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Effects of Earthing up and Pruning Systems on Post-Harvest Quality of Tomato (*Solanum* lycopersicon)

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Authors' contributions

This work was carried out in collaboration among all authors. Author IKK designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors GOOA and MM managed the analyses of the study. Author GOOA managed the literature searches. Author CTK performed the formatting and aligning of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Tomato is a popular and extensively cultivated vegetable among the economically promising commodities in the horticulture sector in Kenya. It provides a wide variety of nutrients with many health-related benefits. This study investigated the effect of integration of pruning and earthing up on postharvest. The experiments were carried out in a split-plot arranged in a randomized complete block design (RCBD) and in CRD for both field and laboratory work respectively. Fruit yield data was taken after each harvest. The results from the analysis of variance for the effect of factors (earthing up and pruning system) and their combined effect showed that there was a significant effect on the average weight loss percentage and total soluble solids in both cultivations. The treatments had a significant effect on the average weight loss percentage, total soluble solids, and fruit firmness in both cultivations. The highest fruit weight loss percentages were recorded from all stem pruning system with no earthing up. The highest fruit firmness (3.41 N mm^{-1} in cultivation 1 and 3.24 N mm^{-1} in cultivation 2) was recorded from a single stem pruning system and earthing up to 30 cm. The highest total soluble solids (TSS) percentage 6.09 % was recorded in both

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cultivations under a single stem pruning system and earthing up to 30 cm. To improve tomato postharvest, farmers are encouraged to consider triple stem pruning system in combination with earthing up to level 30 cm.

Keywords: Earthing up; pruning system; postharvest; tomato.

1. INTRODUCTION

Tomato (*Solanum Lycopersicon*), is a popular and extensively cultivated vegetable. It is among the promising commodities in horticultural production in Kenya. It is the fourth most popular fresh-market vegetable after potatoes, cabbages, and onions because of its great yield potential and high nutritive value [1]. Over the years, tomato production in Kenya has intensified [2]. Despite numerous benefits from the crop, many challenges are making its production unprofitable in most developing countries especially those in Africa. The challenges faced by producers is seen either in production, postharvest, marketing or a combination of any of them. The purpose of this paper is to look at the challenges that result in postharvest losses and recommend some low-cost intermediate technologies needed to remedy losses.

Postharvest losses, however, have remained high due to a myriad of impediments, key among them being poor cultural practices. Therefore, the postharvest shelf life of tomato could be increased through the application of better cultural practices such as proper pruning system and earthing up level. Earthing up is a technique in horticulture of piling soil around the base of the plant [3]. The technique triggers the initiation of plant roots that come in direct contact with nutrients through a process of interception as it grows [4]. It encourages the development of additional roots and root hair to help improve stem length as well as suckers [5]. Plants absorb nutrients primarily through their roots and therefore good growth and proliferation of the roots are essential in partitioning and set of functional equilibrium [6]. It also improves the distribution of nutrients, water and air circulation which are important in the soil [7].

Quality is established by the characteristics and attributes that are involved in satisfying the demands, needs and expectations of the tomato consumer [8]. Tomato Producers are always concerned with good appearance and few visual defects may affect the quality [9]. Colour appearance, firmness, ripening behaviour and shelf life are the most important factors to retailers and market distributors [10,8].

Consumers, on the other hand, consider good quality tomatoes as those that are, firm, and offer good flavour and nutritive value [11,3]. Many preharvest and postharvest factors influence the composition and quality of tomatoes [12]. These include inherent genetic and environmental factors such as climatic conditions (temperature, light, pollutants) and cultural practices (soil nutrient application, water supply, use of agricultural chemicals, and harvesting methods). The maturity stage at harvest and postharvest handling procedures also affect tomato quality and its maintenance [9].

