CHAPTER ONE

1.0 INTRODUCTION

Tomato, *(Lycopersicon lycopersci)* is one of the most widely cultivated vegetable crops in Africa and in the world as a whole (Peirce, 1987, Opena and Kyomo, 1990). World tomato production in 2001 was about 105 million tons of fresh fruits on an estimated 3.9 million hectares of land. As it is relatively a short duration crop and gives a high yield, it is economically attractive and the area under cultivation is increasing (Naika et al., 2005). In the SADC region, Opena and Kyomo (1990) prioritized vegetables as follows: tomato, cabbage, onion, mustard, and indigenous vegetables. In Botswana, ,tomato is ranked among the top three vegetable crops namely cabbage, tomato and onions in their order of importance (TAHAL report 2000).

Tomato is ranked at the top of all fruits and vegetables as a source of vitamins and minerals in the U.S. (Stevens, 1974). Tomato plays a major role in human nutrition. It is an excellent source of phosphorus, iron and vitamin A, B and C; (Cobley and Steele, 1976, Varela et al.,2003 and Naika et al., 2005). As a vegetable it constitutes an important component in man's diet, especially in developing countries. However, per capita consumption of vegetables in developed countries tends to be higher than in developing countries, possibly because people in developed countries have a better appreciation of the nutritional value of vegetable crops (Peirce, 1987, vegetable production training manual, 1992).

The yield potential of tomato have been reported to range from 60 to 100 tons per hectare (Varela et al., 2003, Bok et al.,2006). However, the productivity of tomatoes in Botswana and some SADC countries among small scale farmers is generally far below the potential of the crop being as low as 7 t/ha. This can be attributed to the lack of tomato breeding efforts to develop tomato cultivars that are adapted to the local environment. There are also some constraints such as pests, diseases, lack of water for irrigation, poor water quality, poor soils which need to be fertilized, expensive inputs such as fertilizers, seeds, chemicals, expensive services such as power/electricity for watering and the difficulties of breeding temperate crops in a tropical environment. Despite the important role played by vegetable crops, in the SADC region, the sector has not been given serious consideration in the plant breeding research program as compared to the attention directed to the staple crops like cereal crops, except in the Republic of South Africa and Tanzania at AVRDC. The only research work being done is adaptive research that is of evaluation of materials developed outside the region. If the vegetable sector can be given the research attention it deserves, this sector can help to diversify both agriculture and diets in the region. There is no doubt that vegetables are very important in improving the quality of life and people's economic status. This clearly shows that tomato research needs or requires more concentrated research effort to develop and select varieties that are of high yields.

Increasing yield for most crop through selection for yield **per se** has been difficult to achieve, since yield is a quantitatively inherited trait with low heritability and much affected by genotype by environment (G X E) interaction. Cramer and Wehner (1998) said that a method to improve yield would be that of indirect selection for traits that are highly correlated with yield but possess higher heritability. These traits, are often referred to as yield components. These traits in tomatoes include; number of harvests per plant, number of branches per plant, number of nodes per branch, number of pistillate flowers, number of fruit per node and marketable or early yield. According to Lungu, (1978) the consideration of yield components in selection is based on the assumption that a strong association exists between yield and yield components and that these component characters have higher heritability than yield. A number of researchers have also investigated the usefulness of morphological and physiological parameters as indices of single plant yield. Singh et al., (2002) observed high genetic variation in tomato for plant height, number of days to fruit set, number of fruit clusters per plant, number of fruits per plant, fruit weight per plant and fruit yield per plant. The high genetic variation observed for these traits offer an opportunity for indirect selection for yield in tomatoes.

However the exploitation of yield components for indirect selection for yield merely based on the knowledge of their correlation to yield might not be successful because a correlation is simply a measure of association between two variables such as yield and yield components. It is important to establish the cause and effect relationships between yield and the yield enhancing components of the crop species that are amenable to the indirect selection approach for yield. Other Statistical tools such as the Path Coefficient Analysis (P.C.A) originally proposed by "Wright (1921)" but first used for plant selection by "Dewy and Lu, (1959)", provides a clear indication for indirect selection criterion; (Dewey and Lu, 1959; and Mc Giffens et al., 1994). The coefficients generated by path analysis measures the cause and effect relationships, that is, direct and indirect influence of, for instance yield components as independent variables upon another character such as yield, as a dependent variable (Dewey and Lu, 1959; and Mc Giffens et al., 1994). Yield components have also been used to improve yield in crops such as wheat (Dewey and Lu 1959) and cucumber (Abu Salena and Dutta, 1988; Solanki and Shah, 1989; Prasad and Singh, 1994a; 1994b; Yi and Cui, 1994; Zhang and Cui, 1994; Cramer, 1997). Rani et al., (2008), found that in tomato, the yield enhancing traits to include traits such as plant height and fruit weight. Among the traits subjected to path analysis, fruit weight exerted very high direct effect upon yield per plant.

The use of indirect selection for yield based on important morpho-physiological yield parameters that have a great influence on yield in tomatoes may provide a new scope for improving tomato yield in our climatic environment. Identification of the important yield enhancing traits in tomatoes in the SADC environment could form a basis for tomato improvement research in the region. This study was carried out with the objectives of determining yield and yield components, and the correlation among the components that explain most of the variation in tomato yield. It was also conducted to determine the direct and indirect effects of the morpho – physiological traits on yield in tomato, that can be used as indirect selection criteria for increasing yield through plant breeding in tomatoes. This study was done based on the hypothesis that there is enough variation in tomato yield components that can be used to increase yield through plant breeding.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Tomato plant

Tomato (*Lycopersicon lycopersci*), is a tender warm season crop. It is characterized by glandular hairs (trichomes) that emit strong aroma when broken. Tomato plants are typically viny, prostrate, and are either determinate, semi determinate or indeterminate based on whether the apical stem terminate in an inflorescence. Most shoots form in the axils of leaves. It has got a deep tap root which may extend to three meters with extensive secondary roots (Peirce,1987, Purseglove, 1988). The fruits are mostly red but there are some other colours such as yellow. There is a lot of variation between cultivars in the size and shape of the fruits, in the thickness of the fleshy mesocarp and in the development of the placenta (Prashanth,2003 and Veershetty,2004).

2.2 Adaptation and climatic requirements

Tomato is native to tropical Central and South America, where it was cultivated in pre – Columbian times. Its wild proginator is thought to have been the cherry tomato, L. esculenton var. cerasiforme, which grows wild in the Peru – Ecuador area though tomatoes were probably domesticated from weedy forms which had spread as far as north Mexico (Cobley and Steele, 1976, Purseglove, 1988). Tomatoes shows a wide climatic tolerance and can be grown in the open wherever there is more than three months of frost free weather. Tomato is more successful where there are long sunny periods. The optimum growing temperatures are 21^0C to 24^0C. At these temperatures good quality seeds will take about seven days to emerge. Temperature affect flowering and pollination. The hot and dry weather leads to drying of the flowers and stops pollination. If temperatures are below 15^oC or above 29^oC, pollen release is restricted resulting in incomplete fertilization of ovules. This causes collapsed fruit walls and formation of deep indentation in the fruit, a phenomenon called catface (Peirce, 1987, Bok et al.,2006).

Tomatoes grows best in light, free draining, fertile loam soil with pH of 5 – 7. However tomatoes can be grown in a variety of soils (Purseglove, 1988, Naika et al., 2005). Regarding fertilizer requirements, tomatoes require an abundance of the three major elements namely, nitrogen, phosphorus, and potassium. Adequate soil nitrogen application is important to enhance foliage growth which has a major bearing on crop maturity and protects the fruits from sunscald. Phosphorus influences fruit quality by stimulating vigorous root growth that enables more nutrients to enter the plant thereby promoting sturdy stem growth and healthy leaf formation. Tomatoes use large amount of potassium. This element is important in stimulating early plant growth and regulating normal carbohydrate and protein metabolism (Seed Biology. 2009. http://www.ag.ohio-state.edu/~seedsci/vsp03.html, Dated 30.04.2009).

In Botswana there is great potential for tomato production. Weather conditions are favorable in some parts of Ngamiland and Chobe where production can be done throughout the year. All year production in other parts of the country is possible under protected environment such as tunnels and greenhouse (Bok et al.,2006).

2.3 Importance of tomato in Global Agriculture.

Tomato plays major role in human nutrition as a vegetable, it constitute an important component in human diet, especially in developing countries (Stevens, 1974). It is the second most consumed vegetable in the world behind potato. Tomatoes are eaten fresh in salads or processed and can be stewed, fried, baked and used to produce soup, or used as juice. In addition to this versatility, tomatoes are also an important source of vitamins and minerals. They are an excellent source of phosphorus, iron and vitamin A, B and C. They also contain small amounts of the B complex vitamins; thiamin, niacin and riboflavin (Cobley and Steele, 1976, Peirce, 1987, Purseglove, 1988, Varela et al., 2003 and Naika et al., 2005).

2.4 Importance of tomato in SADC region.

Tomatoes are grown for home consumption in the backyard gardens of almost every homestead across sub – Saharan Africa. It is a cash crop for both smallholders and medium – scale commercial farmers (Varela et al., 2003). Vegetables serve as an important source of vitamins and minerals to the local populations particularly in the growing urban areas. The vegetables crops are of nutritional importance to the low income farmers in Africa. They are cheap source of protein, are important to those who cannot afford to purchase adequate quantities of animal protein and to vegetarian who mainly depend on plant protein. Hence sometime they are called poor man's meat (Opena and Kyomo, 1990). The crop helps to reduce poverty by bringing some income to farmers. Representative values for nutrients per 100g of edible portion of tomato fruit had been reported as follows; water 93g, calories 21g, protein 1.0g, fat 0.2g, carbohydrate 4g, fibre 0.6g, calcium 10mg, phosphorus 24mg, iron 0.6mg, B-carotene equiv 450mg, thiamine 0.06mg, riboflavin 0.04mg, niacin 0.6mg and ascorbic acid 26mg (Rice et al., 1990).

2.5. Tomato Plant yield components

2.5.1 Plant Population / Plant number per hectare

Studies have indicated that higher plant densities have increased yield in tomatoes. However the plant population per hectare is influenced by the genotype (Bryan et al.,1967, Fery and Janick, 1970, Wilcox, 1970, Zahara, 1970, Navarro and Locascio, 1971, Zahara and Timm, 1973, Kays and Nicklow, 1974 and Csizinszky, 1980). At higher than optimum plant densities, marketable fruit yields per hectare remain constant or decrease and mean fruit size is generally smaller. Likewise, fruit quality often decrease at high plant populations since insect and diseases are generally more difficult to control. This possibly may be attributed, at least in part to higher relative humidity and inadequate pesticide coverage in a dense plant canopy (Stoffella et al., 1988).

2.5.2 Plant height

Tomato is an annual plant which can reach a height of over two meters (Naika et al., 2005). Joshi et al., (2004), have reported tomato mean plant heights of 121.36 cm. Height is among characters with high heritability (Veershetty,2004, Mohanty,2003, Singh et al., 2000). Apart from fruit characteristics, the plant habit of tomato separates them into two distinct groups, those that are determinate and indeterminate cultivars. Determinate cultivars reach a height of 1.0 to 1.2 meters, at which stage the lead growth develops into a flower truss and similar things happen to all lateral branches.

Indeterminate plants produce one or two stems, which grow on and on (as do laterals that are not removed) until they are stopped by removing the growing point. Indeterminate types usually have smaller fruits and reach maturity later. They bear fruits over a long period and are ideally suited to staking and pruning, both in open ground and in tunnels. They have much smaller pedicel scar than larger fruited sorts (Naika et al., 2005). They allow continuous production of high quality fruits (van der Vooren et al., 1986). The Determinate types have a relatively concentrated fruit set which lasts only two or three weeks and the fruit ripen much faster than those from indeterminate types (Naika et al., 2005).

2.5.3 Number of trusses per plant and fruit number per truss

The number of trusses per plant varies among different varieties. According to Nyirongo, (1995) and Marimbe, (1995) the number of trusses per plant can vary from 6 to 9 and 6 to 8 respectively. Mean fruit number per truss had been reported by different researchers as follows; 3.50 fruits (Joshi et al.,2004), 4.33 fruits (Veershetty, 2004), 4.47fruits (Prashanth,2003), 4.40 fruits (Singh et al., 2000) and 2.38 fruits (Bora et al.,1993).

The number of trusses and fruit number per truss has got an impact on the yield obtained. Regulating the number of trusses and fruits per truss through pruning significantly affects the quality and quantity of fruit in some tomato cultivars. Six trusses gave the highest yield and best quality. This could be due to the fact that photosynthesis becomes sufficient for the development of tomato fruit. In contrast, when less than six trusses were left per plant, the fruit were larger but the total yield was low. Maintaining the appropriate number of trusses per plant is important in the production of high quality tomato fruit (Artur, 1995). The study done by; Artur, (1995) showed that the number of fruits per truss can be more than six. Read and Fieldhouse (1970), found that yield increase in tomato is attributed to more flowers per cluster, greater number of fruits set per cluster and thus more fruit per plant.

