Influence of Stage and Intensity of Truss Pruning on Fruit Yield and Quality of Tomato (*Solanum lycopersicon*L.*)*Under Field Condition at Melkasa

M.Sc. Thesis

By

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Jimma, Ethiopia

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STATEMENT OF THE AUTHOR

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BIOGRAPHICAL SKETCH

Berhanesh Tamirat Shifamo was born on June 6, 1990G.C at Hossana town, SNNPRS. She attended her Primary, Secondary and Preparatory Schools at Fonko, Wachamo Secondary and Preparatory Schools, respectively. After successful passing of the Ethiopian Entrance Exam, she joined Jimma University, College of Agriculture and Veterinary Medicine in 2000 E.C and graduated with B.Sc. degree in Horticulture in 2002 E.C.

After her graduation, she was employed by Ministry of Agriculture and Rural Development office, department of Agricultural Inputs Supply section and served for 3 years as Plant seedling seed multiplication supply quality control expert in Hadiya Zone, Analemo Woreda. Then she joined School of Graduate Studies of Jimma University in 2006 E.C to pursue her studies leading to Master of Science in Horticulture (Vegetable Science).

DEDICATION

I dedicate this thesis manuscript to my father Tamirat and my mother Aster, my brother Dillnessaw and my sisters Ermishe, Kidist and Amen as well as for my dear husband Mandefro for nursing me with affections and love and their dedicated partnership for the success of my life.

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ACRONYMS AND ABBREVATIONS

ANOVA	Analysis of Variance
CV	Coefficient of Variation
LA	Leaf Area
LSD	Least Significant Difference
NFT	Nutrient Film Technique
TSS	Total Soluble Solid
LW	Leaf Width
GA	Gibberellic Acid
2, 4-D	2, 4-Di cholorophenoxy acetic acid
IAA	Indole Acetic Acid
NAA	Naphthalene Acetic Acid
ATA	Auxin Transport Autoinhibition
4-CPA	4- ChloroPhenoxy Acetic acid
IM	Internal region of the Mesocarp
MARC	Malkassa Agricultural Research Center
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
SAS	Statistical Analysis System

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Influence of Stage and Intensity of Truss Pruning on Fruit Yield and Quality of Tomato (*Solanum lycopersicon*L.)Under Field Condition at Melkassa

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ABSTRACT

The influence of stage and intensity of truss pruning on yield and quality of tomato (Solanum lycopersicon L.) was investigated in the open field at Melkassa Ethiopian Institute of Agricultural Research Center. Three stages of pruning (bud, anthesis, fruit set) and four levels of pruning (control, one-truss, two-truss and three-truss) were arranged in RCBD with three replications. Total leaf area, number of flower per truss, fruit set percentage, individual fruit fresh weight, individual fruit dry weight, Fruit dry weight per plant, pericarp thickness, total soluble solids content were significantly affected by the interaction effects of stage and intensity of truss pruning. On the other hand the interaction effect was not significant for marketable, unmarketable, and total fruit yield per plant and hectare. Stage of pruning also did not show a significant effect for marketable, unmarketable, and total fruit yield per plant and hectare. Increasing the level of pruning decreased both marketable and total fruit yield while increasing the unmarketable yield. Removing the truss at bud or anthesis stage encouraged fruit with larger diameter than removing them at fruit set stage. Fruit diameter significantly increased with increasing level of pruning. Increasing the intensity of pruning resulted also in fruit with significantly higher pH compared to the control. Tomato fruit with the highest total solids content was obtained when two trusses were removed at bud stage. In general the study revealed that truss pruning significantly improves fruit quality of tomato but reduced the yield. Since, the experiment was conducted for one season at one locationit is difficult to give a clear cut recommendation when and at what intensity the pruning should regulate fruit size and improve fruit yield. To give a tangible conclusion, it is very crucial that further study should be conducted on other improved tomato varieties to determine the effect of pruning.

***Keywords**: Tomato, Yield, Quality, Stage and Intensity.*

1. INTRODUCTION

Vegetable production is one of the agricultural activities and among the fastest growing in the world and has great potential for alleviating poverty, especially among the rural poor (Kanyomeka and Shivute, 2005).Tomato *(Solanum lycopersicon L.*) production is one of the most important vegetables crops grown next to potato and sweet potato in the world and has the potential for increased production because of its high demand (Hanson *et al*., 2001). Both small scale and largescale farmers produce this crop. The crop is highly nutritious, particularly more a rich source of vitamin A and C, andantioxidants than any other vegetables and therefore improves the health of consumers. Tomato also servesas carotenoids: alpha-carotene, beta carotene, and neurosporene (Simonne *et al*., 2006). Thus, one medium-sized tomato provides 57% vitamin A, 25% vitamin C, 8% of iron and 35%, calories. They also contribute to B vitamins, potassium, iron and calcium to the diet (Terry Kelley and Boyhan, 2006). In addition, extracts from tomato fruit are used in traditional medicine to treat ulcers, wounds, hemorrhoids, burns and edema during pregnancy (FAO, 1996). In addition, it serves also as a good source of income especially for small holder farmers.

Tomato is considered as a tender warm season crop but is actually a perennial plant although it is cultivated as an annual. It is sensitive to frost and will not successfully grow in the cooler areas. Most cultivated tomatoes require around 75 days from transplanting to first harvest and can be harvested for several weeks before production declines. Ideal temperatures for tomato growth are 21-29^{0}c during the day and 18-21^{0}c at night. Significantly higher or lower temperatures can have negative effects on fruit set and quality (Terry Kelley and Boyhan, 2006). In Ethiopia, tomato crop is grown between 700 and 2000 m.a.s.l with the annual rain fall of 700 to over 1400 mm in different season and areas.

China is the top producer, growing 35% of the total world's tomato harvested area (FAO, 2010). USA, India, Turkey, Egypt, Italy and Iran are other top countries in descending order. From Africa Egypt and Nigeria are the main tomato producers (FAO, 2012).Although tomato is widely grown in Ethiopia, the total production and productivity is far below than the average of major producers in the world and as well in Africa. According to FAO (2010), the

average yield of tomato in Ethiopia is ranging from 6.5-24.0 ton ha^{-1} compared with average yields of 51, 41, 36 and 34 ton ha^{-1} in America, Europe, Asia and the entire world, respectively. It has been also reported the current productivity of this crop under farmers' field is 9 ton ha^{-1}, whereas yield up to 40 ton ha^{-1} be recorded on research plots (Tesfaye, 2008). Whichever way the crop is grown, the yields do not always reach the full production potential and, thus growers are challenged by inconsistent production, low yields and low quality in the country. This is probably because of inadequate agronomic management, shortage of improved varieties, diseases, insect pests, lack of information on soil fertility, high post-harvest loss, and adverse environmental factors such as extreme temperatures and rain fall, which are the major production constraints (Meseret, 2010). Thus, improved agronomic management such as pruning and staking could improve the yield and quality of tomatoes. This leads to improving smallholders' tomato production which contributes in enhancing food security and to alleviating poverty.

Pruning in tomatoes has been reported to increase yields and quality (Hadfield, 1989). Pruning is the removal of suckers (axillary shoots), flower and fruits. The degree to which pruning is needed may vary with the variety used, and the practice can significantly impact yield and quality. It is believed that pruning of some flowers and fruits of tomato results in assimilate re-distribution to the remaining fruits, increasing their size (Rubatzky and Yamaguchi, 1996). On the other hands, plants vigorous foliage and that are not pruned will produce more, but smaller fruits, (Terry Kelley and Boyhan, (2006).Thus, fruits are the major portion of photoassimilates in crops like tomato and pepper, as variation in fruit number influences of fruits size (Gautier *et al.,* 2001).

Fruits are active sinks among the plant organs and the extent of re-distribution of assimilates to the remaining fruits appears to depend mainly on the sink-strength (which varies with the age of fruits) and on the stage of pruning (KinetandPeet, 1997). Bhatt and Rao (1997) have pointed out that removal of the fruit in the first flowering node of bell pepper plants ten days after fruit set did not increase the partitioning of dry mass to fruits. However, with the advancement of fruit growth, fruit on the first flowering node acts as a major sink up to 20 days after flowering, and afterwards becomes a weaker sink. Bangerth and Ho (1984) have

also reported that the sink-strength of tomato fruit varies depending on the position of the truss on the stem and position of the fruit within the truss. Lower trusses and proximal fruits have higher sink strength than upper trusses and distal fruits.

In general, maintaining fruit size with in a preferred size is achieved by controlling fruit number through fruit thinning and thus, increasing the supply of assimilates to the remaining fruits (Cockshull and Ho, 1995). If too many fruits are pruned from the plant, those remaining may be more prone to growth disorders, such as cracking (Morgan and Lennard, 2000), blossom end rot (Dekreij, 1992) as well as fruit deformation (Aloni *et al.*, 1999). Redistribution of assimilates to the remaining fruits may not completely compensate for the loss of fruits, if pruning is done in excess or too late, for instance after the fruit subjected to pruning has already accumulated a large quantity of assimilates. The degree to which plants can compensate for reduced fruit numbers by increased fruit size depends on factors like cultivar, seed number, and fruit position. Furthermore, low sink demand brought about by fruit or flower pruning is said to have a negative feedback control on photosynthesis. To avoid yield losses the degree of thinning must be adjusted to obtain a desirable fruit size and yield in the remaining fruits (Cockshull, and Ho, 1995).

However, other researchers have reported conflicting results that pruning either reduces tomato yields and/or quality or has no effect at all on tomato production (Resh, 1997). It is, therefore not clear whether tomato pruning is worthwhile or not. In Ethiopia, flower and fruit pruning is not a very common practice, as farmers do not know its benefits, and little research has been done to investigate the effect of pruning on yield and quality of tomato fruits. Therefore, the present study was conducted with the following objectives.

