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EFFECTS OF SALINITY ON YIELD AND POSTHARVEST QUALITY OF TOMATO (LYCOPERSICON ESCULENTUM MILL.)

ABDUL-RAQEEB ALI AHMED AL-ERYANI.

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By

ABDUL- RAQEEB ALI AHMED AL- ERYANI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Agricultural Science

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Special dedicated

To

My beloved father and mother

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements of the degree of Master of Agricultural Science

EFFECTS OF SALINITY ON YIELD AND POSTHARVEST QUALITY OF TOMATO (*Lycopersicon esculentum* Mill.)

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Chairman: Associate Professor Dr. Mohd. Razi Ismail, Ph.D.

Faculty: Agriculture

The effects of salinity on the yield and chemical composition of tomato (*Lycopersicon esculentum* Mill.) fruits produced in soilless culture under protected environment were investigated. Two experiments were carried out at Hydroponic Complex, Crop Science Department, Faculty of Agriculture, Universiti Putra Malaysia.

Increasing salinity (EC) from 2 $mScm^{-1}$ (control) to 6 $mScm^{-1}$ linearly reduced total yield, size, firmness and water content of tomato fruits, and dry weights of roots and shoots of plants. The incidence of blossom end rot (BER) was higher at high salinity level as a consequence of deficiency of Ca content, which was found to decrease with increasing salinity levels. On the contrary, high salinity conditions resulted in increasing total soluble solids, carbohydrates (fructose, glucose, sucrose), titratable acidity and ascorbic acid (Vitamin C) concentrations and dry matter content of tomato fruits. The redness (a*) values gradually increased with increasing salinity level from ECs 3 to 6 mSm^{-1}, whereas the lightness (L*) and yellowness (b*) values decreased. These observations indicated that it is possible to obtain a good quality tomato fruits with acceptable yield reduction at EC 4.5 $mScm^{-1}$.

Salinity affected both shelf life of tomato fruits stored at ambient temperature (21°C) or in cool condition (15°C) with relative humidity (RH) between 48-66% and 91-92%, respectively. There was a negative relationship between salinity and fruit shelf life, probably due to an increase in polyglacturonase activity, which enhances softening and hence causes shorter shelf life.

In another experiment, both high (6 $mScm^{-1}$) and moderate (3 $mScm^{-1}$) salinities were applied at different growth stages of plants development. Saline irrigation at EC 3 $mScm^{-1}$ during late developmental stages (onset of ripening) improved the quality of the fruits with acceptable yield reduction (fresh weight, number and size of fruits). In general, maintaining the proper ECs 3 and 4.5 $mScm^{-1}$ appplied at onset of ripening and flowering stages, respectively resulted to in an acceptable yield reductions and high quality products.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains Pertanian

KESAN KEMASINAN KE ATAS HASIL DAN KUALITI PASCA TUAI TOMATO (*Lycopersicon esculentum* Mill.)

Oleh

ABDUL-RAQEEB ALI AHMED AL-ERYANI

February 2004

Pengerusi: Profesor Madya Dr. Mohd. Razi Ismail, Ph.D.

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Kajian ke atas kesan kemasinan terhadap hasil dan komposisi kimia buah tomato (*Lycopersicon esculentum* Mill.) telah dijalankan menggunakan media tanpa tanah di bawah persekitaran terkawal. Dua eksperimen telah dijalankan di Unit Hidroponik, Jabatan Sains Tanaman, Fakulti Pertanian, Universiti Putra Malaysia.

Peningkatan kemasinan (EC) dari 2.0 $mScm^{-1}$ (kawalan) kepada 6.0 $mScm^{-1}$ mengurangkan jumlah hasil, saiz, kekerasan dan kandungan air buah tomato, berat kering akar dan pucuk pokok tomato. Walaubagaimana pun, kejadian reput pangkal buah adalah tinggi pada tahap kemasinan yang tinggi disebabkan oleh kandungan kalsium yang di dapati berkurangan dengan meningkatnya paras kemasinan. Tetapi, keadaan kemasinan yang tinggi di dapati meningkatkan jumlah bahan terlarut, karbohidrat (fruktos, glukos dan sukros), keasidan titrat dan asid askorbik (vitamin C) serta kandungan bahan kering buah tomato. Nilai kemerahan (a*) meningkat seiringan dengan peningkatan kemasinan dari EC 3.0 ke 6.0 $mScm^{-1}$, manakala nilai kejelasan

(L*) dan kekuningan (b*) menurun. Pemerhatian ini menunjukkan kemungkinan untuk mendapatkan kualiti buah tomato yang baik dengan pengurangan hasil yang boleh diterima pada EC 4.5 $mScm^{-1}$.