2.5.4 Number of pickings

The first harvest from tomato is possible 45 to 55 days after flowering, or 90 to 120 days after sowing (Naika et al., 2005). Timely harvesting of tomato is very important to avoid post harvest losses. The high water content of tomatoes makes them vulnerable to post harvest losses. Tomato fruit had been reported to be 93% water (Rice et al., 1990). High water content provide conducive environment to various micro organisms which cause damage to the fruit. It is necessary to harvest several times as the fruits of tomato plants do not all ripe at the same time. Tomato ripening is continuous as its fruit do not all ripe at once. Harvesting can continue for about one month depending on the climate, diseases, pest and the cultivar type planted. During one season tomatoes must be harvested 4 to 15 times (Naika et al., 2005).

2.5.5 Fruits number per plant and average fruit size

Number of fruits per plant had been reported to range as follows; 27.33 to 64.67 (Kumar et al.2006), 14 to 65 (Upadhyay et al.2005), 8.08 to 41.56 (Joshi et al.2004). Mean fruit number per plant had been reported to be 19.65 (Haydar et al., 2007), 43.09 (Kumar et al., 2006) and 33.20 by (Upadyyay et al., 2005). Average fruit weight ranges had also been reported by different scholars 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 appears to be significant genetic variation for these traits in tomatoes. This is important because the success of crop improvement depends on the magnitude of genetic variability.

2.5.6 Tomato flower and maturity period

Tomato flowers had been reported to grow up to 2 cm in diameter. Flowers are borne in inflorescences of between four to twelve flowers. Its six petals are yellow and up to 1cm in length (Rice et al., 1990). Marimbe, (1995), reported that maturity period of tomatoes varieties differ. The period varies from 83 to 89 days. The crop reaches 50 percent maturity at 66 to 71 days (Nyirongo, 1995, Marimbe , 1995). Maturity period of Expresso (semi determinate) and Sixpack (determinate) had been reported to be 80 days after transplanting (Bok et al. 2006). Naika et al. (2005), also reported that the first harvest is possible 45 to 55 days after flowering, or 90 to 120 days after sowing.

2.6 Tomato breeding

Plant breeding in the SADC region is largely confined to the staple food crops like maize, sorghum, millet and wheat. However the most nutritive group of crops – the vegetables have had very little research attention. Tomato improvement has been done using the methods for self pollinated crops. The aims of tomato breeding has been to increase yield and other important traits as well as removing other constraints/barriers which lowers yield. Yield increase is based on the elimination of limits to yields as well as direct selection for yield per se (Frankel, 1947). Yield is a product of a number of components. It is a product of traits like number of plants per unit area, number of trusses per plant, number of fruits per truss, weight of single fruit and plant height.

The correlation of these components to yield and among themselves is of considerable importance to crop improvement. Yield components have been used in analyzing and identifying sources of variation in yield which can be exploited for improving cultivars to give higher yields (Fiez et al.,1991). Knowledge of how these morpho – physiological components of yield associate with each other and yield is very useful in improving, the hard to improve traits in plant breeding such as yield, which its direct selection is not effective (Tikka, 1975). If there are many components contributing to yield, it is important to partition their correlation into direct and indirect effects (Giriraj and Vijayakumar, 1974). Path analysis has proven useful in providing additional information that distinguishes between the direct and indirect effect relationships (Gravios and Helm, 1992). Therefore to have an effective breeding program, it is necessary to assess the importance of various quantitative characters to yield and select them for a genetic improvement in yield.

Work on the direct and indirect effects of yield components has been done in various crops e.g. rice, mungbean, wheat and tomato. However it is important to note that differences or slightly different results are obtained even working with the same crop. The differences could be caused by different environmental conditions under which the crop is grown. The soil (predictable component) could be the same but the climatic weather conditions such as temperature and rainfall unpredictable components differ from place to place (Eberhart and Russel, 1966). Crop management practices also differ from one researcher to another.

2.6.1 Selection for yield using yield components

Many factors interact to influence the yield of a crop. These include weather, soil, agronomic practices and choice of cultivar. Some of the factors can be modified and some cannot. It is generally recognized that choice of cultivar has an important influence on crop yields. Yield potentials of some crops have increased over time as more and more knowledge on factors that influence yield gets revealed, these factors are called the yield components. Some researchers have speculated in recent years that improvement in yield potential cannot continue much longer or that yield increases have already ceased (Fehr,1984). The question being asked is that, can this speculation be substantiated by appropriate scientific investigation? The answer is likely to be no as there are tools that can be used to break that plateau in yield and selection based on yield components. These are components like plant height, mean fruit weight, fruit number per truss and number of primary branches.

2.6.2 Correlation

Correlation analysis is an important tool in statistics analysis. Correlation between two variables is a measure of association between the two variables. The correlation can be negative or positive. Both negative and positive correlation coefficients are important in plant breeding as the two show the strength of association between any two characters under study. Selection can be done basing on the relationship of plant characters which can be used to improve plant yield. Correlation is important as it has been reported by

(Rogler, 1954, Kneebone, 1956). These researchers demonstrated with cereal crops that there is a positive relationship between seed size and seedling vigour and have said that selection for large seeded grass species will result in strain with superior ability to establish. In breeding work knowledge of characters interrelationship among themselves is necessary if selection for the simultaneous improvement of the characters is to be most effective (Dewey and Lu, 1959). In tomato positive correlation of component traits with fruit yield had been reported as follows; plant height with fruit yield per plant (Joshi et al.,2004, Prashanth, 2003). Fruit per truss with fruit yield per plant (Singh et al.,2004). Number of fruits per plant with 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).

Yield is a complex entity associated with number of components. It is the prime concern of the plant breeders in the global world and is the final factor on which selection programs are to be envisaged. All changes in yield must be accompanied by changes in one or more characters (Graffius, 1964). All changes in the components need not, however, be expressed by changes in yield. This is due to varying degrees of positive and negative correlation between yield and its components and among components themselves (Rani et al., 2008).

2.6.3 Path Coefficient analysis

The path coefficient method was introduced as a statistical method for analysing breeding experiments by Wright, (1921, 1934). Path analysis is a statistical method for determining the magnitude and direction of multiple effects on a complex process

(McGiffen et al., 1994). The method is used to analyze correlation in a system of related variables. Path coefficient is a standardized partial regression coefficient and as such measures the direct influence of one variable upon another and it permits the separation of the correlation coefficient into components of direct and indirect effects (Kambikambi, 1996). The use of path analysis requires a cause and effect situation among variables. This technique has been used quite widely by animal breeders and geneticists (Dewey and Lu, 1959). However the literature have shown that the technique is now widely used by plant breeders. If the cause and effect relationships are well defined, it is possible to represent the whole system of variables in the form of a diagram called a path diagram (Dewey and Lu, 1959). In field crop research and in agriculture, the path coefficient analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Milligan et al., 1990). Path analyses have been used to identify important yield components in various crops including rice (*Oryza sativa L*); (Gravois and McNew, 1993, wheat (*Triticum oestivum L*); Costa and Kronstad,1994 and soya bean (*Glycine max)*; Pandey and Torrie,1973; Akhter and Sneller, 1996; Board et al., 1997, 1999a and Shukla et al.,1999). The current method for calculating the total correlation between independent and dependent factors through path analysis is to standardize the data, determine the simple correlation between independent factors, and regress all dependence factors on each independence factor separately in order to obtain the direct effects in the form of partial regression coefficient (path coefficient) (Li, 1975). PATHSAS has been used successfully in cucumber (*Cucumis sativus L.*) to calculate the path coefficient and correlation between fruit yield and yield components (Cramer and Wehner, 1998). PATHSAS is a SAS computer program for path coefficient analysis of quantitative data that is compatible with any computer system that can run SAS (Cramer and Wehner,1998).

The available literature on path analysis with other component traits in tomato by different researches had been reported as follows; Padda et al.,(1971) and Rathod, (1997) observed that number of fruits per plant had the highest positive direct effect on yield. Path coefficient analysis by Vikram et al., (1998) indicated that mean fruit weight is the most important yield attributing traits after fruit per plant. Sharma and Verma, (2000) reported that number of fruits per plant had the highest direct effect on fruit yield per plant closely followed by pericarp thickness, fruit diameter, average fruit weight, fruit length and plant height in that order. Anikumar et al.,(2003) reported from the path analysis that selection should be based on more number of fruits with higher average fruit weight. Joshi et al.,(2004) showed that the number of fruits per plant is the most important yield contributing trait followed by fruit length, fruit breadth and plant height.

2.7 Heritability of some of tomato yield components

The success of any crop improvement program depends on the presences of genetic variability and to the extent to which the desirable trait is heritable. The presence of genetic variability in the breeding material has been emphasized by Falconer (1960), so as to exercise critical selection pressure. Heritability in broad sense which is the heritable variation was estimated as a ratio of genotypic variance to the phenotypic variance and expressed in percentage (Harson et al.,1956).The heritability percentage was categorized as low (0-30%), moderate (30 – 60%) and high (60% and above) as suggested by Robinson et al., (1949).

High heritability has been reported in tomato by different scholars in the following yield components, plant height (Veershetty, 2004, Arunkumar and Veeraragavathatham, 2005, Upadhyay et al.,2005). Number of fruits per cluster (Singh et al.,2000, Prashanth, 2003,Veershetty, 2004). Number of fruits per plant (Upadhyay et al., 2005, Kumar et al., 2006, Haydar et al., 2007). Average fruit weight (Prashanth, 2003, Mohanty, 2003, Arunkumar and Veeraragavathatham, 2005). Total fruit yield per plant (Parvindersingh et al., 2002, Upadhyay et al., 2005, Haydar et al., 2007). High heritability reported by these scholars clearly indicate that the improvement of these traits in tomato can be obtained by simple selection.

Other scholars had reported moderate to high heritability in tomato yield components. This has been reported in the following components; number of fruit per plant, average fruit weight and fruit yield (Sivaprasad, 2008). According to Sivaprasad, (2008), moderate to high heritability of these traits suggest that the environmental factors also play an important role in the expression of these traits. Thus improvement of fruit yield through its component traits should not only based on simple selection but also on progeny tests. Low to moderate heritability was observed for fruits per truss, indicating the role of the genotype by environment (G X E) interaction in the expression of this trait (Sivaprasad, 2008)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Procedures

The experiment was carried out at the Department of Agricultural Research, Sebele Research Station, in Gaborone, Botswana during 2010/11 growing season. Sebele Research Station is located at Latitude 240^0 34'S and Longitude 250^0 57' S at an altitude of 994 meters above sea level (Monamodi et al., 2003).

Twelve tomato genotypes including two checks of semi determinate and determinate types were used in the study. Ten of these were elite lines developed by the Asian Vegetable Research and Development Centre (AVDRC) obtained from Africa Regional Program (ARP), at Arusha, Tanzania. The varieties used as checks were commercial tomato varieties from South Africa. Determinate varieties are those varieties that will stop growing after flowering and are bushy. Semi determinate tomatoes have habits of determinate and indeterminate hence they are semi bush types. The elite semi determinate lines used were: LBR – 6, LBR – 9, LBR – 10, LBR – 11, LBR – 16 and a commercial variety Expresso. The elite determinate lines were: CLN3022F2-37-29-9-17, CLN3022F2-37-37-12-19, CLN3022F2-37-29-10-17, CLN3022F2-154-22-5-5, CLN3022F2-154-22-9-3 and a commercial variety Sixpack. Table 1 shows the twelve tomato lines used in the study. The rationale for using the above materials is that the checks are readily available and popularly grown by farmers in Botswana. The AVRDC materials were used as the determinate lines were reported to be resistant to tomato yellow leaf curl virus. The semi determinate were reported to be resistant to both early and late blight.

Table 1 : Tomato ((*Lycopersicon lycopersci)* genotypes used in the study with their corresponding character

Name/ Selection	Growth Type	Type/Selection
Sixpack	Determinate	Check
CLN3022F2-37-29-9-17	Determinate	Elite line
CLN3022F2-37-37-12-19	Determinate	Elite line
CLN3022F2-37-29-10-17	Determinate	Elite line
CLN3022F2-154-22-5-5	Determinate	Elite line
CLN3022F2-154-22-9-3	Determinate	Elite line
Expresso	Semi - determinate	Check
LBR – 6	Semi - determinate	Elite line
LBR – 9	Semi - determinate	Elite line
LBR - 10	Semi- determinate	Elite line
LBR – 11	Semi-determinate	Elite line
LBR – 16	Semi-determinate	Elite line

3.2 Agronomic Procedures

The needed agronomic and plant protection procedures were done to maintain healthy plants as tomatoes are very vulnerable to pest and disease problem. Fertilizer application was done as per recommendation (Bok et al., 2006). Preventative spraying with Abametrin against red spider mites was done twice on the 10th October 2010 and 29th October 2010. Dithane M45 was applied as a preventative measure against blight on the

16th November 2010 .Weeding was done by hand hoeing, spraying by knap sack sprayer. The trial was watered using drip irrigation system. Tomato plant must have ample water but it is important not to water them so much, as nutrients can be leached deeper into the soil profile beyond the reach of plant roots. Total amount of water used for determinate and semi determinate was 187 cubic meters and 200 cubic meters respectively. Watering was done in the morning daily and sometime it was done after a day depending on the climatic condition. During raining period no watering was done.