General objective

- To determine the appropriate stage and intensity of truss pruning in tomato for optimum yield and quality.

Specific objective

- To evaluate the effect of truss pruning at different stage and intensities on yield and quality of tomato and
- To generate baseline information for further performance evaluation.

2. LITERATURE REVIEW

2.1. The Tomato Crop

The tomato belongs to the *solanaceae* family and the genus *Lycopersicon*, a genus that consists of a relatively few species of annual or short lived perennial herbaceous plants (George *et al.*, 1983). The cultivated tomato belongs to a species *Lycopersicon esculentum* Miller (Taylor, 1986) in the sub genera Eucopersicon (Gould, 1983). According to Taylor (1986) the cherry tomato (*Lycopersiconesculentum*variety ceraciforme) is direct ancestor of the modern cultivated forms. Cultivated tomato is normally a self-pollinated crop with somatic chromosome number of 24.

The center of origin of tomato is believed to be in Tropical America probably Mexico or Peru and the name tomato is of South American origin (Gould, 1983). He also noted that The Mexicans who were eating the fruit called it 'tomato'. According to Gould (1983) the tomatoes were taken to Europe from Mexico or Peru during the early sixteenth century, but the cultivation for the market has been practiced since about the1800. It was introduced to Africa in the 16th century (George *et al.*, 1983).

Tomato plants have long been used as experimental material for research in physiology, pathology and genetics, and consequently, a great wealth of information on the interactions between growing conditions and plant development has been accumulated and used to improve cultivation (Atherton and Rudich, 1986). The genetic material of tomato is most versatile and has been widely studied (Stevens and Rick, 1986); this has formed the basis for recent successful applications of biotechnology (Nevins and Jones, 1987). Intrinsically, cultivated tomato has a very high partitioning of assimilate to the developing fruit (Ho, 1984).

This potential for high yield has been exploited by advances in soilless culture, integrated biological or chemical control of pests and disease, and the optimization of growing environments using computer controlled glasshouses.

2.2. Factors Influencing Tomato Flower Development

2.2.1. Growing conditions

While the priority of assimilate partitioning may be determined by intrinsic potential sink strength of all the sink organs, the actual sink strength may still be affected by the growing conditions (Ho, 1988a). It is envisaged that both the priority of partitioning and the intensity of the sink competition may be altered when the sink strength of one sink organ is changed by the growing conditions.

2.2.1.1. Irradiance

Both the initiation of the inflorescence and the development of the flowers require a certain level of assimilate supply. The initiation of the first inflorescence is delayed by low light as more leaves are initiated prior to the inflorescence (Picken*et al.*, 1985). At the macroscopic appearance of the first inflorescence, low irradiance (e.g., 9Wm-2 for 8 hours daily) progressively reduced the degree of flower development in the first flower, to a total abortion over a period of 10 days (Kinet, 1977a). Low light integrals reduced the number of flowers and impaired the flower development. The effects of low irradiance on floral development are likely due to the lack of assimilate supply.

2.2.1.2. Carbon dioxide

Commercial success of early greenhouse tomato crops in northern Europe depend on CO_2 enrichment to increase the assimilate supply to the flower, and to enhance subsequent fruit development. By increasing the CO_2 concentration in the greenhouse to three times the atmospheric level (i.e. ca.1000$\mu l l^{-1}$), the rate of photosynthesis is increased, giving a response equivalent to a 30% increase in winter light level (Hurd, 1968); this results in normal floral development of the previously arrested inflorescence (Cooper and Hurd, 1968). However, the availability of assimilate only affects the degree of sink competition, but not the priority of the sink organs in assimilate partitioning. Therefore, the use of supplementary lighting

orCO_2enrichment to secure flowering in the winter is only successful when there is surplus assimilate after the demand of vegetative organs is met (Kinet, 1977b).

2.2.1.3. Temperature

Initiation of floral primordial can be hastened by low temperatures which reduce the production of leaf primordial and the growth of the young leaves (Hussey, 1963). The optimum temperature for vegetative growth is 18^0C to 25^0C, lowering the night temperature to between 10^0C and 13^0C can induce the seedlings to produce fewer leaves before the inflorescence and a higher flower number in the first inflorescence (Hurd and Cooper, 1970).

Reversal of the priority by low temperature in favor of the flowers at the expense of either young leaves or roots may also be mediated by hormonal regulation (Phatak*et al*., 1966; Abdul and Harris, 1978). Similarly, the priority of the flower can be improved by reducing the sink strength of the competing roots. When the root-zone temperature was reduced from 15^0C to 10^0C at the seedling stage, the number of leaves before the flowering was reduced (Phatak*et al*., 1966).

Under optimal temperatures but insufficient light, floral development may suffer, or even result in abortion. In green house, the air temperature may be reduced to match the light conditions. Although low ambient temperature increases flower number, fruit set may be poor as a result of poor pollen production under low light (Picken, 1984) or completely inhibited as a result of low viability of the pollen at a temperature of 10^0C. Furthermore, temperature higher than 25^0C may also reduce the fruit number (Charles and Harris, 1972).As temperature affects floral initiation, floral development, fruit set and fruit growth simultaneously in an indeterminate plant, the temperature effects on assimilate partitioning in relation to fruit yield are very complex. The growth of a tomato fruit, e.g., fresh weight gain, without the effect of sink competition, can be described by a sigmoid curve (Ehret and Ho, 1986). The early slow growth phase of two weeks is mainly caused by cell division and initial cell enlargement, while the final growth phase of 2 weeks is dominated by intensive metabolic activity (Ho and Hewitt, 1986).

In between, during the rapid growth phase of 3-5weeks, both the daily dry matter and water accumulations reached their maxima about 3 weeks after anthesis (Ho *et al*., 1987). The rate of import of assimilate during this rapid growth phase is crucial to the final fruit weight, as final fruit size is positively related to the maximum growth rate (Grange and Andrews, 1993).

2.2.1.4. Water

The daily rate of volume growth is enhanced by higher temperature, but reduced by water stress (Pearce *et al.*, 1993a). Although fruit growth relies primarily on the assimilate supply, the daily volume growth is not related to the concurrent photosynthetic rate; the supply of assimilate to the fruit can be sustained for up to a day when the plant is kept without light. On the whole, water stress has a more profound and immediate effect on fruit volume growth(Pearce *et al*., 1993b) and the final fruit size can be substantially reduced by osmotic stress, but the import of assimilate is not affected (Ehret and Ho, 1986). It appears that water stress in the plant may reduce the phloem sap volume but increase the sap concentration, so that the rate of assimilate import may remain constant (Ho *et al*., 1987).

Temperature has a more complex effect on final fruit size. On the one hand, higher temperature increases the rate of carbon import (Walker and Ho, 1977b) and volume growth when the fruit is not under water stress (Pearce *et al.*, 1993a). On the other hand, higher temperature can enhance canopy transpiration to induce water stress, resulting in lower fruit volume growth (Pearce *et al*., 1993b). As a long- term adaptive response to high temperature, the duration of fruit growth as well as the final fruit size is often reduced (Dekoning, 1994).Therefore, the beneficial effect of high temperature in increasing fruit size may only be realized when the assimilate supply is unlimited and water stress is prevented.

2.2.1.5. Salinity

The growth of a fruiting tomato plant is very tolerant to salinity in the root zone. For example, neither the biomass nor the partitioning of the dry matter among organs was significantly affected by salinities up to 6 mS cm-1 in the nutrient film technique (NFT) solution (Ehret and Ho, 1986). Even when the biomass was reduced by increasing the salinity to 15 mS cm-1, the partitioning of dry matter was still not affected (Ho and Adams, 1994). It appears that

osmotic stress reduces sink growth evenly and thus the proportional distribution of assimilate, governed by the priority among sink organs, is not disturbed.

2.2.2. Competition among vegetative organs

The potential fruit set is determined by floral development. In commercial practice, early fruit set under low light can be achieved by restricting root growth (Cooper and Hurd, 1968) or removing some young leaves (Kinet, 1977b). In effect, the fruit set is facilitated by reducing or removing the competing sink organs for better assimilate supply. However, this kind of physical treatment as well as other physiological treatments such as low temperature, only gives a temporary benefit in favor of reproductive growth. As the removal of young leaves reduces the photosynthetic area and thus the assimilate supply, the fruit growth of subsequent trusses will be retarded. Root restrictions must also be removed after the fruit set in the first truss to ensure healthy shoot development for further fruit production.

2.3. Effect of Gibberellins and Auxin on Parthenocarpic Fruit Growth in Tomato

The effect of applied gibberellin (GA) and auxin on fruit-set and growth has been investigated in tomato *(Solanumlycopersicum L.*) cv Micro-Tom. It was found that to prevent competition between developing fruits only one fruit per truss should be left on the plant (Juan *et al*,2007).Unpollinated ovaries responded to GA3 and to different auxins [indol-3-acetic acid,naphthaleneacetic acid, and 2,4-dichlorophenoxyacetic acid (2,4-D)], 2,4-D being the most efficient. GA3- and 2, 4-D-induced fruits had different internal morphology, with poor locular tissue development in the case of GA, and pseudoembryos development in the case of 2, 4-D.Also, GA3 produced larger cells in the internal region of the mesocarp (IM) associated with higher mean C values, whereas 2, 4-D produced more cell layers in the pericarp than pollinated fruits. The smaller size of GA3- compared with 2, 4-D-induced fruits were due to them having fewer cells, only partially compensated by the larger size of IM cells.

