT (0.40cm) and Tengeru-2010 (0.40cm). Tanya and Jaguar F1 also recorded the longest shelf life of 24.6 days and 24.0 days respectively. This finding is similar to Vishwanath *et al*., (2014)

Tomatoes with higher pericarp thickness have a longer shelf life (Nautiyal and Lal, 1983).

Raina *et al.* (1980), also reported that for transportation and canning, the pericarp thickness should be more than 6mm. This makes the variety Jaguar F1 and the accession Tanya more suitable for tomato processing in terms of their fruit pericarp thickness.

5.1.10 Correlation Analysis

Yield and yield components and quality traits are one of the most economically important traits used in selections programs and are usually targeted by plant breeders. Falconer and Mackay (1996), reported that many significant traits in crops are positively or negatively correlated since they are influenced by the same gene or they are structurally related. Correlation between traits gives one insight to conclude whether or not selection for a particular trait will influence another (Girdthai *et al.*, 2012).

The present study showed that fruit yield correlated positively and significantly with number of leaves, number of trusses per plant, number of fruits per truss, number of fruits per plant, percentage fruit set, pH, fruit length, and single fruit weight. However, fruit yield showed a negative association with number of days to 50% flowering. The traits with significantly positive correlation with fruit yield could therefore be selected for maximizing fruit yield in tomato by plant breeders. These findings are in agreement with previous researchers including Singh *et al.*, (2004), Haydar *et al*. (2007), Kumar *et al.,* (2006), Prashanth (2003) and Joshi *et al.,* (2004). These researchers independently reported a positive and significant correlation of fruit yield with number of fruit per truss, average fruit weight and number of fruit per plant.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The study reveals that:

1. Most of the accessions did not show variation in stem pubescence, leaf type, anthocyanin coloration of stem and leaf veins, inflorescence type, fruit size variation within a plant, intensity of greenback and exterior color of immature fruit though these traits are very helpful in identification of a particular cultivar.
2. The best performance in terms of some morphological attributes and yield were recorded by the accession CLN3212C and the variety Jaguar F1.
3. In terms of yield, CLN3212C, Jaguar F1 and Tanya obtained a maximum yield of 34.81t/ha, 34.48t/ha and 20.98t/ha respectively.
4. The accession FMTT1733E recorded the highest brix (5.60) while thickest pericarp was recorded by the accession Tanya (0.80cm) followed by Jaguar F1 (0.73). Tanya and Jaguar F1 also had the longest shelf life of 24.6 days and 24.0 days respectively.
5. Finally, the study reveals significant positive correlation between fruit yield with number of leaves, number of truss per plant, number of fruit per truss, percentage fruit set, pH, fruit length, number of fruit per plant and single fruit weight.

6.2. RECOMMENDATIONS

1. The accession CLN3212C, Jaguar F1 and Tanya could be cultivated by farmers who desire high yielding tomato cultivar to grow in their Envirodome greenhouse.
2. The accession, FMTT1733E and the variety Jaguar F1 to farmers who want to cultivate tomato for processing.
3. Further studies using different fertilizer rates could be evaluated for the growth, yield and quality of the identified accessions and varieties under the Envirodome greenhouse conditions.

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APPENDIX

Appendix 1: ANOVA Variate: %fruit set

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	20.3	10.2	0.08	
Block.*Units* stratum					
Accession	7	3827.3	546.8	4.39	0.009
Residual	14	1742.3	124.5		
Total	23	5590.0			

Appendix 2: ANOVA Variate: Brix

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.61583	0.30792	3.79	
Block.*Units* stratum					
Accession	7	7.34500	1.04929	12.91	<.001
Residual	14	1.13750	0.08125		
Total	23	9.09833			

Appendix 3: ANOVA Variate Chlorophyll

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	32.901	16.450	1.86	
Block.*Units* stratum					
Accession	7	443.807	63.401	7.17	<.001
Residual	14	123.766	8.840		
Total	23	600.473			

Appendix 4: ANOVA Variate Fruit Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.2908	0.1454	0.57	
Block.*Units* stratum					
Accession	7	13.7650	1.9664	7.68	<.001
Residual	14	3.5825	0.2559		
Total	23	17.6383			

Appendix 5: ANOVA Variate Fruit length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1.4058	0.7029	1.13	
Block.*Units* stratum					
Accession	7	37.1629	5.3090	8.56	<.001
Residual	14	8.6808	0.6201		
Total	23	47.2496			

Appendix 6: ANOVA Variate Number of leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2.333	1.167	0.23	
Block.*Units* stratum					
Accession	7	87.833	12.548	2.45	0.073
Residual	14	71.667	5.119		
Total	23	161.833			

Appendix 7: ANOVA Variate Number of locules

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.5833	0.2917	1.20	
Block.*Units* stratum					
Accession	7	49.9583	7.1369	29.24	<.001
Residual	14	3.4167	0.2440		
Total	23	53.9583			

Appendix 8: ANOVA Variate Pericarp Thickness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.005833	0.002917	0.34	
Block.*Units* stratum					
Accession	7	0.486667	0.069524	8.06	<.001
Residual	14	0.120833	0.008631		
Total	23	0.613333			