3.3 Soil type and Meteorological data

The soil type at the site is Ferric Luvisol, medium grained sandy loam soil (Mazhani, 1990). Sebele is located in a medium rainfall area with annual average of 400 mm. The soil was analyzed to know the fertility status of the soil. For phosphorus Bray II method was used and ultra violent visible petrometer. Calcium and magnesium were determined with Atomic Absorption Spectrophotometer while Sodium and potassium were determined with Flame Photometer. The exchangeable bases were extracted with ammonium acetate, distilled and then automatic titration was used. Ultra violent visible petrometer was used for organic carbon. For pH a pH meter was used. The analyzed soil results are as shown in Table 2. The total monthly rainfall values and monthly average of minimum temperature, maximum temperature, relative humidity at 0800 hours and 1400 hours from Department of Agricultural Research meteorological station were as presented in Table 3 under results section.

Table 2 :Soil Analysis Parameter Results

Location	Ca (meq/100g)	CEC (Cmol/kg)	K (meq/100g)	Mg (meq/100g)	Na (meq/100g)	OC (%)	P (mg/kg)	pH
Sebele	4.31	3.02	0.13	1.04	0.14	0.364	798.594	6.78

3.4 Experimental Design

The experimental design used was the Randomized Complete Block Design with four replications for both growth types. The two growth types of tomato; determinate, and semi determinate were planted in two separate blocks. Five elite lines of determinate and semi determinate were planted with one commercial variety in each case (Table 1). Each plot was made up of three rows of 2.0 meters in length , separated by a width of 1.2 meters. The intra row spacing was 0.4 meters for all the growth types which gave a plant population of 20833 plants per hectare. Each experimental unit was bordered by one row to minimize border effects on the sides.

3.5 Data collection and methods used

At harvest, data for yield and yield components was obtained. Data was collected from the middle six tagged plants in a plot. A plot was made up of three lines each line having five plants. Thus two plants from each row were randomly chosen and tagged for use. For total yield, all the plants in a plot were used. Yield components recorded from the six tagged plants in a plot included : plant height, fruit number per truss, number of trusses per plant, weight of fruits per truss, weight of fruits per plant, singe fruit weight, flower numbers per truss. Another yield component such as: days to 50 percent flowering, was recorded from all plants in the whole plot.

Methods used for some of the components were as follows:

i. Plant height- Was measured at first harvesting and it consisted of the average height of the middle six plants from each plot. The plant height was measured from the soil surface to the last growth point.

ii. Days to 50 percent flowering – Number of days from planting until half of the plants in a plot were at 50 percent flowering.

iii. Fruit yield – Weight of fruits from the whole plot.

iv Fruit number per truss – The number was obtained from the tagged six plants in a plot and computed an average figure

v Truss number per plant - The number was obtained by counting trusses from the tagged six plants in a plot. An average figure was computed.

vi Single fruit weight – Average weight was recorded in kilograms. Five fruits were randomly sampled from each of the tagged six plants.

vii Fruit number per plant – Number of fruits per plant was counted from the six tagged plants in each plot. An average figure was computed

viii. Total soluble solids – Refractometer machine was used (Plate C)

ix Flower number per truss – Flowers were counted from trusses of tagged plants (Plate B). An average figure was computed.

x. Marketable fruit number - This included fruits which qualify for all the three grades of tomatoes used by the Department of Agricultural Research. Thus marketable fruit yield referred to in this research was closed to the total fruit yield, only badly damaged fruits were termed unmarketable.

3.6 Data analyses

The collected data on different components were compiled and analyzed statistically using the SAS,(Statistical Analysis System 1990). Data were subjected to analysis of variance (ANOVA) using General linear model procedure of SAS. Means were separated using Fisher LSD. Simple correlation analyses were done to find out traits that are positively correlated to yield. A stepwise multiple regression was done to determine the contribution of the various traits to yield, then a path coefficient analysis was also carried out to estimate the direct and indirect effects of components identified by stepwise multiple regression on yield (Wright, 1921; Dewey and Lu, 1959).

CHAPTER FOUR

4.0 RESULTS

4.1 General observation

Tomato seedlings were planted in June 2010 during winter. The seedlings were planted and raised in a closed environment using BCA greenhouse. The growing season of 2010/2011 was characterized by cold winters and good amount of rainfall during the conduct of the research. Table 3 showed that the minimum temperatures ranges was from 1.2^0C to 18.8^0C, maximum temperatures was from 21.9^0C to 34.0^0C. Total amount of rainfall received from October 2010 to February 2011 was 306 mm giving a monthly average of 61.2 mm. Relative humidity range was 59% to 89% at 0800hrs and 22% to 46% at 1400hrs. For vegetable production soil test results showed that the results were fine (Table 2).

Generally the growth of the plants was very good. There were no major pest and disease problems. The mean height for the determinate varieties was 49.54 cm, while that one of semi determinate was 63.6 cm. Mean for days to reach 50 percent flowering was 28.25 and 33.08 for determinate and semi determinate varieties respectively.

Table : 3 Monthly average temperature data, relative humidity and total monthly rainfall at Sebele during the crop growing period of 2010/2011

Month/ Year	Minimum temperature (^{0}C)	Maximum temperature (^{0}C)	Monthly Total Rainfall	Average monthly relative humidity (%) at 0800hrs	Average monthly relative humidity (%) at 1400hrs
June 2010	1.2	21.9	-	89	37
July 2010	2.9	22.8	-	86	36
August 2010	4.4	26.4	-	81	28
September 2010	9.5	31.4	-	59	22
October 2010	15.0	34.0	4.1	61	33
November 2010	17.2	33.0	40.0	61	35
December 2010	18.3	32.4	88.3	73	44
January 2011	18.8	29.9	133.8	81	46
February 2011	17.4	31.0	39.8	79	44

4.2 Semi determinate genotypes

The analysis of variance (Table 4) shows that there were significant differences among the six varieties for yield and some of the yield components. Significant differences among varieties were observed for yield, marketable fruit number, fruit weight per truss, days to 50 percent flowering and plant height. There were no significant differences among varieties for truss number per plant, fruit number per plant, fruit number per truss, fruit weight per plant, single fruit weight, fruit dry matter, total soluble solids and flower number per truss.

Mean performance presented in Tables 5 and 6 revealed that there were significant differences among genotypes involved in the study in yield and yield components. However there were also no significant differences in some characters. Results showed that Expresso performed better than the AVRDC materials in most components Tables 5 and 6. There was significant difference in plant height, yield, days to 50 percent flowering, truss number per plant, fruit weight per truss, fruit number per truss, marketable fruit number and flower number per truss Table 5 and 6.

Table 4: Summary of ANOVA for yield and yield related components for the semi - determinate tomatoes grown at Sebele, Gaborone, Botswana in 2010/11 season

Source	df	YLD	YC1	YC2	YC3	YC4	YC5	YC6	YC7	YC8	YC9	YC10	YC11	YC12
Rep	3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Genotype	5	**	**	ns	**	ns	ns	ns	**	ns	ns	**	ns	ns
Error	15	18.26	1028.80	4.608	0.0009	32.44	0.069	0.557	8.277	0.00042	0.000019	23.54	0.206	0.237
Total	23													

Key ** Significant at 1% and ns is none significant

Key: YLD = Yield, YC1 = Marketable fruit number, YC2 = Truss number per plant, YC3 = Fruit weight per truss, YC4= Fruit number per plant, YC5 = Fruit number per truss, YC6 = Fruit weight per plant, YC7 = Days to 50% flowering, YC8 = Single fruit weight, YC9 = Fruit dry matter, YC10 = Plant height, YC11 = Total soluble solids, YC12 = Flower number per truss.

Table 5: Means performance of plant morphological characteristics of semi- determinate tomato*(Lycopersicon lycopersci)* genotypes grown at Sebele, Gaborone, Botswana in 2010/11 season

Variety	Plant height (cm)	Flower number truss^{-1}	Truss number plant $^{-1}$	Days to 50% flowering
LBR-6	65	6.04	14.00	30.25
Expresso	61.5	6.12	12.25	32.00
LBR – 9	67.05	5.58	10.00	30.75
LBR-10	69.95	5.37	10.50	39.75
LBR-11	62.35	6.08	11.25	34.75
LBR - 16	55.75	5.37	9.25	31.00
Means	63.6	5.76	11.20	33.08
CV%	14.70	8.45	19.15	8.69
LSD (0.05)	5.86	0.734	3.23	4.33

Table 6: Means performance of fruit yield and fruit characteristics of semi - determinate tomato*(Lycopersicon lycopersci)* genotypes grown at Sebele, Gaborone, Botswana in 2010/11 season

Variety	Yield (t/ha)	Single fruit weight (kg)	Fruit dry matter	Marketable fruit number	Fruit number $plant^{-1}$	Fruit number $truss^{-1}$	Fruit Weight $plant^{-1}$ (kg)	Fruit Weight $truss^{-1}$ (kg)	Total soluble solids
LBR-6	59.10	0.105	0.035	427.0	27.5	2.00	2.97	0.21	5.07
Expresso	67.04	0.122	0.037	425.7	27.0	2.20	3.12	0.25	4.87
LBR – 9	58.76	0.132	0.040	332.0	22.0	2.13	2.99	0.29	5.03
LBR-10	53.96	0.119	0.040	351.2	19.5	1.86	2.21	0.21	5.00
LBR-11	64.10	0.130	0.040	432.0	24.5	2.19	2.52	0.22	4.68
LBR - 16	51.58	0.107	0.040	335.5	18.7	1.87	2.18	0.22	4.83
Means	59.09	0.119	0.03	383.91	23.20	2.04	2.66	0.236	4.91
CV%	7.22	32.15	11.46	8.35	24.54	12.85	27.98	13.34	14.51
LSD (0.05)	6.43	0.024	0.0067	48.3	8.58	0.396	1.12	0.04	0.44

4.3 Relationship between yield and other parameters for semi determinate

Yield was studied with respect to its simple relationship to other traits measured and also the cause and effect relationships of traits on yield and the direct and indirect effect of the same traits on yield.

4.3.1 Correlation

Simple correlation analyses were conducted among various components measured to determine the strength of association of these traits for yield and also to estimate the inter component correlations among them. Results for semi determinate tomatoes are presented in Table 7. The results showed that of the thirteen morpho-physiological traits measured only six were significant and positively correlation to yield, while the rest were not. Tomato fruit yield exhibited a strong positive correlation with marketable fruit number (r = 0.68), followed by fruit number per plant (r = 0.54) and the third important character was fruit weight per plant at (r = 0.50).

Inter component correlations (Table 7) show that there were significant positive correlations between number of fruits per plant and number of trusses per plant; number of fruits per truss and number of fruits per plant; fruit weight per plant and number of trusses per plant; fruit weight per plant and number of fruits per plant; fruit weight per plant and number of fruits per truss; marketable fruit number and number of truss per plant; marketable fruit number and number of fruits per plant; marketable fruit number and number of fruits per truss; flower number per truss and marketable fruit number; fruit dry matter and fruit weight per plant; fruit weight per truss and number of fruits per truss; fruit weight per truss and fruit weight per plant.

Table 7: Inter component correlations among variables which were correlated to yield for semi - determinate tomato*(Lycopersicon lycopersci)* genotypes grown at Sebele, Gaborone, Botswana in 2010/11 season

	No of truss plant $^{-1}$	No of fruits plant $^{-1}$	No of fruits truss $^{-1}$	Fruit Weight plant $^{-1}$	Marketable Fruits number	Flower Number truss $^{-1}$	Plant height	Total soluble solids	Single fruit weight	Fruit dry matter	Days 50%	Fruit weight truss $^{-1}$	Yield (t/ha)
No of truss plant $^{-1}$	1.00	0.86*	0.008	0.81*	0.41*	0.36	0.06	-0.17	0.17	-0.32	-0.22	0.02	0.41*
No of fruits plant $^{-1}$		1.00	0.49*	0.91*	0.54*	0.38	-0.008	-0.11	0.20	-0.42	-0.26	0.37	0.54*
No of fruits truss $^{-1}$			1.00	0.39*	0.45*	0.21	-0.14	0.13	0.10	-0.26	-0.19	0.66*	0.44*
Fruit Weight plant $^{-1}$				1.00	0.26	0.23	0.09	-0.12	0.30	-0.40*	-0.27	0.59*	0.50*
Marketable Fruits number					1.00	0.62*	0.003	-0.13	-0.18	-0.19	-0.24	-0.06	0.68*
Flower Number truss $^{-1}$						1.00	-0.04	-0.20	-0.006	-0.11	-0.33	-0.04	0.47*
Plant height							1.00	-0.04	0.05	-0.20	0.34	0.12	0.10
Total soluble solids								1.00	0.04	0.03	-0.00	0.05	-0.11
Single fruit weight									1.00	-0.20	0.21	0.30	0.32
Fruit dry matter										1.00	0.09	-0.29	-0.25
Days 50% flowering											1.00	-0.24	-0.21
Fruit weight truss $^{-1}$												1.00	0.35
Yield (t/ha)													1.00

*Indicates significance at 0.05 level of probability

4.3.2 Stepwise multiple regression

A stepwise multiple regression analysis was conducted using yield as a dependent variable and the morpho-physiological components as the independent variables. The stepwise multiple regression analysis was carried out in order to identify the components which have the greatest influence on yield, that is, those that have the greatest cause and effect relationship on yield. Table 8 presents the results of the stepwise multiple regression analysis. Marketable fruit number had a significant influence on yield explaining 47.5% of the total variation in yield. Addition of other variables (single fruit weight, fruit weight per truss, fruit number per truss) showed significant stead according to the total variation in yield expressed as R^2 from 47.5% to 81.8%. Further addition of other variables did not amount to significant difference according to the total variation in yield, thus were not included in the model.

