Research Application Summary

Influence of soil moisture levels and packaging on postharvest qualities of tomato

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Abstract

Plants respond to reduced soil water availability without experiencing any detectable change in shoot-water relations. The tomato seedlings (cv. 'Moneymaker') were planted in plastic pots under greenhouse conditions under five different soil moisture levels (20%, 40%, 60%, 80% and 100% of the pot capacity). They were then assessed for postharvest qualities including use of different types of packaging [non-packaged (control), perforated and non-perforated high density polythene bag (HDPE)]. Plant growth and yield were reduced due to moisture stress but postharvest qualities were enhanced. Packaging positively influenced tomato fruit quality and extended tomato shelf life.

Key words: Fruit qualities, packaging, postharvest, soil moisture levels, tomato

Résumé

Les plantes réagissent à la réduction des quantités d'eau disponible dans le sol sans manifester de changement visible dans les relations eau-racines. L'influence du stress hydrique et de l'emballage sur les qualités post-récoltes a été étudiée sur la tomate cultivée (*cultivar* 'Moneymaker') dans des pots en polyéthylène sous 5 niveaux de déficit en eau disponible (20%, 40%, 60%, 80% et 100%) en conditions de serre afin d'identifier les effets d'une irrigation déficitaire sur la croissance et le rendement de la tomate, ensuite et d'évaluer les qualités post-récoltes sous emballages (perforés, non-perforés et non-emballés). La croissance et le rendement avaient été réduits sensiblement sous l'influence de l'eau déficitaire mais les qualités post-récoltes avaient été améliorées. L'emballage a aussi eu d'influences positives sur les qualités de fruits et ainsi prolongé la durée de conservation avant la vente des produits.

Mots clés: Tomate, Niveaux d'eau disponible, Post-récolte, Qualités de fruits, Emballage

Background

Tomato (*Lycopersicon esculentum* Mill) is one of the popular vegetable in the tropical and subtropical regions and plays a vital role in providing a substantial quantity of vitamin C and A in human diet. As a vegetable fruit, it is highly perishable like most horticultural commodities and is often exposed to stresses either imposed by other organisms (biotic) or arising from imbalance of environmental factors (abiotic). Water plays an important role in plant life; it is the limiting factor for agricultural crops production. However, the effects of water deficit differ depending on the developmental stage of the crop (Nuruddin, 2001). Therefore for judicious use of water, attempt should be made to obtain maximum yield with minimum water supply. Plant water status controls the physiological process and conditions which determine the quality and quantity of its growth. Soil moisture deficit usually has morphological effects on the growth of plants, which eventually results in yield reduction. Adequate soil moisture during preharvest periods is essential for the maintenance of postharvest quality. During the growing season, water stress can affect the size of the harvested plant organ, and lead to soft or dehydrated fruit that is more prone to damage and decay during storage (Shewfelt and Prussia, 1993). The objective of this study was to determine the postharvest quality of tomato under varying soil moisture stress (water deficit).

Literature Summary

Postharvest qualities of tomatoes partly depend upon preharvest factors such as cultural practices, genetic and environmental conditions (Meaza *et al*., 2007). Quantitative and qualitative losses occur in tomatoes as in many other horticultural commodities between harvest and consumption. Reduction of postharvest losses can increase food availability to the growing world population, decrease the area needed for production, and conserve natural resources (Kader, 1986). It is important to mention that qualitative losses, such as loss in edibility, nutritional quality, caloric value, and consumer acceptability of fresh produce, are much more difficult to assess than are quantitative losses. According to Kader and Rolle (2004), the principal purpose of packaging is to reduce damage in transport. Packaging protects the produce from mechanical injury and contamination during marketing. It also keeps the produce in a sensibly sized unit for handling and marketing purposes, maintains the fruit weight, minimizes fungal infections, prolongs the product's shelf life and protects the produce from mechanical injury and contamination during marketing.