Tomato flavour depends upon sweetness and sourness and each of them is correlated with the other [13]. It is one of the most important quality attributes to consumers and it frequently influences the purchase of certain fruit types and sources [14]. The flavour is an important attribute of processed tomato and consists of taste and aroma [15,16]. Taste is due to sensations felt on the tongue while aroma is due to the stimulation of the olfactory senses in the nose by volatile organic compounds. Flavour of tomato is largely determined by the sugar estimated by brix and acid composition of the fruit [17]. Estimated brix value is greatly dependent on the amount of nutrients taken up from the soil by the plant. Tomato varieties having a smaller number of locules, higher pericarp, and good firmness are preferred by the consumers. Locules present in tomato fruit play an important role in governing its quality as it is primarily correlated with fruit size [18].

The use of earthing up and pruning systems could potentially aid farmers to attain the utmost achievable postharvest level. However, most of the tomato farmers frequently give less regard to combining earthing up and pruning system. Most efforts have gone towards improving tomato postharvest quality through pruning [19]. Therefore, this study aims at contributing and solving some of these constraints by researching to find out appropriate earthing up level and pruning system for tomato production and postharvest that can be utilized in the future.

2. MATERIALS AND METHODS

2.1 Site Description and Experimental Design

The tomatoes were grown at Chuka University Research and teaching farm for cultivation 1 while cultivation 2 was carried out on a farm at Ndagani within the University neighbourhood. Soils in this area are classified as humic nitisols [18] and they are of volcano origin with basic and ultrabasic igneous rocks.

The study used a split plot experiment in randomized complete block design (RCBD) and replicated three times. Each subplot had six tomato fruits. There were two factors, the pruning system and earthing up. The tomato fruits were collected from four levels of earthing up (no earthing up, earthing up to 10 cm, earthing up to 20 cm and earthing up to 30 cm) and three levels of pruning system (single stem or control level, double stem and triple stem) the treatment were made up by a combination of factor levels resulting to 12 treatments in this study. Where; SS0=Single Stem no x Earthing Up (Control), SS1=Single Stem x Earthing up to 10 cm, SS2=Single Stem x Earthing up to 20 cm, SS3=Single Stem x Earthing up to 30 cm, DS0=Double Stem x no Earthing up, DS1=Double Stem x Earthing up to 10 cm, DS2=Double Stem x Earthing up to 20 cm DS3=Double Stem x Earthing up to 30 cm, TS0=Triple Stem no x Earthing up, TS1=Triple Stem x Earthing up to 10 cm, TS2=Triple Stem x Earthing up to 20 cm, TS3=Triple Stem x Earthing up to 30 cm.

Describe how the postharvest experiment was set up.

2.2 Data Collection

2.2.1 Fruit weight loss percentage

Four tomato fruits were randomly selected and weighed after every harvest in each plot. The initial weight of each tomato was recorded. Thereafter the tomatoes were kept for seven days at room temperature. Final weight was taken and percentage weight loss was determined by dividing the differences between initial weight and final weight over the initial weight as described by [20]. Those that had a small percentage of weight loss were considered best in quality.

$$\text{Weight loss (\%)} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

2.2.2 Colour changes

Four fully matured green tomatoes from each plot were randomly selected, the tomatoes were kept at room temperature. The number of days taken to fully ripen was taken by comparing the change in colour using tomato colour charts according to [21]. Those tomato fruits that took longer period to ripen were considered best in quality since they can stay longer in post-harvest.

2.2.3 Fruit firmness

Four tomato fruits were randomly selected per treatment and their firmness determined using Fruit Hardness Tester (FHP-803). A Fruit Hardness Tester was used to punch the fruit at five locations. Readings were recorded in (N mm^{-1}) and then the average reading was used in data analysis. The quality of fruits was graded based on firmness. Those with 2 N mm^{-1} and beyond were considered to be of high quality according to [19].

Colour 1	Green.
Colour 2	Breaker, definite break in colour <10% of the fruit surface.
Colour 3	Turning, more green than red.
Colour 4	Pink, more red than green.
Colour 5	Light red, trace of green.
Colour 6	Full red.

Fig. 1. Tomato colour chart corresponding to stages of fruit ripeness

2.2.4 Tomato fruit Total Soluble Solid (TSS) º BX

The total soluble solids content of the juice of four randomly selected, table ripe tomato fruits per plot was measured using a hand-held refractometer (0-30% Brix). The fruit surface was cut using a knife, the juice squeezed into the refractometer opening and the refractometer cap replaced. The reading was recorded and the refractometer was cleaned with moist tissue for the next reading. Fruits with a 4-9% Brix were considered to have high quality [14].