Table 8 : Stepwise multiple regression of tomato yield on the components for semi determinate genotypes

Variable	Partial R-Square	Model R-square	F-Value	Pr>F
Marketable fruit Number	0.4751	0.4751	19.92	0.0002
Single fruit weight	0.2079	0.6830	13.77	0.0013
Fruit weight per truss	0.0755	0.7585	6.25	0.0212
Fruit Number per truss	0.0599	0.8184	6.27	0.0215

4.3.3 Path coefficient analysis

Components identified by step wise multiple regression were partitioned into direct and indirect effect. The diagram shown in Figure 1 facilitates the understanding of the nature of the cause and effect system. The figure shows the causal relationship between the response variable yield (5) and the four component variables shown in the key. Path coefficients are represented by $\mathbf{P_{15}}$, $\mathbf{P_{25}}$, $\mathbf{P_{35}}$ and $\mathbf{P_{45}}$, which correspond to direct effects on yield from the four components. For any two component variables (eg 1 and 2), their correlation (r_{12}) multiplied by the path coefficient of the second component variable (eg P_{25}) gives the indirect effect of one component (1) on (5) through the effect of another component (2).The direct and indirect path coefficients of the identified components are as presented in (Table 9). Results, showed that marketable fruit number had the strongest positive direct effect of 0.989 on yield followed by fruit weight per truss with 0.592 and then single fruit weight with 0.369. Fruit number per truss had a negative direct effect of – 0.434 however it had two good indirect effects via marketable fruit number of 0.445 and fruit weight per truss 0.394 . Other variables did not have any good indirect effect.

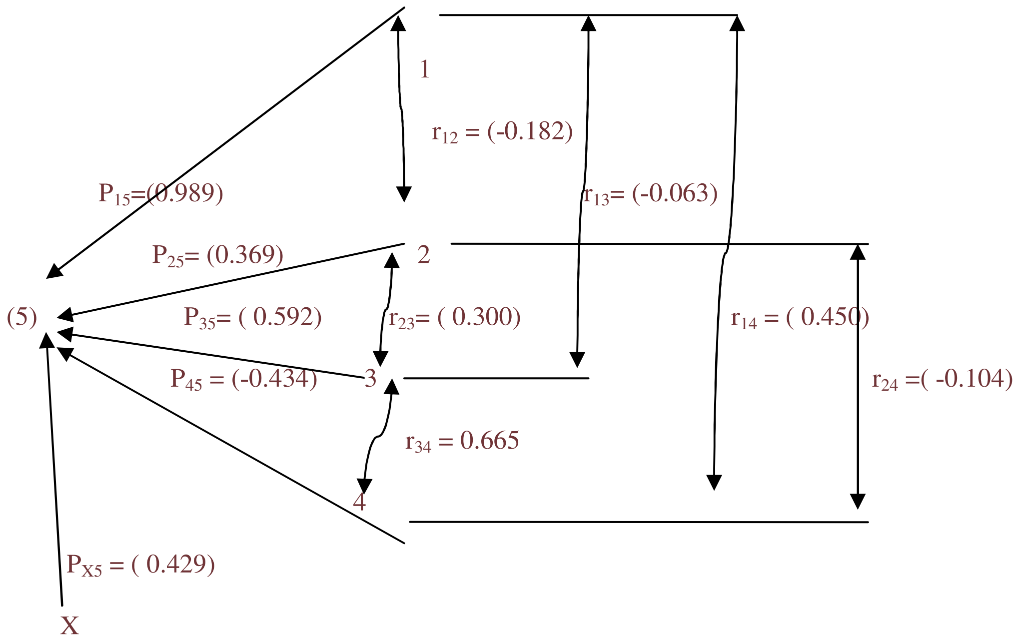

Figure 1: A Path diagram and coefficient of factors influencing tomato fruit yield for semi determinate genotypes.

Key : 1 = Marketable fruit number 2 = Single fruit weight 3 = Fruit weight per truss

4 = Fruit number per truss

Table 9: The direct and indirect effects of different components on tomato fruit yield of semi determinate tomato grown under field conditions.

Type of effect	Coefficients
Marketable fruit number	
Direct effect	0.989
Indirect effect via Single fruit weight ($r_{12}P_{25}$)	-0.067
Indirect effect via fruit weight per truss ($r_{13}P_{35}$)	-0.037
Indirect effect via fruit number per truss ($r_{14}P_{45}$)	-0.195
Single fruit weight	
Direct effect	0.369
Indirect effect via marketable fruit number ($r_{12}P_{15}$)	-0.180
Indirect effect via fruit weight per truss ($r_{23}P_{35}$)	0.178
Indirect effect via fruit number per truss ($r_{24}P_{45}$)	-0.045
Fruit weight per truss	
Direct effect	0.592
Indirect effect via Single fruit weight ($r_{23}P_{25}$)	0.111
Indirect effect via marketable fruit number ($r_{13}P_{15}$)	-0.062
Indirect effect via fruit number per truss ($r_{34}P_{45}$)	-0.289
Fruit number per truss	
Direct effect	-0.434
Indirect effect via fruit weight per truss ($r_{34}P_{35}$)	0.394
Indirect effect via single fruit weight ($r_{24}P_{25}$)	0.038
Indirect effect via marketable fruit number $r_{14}P_{15}$)	0.445

The residual was calculated using the following formula (Dewey and Lu, 1959).

$1 = (Px_5^2 + P_{15}^2+P_{25}^2+P_{35}^2+P_{45}^2)+ (2\ P_{15}r_{12}\ P_{25+}\ 2P_{15}r_{13}\ P_{35+}\ 2P_{15}r_{14}\ P_{45}) + (2\ P_{25}r_{23}\ P_{35\ +}\ 2\ P_{25}r_{24}\ P_{45}) + (2\ P_{35}r_{34}\ P_{45})$

$1 = Px_5^2\ +0.816$

$1 – 0.816 = Px_5^2$

$0.184 = Px_5^2$

$\sqrt{0.184} = P_{X5}\ = 0.429$

4.4. Results for Determinate tomato genotypes

The analysis of variance (ANOVA) and means of all parameters studied are as shown in Tables 10, 11 and 12. Table 10 showed that there was significant differences among the six varieties in yield; days to 50 percent flowering; single fruit weight, plant height and total soluble solids. There was no significant differences in parameters such as marketable fruit number; truss number per plant; fruit weight per truss; fruit number per plant; fruit number per truss; fruit weight per plant; fruit dry matter; and flower number per truss.

Table 12 shows that Sixpack had the highest yield numerically, followed by CNL 3022F2-37-37-12-19 and CNL 3022F2-37-29-9-17 in that order although there was no significant difference among them. CNL 3022F2-37-37-12-19 performed identically to CNL 3022F2-37-29-9-17 but yielded significantly different from CNL 3022F2-154-22-9-3, CNL 3022F2-37-29-10-17 and CNL 3022F2-154-22-5-5. Elite line CNL 3022F2-154-22-5-5 numerically had the lowest yield although it was not significantly different from the last four.

Summary of ANOVA and mean performance of parameters measured are as presented in tables 10, 11 and 12.

Table 10: Summary of ANOVA for yield and yield related components for the determinate tomatoes grown at Sebele, Gaborone, Botswana in 2010/11 season

Source	df	YLD	YC1	YC2	YC3	YC4	YC5	YC6	YC7	YC8	YC9	YC10	YC11	YC12
Rep	3	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns
Genotype	5	**	ns	ns	ns	ns	ns	ns	**	**	ns	*	*	ns
Error	15	28.323	5928.141	3.399	0.00045	45.424	0.184	0.109	14.077	0.000084	0.00027	14.508	0.064	0.663
Total	23													

** Significant at 1% * Significant at 0.05

Key :YLD = Yield, YC1 = Marketable fruit number, YC2 = Truss number per plant, YC3 = Fruit weight per truss, YC4= Fruit number per plant, YC5 = Fruit number per truss, YC6 = Fruit weight per plant, YC7 = Days to 50% flowering, YC8 = Single fruit weight, YC9 = Fruit dry matter, YC10 = Plant height, YC11 = Total soluble solids, YC12 = Flower number per truss.

Table 11: Means performance of plant morphological characteristics of determinate tomato*(Lycopersicon lycopersci)* genotypes grown at Sebele, Gaborone, Botswana in 2010/11 season

Variety	Plant height (cm)	Flower number truss^{-1}	Truss number plant $^{-1}$	Days to 50% flowering
Sixpack	54.16	7.25	9.45	24.50
CNL3022F2-37-29-9-17	52.91	5.75	7.58	35.0
CNL3022F2-37-37-12-19	49.16	6.75	10.20	25.50
CNL3022F2-37-29-10-17	47.08	6.25	10.91	25.0
CNL3022F2-154-22-5-5	44.99	6.75	8.29	33.50
CNL3022F2-154-22-9-3	48.96	6.50	10.16	26.0
Means	49.54	6.54	9.43	28.25
CV%	7.68	12.45	19.53	13.28
LSD(0.05)	5.74	1.22	2.77	5.654

Table 12: Means performance of fruit yield and fruit characteristics of determinate tomato*(Lycopersicon lycopersci)* genotypes grown at Sebele, Gaborone, Botswana in 2010/11 season

Variety	Yield (t/ha)	Single fruit weight (kg)	Fruit dry matter	Marketable fruit number	Fruit number plant^{-1}	Fruit number truss^{-1}	Fruit Weight plant^{-1} (kg)	Fruit Weight truss^{-1} (kg)	Total soluble solids
Sixpack	62.04	0.090	0.025	702.50	23.29	2.469	1.54	0.164	4.77
CNL3022F2-37-29-9-17	54.10	0.067	0.020	656.75	19.00	2.480	1.12	0.145	5.34
CNL3022F2-37-37-12-19	59.10	0.062	0.017	748.50	26.70	2.555	1.38	0.132	4.92
CNL3022F2-37-29-10-17	48.96	0.062	0.015	657.25	29.37	2.622	1.56	0.141	5.04
CNL3022F2-154-22-5-5	46.58	0.072	0.020	586.25	20.33	2.524	1.28	0.157	5.14
CNL3022F2-154-22-9-3	53.76	0.067	0.017	588.00	25.87	2.521	1.62	0.158	4.68
Means	54.09	0.07	0.019	656.54	24.09	2.52	1.42	0.149	4.98
CV%	9.83	13.02	23.33	11.72	27.96	17.00	23.29	14.19	5.07
LSD (0.05)	8.02	0.013	0.0251	116.0	10.15	0.648	0.499	0.032	0.381

4.5 Relationship between yield and other parameters for determinate genotypes

As was the case with semi determinate, in the determinate yield was also studied with respect to its simple relationship to other traits measured and also the cause and effect relationships of traits on yield as well as the direct and indirect effect of the same traits on yield.

4.5.1 Correlation

Simple correlation analyses were conducted among various components measured to determine the strength of association of these traits for yield and also to estimate the inter component correlations among them. Results are presented in Table 13. The results showed that of the thirteen morpho-physiological traits measured only two were significant and positively correlation to yield, while the rest were not. Tomato fruit yield exhibited a strong positive correlation with marketable fruit number (r = 0.64) and plant height (r = 0.52)

Results for the inter component correlations (Table 13) showed that there were significant positive correlations between fruit number per plant and fruit number per truss; fruit number per plant and number of truss per plant; flower number per truss and total soluble solids; fruit weight per plant and total soluble solids; fruit weight per plant and fruit number per truss; fruit weight per plant and number of truss per plant; fruit weight per plant and fruit number per plant; plant height and marketable fruit number; days to 50 percent flowering and marketable fruit number; days to 50 percent flowering and total soluble solids; days to 50 percent flowering and number of truss per plant; days to 50 percent flowering and fruit number per plant; fruit weight per truss and fruit number per truss; fruit weight per truss and fruit number per plant; fruit weight per truss and fruit weight per plant (Table 13).