Study Description

Field experiment. Tomato seeds (cv. 'Moneymaker') were sown in plastic pots (20.32 x 35.56 cm in size) under a polythene covered greenhouse at the Horticulture Research and Demonstration Field, in Egerton University (Kenya). Each pot contained 10 kg of air dried soil (a mixture of sand, top soil and manure at the ratio of 1:2:0.5). Seedlings were watered daily for two weeks in order to allow the root system to develop before initiating treatments Thereafter, plants were subjected to 5 different soil moisture levels (20%, 40%, 60%, 80% and 100% of the pot capacity) until harvesting. Each water treatment was replicated four times and had 6 plants per replicate. Pots were arranged in a randomized complete block design (RCBD) and were covered with black plastic to prevent evaporation. They were put on top of a plastic paper to avoid direct contact with the soil surface. The water amounts were determined based on the percentage of pot water capacity. Data collected included plant height, stem diameter, internode length, transpiration, stomatal conductance, chlorophyll content, leaf temperature, leaf relative water content (LRWC), flower abortion, fruit diameter and number of fruits per plant.

Laboratory experiment. For the postharvest qualities, tomato fruits were harvested at the breaker stage and kept in a cold chamber at a temperature of 21 ± 2 ºC. For each water treatment, 5 fruits arranged in a split-plot under a randomized complete block design (RCBD) were put into 3 packaging treatments (not packaged, perforated package and non-perforated package) to assess the fruit colour change, fruit weight loss, titratable acidity (TA), the total soluble solids (TSS), fruit firmness and the fruit shelf life. The type of packaging used was the polybag, commonly used in the market: high density polythene bag (HDPE: 0.22 x 6.37 cm of size; 0.02 mm of thickness). The polybags were then perforated with a punch (Model: Kangaro Punch DP 520-8cm of 2.5mm punching probe). Fruit colour change was determined using the tomato colour chart (Abdullah *et al.*, 2004). Fruit firmness was determined on 2 fruits per treatment per replication using a hand-penetrometer [Fruit pressure tester, Model: *FT 327* (*1-12 Kg*), with 0.7 x 0.92 mm of probe's size] and was recorded at the equatorial surface for each individual fruit using a destructive technique. 2 fruits per treatment per replicate were used to measure the total soluble solids content by a hand-held refractometer [Model SKU: MT- 032 (Brix, 0-32%)]. Fruit juice (5ml) from 2 fruits per treatment per replicate was titrated with 0.1N NaOH to pH 8.1 using phenolphthalein as an indicator and the percentage titratable acidity (TA) was calculated using the following formula by Monash Scientific (2003):

$$TA\ (g/l) = \frac{T \times M \times 0.75}{V \times 10 \times 0.1}$$

Where, M= Molarity (M) of 0.1M NaOH; V= Volume (ml) of sample and T = Titre (ml) of 0.1 M NaOH.

The fruit shelf life was considered to have elapsed when the fruits lost 75% of their initial weight (Marcos *et al*., 2005) and/or started showing signs of shrivelling and decay. Data collected were subjected to Analysis of Variance (ANOVA) and mean separations were done using Duncan Multiple Range Test (DMRT) at 5% level of significance.

Fruit weight loss. Soil moisture levels had significant effects on the fruit weight. Up to 16 days after harvest (DAH), treatment effects were significant. From 20-24 DAH, fruits harvested from 100% and 80% PC did not exhibit any significant differences in weight (Table 1). The effect of packaging was not significant up to 12 days after harvest (DAH). Weight loss for fruits in non-perforated package was significantly lower compared to the control (non-packaged fruits) at 16 and 24 DAH although there were no significant differences in the weight of fruits packaged in perforated and non-perforated (Fig. 1).

Fruit colour change. Water level treatments significantly influenced tomato fruit colour.Fruits from the 60% PC developed colour at a faster rate compared to fruits from 20% PC at 8-16 DAH (Table 2). Packaging also had an influence on the tomato fruit colour change. Packaged fruits (perforated and non-perforated) exhibited a faster colour change compared to the

Table 1. Influenced of soil moisture level on fruit weight (g) of tomato *cv*. 'money maker'.