2.3 Data Analysis

Data was subjected to the Analysis of Variance using Statistical Analysis System version 9.4 at a probability level of 5 % and where the F-test was significant, Least Significant Difference was used in mean separation.

3. RESULTS AND DISCUSSION

3.1 Effect of Earthing up Levels and Pruning Systems on postharvest Fruit Weight Loss

Analysis of variance for the effect of earthing up and pruning system and their interaction effect showed that the highest percentage of weight loss was recorded in control experiment at 22.97 % in cultivation 1 and 22.95% in cultivation 2 after seven days of post-harvest storage at room temperature. Earthing up to level 30 cm recorded the least average percentage weight loss at 5.03 % and 5.00 % in cultivation 1 and 2 respectively. Fruits weight loss percentage did not vary significantly under different pruning systems in both cultivations (Table 1).

The combined treatment SS0 was not significantly different from DS0 and TS0 that recorded averagely the highest percentage weight loss of 22.96% in cultivation 1 and 22.97% in cultivation 2. Whereas the treatment TS3 was not statistically significant ($P<0.05$) to SS3 and DS3. Treatment TS3 recorded averagely the least percentage weight loss at 5.01% in cultivation 1 and 4.99% in cultivation 2 (Table 2).

Irrespective of the pruning system, earthing up levels significantly influenced percentage fruit weight loss (Table 2). The treatments (SS0, DS0 and TS0) reduced the exposure of tomato roots to moisture at the root zone which would arguably reduce moisture content in the fruits, the significant reduction in moisture content in the fruits may also lead to a negative impact on weight loss percentage. This may explain the increased weight loss percentage in the SS0, DS0 and TS0 as compared to SS3, DS3 and TS3 treatments. Earthing up may have improved nutrient uptake and partitioning in the plant. This enhanced photosynthetic efficiency, which ultimately increased the development of quality tomato fruits pericarp. The quality of the pericarp influences retention of water in the fruit during post-harvest which could potentially lead to reduced weight loss percentage [22]. According to [23], the effectiveness of a thick pericarp in reducing weight loss in fruits has been attributed to its inhibitory effect on both respiration and transpiration.

Table 1. Tomato earthing up and pruning system levels weight loss percentage in two cultivations (2019/2020)

Cultivation	EU	Weight loss (%)	PS	Weight loss (%)
1	EU0	22.97 a*	SS	14.44 a
	EU1	18.12 b	DS	14.58 a
	EU2	11.96 c	TS	14.53 a
	EU3	5.03 d	CV%	5.08
	CV%	5.08	LSD	0.29
	LSD	0.34		
2	EU0	22.95 a	SS	14.53 a
	EU1	17.88 b	DS	14.55 a
	EU2	11.67 c	TS	14.56 a
	EU3	5.00 d	CV%	4.08
	CV%	4.08	LSD	0.24
	LSD	0.27		

**Means followed by the same letter(s) along the column for earthing up and pruning systems are not significantly different at 5 % probability level*

The current results are in agreement with the findings of [24] who studied on preharvest and postharvest factors affecting the quality and shelf life of harvested tomatoes. They observed that a higher percentage of weight loss in tomato was due to thin pericarp development due to nutrient uptake deficit. They further confirmed that excess weight loss accelerates senescence, which may also reduce the fruit shelf life. Similar results were observed by [4] who reported that fruit weight loss is normally due to senescence or desiccation of tomato fruits and is mostly dependent on the transpiration driving force (vapour pressure deficit). Thus, the higher the respiration rate, the faster the water loss and the higher the weight loss. Tomato fruits that lose less weight are more desirable to farmers because they have enhanced postharvest shelf life by maintaining firmness. Calcium ions maintained cell turgor pressure and membrane integrity through stabilizing the plasma membrane by binding to proteins and phospholipids at the membrane surface helps in improving fruit firmness.