Simultaneous application of GA3 and 2, 4-D produced parthenocarpic fruits similar to pollinated fruits, but for the absence of seeds, suggesting that both kinds of hormones are involved in the induction of fruit development upon pollination. It is concluded that Micro-

Tom constitutes a convenient model system, compared to tall cultivars, to investigate the hormonal regulation of fruit development in tomato (Juan *et al*, 2007).

2.4. Influence of pruning on Fruit yield and Quality of Tomato

Pruning is an important cultural practice to enhance the ratio of foliage to fruit production and also for greater light penetration, aeration, disease management, and ease of harvesting. It also allows for some regulation of fruit size and flowering (Rubatzky and Yamaguchi, 1996).Removal of axillary shoots is usual if plants are staked; this normally increases the quality and early yield of fruits but may result in a reduction of total yield compared with the same planting density of unstaked and unpruned plants. Staked and pruned plants are also more liable to sun scald. Determinate types of tomato do not normally require staking or pruning (Tindall, 1983).There is a great variety of growing habits among cultivated tomatoes (Ho, 1984). For instance, the determinate type of tomato may grow to a bush of 1m in radius, producing 3-9 trusses over a period of 3-4 months in the field, while the indeterminate type may grow to 9m in height, producing more than 35 trusses over a period of 10-11 months in the greenhouse.

The total dry matter production and partitioning within the plant can differ considerably between these two types of tomato. For example, a determinate tomato plant growing inCalifornia without deleafing would accumulate 445g dry matter with a harvest index (percentage of fruit dry matter in relation to plant dry matter) of 55% (Hewitt and Marrush, 1986). In contrast, an indeterminate tomato plant grown in the United Kingdom, without side shoots, might accumulate 1250g dry matter with a harvest index of 69% (Cockshull*et al*., 1992). The fruit yield is determined by the balance between vegetative and reproductive growth within a given supply of assimilates.Slack and Calvert (1977) considered three possible effects of truss removal from tomato plants on the ultimate fruit yield**:** 1) Total yield may be reduced in direct proportion to the loss of yield potential. This will occur if the level of assimilates received by the remaining trusses is un affected by the loss of trusses, and will imply that assimilates which is going to use for fruit production may otherwise be used for

other purposes. 2) Total yield may be unaffected, which would imply that the available assimilates were wholly redistributed to other trusses.

Since fruits are the strongest sink for assimilates in tomatoes, a change in fruit number is mainly compensated by a corresponding inverse change in mean fruit size rather than by a substantial change in fruit: shoot ratio (Cockshull and Ho, 1995). 3) There may be a lessthan-proportional reduction in total yield, due to the redistribution of some, but not all of the available assimilates.Cockshull and Ho (1995) noted that removing 30% of the available fruit from the distal end of the first three trusses increased average fruit weight of the remaining fruit and the yield of top trusses. Truss thinning, however, did not significantly influence dry matter content as well as the total fresh weight of the fruit. It was suggested that there was redistribution of assimilates to the remaining fruit in the trusses and between trusses.

However, the redistribution to the remaining fruit did not completely compensate for the loss of fruit. Similarly, Tanaka and Fujita (1974) found that when the first truss was removed, the fruit of the second truss became larger, but the weight of fruit of the second truss under these conditions was smaller than the total weight of fruit of the first and second trusses under ordinary conditions. Furthermore, Ehret*et al.* (1993) observed higher foliage: fruit ratios when some fruit were pruned from tomato plants as compared to none pruned ones; and an increase of about 50-60 % in the average fruit weight was achieved. Similar results were found by Heuvelink and Buiskool(1995).

2.4.1. Stage of pruning

A study conducted by Bhatt and Rao (1997) indicated that the removal of fruit in the first flowering node of bell pepper plants 10 days after fruit set did not increase the partitioning of dry mass to fruit on upper nodes of the plant. With the advancement of fruit growth, the first flowering node fruit acts as a major sink for photosynthates (10.2%) up to 20 days after flowering, and afterwards becomes a weaker sink (Bhatt and Rao, 1993). Alley and Kelly (1992) found that the inhibitory effect of old fruit on the increase in fresh mass, length, diameter and pericarp thickness of younger ones was significant only from flower bud

inception through weeks two and four after fruit set. In line with this, Bertin*et al.* (2002) concluded that cell division is main limiting factors for fruit growths under low assimilate supply, although cell enlargement during further fruit development is also affected.Kirti and Nettless (1961) illustrated the importance of competition alleviation very early in the development of the fruit, that is, when buds were being formed by cell multiplication. This stage is responsible for determining the number of growth units of the fruit. In accord to this, Alley and Kelly (1992) reported that de-budding the first three nodes of pepper plants was more effective than de-flowering or de-fruiting.

2.4.2. Effects of pruning on fruit quality attributes

2.4.2.1. Fruit size

Final size of cultivated tomato fruits varies from about 15g in cherry tomato to more than 450 gm in beefsteak tomato. Despite this great variation in size the duration of fruit maturation is less variable in the range of 40 to 65 days and the dry matter content of the ripe fruit is in the range of 5% to 7.5% for most cultivated tomatoes (Davies and Hobson, 1981). Therefore, the rate of dry matter accumulation by a tomato fruit varies substantially among cultivars. A number of studies show the influence of pruning on fruit size. Saglam*et al.* (1999) conducted a study to determine the effect of the number of fruit per truss (four, six or eight) on quality of tomatoes. Average fruit size was increased by decreasing the number of fruit per truss. Likewise, in a field trial of tomato, growth limited to six inflorescences and removal of 10% of the flowers from the trusses produced the best quality in terms of fruit size (Ramirez *et al*., 1977). Similar results were found by Kusumo (1978) as well as Cockshull and Ho (1955).

Balde*et al*., (2002) reported that reduction of fruit load from five fruits to one fruit per truss after 30 days of removal resulted in an increase of flower bud length and fruit diameter by 38% and 28%, respectively. An increase in total number of flowers has been shown to increase competition for photosynthate within a plant and thus decrease fruit size (Van Ravestijn and Molhoek, 1978). This size reduction effect can be the result of both competitions between inflorescences (Fisher, 1977) or among fruits on a single inflorescence (Veliath and Ferguson, 1972). Bertin*et al*(2001*)* investigated the influence of source – sink

balance on the quality of tomato by fruit and leaf pruning. Where the source: sink ratio was high, fruit size was not bigger than where the source: sink ratio was low. Fruits can grow to their potential sizes under non limited assimilate supply and no further growth takes place if the supply of assimilates is increased further (Ho, 1988).Thus, Bertin*et al*... (2001) reasoned that the plants in all the treatments were not source limited as all the trusses were thinned to a maximum of six fruit and all the side shoots were pruned

2.4.2.2. Dry matter content

The dry matter content (dry matter as percentage of fruitweight) of a tomato fruit is determined by the balance of the accumulation assimilates and water. While the import of assimilate depends on the effect of light on canopy photosynthesis and of temperature on fruit metabolism, the import of water is affected by plant water relations, which, in turn, is affected by root water absorption and leaf transpiration. For instance, the relatively high dry matter content of greenhouse tomato fruit in the summer (Ho, 1988b) is likely to result from the higher assimilate supply combined with limited water supply caused by water stress.

The essential role of assimilate supply on dry matter content has also been demonstrated by experiments in which the dry matter content was either increased by increasing the ratios of leaf to fruit or reduced by shading the plant (Davies and Hobson, 1981). Probably, for similar reasons dry matter content is related to the plant growth patterns. For example, the dry matter content of fruit from the indeterminate form is higher than that from determinate and dwarf forms of the same cultivar (Emery and Munger, 1970). A higher solid content of tomato fruit for processing has been the goal for plant breeders, as this would reduce the cost of processing (Stevens and Rick, 1986). A change in the balance of phloem and xylem sap translocation to the fruit due to fruit pruning is a cause of the increase in total solids of fruit (Tsedal, 2004).

According to De kreij (1992), low fruit load is said to favor disequilibrium between xylem and phloem sap absorption by the fruit in favor of the phloem sap, Among modern cultivars, the dry matter contents of ripe fruit are generally inversely related to the total sugar content of the fruit (Ho, 1988b) or to the ratio of soluble to total solids (Young *et al*., 1993).

2.4.2.3. Hollowness

Other quality aspects like hollowness of fruit also seem to be affected by pruning. In a study done by Oliveira *et al.* (1996) there was a decrease in the percentage of hollow fruit when fewer trusses were left on the tomato plants.

2.4.2.4. Pericarp thickness

Alley and Kelly (1992) observed similar results in sweet pepper where older fruit inhibited the increase in pericarp thickness of young fruit, and removal of the older fruit significantly increased the pericarp thickness of the young fruit. Bertin*et al.* (2003) on two tomato lines(CF14-L and CF12-C) reported that pericarp thickness of CF14-L basal fruits did not change after truss pruning due to the compensation between the reduced number of cell layers and the increase in mean cell size . However, the pericarp thickness of CF14-L tip fruits increased after pruning because of bigger cells and a similar number of cell layers. In the CF12-C line, only tip fruits were sensitive to pruning and their pericarp thickness significantly increased after pruning due to a two fold increase of the mean cell area.The pericarp thickness of fruit positively correlated (r=0.82) with fruit size (Tsedal, 2004).This is similar to the observation of Stevens *et al*. (1977) where large fruit had thicker pericarp than small fruit. According to Stevens *et al. (*1977) and De Bruyn*et al. (*1971) the pericarp of tomato contained more reducing sugars and total soluble solids than the locular tissue. As sugars are the major components of a tomato fruit and of the photoassimilates, a correlative increase in pericarp thickness and fruit size can be expected with increasing source: sink ratio (Tsedal, 2004).