Moisture level	Days after harvest						
	0	4	8	12	16	20	24
100% PC	59.13a*	58.05a	57.41a	56.80a	56.25a	55.66a	54.65a
80% PC	54.09b	53.29b	52.76b	52.20b	51.73b	51.30a	50.75a
60% PC	41.30c	40.63c	40.21c	39.79c	39.37c	39.04b	38.61b
40% PC	35.13d	34.56d	34.19d	32.82d	33.44d	33.12c	32.60c
20% PC	27.00e	26.47e	26.15e	25.83e	25.51e	25.24d	24.69d

*Means with the same letter(s) within a column are not significantly different at P≤0.05.

unpackaged fruits at 16 DAH. Control fruits were discarded (Fig. 2).

Fruit firmness. Soil moisture levels had a significant influence on fruit firmness. Fruits from 40% PC were firmer than fruits from 80% PC at 2 DAH (Table 3). Unpackaged (control) fruits were firmer compared to fruits from the non-perforated package at 4-8 DAH, though the differences were not significant in fruits from the perforated package (Table 4).

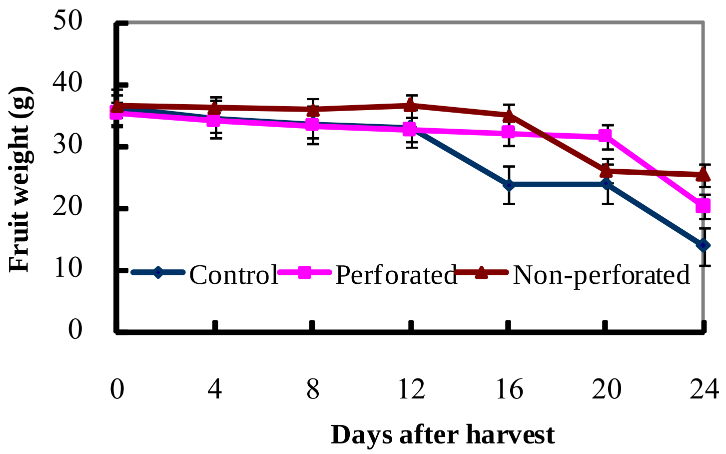

Figure 1. Effects of packaging on weight of tomato fruits.

Table 2. Influence of moisture levels on fruit colour change of tomato *cv.* 'money maker'.

Moisture levels	Days after harvest				
	0	4	8	12	16
100% PC	2.11ab*	3.22a	4.56ab	5.33a	5.11a
80% PC	2.00b	3.00a	3.89ab	4.78ab	5.56a
60% PC	2.22ab	3.33a	4.67a	5.22a	4.89a
40% PC	2.22ab	3.00a	4.00ab	4.33b	4.67a
20% PC	2.33a	3.00a	3.56b	4.11b	3.56b

*Means with the same letter(s) within a column are not significantly different at $P \leq 0.05$.

Fruit total soluble solids (TSS). The highest levels of TSS were observed in fruits from plants subjected to 20% PC. The TSS content in fruits from 20% PC was significantly higher than in fruits from other water levels at 2, 6 and 10 DAH. At 4 and 8 DAH, fruits from 20% PC had significantly higher TSS than those in 100% PC, 80% PC and 60% PC, but not 40% PC (Table 5). Packaging had no influence on the fruit TSS.