Kemasinan memberi kesan ke atas jangkahayat buah tomato yang disimpan pada suhu bilik (21 ^{0}C) dan bilik sejuk (15 ^{0}C) dengan kelembapan relatif (RH) masing – masing 48-66% dan 91-92%. Perhubungan negatif ditunjukkan di antara kemasinan dengan jangkahayat buah tomato, berkemungkinan disebabkan oleh peningkatan aktiviti polygalacturonase, yang meningkatkan kelembutan isi buah dan menyebabkan jangkahayat yang pendek.

Dalam eksperimen yang berasingan, kedua-dua kadar kemasinan tinggi (6.0 $mScm^{-1}$) dan sederhana (3.0 $mScm^{-1}$) telah diberikan pada peringkat tumbesaran yang berbeza. Pengairan dengan kadar kemasinan 3.0 $mScm^{-1}$ pada akhir peringkat pembentukan buah (permulaan kemasakan) meningkatkan kualiti buah walaupun hasilnya berkurangan. Pada amnya, pengekalan kadar kemasinan 3 dan 4.5 $mScm^{-1}$, pada peringkat permulaan kemasakan buah dan peringkat pembungaan boleh menghasilkan buah yang berkualiti tinggi dengan pengurangan hasil yang boleh diterima.

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I certify that an Examination Committee met on 12th February 2004 to conduct the final examination of Abdul Raqeeb Ali Ahmad Al Eryani on his Master of Science thesis entitled "Effects of Salinity on Yield and Postharvest Quality of Tomato (*Lycopersicon esculentum* Mill.)" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Agriculture Science. The members of the Supervisory Committee are as follows:

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DECLARATION

I here by declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

ABDUL– RAQEEB ALI AHMED AL– ERYANI

Date: 05 APR 2004

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INTRODUCTION

In drought areas where water resources are limited, poor quality water is increasingly being used, although such irrigation water is one of the major sources of salinity, which may result in crop yield reductions and soil degradation (Oster, 1994). In countries like Yemen, drought and salinity are prevalent especially in coastal areas and ground water that contains high concentrations of NaCl is being used by farmers for irrigation. However, the use of such water leads to long-term environmental problems such as permanent soil salinization and soil degradation. Likewise, the usage of saline water induces an effect that results in reduced crop yield and quality. Salinity reduces the relative growth rate of plants and restricts leaf expansion.

Tomato is a widely distributed annual vegetable crop which is consumed fresh, cooked or processed such as canning, juice, pulp, paste or a variety of sauces (FAO, 1995). In Malaysia, tomato is mostly cultivated in highlands such as Cameron Highlands. Local farmers successfully cultivate high temperature resistant tomato variety. Presently, cultivation of tomato under protected conditions is being attempted and problems such as salinity were prevalent either due to the use of nutrient solutions or environmental contamination of land by sources of salinity.

In today's world market, fruit flavour is of paramount importance to guarantee consumer satisfaction. Tomatoes grown under saline conditions produce fruits with a higher content of sugars and organic acids, which contributes to improved market quality of the fruit. However, significant increase in total solids (TS) and total soluble solids (TSS) of fruits produced by salinized plants can compensate for the reduction of fresh yield when the yield is expressed on a dry weight basis (Ehert and Ho, 1986; Mizrahi *et al.*, 1988; Gao *et al.*, 1996).

Tomato plants which grow under salinity conditions may have a good quality characteristics that may improve the taste without reducing other quality aspects. However, tomato fruits developed under salinity conditions tend to have tough skin and enhanced wax layer of the skin that gives good appearance and reduces water loss. These characteristics may help to maintain longer shelf life during handling and under storage. Therefore, regulating the salinity level may be of much benefits for exporting, industrial processing or fresh marketing of the fruits. Though a few work had been done on the effect of various salinity levels on post-harvest quality and storability of tomato, not much works were being done on the imposition of salinity at different phenological stages of the plants. Hence, the objectives of this study are to determine the effects of different levels of salinity on yield, postharvest quality and storability of tomato and improvement of yield and quality by manipulating salinity levels at different phenological stages of plant.