2.5. Influence of pruning on assimilate partitioning in Tomato

The growth pattern of a tomato plant suggests that there is a definite priority in assimilate partitioning among the growing organs. Various sink organs have different abilities to attract assimilate (i.e., sink strength), and thus the priority of an organ in receiving assimilate is the result of competition among sink organs (i.e., sink competition). This priority is best assessed by the proportional assimilate distribution when assimilate supply is limited, as assimilate will

first be taken up by the strong sink. The weaker sinks may or may not receive assimilate depending on its availability (Ho, 1984).

Tomato is a potentially high-yield crop with a harvest index of about 65%. During fruiting, fruit growth accounts for 80 to 90% of the plant fresh weight gain and fruits are therefore the strongest sinks for assimilate. At initiation, an inflorescence is a weak sink in comparison with apical shoots. When assimilate supply is inadequate, the inflorescence has a reducedlevel of endogenous cytokinin and the degree of abortion is inversely related to the activity of sucrose hydrolase. Application of cytokinin plus gibberellins to the inflorescence increases its capacity to attract assimilate at the expense of apical shoots (Ho, 2004).At fruit set, cell division is activated and the ovary starts to accumulate reducing sugars and starch. Both the final cell number and the potential cell size are determined in the first two weeks and may be related to the levels of cytokinin and auxin. At the early stage of rapid growth a fruit accumulates imported assimilates, mainly in the forms of hexoses and starch.

The rate of starch accumulation increases with the absolute fruit growth rate and affects the final soluble solids content of a fruit. The change in the fruit growth rate during fruit development does not coincide with the changes in the endogenous hormone levels of the fruit. A fruit competes for mainly in the assimilate with others same truss (Ho, 2004).

2.5.1. Priority of assimilate partitioning during plant development

When the first inflorescence develops on a young tomato plant, a low assimilate supply, caused by either low light (Kinet, 1977a) or high plant density (Russell and Morris, 1982) induces inflorescence or flower abortion, well before the growth of the shoot and roots is affected (Cooper, 1964). Once fruiting has started developing on determinate tomato plants, the growth of both the shoot and roots levels off (Hewitt and Marrush, 1986). In an indeterminate plant, the fresh weight gain by fruit accounts for nearly 80% of the plant gain (Hurd*et al*., 1979).

As fruit accumulate more water than other organs, the difference in dry matter gain between organs is smaller. However, the daily plant dry matter accumulation rate in all the fruit is consistently higher (2.05g) than that of leaves (1.52g) and stem (0.8g) (Maher, 1976). When assimilate supply is limited, fruit takes up most of the available assimilate. The subsequent inflorescence development is delayed and the growth of shoot and roots is retarded further, even causing early leaf senescence or root death (Hurd*et al*., 1979).A strong competition for assimilate between fruit and roots can be aggravated, for instance when fruit growth is enhanced by growth regulator treatment (Starck*et al.,* 1989).

2.5.2. Phyllotaxy/ vascular system and sink competition

Competition between sink organs for assimilate may be facilitated by the common transport path between some sink organs and their common source leaves. There are four vertical vascular strands in the stem connecting with the adjacent leaves (Shishido*et al,* 1988) the arrangement of leaves below the first inflorescence can be described by a 2/5phyllotaxis on the stem (Ho and Hewitt, 1986). The first inflorescence is mainly supplied by leaves 1, 3, 6 and 8 with a divergence of less than 90 degrees from the inflorescence, while the apex is supplied by leaves 1-4 and the roots by leaves 5-9 (Russell and Morris, 1983). As leaves 1, 3, 6 and 8 supply the first inflorescence as well as apex, and roots and all of these leaves are connected to the same vascular strand, there is direct competition among these sink organs for the same pool of assimilate. Above the first inflorescence, there are three leaves between adjacent inflorescences, with the lower two about 90 degrees from the inflorescence and the upper most one 180 degrees from the inflorescence. In effect, all the inflorescences are in one vertical row, and the leaves in three rows. Most likely, each fruit truss would attract assimilate mainly from the leaves in the two adjacent rows both just below and above the truss. Because of lack of direct vascular connection between the trusses and the opposite leaves, relatively less assimilate from these leaves would be supplied to the trusses (Shishido, 1991).

As fruit attract assimilate locally, the supply of assimilate to the apex and the roots may be mainly confined to a few upper leaves and the bottom leaves, respectively. Such distribution pattern of assimilate in fruiting tomato plants are consistent with the high proportion of dry

matter accumulation by the fruit. Within each truss, the fruit on one side tend to receive more assimilate from leaves on the same side of the stem (Shishido and Hori, 1991). However, localized distribution of assimilate for an individual fruit or truss is not absolute. Assimilate targeted for a truss can be readily distributed to trusses both above and below if the truss is removed, and the gain in those remaining trusses accounts for up to 70% of the surplus assimilate (Slack and Calvert, 1977).

2.5.3. Hormonal regulation of sink priority

Although the priority among sink organs for assimilate may be determined by their relative sink strength, neither the determinants of sink strength nor the mechanism of sink competition in tomato is well defined. It is not yet known why an initiating inflorescence should be a weaker sink than the shoot apex or roots (Ho *et al*., 1989). However, an aborting inflorescence caused by poor competition for a limited supply of assimilate can be revitalized by applying cytokinin and gibberellic acid to the ovary alone (Kinet*et al.,* 1978). In this case, the sequence of events suggested that the hormonal treatment restarted the cell division in the ovary (Kinet*et al*., 1986) and was followed by intensified sugar metabolism before there was an increased import of assimilate at the expense of that for the apex (Kinet, 1987).

This suggests that the normal low sink strength of flowers is due to low cell division activity and that the enhanced cell division activity in the ovary caused by the hormonal treatment may generate sink strength greater than that of the apex. In that sense, the diversion of assimilate from apex to flower is due to a change of priority which is caused by enhanced sink strength of the flower alone. Similar roles of hormones in regulating sink strength through cell division activity were also observed when 4- chlorophenoxyacetic acid (4-CPA) was applied to gibberelic acid or auxin (IAA-) induced parthenocarpic tomato fruit (Bunger- Kibler and Bangerth, 1982). It appears that cell division activity in the ovary before and after anthesis may determine the sink strength, which may be regulated by endogenous hormones (Vargas and Bruinsma, 1986).

2.5.4. Sink strength

The sink strength of an organ can be quantified by the potential growth rate of a sink, that is, the growth rate under conditions of non-limiting assimilate supply (Marcelis and Heuvelink, 1999). Potential growth rate is a dynamic parameter that may change with developmental stage or temperature. In tomato, a developing inflorescence is a weaker sink for assimilates than the expanding leaves, but a truss with growing fruit is a stronger sink than young leaves and roots. The potential sink strength of the inflorescence increases from flowering to fruiting stage. The priority between sinks for assimilates changed from roots > young leaves >Inflorescence in a flowering plant to fruit > young leaves > flowers > roots in a fruiting tomato plant (Ho, 1988).

The sink- strength of tomato fruit also varies depending on the position of the truss on the stem and position of the fruit within the truss. Lower trusses and proximal fruit have higher sink strength than upper trusses and distal fruit. Bangerth and Ho (1984) associated this with the variation in the number of cells that fruit from various positions of the plant attain at anthesis. Besides, Bertin (1995) has reported that, within one inflorescence, the vascular area of the rachis was reduced at the inflorescence extremities, which could contribute to the restriction of assimilates to distal fruit, rendering them weaker sinks.

Changes in sink-strength can be attributed to the growth pattern of the fruit. Cumulative fruit growth in tomato is expressed in the form of a sigmoid curve. An initial two- week period of slow absolute growth is followed by 3-5 weeks of rapid growth up to the mature green stage and finally a period of slow growth for two further weeks. Cell division is limited to the early slow growth phase (Monselise*et al.*, 1978).

2.5.5. Assimilate partitioning as affected by transport distance

In addition to sink-strength, relative distance of sources and sinks is assumed to affect assimilate partioning. Slack and Kalvert (1977) investigated the effect of removing individual trusses on yield of glasshouse green tomatoes. It was found that removing a truss resulted in

yield increases on some of the remaining trusses both above and below the one removed. The largest increases occurred on the trusses immediately above and below the one removed and there was a general tendency for the increase to be smaller the further away (in both directions) the truss was from the removed truss. According to Tanaka and Fujita (1974) the major portion of carbon received by each truss is derived from leaves in the immediate vicinity of the truss. Thus, in the absence of adjacent carbon sink, the available material moves towards the remaining trusses and is absorbed by them in amounts related to their distance from the providing leaves.

In similar experiment by Slack and Calvert (1977) the greatest restitution for a missing truss occurred when middle trusses were removed. Removing earlier or later trusses resulted in diminishing total yields. It was suggested that there are separate upward and down ward path ways for the photosynthate translocated from tomato leaves. Bonnemain (1965) found that carbon was translocated from every tomato leaf in two directions, upward towards the apex via internal phloem and down ward towards the root via external phloem. Thus, it was hypothesized that only partial restitution could be made for the loss of an early truss because there are few, if any, fruit sinks at a lower level. However, almost full restitution may be expected when a middle truss is lost (Slack and Calvert, 1977).Heuvelink (1995) argued that the results of Slack and Calvert (1977) could also be explained without assuming a distance effect on assimilate partitioning. Trusses closest to the excised truss show the highest yield increase as earlier initiated trusses have a shorter growth period left to profit from removing a truss, while latter initiated trusses miss a larger part of the period where removal of the truss plays a role. Trusses closer to the excised truss, however, exhibit highest sink strength (potential growth rate) in the period where excision has the largest influence on total sink strength (Heuvelink, 1995).