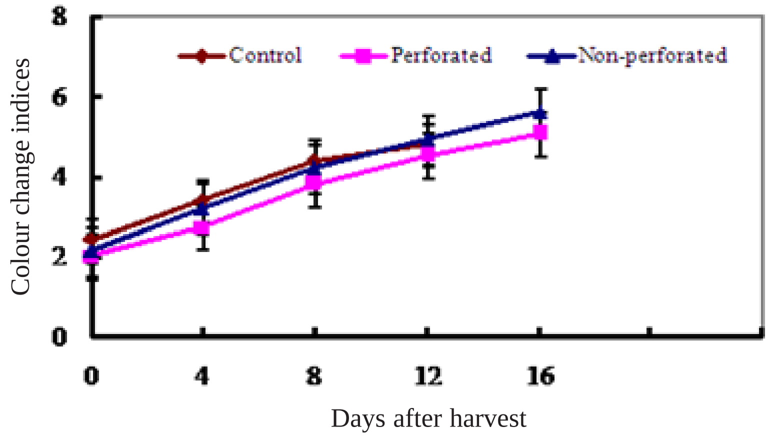

Figure 2. Influence of packaging on tomato fruit colour change.

Table 3. Influence by soil moisture levels on tomato fruit firmness (kgf).

Moisture levels	Days after harvest					
	0	2	4	6	8	10
100% PC	4.16a*	3.61ab	2.82a	3.58a	3.13a	2.57a
80% PC	5.24a	3.56ab	3.56a	3.50a	3.08a	2.69a
60% PC	4.71a	3.26b	3.13a	3.61a	3.89a	3.30a
40% PC	5.09a	4.81a	3.64a	3.66a	3.74a	2.96a
20% PC	4.04a	4.50ab	3.81a	3.42a	3.88a	2.54a

*Means with the same letter(s) within a column are not significantly different at $P \leq 0.05$.

Table 4. Influence by soil moisture levels on tomato fruit firmness (kgf).

Packaging	Days after harvest					
	0	2	4	6	8	10
Control	4.79a*	4.03a	4.13a	4.17a	3.96a	3.17a
Perforated	4.33a	3.84a	3.37ab	3.53ab	4.00a	2.99a
Non-perforated	4.83a	3.97a	2.68b	2.95b	2.69b	2.28a

*Means with the same letter(s) within a column are not significantly different at $P \leq 0.05$

Fruit titratable acidity (TA). Soil moisture levels had significant effects on the fruit titratable acidity. Fruits from 20% PC had the lowest acidity content than the other water treatments at 4 and 8 DAH, though there were no significant differences in fruits from 20% PC and 40% PC throughout the experiment. The highest titratable acidity content was observed in fruits from 60% PC; however, no significant difference was observed in fruits from 100% PC, 80% PC and 60% PC (Table 6).

Significantly lower levels of TA were observed in fruits from the non-perforated bags than in control packages at 10 DAH. Perforated packaged fruits had significantly higher level of TA compared to non-perforated packaged fruits at 2 and 10 DAH (Table 7).

Table 5. Effects of moisture levels on percent total soluble solids of tomato fruit.

Moisture levels	Days after harvest					
	0	2	4	6	8	10
100% PC	4.58bc*	4.48bc	4.63bc	4.43b	4.22b	4.30c
80% PC	4.28c	4.32c	4.38c	4.51b	4.21b	4.31c
60% PC	4.69bc	4.54bc	4.90b	4.67b	4.58b	4.48c
40% PC	5.00ab	4.94b	5.12ab	4.98b	5.11a	5.17b
20% PC	5.34a	5.72a	5.59a	5.94a	5.37a	5.78a

*Means with the same letter(s) within a column are not significantly different at $P \leq 0.05$.

Table 6. Effects of moisture levels on percent titratable acidity of tomato fruit.

Moisture levels	Days after harvest					
	0	2	4	6	8	10
100% PC	9.08ab*	9.98a	7.87a	7.92ab	6.04bc	6.64a
80% PC	8.10ab	9.45ab	8.04a	9.79a	8.88ab	8.80a
60% PC	9.50a	7.95abc	8.04a	8.82ab	7.92abc	8.80a
40% PC	6.36bc	6.08c	7.58a	8.03ab	9.31a	7.10a
20% PC	5.19c	7.25bc	5.01b	7.82b	5.56c	7.57a

*Means with the same letter(s) within a column are not significantly different at $P \leq 0.05$

Table 7. Fruit titratable acidity (%) as influenced by packaging.