3.2 Effect of Earthing up Levels and Pruning Systems on Ripening of Tomato Fruits

The number of days taken to fully ripening at postharvest tended to vary with different earthing up levels and pruning systems. Fruits from the control experiment recorded an average number of 3.00 and 2.96 days in cultivation 1 and 2 respectively (Table 3). Single stem pruning system recorded a higher average number of days 5.16 in cultivation 1 and 5.14 in cultivation 2 compared to the control. The number of days were not significantly (0.05) different for double and triple stem pruning systems in both cultivations (Table 3).

Analysis of the treatment effect showed that treatment SS3 recorded higher average number of days to fully ripen at (7.5) days in cultivation 1 and (7.4) days in cultivation 2. There was not significant ($P<0.05$) differences in the ripening period recorded under treatment DS3 and TS3 in cultivation 1. The fruits from the treatment TS0, SS0 and DS0 recorded the least average number of days to fully ripen in both cultivations as shown in Table 4.

Table 2. Tomato weight loss percentage at different treatments in cultivation 1 and 2

Treatment	Cultivation 1 Means	Cultivation 2 Means
SS0	22.96a*	22.97a
SS1	18.25b	18.34b
SS2	11.85c	11.93c
SS3	5.05d	5.01d
DS0	22.97a	22.93a
DS1	18.05b	18.23b
DS2	12.26c	12.06c
DS3	5.03d	5.01d
TS0	22.96a	22.96a
TS1	18.05b	18.20b
TS2	11.76c	11.95c
TS3	5.01d	4.99d
LSD	0.5947	0.4765
C.V	5.0699	4.0532

**Means followed by the same letter(s) along the column for earthing up and pruning systems are not significantly different at 5 % probability level. Mean separation was done within each cultivation*

Table 3. Tomato fruit ripening period at different earthing up levels and pruning system in cultivation 1 and 2

Cultivation	EU	Days	PS	Days
1	EU0	3.00d*	SS	5.16a
	EU1	4.11c	DS	4.79b
	EU2	5.27b	TS	4.66b
	EU3	7.11a	CV%	11.92
	CV%	11.92	LSD	0.234
	LSD	0.271		
2	EU0	2.96d	SS	5.14a
	EU1	4.05c	DS	4.67b
	EU2	5.23b	TS	4.65b
	EU3	7.05a	CV%	5.086
	CV%	5.086	LSD	0.099
	LSD	0.114		

**Means followed by the same letter(s) along the column for earthing up and pruning systems are not significantly different at 5 % probability level. Mean separation was done within each cultivation*

Table 4. Tomato fruit ripening period at different combined effect of earthing up and pruning systems in cultivation 1 and 2

	Cultivation 1	Cultivation 2
Treatment	Means	Means
SS0	3.3fg*	3.3h
SS1	4.3e	4.2f
SS2	5.5c	5.5d
SS3	7.5a	7.4a
DS0	2.9g	2.8i
DS1	3.7f	3.7g
DS2	5.0d	4.9e
DS3	7.0b	7.1b
TS0	2.6g	2.7i
TS1	4.2e	4.1f
TS2	5.3cd	5.1e
TS3	6.8b	6.6c
LSD	0.47	0.2
C.V	12.04	5.13

**Means followed by the same letter(s) along the column for earthing up and pruning systems are not significantly different at 5 % probability level. Mean separation was done within each cultivation*

The increase in the number of days taken by the tomato fruits in SS3, DS3 and TS3 treatments was apparent due to water and nutrient uptake facilitated by earthing up relative to other treatments SS0, DS0 and TS0. This suggests that tomato had a high level of water and nutrient reserves allocated to the fruits. Earthing up possibly enhanced moisture uptake for root proliferation which minimizes the competition for nutrients in the fruits. The partitioning of nutrients led to the development of quality fruits, therefore, exhibiting longer shelf life [25,26]. The increase in uptake of nutrients and partitioning is also associated with the proper pericarp developments that is important in tomato shelf life [24] The results of the current study are in agreement with the findings of [27] and [4] who found that an increase in tomato nutrient uptake and partitioning significantly delayed the ripening period consequently increasing the shelf life.