2.5.6. One common assimilate pool

Despite the fact that in some cases partitioning is related to the relative distance between sinks and sources (Marcelis, 1996), distance is generally not an important factor in dry matter partitioning at the whole plant level. Schapendonk and Brouwer (1984) reported that increasing the distance between source leaves and fruit had no effect on fruit growth in

cucumber. Moreover, Heuvelink (1995) showed that in tomato plants with two shoots and a shoot length of more than 2 m, dry matter partitioning between vegetative and generative parts was not affected whether the fruit were located on only one shoot or whether the same number of fruit was divided over the two shoots. It was concluded that the effect of distance (transport resistance) and the compartmentation of the plant into source-sink units could be omitted when modeling dry matter distribution and one common assimilate pool available to all sinks can be assumed. Recently, Andriolo*et al.* (2000) conducted a similar trial with tomato, and comparisons of fruit dry mass indicated that fruit position did not affect dry matter distribution, supporting the hypothesis of one common pool of assimilates circulating freely in the plant. In contrast to this, Marcelis (1996) reasoned that some of these results could be explained by the fact that sometimes sinks were functioning close to assimilate saturation (sink limitation). The model on phloem transport proposed by Minchin *et al*. (1993) accepts that transport resistance does not affect partitioning when sinks are functioning at saturation. Hence, the role of distance on translocation is still controversial.

3. MATERIALS AND METHODS

3.1. Experimental Site

The field experiment was carried out at vegetable nursery in Melkassa Agricultural Research Center of the Ethiopian Institute of Agricultural Research Center from July to November 2015. The Center is geographically located at latitude of 8̊24'N, longitude of 39˚21' E and at altitude of 1,550 meters. It is situated at about 107 km from Addis Ababa and 17 km from Adama on the way to Assela. (ASTI-EIAR Country FACT SHEET, 2014).

The area receives average annual rain fall of 890mm with mean maximum and minimum temperatures of 27.3^0C and 11.3^0C, respectively and it has a gentle slope of 1-3% and the texture of the soil is sandy loam.

3.2. Experimental Material and Treatments

Melkashola variety was used for the study, because it is a model plant and fast growing type among vegetable crops. It is a processing market fruit type, and characterized by more or less indeterminate growth habit (i.e. flowers indefinitely throughout the plant's life) with globular fruit shape (Habtie, 2007). The experiment consisted of four levels of pruning (first truss the first two trusses , the first three trusses and without pruning (control)) and three stages of pruning (at bud stage when the flower bud is visible, at anthesis when the first flower in a particular truss opens, and at fruit set when the first fruit is 2mm in diameter).

3.3. Experimental Design

The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications. Each experimental plot had a gross area of 13.5m^2 with 2.7m length and 5m width and a net harvest area of 4.86m^2 (2.7m × 1.8m). The distance between plots and blocks were 1m and 1.5m, respectively. Plants were spaced at 100cm between rows and 30 cm within a row. Each plot had five rows with a plant population of 45 per plot which is equivalent to 33333 plants per hectare.

3.4. Agronomic Practices

Pruning

There are few hard and fast rules in tomato pruning, and many varying opinions. Good pruning achieves the optimum balance between vegetative growth and fruit production. Pruning will impact fruit size, fruit quality and yield, so it is important to strike the right balance between reducing vigorous foliage and stripping the plant. Good pruning helps increase fruit size and enhance earliness. However, pruning too heavily can reduce yield and increase problems with sunburn, blossom end rot, and cat facing.

In determining how to prune tomato crop, the grower should consider the growth habit (determinate or indeterminate) of plants. Indeterminate tomatoes are more heavily pruned than determinate ones, but even determinate tomatoes often require some level of pruning. Next, consider any special features of specific variety including any recommendations from seed supplier. The amount of pruning needed can vary with variety.

Pruning is usually started as the plants are first being staked or supported, sometimes before stringing them to avoid interference with the lines. Tomato plants are pruned by selectively removing suckers, the shoot that grows between the main stem and a leaf. Suckers should be broken off while they are still small, between 2-4 inches in length. Prune plants only when the leaves are dry to reduce the spread of disease.

Plants in the trellis system are generally trained to two stems: the main stem and the stem that develops from the sucker just below the first flower cluster. Suckers below this one should be removed. The remaining two stems should be twined around the vertical string support as the plant grows. If very vigorous plants grow above the top of the stake system, they may need to be topped. (Diver, S., G. Kuepper, and H. Born. 1999).

In my experiment, Seedlings were raised for about 28 days (from Auguest13 to September 10, 2015) on a well prepared seed bed. The area of the seed bed was 10 m^2 (two beds each having a size of 1m × 5m). The recommended seed rate of 300 g/ha and a fertilizer rate of 100kg/ha Diammonium phosphate (DAP) and 50 kg/ha Urea were applied at sowing (Habtie, 2007).

Proper management (weeding and watering) practices were applied in order to produce healthy seedlings. Seedlings were hardened for 10 day before transplanting to the field to enable them withstand the field conditions. This was done by reducing the frequency of watering from daily application to two days and then to three days interval and allowing the soil water to fall as the seedlings become ready for field planting.

The experimental field was ploughed using tractor and leveled with hand. Healthy, vigorous, stocky and succulent seedlings were selected for transplanting. Transplanting was done late in the afternoon to reduce the risk of poor establishment due to excessive transpiration. The recommended fertilizers were applied at a rate of 200 kg/ha DAP by broadcasting at transplanting and split application of 100 Kg/ha urea (50 kg at transplanting and the rest 50 kg four weeks after transplanting). The experimental plots were free from weeds by weeding manually by hand. The width and the depth of the furrow in all of the plots were equal in order to apply equal amount of irrigation water for all of the plots. Malathion was applied at the rate of 1.5 l/ha to kill leaf miners. The chemical was sprayed being diluted in water. Earthing up of the soil was done two times (four and six weeks after transplanting). Staking was done at fruit set in order to prevent the fruits from falling on the ground. The side shoots (the suckers) were removed every week.

3.5. Data collected

3.5.1. Total leaf area (cm^2)

Five plants were randomly selected from the center of the two rows. The mean of the total leaf area of a plant in a plot was obtained by adding the total leaf area of the selected plants and then dividing the sum by the number of selected plants. The total leaf area of a plant was obtained by multiplying the area of each leaf by the total number of leaves in the plant. The area of each leaf was calculated using formulae developed by Blanco and Folegatti (2003) as:

$LA = 0.708 (LW)^2 - 10.44LW + 83.4$

Where: LA= Leaf Area

LW= Leaf Width (cm)

3.5.2. Yield assessment

Data on yield component was taken from the two central rows and five plants were also selected for the determination of yield and yield components these included:

Number of flowers per truss: Tomato plants were tagged from each plot for this purpose and the numbers of flowers were counted from lower, middle and upper trusses; the mean number of flowers per truss was computed.

Fruit set percentage: was obtained by dividing number of fruits by the number of flowers per truss and means from lower, middle and upper part was calculated.

Number of fruit per truss: number of fruits in all the trusses in each selected plant was counted and then the total number of fruits in all the trusses was divided by the number of trusses.

Number of fruit per plant: This is the total number of fruits of successive harvests and the average number of fruits per plant was obtained by counting the total number of fruits in each selected plant and then dividing it by the number of selected plants.

Fresh weight of individual fruit (g): This was obtained by dividing total fruit fresh weight per plant by the total number of fruit per plant.

Dry weight of individual fruit (g): three fruits of different size large medium and small were selected from each plot and all the selected fruits were chopped into pieces for hastening the time of drying and they were dried in an oven at a temperature of 72^0C until constant weight was obtained. The dry weight of the fruits was added and the sum was divided by the number of fruits to obtain the mean dry weight of individual fruit.

Fruit dry weight per plant (g): This was obtained by multiplying total number of fruit per plant by the average dry weight of individual fruit.

Marketable fruit yield per plant (kg):fruits whose diameter were > 3cm and which were free of damage were considered as marketable at each harvest; the average marketable fruit yield per plant was obtained by adding the marketable fruit yield obtained from the selected plants and then dividing the sum by the number of selected plants. The total marketable fruit yield per plant is the sum of successive harvests.

Unmarketable fruit yield per plant (kg): fruits whose diameter were ≤ 3cm and which were damaged by insect, diseases, sun burn, etc. were considered as unmarketable and the average marketable fruit yield per plant was obtained by adding unmarketable fruit yield obtained from the selected plants and then dividing the sum by the number of selected plants.

Total fruit yield per plant (kg): This was obtained by adding average marketable and unmarketable fruit yield per plant of successive harvests.

Total fruit yield per hectare (ton): This was obtained by converting the marketable fruit yield obtained from the net harvest area ($4.86m^2$) into hectare. At each harvest, all the marketable fruits were harvested from the net harvest area and the total marketable fruit yield of successive harvests was converted into hectare.

3.5.3. Fruit quality

Fruit diameter (cm): five fruits of different size (very large, large, medium, small and very small) were collected from each selected plant and the diameter of each fruit was measured by using caliper. The mean diameter of a fruit was obtained by adding the diameter of all the selected fruits and then dividing the sum by the number of selected fruits.

Pericarp thickness (mm): five fruits of different size (very large, large, medium, small and very small) were collected from each selected plant. Each fruit was cut into two halves through the equator and the thickness of the pericarp was measured by a caliper. The mean thickness of the pericarp was obtained by adding the pericarp thickness of all the selected fruits and then dividing the sum by the number of selected fruits.

