THE EFFECT OF POTASSIUM FERTILIZER ON YIELD AND QUALITY OF PROCESSING TOMATOES.

By

Muhannad Jawdat Al-Azizi

Supervisor

Dr. Mahmoud Kasrawi

عميد كلية الدراسات العليا

Co-Supervisor

Dr. Butros Hattar

Submitted in Partial Fulfillment of the Requirement for the

Degree of Master of Science in

Horticulture Science

Faculty of Graduate Studies

University of Jordan

December 1998

Committee Decision

This thesis was successfully defended and approved on December 23ed, 1998.

Examination Committee | Signature

Dr. Mahmoud Kasrawi / Chairman
Prof. of Plant Breeding

Dr. Butros Hattar / Member
Assoc. Prof. of Soil Fertility

Dr. M. A. Suwwan / Member
Prof. of Vegetable Production and Physiology

Dr. Thabet F. Allawi / Member
Assoc. Prof. of Biological Control and Acarology

Dr. Rida A. Shibli / Member
Assoc. Prof. of Plant Tissue Culture and Physiology.

Dedication

To whose giving dose not cease

my Father and Mother

To my Brothers and Sisters

With love

Acknowledgement

I would like to express my thanks to my supervisor Prof. Mahmoud Kasrawi for his support and help in my research and my thanks to Dr. Butros Hattar for his support. A special thanks for committee members Prof. M. A. Suwwan, Dr. T. Allawi and Dr. R. Shibli.

A special thanks to my colleagues for their help and to every one who help in this study.

List of Contents

List of Tables

List of Appendices

Abstract

The Effect of Potassium Fertilizer on Yield and Quality of Processing Tomatoes

By

Muhannad Jawdat Al- Azizi

Supervisor

Dr. Mahmoud Kasrawi

Co-supervisor

Dr. Butros Hattar

Tomato *Lycopersicon esculentum* is the most important vegetable crop in Jordan. An openfield experiment was conducted at University of Jordan Research Station in Jordan Valley for seasons 1997 and 1998. Three cultivars used ('Faridah' , 'Wafa' and 'Guardian') and four potassium fertilizer levels (0, 50, 100, 150 Kg K_2SO_4 / ha.) were used

Application of potassium fertilizer increased tomato early yield, total yield, total soluble solids, titratable acidity, dry weight, leaf potassium content and fruit potassium content, but did not affect fruit firmness, specific gravity, pH, juice yield, and juice color in 1997 season. In the 1998 season, potassium fertilizer application increased tomato fruit yield, total soluble solids, dry weight, juice titratable acidity, juice color, leaf potassium content and fruit potassium content in all sampling dates

except color in date 1 and leaf potassium content in date 3. Potassium fertilizer application decreased juice pH, but did not affect fruit number per plant, juice yield , fruit firmness and fruit specific gravity in all sampling dates. The higher yield and best quality was achieved at 100 Kg K_2SO_4 / ha.

'Faridah' has lower pH in 1997 and lower yield and fruit and leaf potassium content in 1998. 'Guardian' has higher pH and lower juice color, fruit firmness and juice yield in 1997, higher leaf potassium content in 1998.

1. Introduction

Tomato (*Lycopersicon esculantum*, Mill.) belongs to the *Solanaceae*. It is originated from Mexico and Central America and then distributed all over the world (Mas, 1983). Tomato is one of the most important vegetable crops worldwide. The world planted area in 1994 was 2850 thousand hectares with a production of 7754 thousand tons (FAO, 1994). In Jordan, tomato is the leading vegetable crop; the planted area in 1995 was 11104.6 hectares with total production of 439736 tons (Annual Agricultural Statistics, 1995). This high production of tomatoes includes fresh market, processing and export.

Specific gravity of the fruit, juice yield, total soluble solids, pH, titratable acidity and juice color of tomato fruits are important parameters that contribute to processing quality. Consumer acceptance, nutritive value and expiry period are affected by quality of processing tomato. Also prices of processing tomato depend on total soluble solids and fruit appearance.

Several factors affect tomato quality such as cultivar, climatic conditions and cultural practices including fertilization. Fertilization process has many benefits incluuding increase of yield, improvement of crop quality and compensating the consumed nutrient minerals in rotation programs. Potassium fertilizer is mostly related to quality factors where it affects total soluble solids, titratable acidity and juice color in tomato in addition to the positive effect on yield.

Since no studies were reported on potassium effect on processed tomato under local conditions, this work was carried out to study the effect of potassium fertilizer on the productivity and fruit quality of three processing tomato hybrids. Quality parameters included: total soluble solids, titrable acidity, juice pH, juice yield, juice color, fruit firmness, and fruit specific gravity.