Table 13: Inter components Correlation of components correlated to yield for the determinate genotypes

	Marketable fruit No	Single fruit weight	Total soluble solids	Fruit No truss $^{-1}$	Fruit dry Matter	Flower No truss $^{-1}$	Truss No plant $^{-1}$	Fruit no plant $^{-1}$	Fruit weight plant $^{-1}$	Plant height	Days to 50% flowering	Fruit weight truss $^{-1}$	Yield (t/ha)
Marketable fruit No	1.00	-0.24	0.06	0.14	0.13	0.26	0.06	0.11	-0.04	0.44*	-0.43*	-0.17	0.64*
Single fruit weight		1.00	-0.23	-0.13	0.11	0.18	0.02	-0.09	0.19	0.26	0.03	0.37	0.30
Total soluble solids			1.00	-0.14	-0.22	-0.42*	-0.32	-0.32	-0.41*	-0.15	0.46*	-0.25	-0.36
Fruit No truss $^{-1}$				1.00	0.02	0.11	0.30	0.69*	0.59*	-0.0086	-0.014	0.73*	0.28
Fruit dry Matter					1.00	0.18	0.11	0.09	0.044	-0.21	-0.036	-0.049	0.38
Flower No truss $^{-1}$						1.00	0.069	0.107	0.146	0.168	-0.135	0.211	0.30
Truss No plant $^{-1}$							1.00	0.88*	0.87*	0.078	-0.55*	0.147	0.23
Fruit no plant $^{-1}$								1.00	0.91*	0.047	-0.42*	0.40*	0.30
Fruit weight plant $^{-1}$									1.00	0.130	-0.37	0.59*	0.31
Plant height										1.00	-0.189	0.105	0.52*
Days to 50% flowering											1.00	0.160	-0.42*
Fruit weight truss $^{-1}$												1.00	0.231
Yield													1.00

*** significant at 0.05 level of probability**

4.5.2 Stepwise multiple regression

Results for stepwise multiple regression are presented in Table 14. As it is the case with semi determinate, marketable fruit number had a significant influence on yield explaining 40.96% of the total variation in yield. Addition of two variables (single fruit weight, total soluble solids) showed significant stead according to the total variation in yield expressed as R^2 from 40.96% to 73.47%. Addition of other variables (fruit number per truss, fruit dry matter, flower number per truss) did not have much contribution to the total variation in yield as they were not significant.

The stepwise multiple regression helped in identifying the variables: Marketable fruit number, single fruit weight, total soluble solids, fruit number per truss, fruit dry matter and flower number per truss to be used in the path coefficient analysis. The above components were further analyzed with path coefficient analysis which is a stronger tool .

Table 14: Stepwise multiple regression of determinate tomato yield on the components

Variable	Partial R-Square	Model R-square	F-Value	Pr>F
Marketable fruit number	0.4096	0.4096	15.27	0.0008
Single fruit weight	0.2265	0.6361	13.07	0.001
Total soluble solids	0.0986	0.7347	7.43	0.013
Fruit number per truss	0.0391	0.7738	3.28	0.0858
Fruit dry matter	0.0285	0.8023	2.60	0.1244
Flower number per truss	0.0241	0.8264	2.36	0.1428

4.5.3 Path coefficients analysis

Components identified by step wise multiple regression were partitioned into direct and indirect effect. Figure 2 facilitates the understanding of the nature of the cause and effect system of yield components to yield. Table 15 presents a summary of the path coefficient analyses. Results in table 15 indicates that marketable fruit number had the strongest positive direct effect of 0.752 on yield followed by single fruit weight with 0.445.The indirect effect of all the variables were generally small in magnitude and were either positive or negative (Table 15).

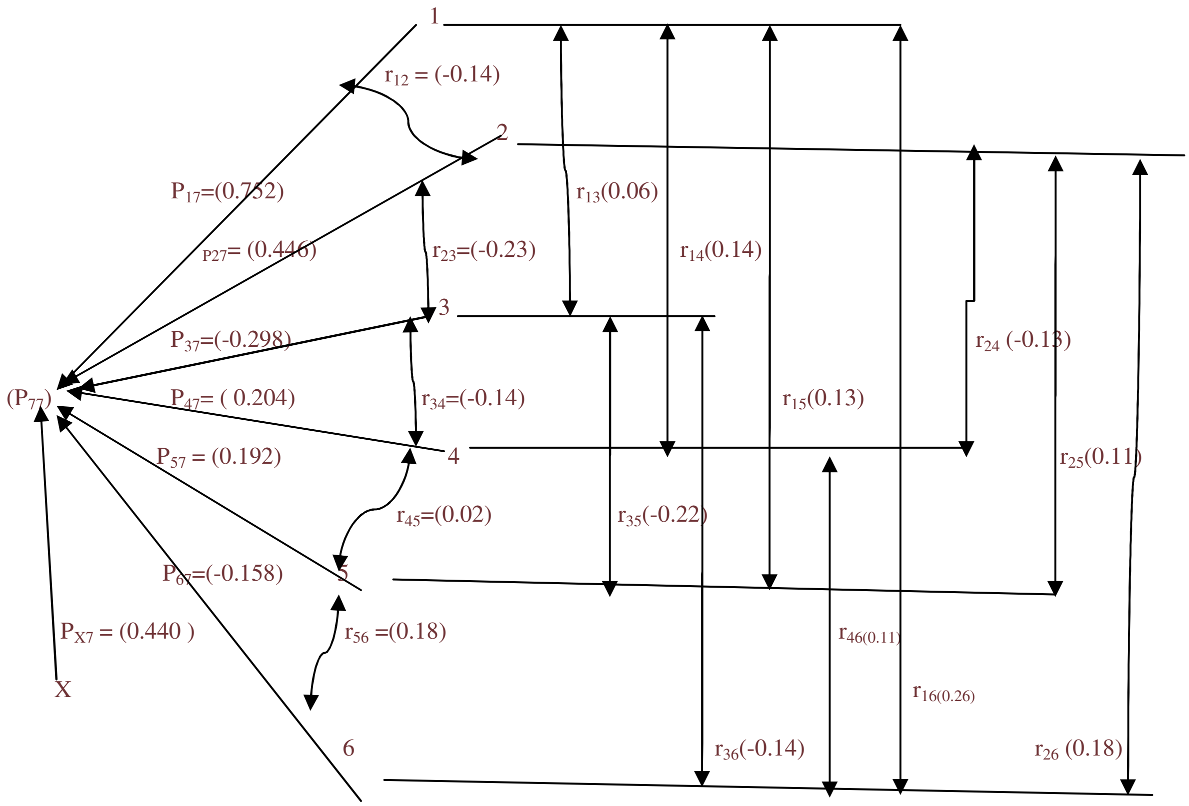

Figure 2: A Path diagram and coefficient of factors influencing determinate tomato fruit yield.

Key :1 = Marketable fruit number 2 = Single fruit weight 3 = Total soluble solids 4= Fruit number per truss 5 = Fruit dry matter and 6 = Flower number per truss

Table 15: The direct and indirect effects of different components on tomato fruit yield of determinate tomato grown under field conditions.

Type of effect	Coefficients
Marketable fruit number	
Direct effect	0.752
Indirect effect via Single fruit weight ($r_{12}P_{27}$)	-0.107
Indirect effect via total soluble solids ($r_{13}P_{37}$)	-0.018
Indirect effect via fruit number per truss ($r_{14}P_{47}$)	0.029
Indirect effect by fruit dry matter ($r_{15}P_{57}$)	0.025
Indirect effect via flower number per truss ($r_{16}P_{67}$)	-0.041
Single fruit weight	
Direct effect	0.445
Indirect effect via marketable fruit number ($r_{12}P_{17}$)	-0.180
Indirect effect via total soluble solids ($r_{23}P_{37}$)	0.069
Indirect effect via fruit number per truss ($r_{24}P_{47}$)	-0.027
Indirect effect via fruit dry matter ($r_{25}P_{57}$)	0.021
Indirect effect via flower number per truss ($r_{26}P_{67}$)	-0.028
Total soluble solids	
Direct effect	-0.298
Indirect effect via single fruit weight ($r_{32}P_{27}$)	-0.103
Indirect effect via marketable fruit number ($r_{31}P_{17}$)	0.045
Indirect effect via fruit number per truss ($r_{34}P_{47}$)	-0.029
Indirect effect via fruit dry matter ($r_{35}P_{57}$)	-0.042
Indirect effect via flower number per truss ($r_{36}P_{67}$)	0.066

Fruit number per truss	
Direct effect	0.204
Indirect effect via total soluble solids ($r_{43}P_{37}$)	0.042
Indirect effect via single fruit weight ($r_{42}P_{27}$)	-0.058
Indirect effect via marketable fruit number ($r_{41}P_{17}$)	0.105
Indirect effect via fruit dry matter ($r_{45}P_{57}$)	0.004
Indirect effect via flower number per truss ($r_{46}P_{67}$)	-0.017
Fruit dry matter	
Direct effect	0.192
Indirect effect via fruit number per truss ($r_{54}P_{47}$)	0.004
Indirect effect via total soluble solids ($r_{53}P_{37}$)	0.066
Indirect effect via single fruit weight ($r_{52}P_{27}$)	0.049
Indirect effect via marketable fruit number ($r_{51}P_{17}$)	0.098
Indirect effect via flower number per truss ($r_{56}P_{67}$)	-0.028
Flower number per truss	
Direct effect	- 0.158
Indirect effect via fruit dry matter ($r_{65}P_{57}$)	0.035
Indirect effect via fruit number per truss ($r_{64}P_{47}$)	0.022
Indirect effect via total soluble solids ($r_{63}P_{37}$)	0.125
Indirect effect via single fruit weight ($r_{62}P_{27}$)	0.080
Indirect effect via marketable fruit number ($r_{61}P_{17}$)	0.196

The residual was calculated using the following formula (Dewey and Lu, 1959).

$1 = Px_7^2 + P_{17}^2 + P_{27}^2 + P_{37}^2 + P_{47}^2 + P_{57}^2 + P_{67}^2) +$

$(2P_{17}r_{12}P_{27} + 2P_{17}r_{13}P_{37} + 2P_{17}r_{14}P_{47} + 2P_{17}r_{15}P_{57} + 2P_{17}r_{16}P_{67})$

$+(2P_{27}r_{23}P_{37} + 2P_{27}r_{24}P_{47} + 2P_{27}r_{25}P_{57} + 2P_{27}r_{26}P_{67}) +$

$(2P_{37}r_{34}P_{47} + 2P_{37}r_{35}P_{57} + 2P_{37}r_{36}P_{67}) +$

$(2P_{47}r_{45}P_{57} + 2P_{47}r_{46}P_{67}) + (2P_{57}r_{56}P_{67})$

$1 = P_{X7}^2 + 0.958 – 0.169 + 0.031 + 0.003 – 0.006 – 0.011$

$1 = P_{X7}^2 + 0.806$

$1 – 0.806 = P_{X7}^2$

$\sqrt{}0.194 = Px_7^2$

$Px_7 = 0.440$

CHAPTER FIVE

5.0 DISCUSSION

The experiment conducted was composed of determinate and semi determinate tomato genotypes. The results of each growth type were presented separately from each other as independent entities. In this section however, the results of two tomato types are being discussed together including their comparative performances.

5.1.1 Analysis of variance and mean performance for the two tomato types

Analysis of variance results for the semi determinate showed that there were significant differences ($p<0.05$) among the genotypes involved in the study in yield and yield components. There were significant differences in yield, marketable fruit number, fruit weight per truss, plant height and days to 50 percent flowering. However there were also no significant differences in some components (Table 4). A comparison of mean performance among the varieties showed that Expresso was the highest yielder with 67.04t/ha which was significantly different from LBR-6 (59.10 t/ha), LBR-9 (58.76 t/ha), LBR-10 (53.96 t/ha) and LBR-16 (51.58 t/ha. The high yielding capacity of Expresso was expected since it had been evaluated and recommended for production. There was no significant difference between LBR-11 and Expresso. Three AVRDC materials (LBR-11, LBR-9, LBR-6) yielded significantly the same. As yield of LBR-11 was not significantly different from that of Expresso, this implied that even the AVRDC materials have the potential to give good yield (Table 6).

Comparing some of the measured yield components between the genotypes the results revealed that Expresso was generally a better cultivar in most of the components measured (Table 5 and 6). Results obtained on the following yield contributing components/characters; fruit number per plant, single fruit weight, plant height and fruit number per truss were similar to the findings of (Hayda et al., 2007, Joshi et al., 2004, Bok et al., 2006 Mohanty, 2002, Naika et. al; 2005, Bora et al., 1993). The mean performance results of the yield components obtained in this study were also similar to results reported by by Shravan et al., (2004) on these characters in tomato. Singh and Raj (2004) and Barman et al., (1995) also had similar findings that tomato genotype showed significant difference in the mentioned traits/components. However there were no significant differences in fruit weight per plant, total soluble solids, fruit dry matter and fruit number per truss among the cultivars. These findings are not in agreement with (Barman et al., 1995, Shravan et al., 2004 and Singh and Raj, 2004). These scholars observed significant differences in some of these traits. The difference between the findings of this study with others could be attributed to difference in climatic conditions under which the experiments were done.

With respect to the determinate type, the analysis of variance for yield and yield components revealed that there were significant differences ($p<0.05$) among the genotypes used in both yield and the measured components (Table 10). Mean performance results (Table 11 and 12) showed that variety Sixpack – (check variety) generally yielded higher but it was not significant to two varieties:- CNL3022F2-37-29-9-17 and CLN3022F2-37-37-12-19. However the check variety was significantly different ($p<0.05$) to three varieties:- CLN3022F2-37-29-10-17,CLN3022F2-154-22-5-5 and CLN3022F2-154-22-9-3. Sixpack which was used as check is an open pollinated variety which had been evaluated and recommended for production in Botswana.

Sixpack out yielded the second highest yielding material CLN3022F2-37-37-12-19 by 4.74% and the lowest yielding material CLN3022F2-154-22-5-5 by 24.92%.