[18] and [28] observed that earthing up of potato crop during the active plant growth period improved the soil condition which enabled proper root growth. They indicated that proper root growth enhanced efficient nutrient absorption which facilitated better growth and development consequently increasing fruit quality which can stay long in the post-harvest period. The current results are also in line with the work of [29] who confirmed that earthing up the potato crop after complete plant emergence resulted in better post-harvest shelf life quality. Tomato fruits which take a longer time to ripen in the post-harvest period are more desirable to farmers because they will be able to keep them for a longer period in the market. More absorption of calcium by fruits retards ethylene production, reduces respiration rates, increases firmness, delay ripening, reduce decay and the occurrence of physiological disorders, hence increased postharvest shelf life.

3.3 Effect of Earthing up Levels and Pruning System on Tomato Fruit Firmness

The analysis of the pruning system on the other hand showed double stem plants recording the highest tomato fruit firmness at 2.36 N mm^{-1} in cultivation 1 and 2.18 N mm^{-1} in cultivation 2. There was a significant ($P<0.05$) difference between single stem and triple stem in cultivation 1 (Table 5).

Table 5. Tomato fruit firmness at different earthing up levels and pruning system in cultivation 1 and 2

Cultivation	EU	N mm-1	PS	N mm-1
1	EU0	1.20 d*	SS	2.86 b
	EU1	1.82 c	DS	2.36 a
	EU2	2.86 b	TS	2.33 ab
	EU3	3.40 a	CV%	4.92
	CV%	4.92	LSD	0.04
	LSD	0.05		
2	EU0	1.05 d	SS	2.12 c
	EU1	1.66 c	DS	2.18 a
	EU2	2.27 b	TS	2.16 b
	EU3	3.24 a	CV%	2.07
	CV%	2.07	LSD	0.01
	LSD	0.02		

**Means followed by the same letter(s) along the column for earthing up and pruning systems are not significantly different at 5 % probability level. Mean separation was done within each cultivation*

Combined earthing up levels and pruning system significantly affected fruit firmness. Earthing up to level 30 cm regardless of pruning system (SS3, DS3 and TS3) recorded the highest average fruit firmness compared to (SS0, DS0 and TS0) experiments in both cultivation 1 and 2 (Table 6). Treatment SS1, DS1 and TS1 were not significantly different in both cultivations.The above observation shows that earthing up greatly influences the productivity of tomato trees. This shows that raising soil increases the surface area for the absorption of minerals, water and other elements that enhance growth of the plant. Studies also show that the surface of tomato stem in contact with soil initiates development of adventurous roots and thus improves efficiency in nutrients and water uptake [30,31]. This phenomenon explains the firmness of tomato fruits with earthing up to 30cm as the absorption. When soil is raised above the stem and the root development is initiated the surface area for the nutrient absorption. Reports shows that Tomato firmness is contributed by calcium ion in the cells that improves cell turgor, membrane integrity, and delays membrane lipid catabolism thus extending storage life of fresh fruits [32]. The increased rhizosphere by raising the soil and adventitious roots improves the ability of plant to efficiently utilize the available calcium ion in the growing media. The results showed an increase in significance with an increasing soil height above the stem.

The art of pruning of stems of tomato have been reported to improve C/N [33] removal of the multiple stems and shoots redirect nutrient to the remaining growing parts that improve growth and development of the plant organs. Pruning of plants improves light interception by the leaves this results in improved photosynthetic process by the plants [34]. In addition, the efficient light interception of light by the leaves enhances transpiration resulting in improved absorption of nutrient by the plant from the soil. The mechanism of nutrients absorption by plants is aided by Vapor pressure deficit (VPD) the main driving force of plant water transport and affects the nutrient [35]. Findings of the current study show that fruits harvested from DS were firm compared to TS and SS. The least firmness was observed in SS pruning system, pruning of tomato tree to a SS reduced the surface area for transpiration and this reduced nutrients absorption and moisture, in comparison with DS and TS firmness was higher however TS reported lower firmness than DS. This results might be as a result of improved transpiration but increased nutrients mobilization to the multiple stems. The available nutrient distributed to all stems reduced the amount of accumulated of calcium ion and other nutrient in fruits of TS and therefore reduced turgor pressure.