Among plant nutrients, potassium is mentioned most often in relation to crop quality. Potassium deficiency caused premature dropping and poor coloration of tomato fruit and relatively poor keeping quality of various fruit and vegetable crops (Black, 1967).

Jolly *et al.* (1988) and Szlek *et al.* (1990) reported that potassium deficiency can induce Fe chlorosis in soybean and tomatoes due to a specific role of potassium in Fe availability at the roots through hydrogen ion efflux. Brady *et al.* (1968) mentioned that stomata guard cells gain turger pressure by importing potassium into the cells and the plants deficient in potassium has lower transpiration.

2.2 Yield:

Extra NPK fertilizer applied at the rate of 142-83-158 pounds per acre to the high fertility level plots increased tomato yield 12% in tomato(Vittum *et al.*, 1962). Potassium fertilizer at the levels of 50, 200, and 350 ppm K_2O in the nutrient solution had little effect on greenhouse tomato yield, which is attributed to the high potassium level in the substrate (65% compost + 35% perlite) (Tsikalas and Manios, 1985).

Kolota and Orlowski (1984) reported that the vigorous plant growth and the highest tomato yield were obtained from plants receiving K_2O at 400 mg/liter soil. However, increasing potassium fertilizer from 90 to 135 Kg/ha caused significant tomato yield increase (4%-24%) at three of the four sites of the experiment with extractable soil K less than 125 mg/Kg; no yield response was observed at the five sites with greater soil potassium supply (Hartz *et al.*, 1996). Also where potassium fertilizer was not applied, potassium deficiency symptom was apparent and tomato yield was reduced (Orphanos and Papadopoulos, 1980).

Eid (1991) reported that the highest tomato fruit yield was obtained when plants were fertilized with 200 Kg N + 64 Kg P_2O_5 + 72 Kg K_2O per faddan (Faddan = 4.2 dunums) which is the highest level used of NPK fertilizer. Other researchers reported that the most favorable fertilization for high tomato yield was the highest level of K at the rate of 166 g K/m² which delayed ripening (Varis and George, 1985).

On the contrary, others showed that the early yield of tomato was depressed by the lowest and the highest levels of potassium (10 and 800 mg K/ liter, respectively) in the nutrient solution (Adams and Grimmett, 1986). Kattan *et al* (1957) reported that the different treatments of fertilizer (including potassium fertilizer at 100 and 200 lb. /acre, lb = 0.45 Kg, acer = 4 dunums) did not affect tomato yield. The K:N ratio increase from 14:1 to 2:1 in the fertigation solution had no significant effect on early or total yield of tomato, with no significant differences in early and total yield between cultivars used (Papadopoulos and Khosla, 1993).

2.3 Total soluble solids:

The increase in total soluble solids improved tomato quality, and increased paste production per unit juice. Extra NPK fertilizer applied at the rate of 142-83-158 pound per acre (pound = 0.45 Kg, acre = 4 dunums) significantly increased the soluble solids of tomato fruits (Vittum *et al.*, 1962). Soluble solids of tomato fruits was increased significantly with increasing potassium fertilizer from zero to 93 Kg K/ha, but no further significant increase occurred with higher K rates (Picha and Hall, 1982). Total soluble solids was increased by the application and increasing application rates of potassium fertilizer in nutrient solution and in irrigation systems (Adams *et al.*, 1978; Rao, 1994).

On the contrary, Hartz *et al.* (1996) found that tomato fruit soluble solids content was not affected by potassium fertilization up to 135 Kg/ha at any site used in the experiment. Kattan *et al.* (1957) indicated that total soluble solids of the processed tomato products did not seem to be related to any fertility factor and a rather wide range of application of potassium (100-200 lb./acre, lb = 0.45 Kg, acre = 4 dunums) failed to exert any significant effect on the total soluble solids of the fruit. Picha and Hall (1982) reported that different cultivars differ significantly in total soluble solids.

2.4 Titratable acidity:

Increasing titratable acidity in tomato fruits improves the flavor of processing tomato. It was found that the increase of NPK fertilizer level to 200 Kg N+ 64 Kg P_2O_5+ 72 Kg K_2O / Faddan (Faddan = 4.2 dunum) led to significant increase in tomato fruit vitamin C and titratable acidity (Eid, 1991). Similar results were found by Vittum *et al.* (1962). Titratable acidity of tomato juice increased with increasing potassium rate from zero to 744 Kg/ ha (Picha and Hall 1982). Increasing potassium fertilizer in the nutrient solution and in the irrigation systems resulted in a significant increase in tomato fruit titratable acidity (Adams and Grimmett, 1986; Rao, 1994). However potassium was an important factor related to acidity in the locular tissue and the entire fruit of tomato (Mahakun *et al.*, 1979). There were significant differences in tomato juice titratable acidity between different cultivars (Picha and Hall, 1982).