Total soluble solid (%): Three ripened fruits were collected from each plot and from each fruit, juice was extracted and the level of the soluble solids in the juice was determined by placing a drop the juice sample on a refract meter (CE S. NO.AO 2371). The prism of the refract meter was washed with distilled water and dried before use between samples. The refract meter was standardized against distilled water. The mean total soluble solid of the fruit was obtained adding the total soluble solid of the three samples and then dividing the sum by the number of the samples.

Fruit pH: Like total soluble solid determination, three ripened fruits were collected from each plot as a sample and 25 ml of juice was extracted from each fruit and poured into a beaker and the juice was stirred by a stirring bar and then electrodes were inserted into the beaker and finally the pH of each fruit was recorded from the pH meter. The pH meter was calibrated using buffer solution before use and the electrodes were rinsed with distilled water between readings. The mean pH of the fruit was obtained by adding the pH of the three samples and then dividing the sum by the number of samples.

3.6. Methods of Data Analysis

The analysis of variance was done using' The SAS system for windows V9.2' software and comparisons of means were made by using Least Significant Difference (LSD) at 5% probability levels.

4. RESULT AND DISCUSSION

4.1. Total Leaf Area

Total leaf area of tomato was affected by the interaction effects of stage and intensity of pruning at 5% probability level (Table 1). The highest leaf area was obtained when three trusses were removed at fruit set stage. As fruits are the major sink of the plant, a reduction in fruit load could favor the distribution of assimilates to the vegetative parts of the plant (stem, leaves and root).Ehret*et al*. (1993) observed higher foliage: fruit ratio when some fruits were pruned from tomato plants as compared to the non-pruned ones. Heuvelink and Buiskool (1995) observed that changes in dry matter distribution under high fruit load were correlated with lower leaf areas. Tekalign (1997) also reported similar findings for potato which flower and fruit removal significantly increased total leaf area. He also indicated that the superior performance in total leaf area of non-flowering and non-fruiting plants to flowering and fruiting variants was due to the development of more lateral branches along with the expanded leaves produced in response to flower and fruit removal. The probable cause of rapid decline in total leaf area in fruiting plants may be due to progressive leaves senescence in several herbaceous annual species(monocarp plants) such as beans, tomatoes, and cereal grains.

Table 1: Total leaf area (cm^2) of tomato as influenced by the interaction effects of stage and Intensity of truss pruning

Stage	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	3049j	3238i	5508f	8669b
Anthesis	2899l	3500h	6467e	8239c
Fruit set	2952k	3721g	7388d	9940a
LSD	0.0001			
CV (%)	7.51			

Figures followed by different letter(s) with in a column and a row are significantly different ($P<0.05$).

4.2. Yield and Yield Components

4.2.1. Number of flower per truss

Number flower per truss of tomato was significantly affected by the interaction effects of stage and intensity of truss pruning as presented in Table2.And the highest Number of flower per truss was obtained when three trusses was removed at anthesis stage and the lowest was from the un pruned plants (Table2).

Table 2: The interaction effect of stage and level of truss pruning on number of flower per truss of tomato

Stage	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	3.0h	3.12g	3.41d	3.71b
Anthesis	2.71i	3.21f	3.61c	4.0a
Fruit set	2.61j	3.0h	3.31e	3.71b
LSD	0.0156			
CV (%)	3			

Figures followed by different letter(s) with in a column and a row are significantly different ($P<0.05$).

An increase in total number of flowers has been shown to increase competition for photosynthetic within a plant and thus decrease fruit size (Van Ravestijn andMolhoek, 1978). This size reduction effect can be the result of both competitions between inflorescences (Fisher, 1977) or among fruits on a single inflorescence (Veliath and Ferguson, 1972).

4.2.2. Fruit set percentage

Fruit set percentage of tomato was significantly affected by the interaction effects of stage and intensity of truss pruning as presented in Table3. This indicates that there is a synergetic effect between stage and intensity of truss pruning. The highest fruit set percentage (69.07%) was obtained when three trusses were removed at bud stage while the lowest (56.41%) was from the unpruned plants. This was in agreement with the findings of Murneek (1926) who

noted that the presence of fruit on a plant could lead to a decrease in inflorescence size and abortion of the flower buds. The average fruit set percentage of the control was less than the other treatments.

Table 3: The interaction effect of stage and level of truss pruning on fruit set percentage of tomato

Stage	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	56.41l	64.41e	65.0c	69.07a
Anthesis	61.03k	61.35j	61.6f	63.41g
Fruit set	63.0h	63.51f	64.64d	67.84b
LSD	0.0437			
CV (%)	2.93			

Figures followed by different letter(s) with ina column and a row are significantly different ($P<0.05$).

4.2.3. Number of fruit per truss

The number of fruit per truss was not significantly affected by the stage of pruning as presented in Table 4. This shows that whether pruning is done at bud or at anthesis or at fruit set, it does not make significant difference on the number of fruit developed per truss. There was a steady and significant increase in the number of fruits per truss with increasing pruning intensity (Table 4). This was in agreement with the findings of Murneek (1926) who noted that the presence of fruit on a plant could lead to a decrease in inflorescence size and abortion of the flower buds. The highest fruit number per truss (7.60) was found in the three trusses pruned treatments followed by two trusses (6.61) pruned treatment. However, the one truss pruned treatment did not differ significantly from the control or two trusses pruned plants. Number of fruit per truss was not significantly affected by the interaction effects of stage and intensity of truss pruning.

4.2.4. Number of fruit per plant

The number of fruit per plant was significantly affected by the stage of pruning and the highest fruit number per plant was obtained when trusses were removed at bud stage (Table4). The number of fruit per plant decreased with increase in the level of pruning intensity(Table 4) and the control treatment gave the highest fruit number as compared to the other treatments. Tsedal (2004) was reported similar result for three-truss pruned treatment that produced a lower fruit number per plant in spite of the fact that it had a slightly higher fruit number per truss than the two-trusses-pruned treatment. The results indicate that pruning three trusses did not increase the number of fruit per truss enough to compensate for the number of fruit lost by pruning. Number of fruits per plant was not significantly affected by the interaction effects of stage and intensity of truss pruning (Table4).

Table 4: Number of fruit per truss and per plant of tomato as affected by different stages and intensity of truss pruning

Stage	Number of fruits per plant	Number of fruits per truss
Bud	7.0a	26.0a
Anthesis	7.0a	26.0a
Fruit set	6.0b	25.0b
LSD	0.0531	0.0474
Intensity		
Control	5.0d	30.0a
One- truss	6.0c	26.0b
Two-truss	6.61b	23.0c
Three-truss	7.6a	22.2d
LSD	0.06	0.06
CV (%)	1.02	0.22

Figures followed by different letter(s) with in a column and a row are significantly different ($P<0.05$).

4.2.5. Fresh weight of individual fruit

Individual fruit fresh weight of tomato was significantly affected by the interaction effects of stage and intensity of truss pruning as presented in Table 5. This indicates that there is a synergetic effect between stage and intensity of truss pruning. The highest individual fruit fresh weight (98.4g) was obtained when three trusses were removed at bud stage while the lowest (76.22g) was from the unpruned plants. This is probably because of sink source ratio decreases with increasing pruning intensity and fruits may grow bigger at a small sink- source ratio than at a large ratio due to the redistribution of assimilates to the remaining fruit(Heuvelink and Buiskool,1994). The result is also in agreement with the findings of Ho and Hewitt (1986) who found that truss pruning involves the removal of young fruit from the trusses as technique to maintain optimum plant balance. This ensures that the plant does not try to fill any fruit and also that the fruit left on the plant can reach their maximum size potential.

Field and Nichols (1994) also reported that fruit thinning can be used to produce more fruit with in the desired marketable fruit size range in all year round. However, a greater understanding of fruit thinning interactions during different plant densities and growing seasons must first be achieved. Pruning inflorescences from a tomato plant (Fisher, 1977) and/or reducing the fruit load on an inflorescence (Veliath and Ferguson, 1972) will lead to an increase in individual fruit size, presumably by increasing the source to sink ratio.

Table 5: The interaction effect of stage and level of truss pruning on fresh weight (g) per plant of tomato

Pruning stage	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	80.33j	86.503i	94.4d	98.4a
Anthesis	86.5i	88.1h	89.6f	91.6e
Fruit set	76.22k	88.53g	96.4b	95.2c
LSD	0.017			
CV (%)	3.56			

Figures followed by different letter(s) with in a column and a row are significantly different (P<0.05)

4.2.6. Dry weight of individual fruit

Dry weight of individual tomato fruit was significantly affected by the interaction effects of stage and intensity of truss pruning (Table 6). The highest individual fruit dry weight (16.12g) was obtained when one truss was removed at anthesis stage. The average individual fruit dry weight of the control was less than the other treatments. The result was in agreement with the findings of Tekalign and Hammes (2005b) who noted that removing flowers and fruits have significantly increased tuber specific gravity and percent dry matter due to the largest proportion of assimilates being diverted to the developing tubers rather than for flower and fruit production. The result contradicts with findings of Heuvelink and Buiskool (1994) who reported a decreased sink-source ratio, as a result of fruit or truss pruning, reduced the fraction of dry matter distributed to the fruit.