Table 6. Tomato fruit firmness at different combined effect of earthing up and pruning systems (Treatment effects) in cultivation 1 and 2

Treatment	Cultivation 1 Means	Cultivation 2 Means
SS0	1.07e*	0.96f
SS1	1.82c	1.66c
SS2	2.83b	2.66b
SS3	3.40a	3.23a
DS0	1.30d	1.14d
DS1	1.83c	1.66c
DS2	2.90b	2.69b
DS3	3.40a	3.25a
TS0	1.24d	1.06e
TS1	1.82c	1.66c
TS2	2.84b	2.66b
TS3	3.41a	3.24a
LSD	0.093	0.0371
C.V	4.9526	2.1301

**Means followed by the same letter(s) along the column for earthing up and pruning systems are not significantly different at 5 % probability level. Mean separation was done within each cultivation*

This study revealed that earthing up level 30 cm irrespective of the pruning system influenced tomato fruit firmness. The increase in fruit firmness in treatment (SS3, DS3 and TS3) as compared to their controls (SS0, DS0 and TS0) is due to the effect of nutrient uptake and partitioning. The fraction of mass partitioning to the fruit is influenced strongly by nutrient uptake and fruit sink strength the latter being a product of sink strength of individual fruits and total number [36]. Sink strength qualified as the development of an organ under non-limiting assimilates and nutrient supply in the fruit which optimises the utilization of imported assimilates and nutrients from the soil leading to the development of quality fruits in terms of firmness [25].

Similar results were reported by [37,38] who indicated that the combination of the pruning system and proper nutrition had a positive effect on tomato pericarp development which consequently improved fruit firmness. This observation is also in agreement with the report by [39] who did a study on simulation of dry matter accumulation, partitioning, and yield prediction in processing tomato and found that proper partitioning of nutrients to the fruits enhance quality fruit development [40]. The integration of pruning and earthing up of soil resulted in improvement of nutrients absorption through increased rhizopher and improved transpiration efficiency. It is important to note that fruit firmness affects the susceptibility of tomatoes to physical damage and consequently their shipping ability and postharvest handling [28,29]. Proper earthing up and pruning system therefore, means less competition among the tomato fruits for growth resources such as water, nutrients, and solar radiation. Tomato plants with sufficient fruit firmness are more desirable to the farmers because of their long shelf life during postharvest [41].

3.4 Effects of Earthing Up Levels and Pruning Systems on Total Soluble Solids in Tomato Fruit

Analysis of the effect of earthing up indicated that total soluble solids content had the highest average in earthing up level 30 cm (6.08% in cultivation 1 and 6.10% in cultivation 2) followed by earthing up levels 20 cm,10 cm and finally the control respectively (Table 7). The pruning system (SS, DS and TS) were not significantly different for total soluble solids in both cultivations (Table 7).

The highest average percentage total soluble solids (6.09 % in cultivation 1 and 6.08 % in cultivation 2) were obtained from the treatment SS3. There was no significant difference in SS3 from treatment DS3 and TS3 in cultivation 1 and 2. The total soluble solids under the treatment TS0 were not statistically significant to SS0 and DS0 in cultivation 2. TS0 recorded the lowest total soluble solids percentages at 3.67 % in cultivation 1 and 3.69 % in cultivation 2 (Table 8).

The effect of earthing up levels on total soluble solids was significant irrespective of the pruning system. The treatments SS0, DS0 and TS0 reduced fruit exposure to excess water from the root zone which arguably would increase soluble solid concentrations in the fruits, the significant reduction impacted negatively on the Brix's value. Reduced water uptake from the soil may have potentially led to the decreased uptake and partitioning of essential nutrients that are necessary for the development of soluble solids in the fruits [11]. This explains the reasons for the lower predicted Brix value in the treatments (SS0, DS0 and TS0) as compared to (SS3, DS3 and TS3).