Significant differences ($p<0.05$) were also revealed between the CLN series themselves. Variety CNL3022F2-37-29-9-17 and CLN3022F2-37-37-12-19 yielded significantly different from variety CLN3022F2-37-29-10-17, CLN3022F2-154-22-5-5 and CLN3022F2-154-22-9-3. No significant differences ($p<0.05$) was found between CLN3022F2-37-29-10-17, CLN3022F2-154-22-5-5 and CLN3022F2-154-22-9-3. Sixpack out yielded the CLN series (AVRDC materials) in most characters measured. Sixpack showed significantly higher figure of single fruit weight as compared to the five CLN series. It was also better in plant height though it was not significantly different from variety CNL3022F2-37-29-9-17, CNL3022F2-37-37-12-19 and CNL3022F2-154—22-9-3 . It does generally well in most components as it is either the best or second best, (Table 11 and 12). These findings are similar to the findings of (Barman et al., 1995, Shravan et al., 2004 and Singh and Raj, 2004).

The semi determinate yielded generally higher than the determinate group. The highest yield recorded in the semi determinate was 67.04t/ha while that of determinate was 62.04t/ha. The lowest yield recorded from semi determinate was 51.58t/ha and for determinate was 46.58t/ha. Semi determinate was also a better performing group in most of the fruits characteristics. Its highest single fruit weight was 0.132kg while that of determinate was 0.090kg. The group also performed better in fruit dry matter, truss number per plant, fruit weight per plant and in fruit weight per truss. The determinate group generally performed better in marketable fruit number and in days to 50 percent flowering as it was earlier. Performance of the two group was almost identical in total soluble solids.

5.1.2 Correlation analysis for the two tomato types

Yield for semi determinate was found to be significantly ($p<0.05$) correlated to the following traits:- number of truss per plant (r = 0.41), fruit number per plant (r = 0.54), fruit number per truss (r = 0.44), fruit weight per plant (r = 0.50), marketable fruit number (r = 0.68), and flower number per truss (r = 0.47), (Table 7). The positive correlation result obtained in this present study on fruit weight per plant was in agreement with the findings of (Rani et al., 2008,Aruna, 1992, Jawaharlal, 1994, Sankari, 2000,Das et al.,1998, and Premalakshmi, 2001). The findings on fruit number per plant is in support of the findings of (Ara et al., 2009, Haydar et al., 2007, Kumar et al 2006). Fruit number per truss results supported the findings of (Singh et al., 2004). Plant height correlation results in this study was not in agreement with (Rani et. al., 2008, Ara et al.,2009). Height was not significantly correlated at ($p<0.05$) to fruit yield.

The inter components correlation (Table 7) showed that truss number per plant was significantly correlated to number of fruit per plant (r = 0.86), fruit weight per truss (r = 0.81) and marketable fruit number (r = 0.41). This is expected because the more the truss number, the plant will have more fruits. However a high significant correlation between truss number per plant and fruit weight per truss was not expected to be so high at (r = 81). This should be lower since if a plant produce more truss, it is expected that the weight of fruits per truss should be lower as the plant will have spend more nutrients in the production of the truss. Number of fruits per plant was significantly correlated to number of fruit per truss (r = 0.49), fruit weight per plant (r = 0.91) and marketable fruit number (r = 0.54). This association is expected since the three traits are closely related. If a plant has more fruits per truss there will be more fruits per plant. At the end this will result in good yield. The number of fruits per truss was significantly correlated to marketable fruit number (r = 0.45), fruit weight per truss (r = 0.66) and with fruit weight per plant (r = 0.39). This is also an expected scenario, since the more fruits per truss, the more will be the fruits to sell and fruits from a truss will have more weight. A significant inter component correlation was also found between flower number per truss with marketable fruits number (r = 0.62). The other one was between fruit weight per truss with fruit weight per plant (r = 0.59) and with number of fruits per truss (r = 0.66).The inter component correlation results of this study is similar to the findings of various scholars (Singh et al., 2004, Kumar et al., 2006,Haydar et al., 2007).

In the determinate group, correlation coefficients of the majority of characters were not significantly correlated ($p<0.05$) to yield,(Table 13). Three components, marketable fruit number (r = 0.64) and plant height (r = 0.52) and days to 50 percent flowering (r = -0.42) were however significantly correlated with yield at ($p<0.05$). Correlation results on plant height were in support of the findings of (Ara et al., 2009). The inter components correlation shows some interesting relationships. The interesting relationship to note was that of total soluble solids which had a negative relationship with all the components except with marketable fruit number and days to 50 percent flowering. This negative relationship indicates that total soluble solids had an antagonistic relationship with most of the measured components including yield (r = - 0.36). Another antagonistic relationship occurs between fruit number per truss and single fruit weight (r = - 0.13). This negative correlation means that if there are more fruits in a truss, the tomato fruit weight will tend to be smaller as fruits will compete for space for attachment in a truss as well as for the nutrients.

Significant inter component correlations occurred between fruit number per truss with the following: fruit number per plant (r = 0.69), fruit weight per plant (r = 0.59) and fruit weight per truss (r = 0.73). This association was expected since it appears reasonable that as more fruits are produced per truss, the plant will have more fruits and the weight of fruits per plant will increase as well. There was also a strong significant correlation between number of trusses per plant with fruit number per plant (r = 0.88), and fruit weight per plant (r = 0.87). This association was also expected because the more the truss number in a plant, such plant will produce more fruits and the end product will be more fruit weight. This is also supported by the a strong positive association between fruit number per plant and fruit weight per plant (r = 0.91). Correlation results of fruits number per truss with number of fruits per plant supported the findings of (Prashanth, 2003, Joshi et al., 2004, Singh et al., 2004)

The study showed that only marketable fruit number was positively correlated to yield across the two tomato types.

5.1.3 Stepwise multiple regression for the two tomato types

The stepwise multiple regression was done as a bridge leading to path coefficient analysis which is a stronger tool for use in indirect selection. The identified components that explain most of the yield variation observed in tomato yield at $p<0.05$, were as presented in (Table 8). A stepwise multiple regression analysis in the semi determinate group identified the following components; marketable fruit number, single fruit weight, fruit weight per truss and fruit number per truss to be explaining most of the variation in yield. Their coefficient of multiple determination (R^2) ranged from 47.51% to 81.84%. The results showed that the most important components in their declining order was:- marketable fruit number by 47.51% at $p<0.0002$, single fruit weight by 20.79% at $p<0.0013$, fruit weight per truss by 7.55% at $p<0.0212$ and fruit number per truss by 5.99% at $p<0.0215$. Combination of the above four components gave the total coefficient of multiple determination (R^2) of 81.84%. The obtained percentage of 81.84% indicates that the four components are important as they account for the majority of variability in tomato fruit yield.

Results of the determinate types showed that only six components are the ones explaining the yield variability in tomato. The six components were; marketable fruit number, single fruit weight, total soluble solids, fruit number per truss, fruit dry mater and flower number per truss. Table 14 presents their detailed contributions to yield.

The results of the stepwise multiple regression analyses indicate that three traits have a great cause and effect relationship on yield in both determinate and semi determinate. These traits are marketable fruit number, single fruit weight and fruit number per truss.

5.1.4 Path coefficient analysis for the two tomato types

Path coefficient analysis was carried out because yield is influenced by many factors. Selection based on correlation may be misleading because it measures only the mutual association between two variables, whereas path coefficient analysis specifically measures the relative importance of different yield components. To find out the direct and indirect effects and to measure the relative importance of casual factors, path coefficient analysis is useful, which permits critical examination of the specific forces acting to produce a given correlation (Bhatt, 1973).

In this study, the path coefficient results for the semi determinate tomatoes (Figure 1 and Table 9) revealed that marketable fruit number gave the highest direct effect of 0.989, followed by fruit weight per truss with 0.592 and single fruit weight with 0.369. The results are in agreement with finding of (Padda et al.,1971, Singh and Mital,1976, McGiffen et al., 1994, Hazarika and Das, 1998, Vikram et al., 1998, Sharma and Verma, 2000, Sankari, 2000, Singh et al., 2002, Rani et al., 2008 and Ara et al., 2009).

The four components are inter related and each component influences tomato fruit yield by its direct contribution and by indirect contribution with the remaining three components. The direct effect results showed three obvious facts that with other variables held constant, increasing marketable fruit number, fruit weight per truss and single fruit weight, the three will increase tomato fruit yield. The indirect effect of other components via these three were generally low (Table 9) implying that they will not be useful as selection criteria. Among the three the best ones applicable to plant breeding would be fruit weight per truss and single fruit weight as the selection criteria. Similar results were reported by (Rani et al., 2008, Ara et al., 2009). Single fruit weight had been reported to be highly heritable as follows: 95.90%, 97.60% and 99.31% (Mohanty, 2002, Prashanth, 2003 and Arunkumar and Veeraragavathatham, 2005), The third component, marketable fruit number could be better achieved through management rather than plant breeding.

Path coefficient analysis in the determinate tomato genotypes (Figure 2 and Table 15) identified the same components as in semi determinate genotypes. The path results showed that three components marketable fruit number (0.752), single fruit weight (0.445) and fruit number per truss (0.204) are the most important selection criteria for improving tomato fruit yield in that order. Considering the three components single fruit weight and fruit number per truss appear to be the best ones applicable to plant breeding. This finding confirmed the findings of (Anikumar et al., 2003, Rani et al., 2008, Ara et al., 2009). Results on marketable fruit number is in agreement with (McGiffen et al., 1994, Sharma and Verma, 2000, Joshi et al., 2004). Fruit number per truss like single fruit weight had been reported to be heritable as follows: 97.40%, 71.10% and 78.80% (Singh et al. 2000, Prashanth, 2003 and Veershetty, 2004)

In both groups, marketable fruit number exhibited the highest direct effect. The two groups differed only on the second most important component. For semi determinate the second most important components was fruit weight per truss while for determinate it was single fruit weight. Single fruit weight came third in the semi determinate. From this it would be rewarding to lay emphasis on fruit weight per truss and single fruit weight while developing selection strategies in tomato breeding.

5.1.5 Correlation and path coefficient analyses for the two tomato types

Correlation results (Table 7) showed that among the four components, only marketable fruit number and fruit number per truss had a significant correlation coefficient ($p<0.05$) with yield. The other two components; single fruit weight and fruit weight per truss were positive but not significant. The second highest in correlation; fruit number per truss ($r = 0.443$) came last in path coefficient analyses with direct effect of -0.434. This results support the findings of (Mc Giffens et al., 1994). He found that yield is a complex trait and is difficult to increase by simply exploiting the strength shown by correlation coefficients. He found that it is important to carry out path coefficient analysis, that provide a clear indication for selection criteria. The negative direct effect (-0.434) of fruit number per truss is expected since it becomes obvious that as more fruits are produced per truss, the average fruit size will decrease because the fruits in a truss will be competing for food reserves. The correlation of fruit number per truss versus single fruit weight also support this argument as their correlation was also negligible and not significant at ($p<0.05$) with ($r = 0.104$). Another correlations worthy of noting are the ones between marketable fruit number and single fruit weight ($r = -0.182$) and marketable fruit number against fruit weight per truss ($r = -0.063$). This negative correlation shows that as more fruits are produced their weight will get reduced.

Although fruit weight per truss is without doubt an important component contributing to tomato fruit yield. The relationship between the two was not significant ($r = 0.352$). The cause of this none significant relationship could be that the correlation between single fruit weight and fruit number per truss is small at ($r = 0.104$). However it is important to note that a significant relationship existed between fruit number per truss and fruit weight per truss (r = 0.665).

According to Singh and Chaudhary, (2004), if the correlation coefficient between the causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and a direct selection through this trait will be effective. Therefore in this study direct selection through single fruit weight will be effective because the correlation of single fruit weight with yield was r = 0.322 which was almost equal to single fruit weight direct effect of (0.369). Singh and Chaudhary, (2004), also found that if the correlation coefficient is positive, but the direct effect is negative, the indirect effects seem to be cause of correlation. In such situations, the indirect causal factors are to be considered simultaneously for selection. Therefore the findings of this study suggest that the indirect effect of other components through fruit number per truss must be considered simultaneously for selection. Findings of this study support the findings of Singh and Chaudhary, (2004), because fruit number per truss had a positive correlation (r = 0.443), while its direct effect was negative at -0.434. This component has got two good positive indirect effect of 0.394 through fruit weight per truss and 0.445 through marketable fruit number.

Table 13 showed that in the determinate, marketable fruit number, single fruit weight, fruit number per truss, fruit dry matter and flower number per truss had positive correlations and only total soluble solids had a negative one. Among the five, marketable fruit number and plant height had positive significant correlations (r = 0.64) and (r = 0.52) respectively. Days to 50 percent flowering was also significant though it was negative at (r = - 0.42). Marketable fruit number had the high direct effect of 0.752 on yield followed by single fruit weight with 0.445. Other traits had low positive and negative direct effects. Low negative and positive indirect effects were observed for marketable fruit number and single fruit weight via other traits (Table 15). This means that those traits with negatives indirect effects acted antagonistically towards marketable fruit number and single fruit weight. Therefore the two traits marketable fruit number and single fruit weight can be used as selection criteria since their direct effect are good to achieve results. For total soluble solids at (-0.298), flower number per truss (-0.158), fruit dry mater (0.192 and fruit number per truss (0.204) their direct selection would not give good results because of their negative direct effects and low positive direct effects. Results on direct effects of single fruit weight is in support with the findings of (Rani et al., 2008, Ara et al.,2009). Correlation result on plant height is significant to yield at (r = 0.52). This findings supports the findings of (Prashanth,2003, Joshi et al., 2004, Rani et al., 2008, Ara et al., 2009).