Packaging	Days after harvest					
	0	2	4	6	8	10
Control	7.33a*	7.15a	7.13a	8.71a	7.44a	8.74a
Perforated	7.78a	9.06a	7.79a	8.20a	7.56a	8.27ab
Non-perforated	7.82a	8.21a	7.00a	8.51a	7.63a	6.49b

*Means with the same letter(s) within a column are not significantly different at $P \leq 0.05$.

Tomato shelf life. Non-packaged fruits (control) had lost 34.23 % of their initial weight at 16 DAH compared to the packaged fruits (9.06% in perforated and 4.43% in non-perforated packages). At the end of the experiment (24 DAH), unpackaged fruits had lost 61.34% of their initial weight, though no significant difference was observed among the packaging treatment (Fig. 3).

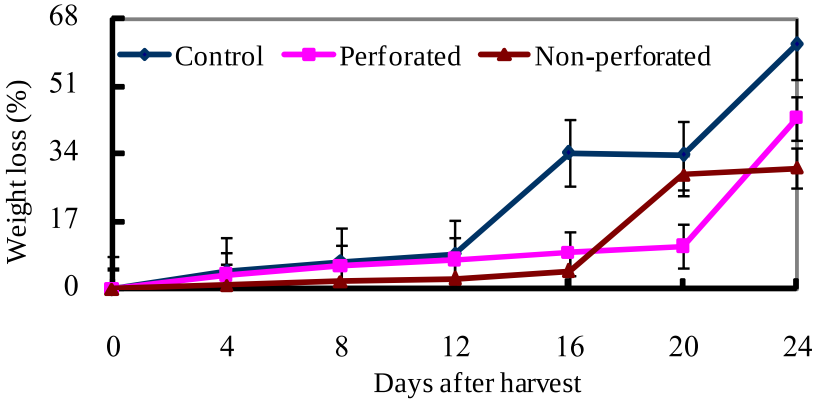

Figure 3. Percentage fruit weight loss of tomato fruits as influenced by packaging.

Discussion

Tomato quality changes continuously after harvesting. Significant differences in fruit weight loss, colour change, fruit firmness, total soluble solids and titratable acidity observed clearly indicate that degradation of fruits commence after harvesting. It is well known that most fresh fruits and vegetables contain so much water (80-90%), thus their quality suffer very quickly from water loss, especially loss of salable weight. Fruit weight loss is normally due to senescence or desiccation of tomato fruits (Batu and Thompson, 1998) and is mostly dependent on the transpiration driving force (vapour pressure deficit: VPD). Thus, the higher the respiration rate, the faster the water loss and the higher the weight loss. According to Abdullah *et al*. (2004), packaging restricts the air movement around the produce, hence minimising fruit weight loss; this may be the reason why the highest percentage in fruit weight loss was observed in unpacked fruits.

In this study, no significant colour change was observed within the first 4 DAH in all the water treatments. Fruits that are harvested at stages prior to full ripeness show an increase in lycopene content during postharvest ripening. Lucille and Grierson (2003) mentioned that at the breaker stage of tomato ripening, lycopene begins to accumulate and its concentration increases. However, ethylene is the dominant trigger for ripening in climacteric fruits, thus it is responsible for initiating fruit ripening and also colour change. The amount of ethylene produced increases with the stage of development, and non water-stressed plants are likely to develop faster compared to water stressed plants and produce more ethylene. This could be the reason why faster colour development was observed in the moderate watered plants.