CHAPTER 2

LITERATURE REVIEW

2. 1 Tomato

Tomato belongs to the genus *Lycopersicon* and *esculentum* is the species mostly grown for its edible fruit. The genus *Lycopersicon* of the family Solanaceae is believed to have originated from Latin America between Mexico and Peru. The tomato crop is adapted to a wide range of climates from the tropics to within a few degrees of the Arctic Circle. However, its broad adaptation, production is concentrated in a few warm and rather dry areas: more than 30% of world production comes from countries around the Mediterranean Sea and about 20% from California (Taylor, 1986; Papadopoulos, 1991).

2. 2 Tomato Handling and Postharvest Process

Successful postharvest handling of vegetable crops requires careful coordination and integration of the various steps from harvest operations to consumer in order to maintain the initial product quality. Horticultural quality refers to those characteristics which are associated with consumers for each commodity that are dependent upon the particular end use, such as sweetness in strawberries and melons, tenderness in snap beans and sweet corn, and crispness in carrots and celery. Quality also refers to freedom from defects such as blemishes, mechanical injury, physiological disorders, decay and water loss. It is important to keep in mind those quality losses for fresh vegetables are cumulative: each incident of mishandling reduces final quality at consumer level (Sargent *et al.*, 1995).

Several factors that reduce quality during postharvest handling, including:

- Harvest at the incorrect maturity stage
- Careless handling at harvest and during packaging and shipping
- Poor sanitation
- Delays to cooling or sub-optimal cooling
- Shipping/storage above or below optimal temperature
- Lack of proper relative humidity
- For some commodities, exposure to ethylene gas.

Numerous technologies and procedures can significantly reduce quality losses during handling. These include the use of drying, curing, temperature conditioning, disinfestation (for exports/imports), ethylene treatment, application of surface coatings, sanitation treatments, controlled atmosphere storage, shipping and modified atmosphere packaging. Two of the most important means for maintaining vegetable quality during postharvest handling are minimizing mechanical injury and managing temperature. Proper handling and temperature management will significantly reduce losses due to decay and accelerated senescence. With vegetables typically being handled several times from harvest to retail level, it is critical that personnel at each step be properly trained and supervised (Sargent *et al.*, 1995).

Fruit ethylene production is associated with colour development and this natural hormone is also involved in fruit softening. Ethylene application can be used to accelerate colour development and fruit softening when provided at or slightly beyond the mature green stage. Ethylene gas (100-150 ppm) is usually applied to the fruit in a sealed ripening room. The best ripening response to ethylene occurs at a temperature of 20-21° C and 85-90% RH for 12-24 h (Sargent *et al.*, 1995).

Fruit deterioration because of excessive softening is a major reason for marketable losses. Rough handling, poorly designed containers and exposure to hot and dry conditions also contribute to significant losses (Sargent *et al.*, 1995).

At many fresh market tomato-packaging facilities, fruit are washed in chlorinated water to remove dirt and to limit postharvest diseases. When cold washwater is used, postharvest decay often increases because of contaminated water entering the fruit through the stem scare. However, when the washwater is equal to or warmer than the fruit temperature, contaminated water is not drawn into the fruit (Rubatzky and Yamaguchi, 1997).

Fresh market fruit are graded for uniform size and quality before packaging; in some facilities this is accomplished mechanically. Occasionally, fruit are waxed to reduce moisture loss and improve appearance (Grierson and Kader, 1986; Rubatzky and Yamaguchi, 1997).

2. 3 Storage Requirements

Horticultural crops may be grouped into two broad categories based on sensitivity to storage temperatures. However, the degree of chilling sensitivity for the lowest safe storage temperature is crop specific. Those crops, which are chilling sensitive, should be held at temperatures generally above 50°F (10°C). Storage below this threshold will give rise to a physiological disorder known as chilling injury. Chilling injury symptoms are characterized by development of sunken lesions on the skin, increased susceptibility to decay, increased shrivel and incomplete ripening (poor flavour, texture, aroma and colour). Those crops that are not sensitive to chilling injury may be stored at temperatures as low as 32°F (0°C). The extent of chilling symptoms is also dependent on the length of exposure to low temperatures. Short exposure times will result in less injury than longer exposure to chilling temperatures (Sargent *et al.*, 1995).