Table 6**:** The interaction effect of stage and level of truss pruning on dry weight (g) of individual fruit per plant of tomato

Pruning stage	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	14.03d	13.87g	13.27j	13.95e
Anthesis	14.11c	16.12a	14.97b	13.8h
Fruit set	12.67k	13.91f	13.67i	11.5l
LSD	0.0342			
CV (%)	4.21			

Figures followed by different letter(s) with in a column and a row are significantly different (P<0.05)

4.2.7. Fruit dry weight per plant

Fruit dry weight per plant was significantly affected by the interaction effects of stage and intensity of truss pruning and the highest fruit dry weight per plant was obtained when one truss was removed at anthesis stage and the lowest was from the plants that received three truss removal at fruit set stage (Table 7). The result was in agreement with the observations of

Guinn and Mauney (1980), Gifford and Evans (1981) and Nederhoff*et al*. (1992) where profound increase in source: sink ratio due to intensive pruning inhibited dry matter production (source activity). Heuvelink and Buiskool (1994) also noted a decreased sink-source ratio, as a result of fruit or truss pruning, reduced the fraction of dry matter distributed to the fruit. The result contradicts with the report of Heuvelink (1997) who stated that despite a lower fraction of biomass allocated to the fruit, fruit pruning may increase dry matter production to such an extent that total fruit yield does not change or even increases.

Table 7: The interaction effect of stage and intensity of truss pruning on fruit dry weight (g) per plant of tomato

Pruning stage	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	425.18b	371.30e	312.14i	315.4h
Anthesis	424.68c	426.97a	348.41g	308.7j
Fruit set	373.60d	356.4f	306.07k	247.12l
LSD	0.081			
CV (%)	3.94			

Figures followed by different letter(s) with in a column and a row are significantly different ($P<0.05$)

4.2.8. Marketable fruit yield per plant

Marketable fruit yield per plant was not significantly affected by the stage of pruning (Table 8).This implies that time of pruning does not have significant effect on the amount of marketable yield that is obtained. However, it was significantly affected by the intensity of pruning and the highest marketable fruit yield per plant was obtained from the control (1.68) while the three-truss pruned treatments gave the lowest (1.466kg) marketable yield which was13.69% lower than the control. This is because over pruning can cause reduced yields and increased physiological disorders such as sun burn, blossom end rot and cat facing which are known to reduce the marketability of tomato fruit (Terry Kelly and Boyhan, 2006).Marketable fruit yield per plant was not significantly affected by the interaction effects of stage and intensity of truss pruning.

4.2.9. Unmarketable fruit yield per plant

Unmarketable fruit yield per plant was not significantly affected by the stage of pruning but it was significantly affected by the intensity of pruning (Table 8). The highest unmarketable fruit yield per plant was obtained from the three- trusses pruned treatments and followed by two trusses pruned treatments. This is because if too many fruits are pruned from the plant, those remaining may be more prone to growth disorders such as cracking (Morgan and Lennard, 2000), blossom-end rot (De Kreij, 1992), sun burn and cat facing (Terry Kelly and Boyhan, 2006) and fruit deformation (Aloni*et al.*, 1999). The incidence of blossom end rot was higher in the three trusses pruned treatments than the other treatments in the current study. Blossom-end rot is a calcium deficiency that occurs at the blossom end of the fruit which is characterized by black, necrotic, sunken tissue at the blossom end. Fruit with necrotic tissue is unsalable and the damage cannot be corrected. Although the tissue is calcium deficient, pre-plant applications of calcium or post plant applications to correct the disorder often have no effect (Terry Kelly and Boyhan (2006). Unmarketable fruit yield per plant was not affected by the interaction effects of stage and intensity of truss pruning.

Table 8: Marketable, unmarketable, total fruit yield per plant and total fruit yield per hectare of tomato as affected by stage and intensity of truss pruning

Stage	Fruit yield per plant (kg)			
	Marketable	Unmarketable	Total fruit yield	Total fruit yield (ton/ha)
Bud	1.62	0.06	1.67	75.12
Anthesis	1.53	0.06	1.59	71.47
Fruit set	1.59	0.0346	1.63	73.2
LSD	0.0067	0.003	0.006	0.27
	ns	ns	ns	ns
Intensity				
Control	1.68a	0.035d	1.71a	77.03a
One -truss	1.617b	0.044c	1.663b	74.74b
Two truss	1.565c	0.057b	1.617c	72.79c
Three-truss	1.466d	0.063a	1.523d	68.49
LSD	0.0079	0.0034	0.0072	0.3097
CV (%)	0.51	0.71	0.46	0.44

Means of the same main effect within a column followed by the same letter are not significantly different at the prescribed level of significance ($P<0.05$).

4.2. 10.Total fruit yield per plant

Total fruit yield per plant was not significantly affected by the stage of pruning but it was significantly affected by the intensity of pruning (Table 8). The highest total fruit yield per plant was obtained from the control followed by the one, two and three truss pruned treatments in that order signifying there is a progressive total yield reduction in response to an increased level of truss pruning. It is generally agreed that the distribution of assimilates among sinks is primarily regulated by the sink strength (Marcelis, 1996); and generative sink strength is assumed to be proportional to the number of fruit, as has been proven by (Heuvelink, 1997). Thus, the reduction in total fruit yield per plant can be explained by the reduction of number of fruit as a result of pruning which leads to reduction in fruit yield. The reduction in total yield in the one and two truss pruned treatments was insignificant because the yield from the remaining trusses increased and almost completely compensated for the

loss of potential yield due to pruning. Total fruit yield per plant was not significantly affected by the interaction effects of stage and intensity of truss pruning.

4.2.4. Total fruit yield per hectare

Total fruit yield per hectare was not significantly affected by the interaction effects of stage and intensity of truss pruning. Total fruit yield per hectare decreased with increasing pruning intensity. The lowest total fruit yield per hectare was obtained from the three trusses pruned treatments as presented in Table 8. This result was in agreement with the idea forwarded by Tindall (1983) who stated that removal of some flowers and axillary shoots is usual if plants are staked; this normally increases the quality and early yield of fruits but may result in a reduction of total yield compared with the same planting density of unstaked and unpruned plants.

4.3. Fruit Quality

4.3.1. Fruit diameter

Fruit diameter was significantly affected by the stage of pruning (Table 9). Tomato fruits with the biggest diameter were obtained when trusses were removed at bud stage even though it was not significantly different from the anthesis stage. Fruit diameter was also significantly affected by the intensity of pruning and it was increased with increasing pruning intensity. This has been explained by the increased allocation of available assimilates to the remaining fruit due to the increase source: sink ratio created by the reduction of sink load (Tanaka and Fujita, 1974; Ramirez *et al*., 1977; Cockshull and Ho, 1995; Saglam*et al.,* 1999). Balde*etal*., (2002) reported that reduction of fruit load from five fruits to one fruit per truss after 30 days of removal resulted in an increase of flower bud length and fruit diameter by 38% and 28%, respectively. An increase in total number of flowers has been shown to increase competition for photosynthate within a plant and thus decrease fruit size (Van RavestijnandMolhoek, 1978). This size reduction effect can be the result of both competitions between inflorescences (Fisher, 1977) or among fruits on a single inflorescence (Veliath and Ferguson,

1972). Fruit diameter was not significantly affected by the interaction effects of stage and intensity of truss pruning.

Table 9: Fruit diameter and pH as influenced by different stages and levels of truss pruning

Stage	Fruit diameter (cm**)**	pH
Bud	45.2a	4.92a
Anthesis	42.7b	4.89ab
Fruit set	41.0c	4.91a
LSD	0.2398	0.0081
Intensity		
Control	38.0d	4.41d
One -truss	40.66c	4.73c
Two truss	45.00b	5.11b
Three-truss	48.33a	5.39a
LSD	0.2768	0.0093
CV (%)	0.67	0.2

Means of the same main effect within a column followed by the same letter are not significantly different at the prescribed level of significance($P<0.05$)

4.3.2. Fruit pH

Fruit pH was not significantly affected by the stage of pruning (Table 9). This shows that whether pruning is done at bud stage or at anthesis or at fruit set, there will not be significant change in fruit pH. Fruit pH significantly increased with increasing pruning intensity. Fruit pH of 4-4.5 is considered to be ideal for processing tomatoes (Dhaliwal*et al*., 2001). Most tomato cultivars have sufficient citric acid to ensure a pH below 4.5, although citric acid or lemon juice is often added to compensate for the reduction in acidity that accompanies ripening.

4.3.3. Pericarp thickness

Pericarp thickness of tomato was significantly affected by the interaction effects of stage and intensity of truss pruning (Table 10). The removal of three trusses at fruit set stage produced fruit with the thickest pericarp (5.7 mm) while the control gave the least (3.5mm). Alley and Kelly (1992) observed similar results in sweet pepper where older fruit inhibited the increase in pericarp thickness of young fruit, and removal of the older fruit significantly increased the pericarp thickness of the young fruit. Bertin *et al.* (2003) on two tomato lines (CF14-L andCF12-C) reported that pericarp thickness of CF14-L basal fruits did not change after truss pruning due to the compensation between the reduced number of cell layers and the increase in mean cell size . However, the pericarp thickness of CF14-L tip fruits increased after pruning because of bigger cells and a similar number of cell layers. In the CF12-C line, only tip fruits were sensitive to pruning and their pericarp thickness significantly increased after pruning due to a two fold increase of the mean cell area.