CHAPTER SIX

6.0 CONCLUSION

Yield per se and some parameters measured were found to be variable among lines within each growth type. The presence of this variability is important because the success of any crop improvement depends on variability and to the extent to which the parameter is heritable. The checks in both groups came up as the top yielding materials. Comparison of mean values of different yield components within each group indicated that the checks were generally better in most of the measured parameters. However it is important to note that, this does not mean that the AVRDC materials are bad performers in all the components measured. Some AVRDC materials did well in other components, as the materials perform equal to or better than Expresso and Sixpack (Table 5,Table 6, Table 11 and Table 12). Results from both growth types show that there was some overlapping in the performance of the measured components across the materials. This variations shows that it is possible to select for yield in tomatoes.

Correlation studies reveled that for semi determinate the following traits exhibited a significant positive correlation with yield; truss number per plant, fruit number per plant, fruit number per truss, fruit weight per plant, marketable fruit number and flower number per truss. For determinate only marketable fruit number and plant height were identified. However it is important to note that in selecting for yield, correlation coefficient though significant can be misleading as correlation is not a strong tool as it does not give a true reflection of cause and effect relationship as PCA does.

Path coefficient analysis revealed that marketable fruit number had a higher direct effect in both determinate and semi determinate tomato types. Fruit weight per truss was the second most important direct effect in semi determinate, while single fruit weight came up as the second trait in determinate group. This indicate the importance of these two traits in deciding the ultimate fruit yield as the two are related. The PCA results had also revealed that fruit number per truss had a higher indirect effect via marketable fruit number for the determinate group.

Finally it can be concluded that there were some commonality/similarities between the two growth type. In both types fruit number per truss is significantly correlated to fruit number per plant, fruit weight per plant with number of fruits per plant (Table 7 and 13). Figure 1 and 2 also showed that the two types are common as they have the same components which were identified as ones directly affecting yield. Therefore the same traits / components can be used as indirect selection for yield improvement in the two growth types. The identified components cut across them.

Yield components found in this study provided a framework for identifying potentially useful traits for yield improvement in tomato. From the findings it is suggested that single fruit weight, fruit weight per truss and fruit number per truss should be given priority over other components for selecting better yielding tomato varieties, especially that these traits have been identified to have high heritability by other workers. However results of this study come out from only one season/ planting with only twelve genotypes, so they should be used with care. More work needs to be done with more genotypes to verify these results. It is also recommended that a multi location trial should be done in the future to build on this work.

REFERENCES

Abu Salena, A. and O.P Dutta.1988. Interrelationship of yield components in cucumber. Veg. Sci.15;79-85

Akhter, M. and C.H. Sneller. 1996. Yield and yield components of early maturing soybean genotypes in the Mid-South. Crop Sci. 36:877–882.

Anikumar, V.R. Thakur, M.C and N.K. Hedau. 2003. Correlation and path coefficient analysis in tomato. Ann.Agric. Re New Series, 24:175-177

Ara, A. R. Narayan., N. Ahmed and S.H. Khan. 2009. Genetic variability and Selection parameters for yield and quality attributes in tomato. India Journal of horticulture.,66: 73 – 78 New Delhi, India.

Artur, F., 1995. Advanced Trial of ARP Fresh Market Tomato lines. Africa Regional Program. Unpublished Report pages 134 – 138.

Aruna, S. 1992. Studies on the performance of certain F1 hybrids in tomato *Lycopersicon esculentum Mill*). MSc. Thesis. Tamil Nadu Agricultural University. Coimbatore.

Arunkumar, R. and V.Veeraragavathatham. 2005. Variability studies in certain Tomato (*Lycopersicon esculentum. Mill*.) genotypes under green house and open conditions in different seasons. South India Hort., 53(1-6): 18-24.

Barman, D., C.K. Sharma, I.P. Singh and S.D.L.C. Sardana. 1995. Genetic variability in exotic lines of tomato (*Lycopersicon esculentum Mill*). *Internat.J . Trop. Agric.,13:265 – 268.*

Bhatt, G.H. 1973. Significance of path coefficient analysis in determining the nature of character association. Euphytica, 22: 338 – 343.

Board, J.E., M.S. Kang and B.G. Harville. 1997. Path analyses identify indirect selection criteria for yield of late-planted soybean. Crop Sci. 37:879–884.

Board, J.E., M.S. Kang, and B.G. Harville. 1999. Path analyses of the yield formation process for late-planted soybean. Agron. J. 91:128–135.

Bok I, M. Madisa, D. Machcha, M. Moamogwe and K. More (ed). 2006. Manual for vegetable production in Botswana. Department of Agricultural Research. Gaborone. Botswana

Bora, G.C., A. Shadeque., L.C. Bora and A.K Phookan. 1993. Evaluation of some genotypes for variability and bacterial wilt resistance. Vegetable Sci.,20(1): 44-47

Bryan, H.H., J.W. Strobel, and J.D Dalton. 1967. Effect of plant populations, fertilizer rates on tomato yields on Rockdale soils. Proc. Fla. *State Hort. Soc. 80: 149 – 150.*

Cobley, L.S. and W.M Steele. 1976. An Introduction to the Botany of Tropical Crops. Second edition. Longman Group Limited London.

Costa, J.M. and W.E. Kronstad. 1994. Association of grain protein concentration and selected traits in hard red winter wheat populations in the Pacific Northwest. Crop Sci. 34:1234–1239.

Cramer, C.S. 1997. Specific combining ability for fruit yield and shape, yield and yield components of cucumber *(Cucumis sativus L.) p*opulations improved using recurrent selection. PhD thesis. N.C. State Univ.,Raleigh. Unpublished

Cramer, C. S. and T.C. Wehner . 1998. Fruit yield and yield component means and Correlations of four slicing cucumber populations improved through six to ten cycles of recurrent selection. J. Amer. *Soc. Hort Sci 123:388 – 395.*

Csizinszky, A.A .1980. Response of tomatoes to fertilizer rates and with in row spacing in two and four row production systems. Proc. Fla. State *Hort. Soc. 93:241 – 243.*

Das, B., M.H. Hozarika and P.K. Das. 1998. Genetic variability and correlation in fruit character of tomato (*Lycopersicon esculentum Mill.*). Annual Agricultural Research, 19: 77 – 80.

Dewey, D.R. and K.H.Lu. 1959. A correlation and path coefficient analysis of components of crested wheatgrass seed production. *Agronomy Journal, 51:515 – 518*

Eberhart, S.A and W.A. Russel. 1966. Stability parameters for comparing varieties. *Crop Science Journal 6:36 – 40.*

Falconer, D.S. 1960. Introduction to quantitative genetics, Ronald Press Company, New York.

Fehr, W.R. 1984. Genectic contributions to yield gains of five major crop plants.

Fery, R.I. and J. Janick. 1970. Response of the tomato population pressure. *J. Amer. Soc. Hort. Sci. 45:614 – 624.*

Fiez, E.T., S.O. Norberg, and D.G. Jolliff. 1991. Yield components in three meadowfoam lines. *Agron. J. 83: 598 – 602*

Frankel, O.H. 1947. The theory of plant breeding for yield. Heredity Lond. 1, 109 – 20.

Giriraj, K. and S. Vijayakumar. 1974. Path coefficient analysis of yield attributes in Mungbean. Indian J. Genet. 34: 27 – 30.

Graffius, R. 1964. A geometry for plant breeding. *Crop Science, 4:241 – 246.*

Gravios, K.A. and R.S. Helm. 1992. Path analysis of rice yield and yield components as affected by seeding rate. *Agron. J. 84: 1 -4.*

Gravois, K.A. and R.W. McNew. 1993. Genetic relationships among and selection for rice yield and yield components. Crop Sci. 33:249–252.

Hanson, G.H., , H.F. Robinson, and R.E. Comstock. 1956, Biometrical studies of yield in segregating population of Korea lespedeza. Agron. J., 48: 268-272

Haydar, A., M.A. Mandal., M.B .Ahmed., M.M. Hannan., R. Karim., M.A. Razvy., U.K Roy, and M. Salahin. 2007. Studies on genetic variability and interrelationship among the different traits in tomato. Middle-East J. Sci. Res., 2(3-4): 139-142.

Hazarika, M.H. and P.K. Das. 1998. Genetic variability and correlation in fruit characters of tomato (*Lycopersicon esculentum Mill*). Annual Agricultural Research, 19: 77 – 80.

Jawaharlal, M. 1994. Genetic studies for fruit yield and quality characteristics in tomato

(*Lycopersicon esculentum Mill*). Ph.D Thesis, Tamil Nadu Agricultural University, Coimbatore.

Joshi, A., A. Vikram, and M.C. Thakur. 2004. Studies on genetic variability, correlation and path analysis for yield and physico-chemical traits in tomato. Prog. Hort., 36(1): 51-58.

Kambikambi, T.T. 1996. Relationship between yield and yield components of sesame (*Sesamum indicum L.)* MSc dissertation. University of Zambia.

Kays, S.J and C.W. Nicklow. 1974. Plant competition: Influence of density on water requirements, soil gas composition and soil compaction. *J. Amer. Soc. Hort. Sci. 99:166 – 171*

Kneebone, W.R. 1956. Breeding for seedling vigor in sand blue stem (*Andropogon balli)* and other native grasses. Agron.J.48: 37 – 40.

Kumar, R., N.K. Mishra., J. Singh., G.K Rai., A. Verma, and M. Rai, 2006. Studies on yield and quality trials in tomato (*Solanum lycopersicon (Mill*) Wettsd.). Vegetable Sci., 33(2): 126-132. et al 2006

Li, C.C. 1975. Path analysis – a primer. Pacific Grove, calfornia: Boxwood Press.

Lungu, M. D. 1978. Classifying winter wheat environments into Adaptive zones as a basis for recommending a Reduction in the number of International Winter Wheat Performance Nursary Test sites. MSc dissertation. University of Nebraska. Lincoln. Department of Agronomy. U.S.A. Unpublished.

Maribe, T. 1995. Advanced Trial of ARP Fresh Market Tomato lines. Africa Regional Program. Unpublished Report pages 81 – 85.

Mazhani, L.M. 1990. Evaluation of stability of performance of twenty five diverse grain sorghum (*Sorghum Bicolor (L)* Moench) genotypes in Botswana. PhD Thesis University of Nebraska.Lincoln.U.S.A. Unpublished.

McGiffen, M.E., D.J. Pantone, and J.B. Masiunas. 1994. Path analysis of tomato yield components in relation to competition with black and eastern black nightshade. *J. of A MER. Soci. Hort. Sci., 119: 6 – 11*

Milligan, S.B., K.A. Gravios, K.P. Bischoff and F.A Martin, 1990. Crop effects on genetic relationships among sugarcane traits. *Crop Sci. 30:927-931.*

Mohanty, B.K. 2002. Variability, heritability, correlation and path coefficient studies in Tomato. Haryana J. Hort. Sci., 31(3&4): 230-233.

Mohanty, B.K. 2003. Studies on variability, heritability, interrelationship and path analysis in tomato. Annals of Agri. Res., 23(1): 65-69.

Monamodi, E.L., I.B. Bok, and S.K Karikari. 2003. Changes in nutritional composition and yield of two sweet potato (*Ipomoea batatas L*) cultivars during their growth in Botswana. *Uniswa Journal of Agriculture. 11:5 - 14*

Naika, S., J.van Lidt de Jeude., M, de Goffau., M. Hilmi and B.van Dam.2005. Cultivation of tomato : production, processing and marketing. CTA. Series no 17

Navarro, A.A and S.J. Locascio. 1971. Influence of population density, row arrangement and fertilizer rate on single – harvest yield of fresh market tomatoes. Fla. *State Hort. Soc. 84: 129 – 131.*

Nyirongo, M.K. 1995. Observational Trial of ARP Fresh Market Tomato lines. Africa Regional Program. Unpublished Report pages pp75 – 80

Opena, R.T. and M.L. Kyomo.(ed.) 1990. Vegetable Research and Development in SADCC Countries: Proceedings of workshop held at Arusha, Tanzania, 9 – 13 July 1990. AVRDC Publication No. 90 – 328.

Padda, D.S., M.S Saimbhi and K. Singh. 1971. Genetic and phenotypic variability and correlation in quality characters of tomato (*Lycopersicon esculentum Mill.*). India J. Agri. Sci., 41:199-202.

Pandey, J.P. and J.H. Torrie. 1973. Path coefficient analysis of seed yield components in soybeans (*Glycine max* (L.) Merr.). Crop Sci. 13:504–507.