It has been shown that controlled or modified atmospheres delay fruit ripening at 12.8°C and that modified atmospheres resulting from the enclosure of mature green tomatoes in polyethylene or other forms of plastic packaging may also delay fruit ripening (Harold *et al*., 2007). In contrast, this study demonstrated that colour change was fast in packaged fruits (especially in the non-perforated package). Our results are distinct from the findings of Harold *et al*. (2007) since our tomatoes were harvested at the breaker stage and kept at 21± 2^{o}C. When fruits are packaged, they are initially subjected to stress due to the reduction in O_2. This may result in an initial increase in respiration and ethylene production. Ethylene may accumulate in the package and this accelerates colour change. Polythene packaging has been reported to result in early ripening and colour development in mature green tomatoes and maintains the best physicochemical quality of fruit during storage to marketing (Moneruzzaman *et al*., 2009).

In this study, fruits from the water stressed plants were firmer compared to those from the well watered plants (100% and 80% PC). Generally, when plants are well watered (without stress), the water concentration in their fruits increase and tend to make the fruits softer during the period of storage. This might explain the higher levels of firmness observed in fruits from the water stressed plants. It has been reported by Crookes and Grierson (1983) that as ripening progresses, the cell wall becomes increasingly hydrated and as the pectin riches middle lamella, it is modified and partially hydrolysed. The change in cohesion of the pectin gel governs the ease with which one cell can be separated from another, which in turn affects the final texture of the ripe fruit. This process occurs early at ripening stage in soft fruit such as tomato. Packaging influenced the tomato fruit firmness. Non-perforated packaged fruits were firmer than perforated packaged fruits because MAP inhibits the synthesis and accumulation of cell wall degrading enzymes by slowing down their activities that cause fruit tissue softening. It has been also reported that low oxygen levels in modified or controlled atmospheres inhibit polygalacturonase activity, thus reducing the rate of fruit softening (Kapotis *et al.*, 2004).

This study shows that higher levels of TSS were found in fruits from stressed plants. It has been widely shown that reduced soil moisture and salt stress increase sugar content in tomatoes (Obreza *et al*., 2001; Hanson and May, 2003; Birhanu and Tilahun, 2010). Although water stress resulted in decreased yield in tomatoes, it increased brix values (Shinohara *et al*., 1995). According to Birhanu and Tilahun (2010), the reduction of fruit size under deficit irrigation is mainly attributed to reduction of water, and this may explain why the fruit total soluble solid content is often higher in the stressed plants. The lowest TSS observed in fruits from the well and moderate water stressed plants (100%, 80% and 60% PC) can be attributed to the higher water uptake by the plants and therefore lead to the dilution of the concentration of TSS. In this study, fruit titrable acidity was found to be significantly lower in fruits from plants that had received 20% PC plants and in control (non-packaged) fruits. There is an inverse relationship between the TSS and TA: as the value of sugar content (TSS) increases, that for the acidity (TA) decreases.

Finally, the results of this study confirm that packaging helps in extending tomato shelf life and this complement the findings of Moneruzzaman *et al*. (2009) who suggested that the use of controlled atmosphere for tomato fruit storage would be of considerable benefit for the long-term storage of fruit. Batu and Thompson (1998) have reported the extension of the shelf life by packaging in polyethylene films which slows the ripening process of tomato. Also, MAP results in accumulation of CO_2 and depletion of O_2 around the fruits, which may increase its storage life. According to Nasrin *et al*. (2008), shelf life of tomato can be extended at ambient temperature up to 17 days without excessive deterioration in quality by treating the fruits with chlorine, and packaging in perforated polyethylene bags.

Conclusion

Water levels and packaging significantly influenced the postharvest qualities (fruit weight loss, colour change, fruit firmness, total soluble solids and titratable acidity) and tomato shelf life was extended in packaged fruits. Severe moisture stress improved the tomato fruit quality by reducing the fruit acidity (TA), in increasing the fruit total soluble solids (TSS) and preserving its firmness. From the results of this study, it is concluded that the higher the water content, the higher the fruit weight loss and the faster the fruit losses its firmness and develops fruit colour change faster. Packaging also influenced positively the tomato fruit quality. Reduced weight and firmness, and short shelf life were observed in unpackaged fruits while packaged fruits had developed a faster fruit colour change and increased the fruit total soluble solids.

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