~~Appendix 9: Variate Plant Height~~

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	183.14	91.57	2.11	
Block.*Units* stratum					
Accession	7	2343.50	334.79	7.70	<.001
Residual	14	608.76	43.48		
Total	23	3135.41			

Appendix 10: ANOVA Variate Shelf life

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1.750	0.875	0.86	
Block.*Units* stratum					
Accession	7	581.625	83.089	81.63	<.001
Residual	14	14.250	1.018		
Total	23	597.625			

Appendix 11: ANOVA Variate Stem Girth

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.002500	0.001250	1.00	
Block.*Units* stratum					
Accession	7	0.020000	0.002857	2.29	0.089
Residual	14	0.017500	0.001250		
Total	23	0.040000			

Appendix 12: ANOVA Variate flowering 50%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.750	0.375	0.33	
Block.*Units* stratum					
Accession	7	375.958	53.708	47.24	<.001
Residual	14	15.917	1.137		
Total	23	392.625			

Appendix 14: ANOVA Variate number fruits per truss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.0833	0.0417	0.18	
Block.*Units* stratum					
Accession	7	24.5000	3.5000	15.08	<.001
Residual	14	3.2500	0.2321		
Total	23	27.8333			

Appendix 15: ANOVA Variate number of trusses

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	12.0000	6.0000	7.00	
Block.*Units* stratum					
Accession	7	641.6250	91.6607	106.94	<.001
Residual	14	12.0000	0.8571		
Total	23	665.6250			

Appendix 16: ANOVA Variate flower per cluster

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.0000	0.0000	0.00	
Block.*Units* stratum					
Accession	7	6.6667	0.9524	1.82	0.162
Residual	14	7.3333	0.5238		
Total	23	14.0000			

Appendix 17: ANOVA Variate: of fruit per plant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	6.333	3.167	0.47	
Block.*Units* stratum					
Accession	7	1416.958	202.423	30.26	<.001
Residual	14	93.667	6.690		
Total	23	1516.958			

Appendix 18: ANOVA Variate pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.000833	0.000417	0.15	
Block.*Units* stratum					
Accession	7	0.089583	0.012798	4.57	0.008
Residual	14	0.039167	0.002798		
Total	23	0.129583			

Appendix 19: ANOVA Variate root length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	3.586	1.793	0.29	
Block.*Units* stratum					
Accession	7	87.498	12.500	2.05	0.120
Residual	14	85.374	6.098		
Total	23	176.458			

Appendix 20: ANOVA Variate: single fruit weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	494.8	247.4	1.14	
Block.*Units* stratum					
Accession	7	23248.7	3321.2	15.27	<.001
Residual	14	3044.6	217.5		
Total	23	26788.1			

Appendix 21: ANOVA Variate fruit yield tons ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	351.0	175.5	0.34	
Block.*Units* stratum					
Accession	7	24211.9	3458.8	6.63	0.001
Residual	14	7306.2	521.9		
Total	23	31869.1			

Plate 1: Experimental set-up

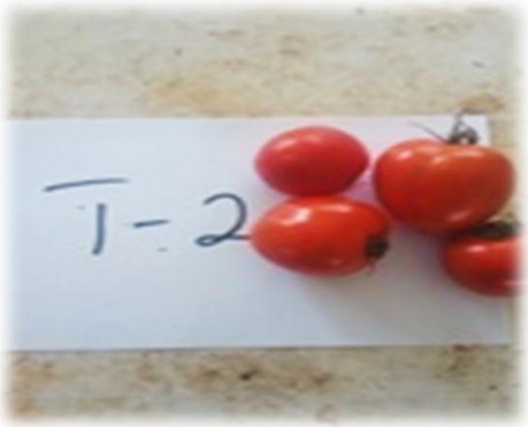
Plate 2: Trellising to keep tomato plants erect

Plate 3: Determination of fruit weight

Plate 4: Number of locules in Jaguar F1

Plate 5: HT Plum shaped

Plate 6:   Tanya Heart shaped



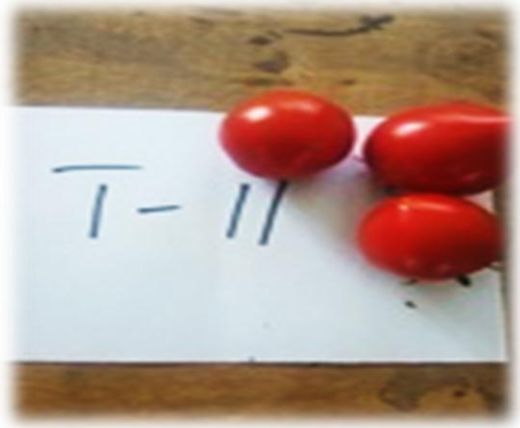


Plate 7: CLN3024A Mixture shapes

Plate 8: Pointed Blossom end shape CLN3900D

Plate 9: Accessions from AVRDC

Plate 10: Slight- Puffiness (Tanya)

Plate 11: Exterior color of immature

Plate 12: ECIMF- CLN3212C fruit (Jaguar F1)