2. 4 Tomato Storage

Tomatoes can be stored successfully for several weeks, but recommended storage temperatures differ with stage of fruit maturation. When mature green fruit are stored, temperatures should be between 13° C and 18° C and 85-95% RH. At these temperatures, chilling damage does not occur, but colour development is slow. The optimum temperature for ripen mature green fruit is between 18° C and 21° C; below 13° C, fruit will not develop a dark red colour. Mature green fruit have been stored for 6 weeks at 13° C in 3% oxygen, 97% nitrogen atmosphere, and upon ripening, there was no noticeable flavour or other quality impairment (Rubatzky and Yamaguchi, 1997).

Red fruit have a shorter shelf life at room temperature but can tolerate storage at lower temperatures than mature green fruit. Firm red fruit can be held at 7-10° C for several days without significant quality losses. For ripe fruit, temperatures less than 7° C will cause chilling damage and the fruit loses firmness, flavour and shelf life. Chilling injury is cumulative and increases with length and level of low temperature. Red fruit can be stored as long as 3 weeks at 0-1.5° C in acceptable condition. However, fruit should be used within a day or two following removal from storage because flavour and textural quality becomes unacceptable. The usual recommendation for red fruit to maintain quality is to avoid low temperature exposure (Rubatzky and Yamaguchi, 1997).

2. 5 Salinity and Soil Salinity

Over the course of history, thriving civilizations declined in part due to their inability to sustain food production on lands that had been salinized. It is estimated that 10 million hectares are now being lost every year as a result of salinity and water logging (El-Haddad *et al.*, 1998).

Excessive use of water for irrigation due to inefficient irrigation distribution systems, poor on-farm management practices and inappropriate management of drainage water causes many of these problems. Inefficient on-farm irrigation practices cause local salinity problems. These problems increase as a result of poor on-farm drainage. Excessive irrigation increases salt loading in water tables and downstream aquifers, which causes regional salinization. Lack of these local and regional drainage systems result in lands being put out of agricultural production (El-Haddad *et al.*, 1998).

Salinity is a threat to the health and productivity of many catchments, and to the rural and urban communities that live on them. It is affecting rural landholders, urban developments, infrastructure (roads and bridges), water users and the environment. In some places, salinity is a natural phenomenon but in others, increasing salinity caused by rising water tables is often the result of particular land use practices, such as over-clearing, urban development, river regulation, irrigation or the cultivation of crops. Salinity from rising watertables is grouped into dryland, irrigation and urban salinity. River salinity and industrial salinity can be observed as related phenomena. Dryland salinity is the build up of salt in the soil surface in non-irrigated areas, usually as a result of a rising watertable. Irrigation salinity is caused by over irrigation, inefficient water use and poor drainage (NSW Department of Land and Water Conservation, 1998).

Soil salinity is a measurement of the total amount of soluble salt in soil. As salinity levels increase, plants extract water less easily from soil, aggravating water stress conditions. High soil salinity can also cause nutrient imbalances, result in the accumulation of elements toxic to plants, and reduce water infiltration if the level of one salt element-sodium is high. In many areas, soil salinity is the factor limiting plant growth. Salt-affected plants are stunted with dark green leaves, which in some cases are thicker and more succulent than normal. In woody species, high soil salinity may lead to leaf burn and defoliation. High salinity causes alfalfa yield to decrease while the leaf-to-stem ratio increases, influencing forage quality. Grasses also appear dark green and stunted with leaf burn symptoms (Kotuby-Amacher *et al.*, 2000).

In most instances, dryland salinity is caused by saline groundwater seeping to the surface of the land. It impacts are on soil quality and water resources, depleting their utility and environmental value. Salinity is usually evident after water tables reach within 1.5 or two meters of the surface when shallow saline groundwater, drawn up by capillary action, is further concentrated by evaporation (Ailie, 2000).