The current results are in agreement with [42], in their experiment on the response of cherry tomato to pruning systems and irrigation rates under greenhouse conditions. The report showed that increase in brix value is attributed to water and nutrient uptake from the soil. This was also in agreement with the findings of [43] and [44] who found that increased nutrient uptake and partitioning through the pruning system increased sugar content in tomatoes. Improved growing condition of tomato plant through manipulation of growth and growing media enhances efficiency in nutrient uptake and photosynthetic processes. Increasing the level of soil and reducing the number of stems enhance uptake and utilization of essentials mineral

Table 7. Tomato total soluble solids (Brix %) at different earthing up levels and pruning system in cultivation 1 and 2

Cultivation	EU	Brix (%)	PS	Brix (%)
1	EU0	3.69 d*	SS	4.75 a
	EU1	4.05 c	DS	4.74 a
	EU2	5.16 b	TS	4.74 a
	EU3	6.08 a	CV%	0.68
	CV%	0.68	LSD	0.01
	LSD	0.01		
2	EU0	3.71 d	SS	4.73 a
	EU1	4.03 c	DS	4.74 a
	EU2	5.11 b	TS	4.73 a
	EU3	6.10 a	CV%	0.83
	CV%	0.83	LSD	0.01
	LSD	0.01		

Means followed by the same letter(s) along the column for earthing up and pruning systems are not significantly different at 5 % probability level. Mean separation was done within each cultivation elements constituents of sugars. This can also be explained based on the sink strength of the fruits in treatment (SS3, DS3 and TS3). The sink strength of fruit is directly linked to its capability to; unload assimilates into the fruit and optimise the utilization and metabolism of imported assimilates [45]. Photosynthetic assimilates (sucrose) unloading from the phloem to the sink is usually facilitated symplastically by water and sugar transporters [45]. For example, sugar transport activities positively correlated with sugar accumulation in pea [35]. Upon transportation into sinks, sucrose can be degraded into glucose, fructose, or other derivatives [46,20].

Table 8. Tomato fruit total soluble solids (Brix %) at different earthing up and pruning systems (Treatment) in cultivation 1 and 2

Treatment	Cultivation 1 Means	Cultivation 2 Means
SS0	3.72f*	3.71d
SS1	4.04e	4.02c
SS2	5.16c	5.09b
SS3	6.09a	6.08a
DS0	3.69f	3.70d
DS1	4.04e	4.03c
DS2	5.15c	5.10b
DS3	6.08ab	6.08a
TS0	3.67g	3.69d
TS1	4.08d	4.04c
TS2	5.16c	5.12b
TS3	6.06b	6.08a
LSD	0.026	0.031
C.V	0.681	0.822

**Means followed by the same letter(s) along the column for earthing up and pruning systems are not significantly different at 5 % probability level. Mean separation was done within each cultivation*

In other research findings [47] reported that storage temperature influences the amount of TSS in a fruit where, at low storage temperature TSS of tomato was lower compared to ambient temperature as well as ripening increasing shelf life. However, reduction of ripening of tomato through calcium application have reported a low TSS content [48]. This finding explain the results where SS3 reported the highest TSS content reduced foliage exposes fruits to the sun and improved nutrient and water uptake by earthing-up contributed to early ripening and higher TSS.

This can also be explained based on the sink strength of the fruits in treatment (SS3, DS3 and TS3). The sink strength of fruit is directly linked to its capability to; unload assimilates into the fruit and optimise the utilization and metabolism of imported assimilates [49]. Photosynthetic assimilates unloading from the phloem to the sink is usually facilitated symplastically by water and sugar transporters [50]. Study shows that sugar transport activities positively correlated with sugar accumulation in pea [51]. Upon transportation into sinks, sucrose can be degraded into glucose, fructose, or other derivatives [46] and [49].

4. CONCLUSION

From the results, it can be concluded that regardless of the pruning system, earthing up tomato to level 30 cm improved the tomato fruit quality by increasing the fruit total soluble solids (TSS) and preserving its firmness. It is therefore worthwhile investing in optimizing growth conditions, i.e. earthing up level 30 cm in combination with triple pruning system.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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