Parvindersingh, P.V., S.R. Surjansingh., D.S. Cheema and M.S. Dhaliwal. 2002. Genetic variability and correlation study of some heat tolerant tomato genotypes. Vegetable Sci., 29(1): 68-70

Peirce, L.C. 1987. Vegetables characteristics, production and marketing. John Wiley and Sons. Inc. Toronto. Canada

Prasad, V.S.R.K. and D.P. Singh. 1994a. Diallel analysis of yield components in slicing cucumber (*cucumis sativus L.*). J. Res. (BAU)6:151 – 154.

Prasad, V.S.R.K. and D.P. Singh. 1994b. Genetic association and interrelationship between yield components in cucumber. J. Maharashtra Agr. Univ. 19;147-148.

Prashanth, S.J. 2003. Genetic variability and divergence studies in tomato (*Lycopersicon esculentum Mill).*M.Sc.(Agri.) Thesis, Uni. Agric. Sci., Dharwad (India).

Premalakshmi, V. 2001. Breeding for yield and post harvest qualities in tomato (*Lycopersicon esculentum Mill*.). Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore.

Purseglove, R. 1988. Tropical Crops Dicotyledons. Fifth edition. Longman Publisher Singapore.

Rathod, S.J. 1997. Evaluation of tomato genotypes for productivity and processing traits .MSc.(Agric.) Thesis, University of Agric Sciense., Dharwad. India.

Rani, I., D. Veeraragavathatham., and D. Sanjutha. 2008. Studies on Correlation and PathCoefficient analysis on Yield Attributes in Root Knot Nematodes Resistant F1 Hybrids of Tomato. *Journal of Applied Sciences Research, 4(3): 287 – 295.*

Read .P.E and D.J. Fieldhouse. 1970. Use of growth Retardants for increasing tomato yields and adaptation for Mechanical harvest. Journal for the American society for horticultural science volume 95: 73 - 78.

Rice, R.P., L.W. Rice and H. D. Tindall. 1990. Fruit and vegetable production in warm climate. The Macmillan Press L.T.D. London and Basingstoke.

Robinson, H.F.,R.E Comstock and P.H. Harvey. 1949. Estimates of heritability and degree of dominance in corn. Agron. J., 41:353-359.

Rogler, G.A. 1954. Seed size and seedling vigor in crested wheat grass. *Agron. J. 46: 216 – 220.*

Sankari, A., 2000. Studies on the development of F1 hybrids in tomato (*Lycopersicon esculentum Mill),* with high yield and resistance to tomato leaf curl virus. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore.

Seed Biology. 2009. Vegetable Seed Production – “Wets” Seeds. [http://www.ag.ohio –

state.edu/~seedsci/vsp03.html. Dated 30.04.2009].

Sharma, K.C and S. Verma. 2000. Path coefficient analysis in tomato (*Lycoerpscion esculentum*). Indian. J. Agric. Sci., 70: 700-702

Shravan, K., T. Singh, B. Singh and J.P. Singh. 2004. Studies on heritability and genetic advance in tomato (*Lycopersicon esculentum Mill).* Prog. Agric., 4:76 – 77.

Shukla, S., K. Singh, and P. V. Pushpendra. 1999. Correlation and path coefficient analysis of yield and its components in soybean (*Glycine max* L. Merrill.). Soybean Genet. Newsl. 25:67–70.

Singh, J.P., D.K Singh and G. Gulshanlal, 2000. Variability pattern in agro-Morphological characters in tomato (*Lycopersicon esculentum L.*) Prog. Hort., 32(1):79-81.

Singh, A.K and N. Raj. 2004. "Variability studies in tomato under cold arid condition of Ladakh." *Hort.J., 17:67 – 72*

Singh, J.K., J.P. Singh, S.K. Jain, J. Aradhana and A. Joshi. 2002. Studies on genetic variability and its importance in tomato (*Lycopersicon esculentum Mill*.). Prog.Hort.,34:77 – 79.

Singh, R.K and B.D. Chaudhary. 2004. Biometrical Methods in Quantitative Genetics Analysis. Kalyani Publishers. New Delhi. India

Singh, H.N. and R.K. Mital. 1976. Genotypic association and path analysis in tomato. Indian Journal of Agricultural Research, 10: 83 – 90.

Sivaprasad, K. 2008. Genetic variability and correlation studies in biparental mating population of tomato (*Solanum lycopersicon (Mill*.) Wettsd). MSc dissertation. University of Agricultural Sciences, Dharwad.

Solanki, S.S. And A. Shah. 1989. Path analysis of fruit yield components in cucumber. *Prog. Hort. 21;322-225*

Stevens, M.A. 1974. Varietal influence on nutritional value. P. 87 – 110. In P.L. White and N.SELVEY (eds.) Nutritional qualities of fresh fruits and vegetables. Futura Publ. Co., Mt. Kisco, N.Y.

Stoffella P.J., S.J. Locascio., P.H. Everett., J.W. Scott and T.K. Howe. 1988. Hort Science Volume 23, Number 6 pp 0991

TAHAL, 2000. "National Master Plan for Arable Agriculture and Dairy Development (NAMPAADD)." Consultancy report. Gaborone. Botswana.

Tikka, S.B.S. 1975. Interrelationship between yield and components in cluster bean. *Indian J. Genet. 35; 340 – 343.*

Upadhyay, M.,J.P. Singh., A. Singh and A. Joshi. 2005. Studies on genetic variability in tomato (*Lycopersicon esculentum Mill*.). Prog. Hort. 37(2): 463 - 465

van der Vooren, J., G.W.H. Welles, and G. Hay – man. 1986. Glasshouse crop production, p 581 – 623. In: J.G. Atherton and J. Rudich (eds.). The tomato crop. Chapman and Hall, London.

Varela, A.M., A. Seif, and B. Lohr. 2003. A guide to IPM in tomato production in Eastern and Southern Africa. CTA/ICIPE/GTZ.

Veershetty, V. 2004. Studies on variability, character association and genetic diversity in tomato(*Lycopersicon esculentum Mill*). M.Sc. (Agric.) Thesis, Uni. Agric. Sci., Dharwad (India).

Vegetable Production Training Manual. 1992. Asian Vegetable Research and Develpoment Center. Taipei.Taiwan.

Vikram, A and U.K. Kohli. 1998. Genetic variability, correlation and path analysis in tomato. Journal of Hill Research, 11: 107-111.

Wilcox, G.E. 1970. Influence of row spacing and plant density on single harvest tomato yields. *J .Amer. Soc. Hort. Sci. 95:435-437*

Wright, S. 1921. Correlation and causation. *J. Agric Res 20:557 – 585.*

Wright, S. 1934. The method of path coefficients. Ann Math Stat 5:161 – 215.

Yin, M. and H. Cui. 1994. Analysis of component traits for early yield in cucumber. Cucurbit Genet. Coop. Rpt. 17;27-29

Zahara, M. 1970. Influence of plant density on yield of process tomatoes for mechanical harvest. *J. Amer .Soc .Hort. Sci. 95:510-512*

Zahara, M. and H. Timm. 1973. Influence of plant density on growth, nutrient composition, Yield and quality of mechanically harvested tomatoes. *J. Amer. Soc. Hort.Sci.98(5):513-516.*

Zhang, M. and H. Cui. 1994. Some morphological parameters involving the mechanism of early yield in cucumber. Cucurbit Genet. Coop. Rpt 17;24-26

LIST OF APPENDICES

Appendix 1: ANOVA Table for yield t/ha (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	58.19	19.40	1.06	0.39
Variety	5	684.07	136.81	7.49	0.001
Error	15	273.92	18.26		
Total	23	1016.19			

Appendix 2: ANOVA Table for marketable fruit number (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	3916.5	1305.5	1.27	0.32
Variety	5	48099.33	9619.86	9.35	0.0003
Error	15	15432.0	1028.80		
Total	23	67447.83			

Appendix 3: ANOVA Table for truss per plant (semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	53.13	17.38	3.77	0.03
Variety	5	58.71	11.74	2.55	0.07
Error	15	69.13	4.61		
Total	23	179.96			

Appendix 4: ANOVA Table for fruit weight per truss (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	0.002	0.00074	0.74	0.54
Variety	5	0.02	0.004	3.85	0.02
Error	15	0.01	0.0009		
Total	23	0.04			

Appendix 5: ANOVA Table for fruit number per plant (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	143.13	47.71	1.47	0.26
Variety	5	278.21	55.64	1.72	0.19
Error	15	486.62	32.44		
Total	23	907.95			

Appendix 6: ANOVA Table for fruit number per truss (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	0.06	0.02	0.27	0.84
Variety	5	0.48	0.10	1.39	0.28
Error	15	1.04	0.07		
Total	23	1.58			

Appendix 7: ANOVA Table for fruit weight per plant (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	4.64	1.55	2.77	0.08
Variety	5	3.48	0.70	1.25	0.33
Error	15	8.37	0.56		
Total	23	16.49			

Appendix 8: ANOVA Table for 50% flowering (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	6.83	2.28	0.28	0.84
Variety	5	264.83	52.97	6.40	0.002
Error	15	124.17	8.28		
Total	23	395.83			

Appendix 9: ANOVA Table for single fruit weight (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	0.002	0.0007	1.59	0.23
Variety	5	0.003	0.0005	1.21	0.35
Error	15	0.006	0.0004		
Total	23	0.011			

Appendix 10: ANOVA Table for fruit dry mater (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	0.00008	0.00003	1.34	0.299
Variety	5	0.00009	0.00002	0.89	0.51
Error	15	0.0003	0.00002		
Total	23	0.0005			

Appendix 11: ANOVA Table for plant height (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	22.33	7.44	0.32	0.81
Variety	5	489.83	97.96	4.16	0.01
Error	15	353.17	23.54		
Total	23	865.33			

Appendix 12: ANOVA Table for total soluble solids (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	0.18	0.06	0.29	0.83
Variety	5	0.42	0.08	0.41	0.83
Error	15	3.09	0.21		
Total	23	3.70			

Appendix 13: ANOVA Table for flower number per truss (Semi determinate)

Source	df	SS	MS	F	pr>f
Rep	3	1.90	0.63	2.66	0.09
Variety	5	2.57	0.51	2.17	0.11
Error	15	3.56	0.24		
Total	23	8.03			

Appendixes for determinate genotypes

Appendix 14: ANOVA Table for yield t/ha (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	21.184	7.06	0.25	0.86
Variety	5	684.50	136.90	4.83	0.008
Error	15	424.85	28.32		
Total	23	1130.53			

Appendix 15: ANOVA Table for marketable fruit number (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	25964.13	8654.71	1.46	0.27
Variety	5	80831.71	16166.34	2.73	0.06
Error	15	88922.13	5928.14		
Total	23	195717.96			

Appendix 16: ANOVA Table for fruit weight per truss (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	0.003	0.0010	2.11	0.14
Variety	5	0.003	0.0006	1.31	0.31
Error	15	0.007	0.0005		
Total	23	0.013			

Appendix 17: ANOVA Table for fruit number per truss (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	0.52	0.17	0.94	0.45
Variety	5	0.06	0.01	0.07	0.99
Error	15	2.77	0.18		
Total	23	3.34			

Appendix 18: ANOVA Table for truss number per plant (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	19.79	6.60	1.94	0.17
Variety	5	32.26	6.45	1.90	0.15
Error	15	50.10	3.40		
Total	23	103.05			

Appendix 19: ANOVA Table for fruit number per plant (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	293.49	97.83	2.15	0.15
Variety	5	314.52	62.90	1.38	0.29
Error	15	681.37	45.42		
Total	23	1289.37			

Appendix 20: ANOVA Table for fruit weight per plant (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	1.14	0.38	3.46	0.04
Variety	5	0.75	0.15	1.37	0.29
Error	15	1.65	0.11		
Total	23	3.54			

Appendix 21: ANOVA Table for total soluble solids (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	0.19	0.06	0.97	0.43
Variety	5	1.20	0.24	3.74	0.02
Error	15	0.96	0.06		
Total	23	2.34			

Appendix 22: ANOVA Table for fruit dry matter (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	0.0009	0.0003	1.10	0.38
Variety	5	0.002	0.0003	1.17	0.36
Error	15	0.004	0.0003		
Total	23	0.007			

Appendix 23: ANOVA Table for plant height (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	96.79	32.26	2.22	0.12
Variety	5	240.10	48.02	3.31	0.03
Error	15	217.63	14.51		
Total	23	554.52			

Appendix 24: ANOVA Table for single fruit weight (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	0.0001	0.00004	0.45	0.72
Variety	5	0.002	0.0004	5.04	0.01
Error	15	0.001	0.00008		
Total	23	0.003			

Appendix 25: ANOVA Table for days to 50% flowering (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	41.83	13.94	0.99	0.42
Variety	5	441.50	88.30	6.27	0.002
Error	15	211.17	14.08		
Total	23	694.50			

Appendix 26: ANOVA Table for flower number per truss (determinate)

Source	df	SS	MS	F	pr>f
Rep	3	0.79	0.26	0.40	0.76
Variety	5	5.21	1.04	1.57	0.23
Error	15	9.96	0.66		
Total	23	15.96			

LISTS OF PLATES

Plate A: Soil analysing

Plate B: Counting Flower number per truss Plate C: Refractometer for TSS

Plate D: Tomato plants in the field

Plate E(a): Tagging trusses in plants

PlateE(b): Tagged Plant for data collection

Plate F: Two tomato **trusses with 4 fruits each**