Table 10. Pericarp thickness as influenced by the interaction effect of stage and level of truss pruning of tomato

	Pericarp thickness (mm)			
Pruning	Control	One-truss	Two-truss	Three-truss
Bud	4.2h	5.0d	4.4g	5.4b
Anthesis	3.5l	4.8e	4.203i	5.2c
Fruit set	4.0j	4.6f	3.7k	5.7a
LSD	0.0066			
CV	4.87			

Figures followed by different letter(s) with in a column and a row are significantly different ($P<0.05$)

4.3.4. Total soluble solid (%)

The TSS content of tomato was significantly affected by the interaction effects of stage and intensity of truss pruning (Table 11). Fruits with the highest TSS content were obtained when

two trusses were removed at bud stage (6.26) and fruit set stage (6.22). The result was supported by the finding of Bertin*et al*. (2000) who reported that the proportion of water to dry matter of tomato fruit was lowered by reducing fruit load. This implies that, as a result of truss pruning, the proportion of dry matter accumulation in fruits surpassed the accumulation of water. This explains the contrasting trends of fruit fresh mass and fruit dry mass per plant since these parameters decrease with an increase in the level of pruning.

An increase in phloem sap concentration can be suggested as a possible reason for increased total solids content of fruit since a similar truss pruning treatment done by Bertin*et al.* (2001) promoted the concentration of dry matter components, including acids and sugars in tomato fruit. They also noted that low assimilate supply in winter and spring production of tomato in absence of water stress, leads to the production of fruit with low dry matter and sugar content due to the dilution of phloem sap. Besides, a change in the balance of phloem and xylem sap translocation to the fruit due to fruit pruning can be suggested as a possible cause of the increase in total solids content of fruit. According to De Kreij (1992), low fruit load is said to favor disequilibrium between xylem and phloem sap absorption by the fruit, in favor of the phloem sap.

Table 11: Total soluble solids content (%) as influenced by the interaction effect of stage and level of truss pruning of tomato

Stage	Intensity of truss pruning			
	Control	One-truss	Two-truss	Three-truss
Bud	4.81j	5.25g	6.26a	6.05e
Anthesis	4.77k	5.2h	6.1c	5.9f
Fruit set	4.76l	5.11i	6.22b	6.08d
LSD	0.0063			
CV (%)	0.86			

Figures followed by different letter(s) with in a column and a row are significantly different ($P<0.05$)

5. SUMMARY AND CONCLUSIONS

Total leaf area, number of flower per truss, fruit set percentage, individual fruit fresh weight, individual fruit dry weight, fruit dry weight per plant, pericarp thickness, total soluble solids content, were significantly affected by the interaction effects of stage and intensity of truss pruning. The treatments where three trusses of tomato were removed resulted in increased total leaf area, number of flower per truss, fruit set percentage, individual fruit fresh weight, pericarp thickness.

Number of fruits per truss, fruit pH and unmarketable fruit yield increased with increasing pruning intensity but number of fruit per plant, marketable fruit yield per plant, total fruit yield per plant and per hectare decreased with increasing intensity of pruning.
Tomato fruit with the highest total soluble solids content was obtained from the treatments that received two truss removals at bud stage.

The treatments where one truss of tomato was removed resulted in increased fruit size, individual fruit dry weight, fruit dry weight per plant and total soluble solids content and free from defects without significant loss of total and marketable yield per plant.

In all the parameters considered, the influence of stage and intensity of truss pruning was thoroughly investigated.

Generally, it was observed that the pruning treatments did not significantly improve the productivity of tomato that was measured in terms of marketable and total fruit yield. On the contrary, truss pruning was found to be effective in improving fruit quality, such as average individual fruit weight, fruit size (fruit diameter), pericarp thickness and total soluble solids. Since, the experiment was conducted for one season at one location, it is difficult to give a clear cut recommendations when and at what intensity the pruning should be effected to regulate fruit size and improve fruit yield and quality. Therefore, it is suggested that further study should be conducted to determine the optimum time and level of truss pruning for different improved tomato varieties in different areas and seasons.

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7. APPENDICES

Appendix Table 1: ANOVA of the effect of stage and intensity of truss pruning on total leaf area per plant

Source of variation	DF	Mean square	F-value
Replication	2	1924105.5	24.06**
Stage	2	2665112.3	33.31**
Intensity	3	69829975.5	873.05**
S×I	6	842063.3	10.53**
Error	22	79980.5	

CV (%) =7.1**, significant at 1% significance level

Appendix Table 2: ANOVA of the effect of stage and intensity of truss pruning on the number of fruit per truss and number of fruit per plant.

Number of fruit per truss				Number of fruit per plant			
Source of variation	DF	Mean square	F-value	Source	DF	Mean square	F-value
Replication	2	0.0000312	0.49ns	Replication	2	0.0000007	0.01ns
Stage	2	0.15138	2353.2*	Stage	2	3.7804007	52573.8*
Intensity	3	10.988	170814**	Intensity	3	113.71	1581395**
S×I	6	0.02	311.37*	SxI	6	0.01586	220.61*
Error	22	0.000064		Error	22	0.0000719	

CV (%) =1.015 **, significant at 1% significance level CV (%) =0.224.

Appendices Table 3: ANOVA of the effect of stage and intensity of truss pruning on fresh weight of individual fruit and dry weight of individual fruit.

Fresh weight of individual fruit				Dry weight of individual fruit			
Source of variation	DF	Mean square	F-value	Source	DF	Mean square	F-value
Replication	2	0.000053	0.48ns	Replication	2	0.000536	1.34*
Stage	2	3.20211	29016*	Stage	2	9.835936	24605.4*
Intensity	3	365.38	3310990*	Intensity	3	3.800669	9507.68*
S×I	6	50.638	458876**	SxI	6	1.6894	4226.17**
Error	22	0.00011		Error	22	0.000399	
CV (%) =3.56				CV (%) =0.034			

ns, *, **, non-significant at 5%, significant at 5% and 1% significance level, respectively.

Appendix Table 4: ANOVA of the effect of stage and intensity of truss pruning on fruit dry weight per plant.

		Fruit dry weight per plant	
Source of variation	DF	Mean square	F-value
Replication	2	0.00198	0.85*
Stage	2	9736.76	41589*
Intensity	3	26632.85	33387*
S×I	6	956.85	408708**
Error	22	0.0023	

CV (%) =3.94*, **, significant at 5% and 1% significance level, respectively

Appendix Table 5: ANOVA of the effect of stage and intensity of truss pruning on number of flower per truss and fruit set percentage.

Number of flower per truss				Fruit set percentage			
Source of variation	DF	Mean square	F-value	Source	DF	Mean square	F-value
Replication	2	0.000586	14.42*	Replication	2	0.00137	2.25ns
Stage	2	0.1580	3886.48*	Stage	2	19.957	32774.5*
Intensity	3	1.77	43536*	Intensity	3	67.81	111367*
S×I	6	0.050	1249.4**	SxI	6	17.33	28469.1**
Error	22	0.00004		Error	22	0.00060	
CV (%) =3				CV (%) =2.93			

*, ** significant at 5% and 1% significance level, respectively.

Appendix Table 6: ANOVA of the effect of stage and intensity of truss pruning on marketable and unmarketable fruit yield per plant.

Marketable fruit yield per plant				Unmarketable fruit yield per plant			
Source of variation	DF	Mean square	F-value	Source	DF	Mean square	F-value
Replication	2	0.000159	8.05ns	Replication	2	0.00000003	1.0ns
Stage	2	0.02378	1203.7*	Stage	2	0.00226	81547ns
Intensity	3	0.07417	3754.8**	Intensity	3	0.00142	51160**
S×I	6	0.000209	10.60ns	SxI	6	0.000063	2275ns
Error	22	0.000019		Error	22	0.00000003	
CV (%) =0.51				CV (%) =7.1			

ns, **, non-significant at 5% and significant at 1% significance level, respectively.

Appendix Table 7: ANOVA of the effect of stage and intensity of truss pruning on total fruit yield per plant and per hectare.

Total fruit yield per plant				Total fruit yield per hectare			
Source of variation	DF	Mean square	F-value	Source	DF	Mean square	F-value
Replication	2	0.0000037	1.21ns	Replication	2	0.000043	6.83ns
Stage	2	0.021	6869.1*	Stage	2	39.926	6261669**
Intensity	3	0.058	19099.4**	Intensity	3	118.147	1853799**
S×I	6	0.000265	86.77*	SxI	6	0.51726	81123.5*
Error	22	0.000003		Error	22	0.0000064	
CV (%) =0.46				CV (%) =0.44			

ns, *, **, non-significant at 5%, significant at 5% and 1% significance level, respectively.

Appendix Table 8: ANOVA of the effect of stage and intensity of truss pruning on fruit diameter and pericarp thickness of tomato.

Fruit diameter				Pericarp thickness			
Source of variation	DF	Mean square	F-value	Source	DF	Mean square	F-value
Replication	2	0.000034	4.30 ns	Replication	2	0.000073	7.38ns
Stage	2	54.855	691588*	Stage	2	0.358	35762.6*
Intensity	3	188.61	2378117**	Intensity	3	4.412	440644*
S×I	6	0.4134	52119.3*	SxI	6	0.2468	24653.5**
Error	22	0.0000079		Error	22	0.00001	
CV (%) =0.67				CV (%) =4.87			

ns, *, **, non-significant at 5%, significant at 5% and 1% significance level, respectively.

Appendix Table 9: ANOVA of the effect of stage and intensity of truss pruning on total soluble solids content and pH.

Total soluble solid				pH			
Source of variation	DF	Mean square	F-value	Source	DF	Mean square	F-value
Replication	2	0.0000534	5.03^{ns}	Replication	2	0.000099	11.35^{ns}
Stage	2	0.02555	2404.49*	Stage	2	0.001967	224.71*
Intensity	3	4.0794	383901*	Intensity	3	1.6569	189200**
S×I	6	0.01125	1059.31**	SxI	6	0.0004	46.24*
Error	22	0.00001		Error	22	0.0000087	
CV (%) =0.86				CV (%) =0.2			

$^{ns, **,}$ non-significant at 5%, and significant at 1% significance level, respectively.