2.5 Juice pH:

Reducing pH of tomato juice improved fruit quality which affects microorganism activity. Vittum *et al.* (1962) showed that the extra NPK fertilizer at the rate 142-83-158 pound/ acre (pound = 0.45 Kg, acre = 4 dunums) had no apparent effect on tomato juice pH. Pericarp pH of tomato fruit did not change with increasing potassium fertilizer up to 186 kg / ha but decreased at potassium rate above 186 kg / ha (Picha and Hall, 1982). In another study, potassium fertilizer up to 200 lb. K_2O/ acre (lb = 0.45 Kg, acre = 4 dunums) did not affect pH of tomato fruit juice (Kattan *et al.*, 1957).

Potassium was an important factor related to acidity in the locular tissue and the entire fruit of tomato; whereas phosphorus was related to buffering activity in the pericarp tissue and the entire fruit (Mahakun *et al.*, 1979), and they found that there was a negative correlation between titratable acidity and pH

2.6 Juice color:

The development of red color in tomato fruit during ripening is mainly due to the synthesis of carotenoid pigments particularly lycopene (Trudel and Ozbun, 1971). They also reported that lycopene content of tomato juice was increased with increasing potassium concentration in the nutrient solution up to 8 meq/ liter with a slight decrease when concentration was increased to 10 meq K/liter. Blotchy ripening is a disorder that involves the failure of the inner pericarp tissue of the tomato fruit to color and soften normally during ripening (Dick and Shattuck, 1987), and they found that potassium treatment markedly reduced the incidence of blotchy fruit of tomato where satisfactory pericarp color for whole pack production can only be obtained when the potassium fertilization regime exceeds 500 kg K_2O /ha. Similar results were found by

Picha and Hall (1981). High nitrogen levels significantly increased the incidence and severity of blotchy ripening and high potassium up to 8 meq K/ liter improved tomato fruit color (Cotter, 1961). On the other hand, extra NPK fertilizer at the rate 142-83- 158 pound /acre shifted the tomato juice color toward a redder hue in the first year and in the second year; NPK fertilizer applied at the rate 158-80-152 pound /acre (pound = 0.45 Kg, acre = 4 dunums) increased tomato juice color but this increase was not significant (Vittum *et al.*, 1962). In contrary, tomato fruit color was unaffected by potassium fertilization up to 135 Kg/ha at any site used in the experiment (Hartz *et al.*, 1996). Kattan *et al.* (1957) found that different cultivars significantly differ in tomato juice color.

2.7 Firmness:

Firmer fruits gave better quality than softer fruits. Firmer fruits tolerate the handling, transport and other physical adverse conditions. Huett (1986) found that the nutrient solution of low nitrogen (1.64 mM) and low potassium (0.64 mM) treatment produced the softest tomato fruit while, high nitrogen (16.14 mM) and high potassium (3.26 mM) treatment produced the firmest fruits. On the contrary, Kattan *et al.* (1957) reported that the potassium fertilization did not affect the firmness of raw tomato fruits. Kasrawi *et al.* (1981) reported that fruit firmness varied significantly between some of the tomato cultivars where 'Cal-J-TM' has the higher firmness and 'Joran Blood' has the lowest firmness. These cultivars were grown under rianfed conditions and irrigated conditions the plants grown under rainfed conditions has firmer fruits than those under irrigated conditions.

2.8 Leaf and fruit potassium content:

It was reported that potassium contributed about 85% of the cation accumulation in tomato fruit tissue, which increased by water deficiency (Mitchel *et al.*, 1991). The potassium content of both tomato fruits and petioles was increased with increasing concentration of potassium up to 10 meq K/liter in the nutrient solution (Trudel and Ozbun, 1971). However, they observed that the ratio of the potassium content of the fruit to that of the petiole generally decreased with increasing concentration of potassium up to 10 meq K/liter in the nutrient solution. Potassium fertilizer at 40 and 80 gm K_2SO_4 /plant increased the concentration of potassium in the tomato leaves (Orphanos and Papadopoulos, 1980). On the other hand, the potassium content of the tomato fruit juices increased with the potassium fertilizer applied up to 400 gm /m^2 by base dressing (Adams *et al.*, 1978).

2.9 Dry weight percentage:

The dry matter content of tomato fruit as a percentage of fresh weight increased at the higher salinity level (Gough and Hobson, 1990). Reducing potassium fertilizer concentration from 3.26 mM to 0.62 mM in the nutrient solution reduced tomato fruit dry weight significantly from 5.82% to 5.47% (Hutte, 1986). Dry weight of the tomato fruits was higher at 372 and 744 Kg /ha than zero and 93 Kg /ha (Picha and Hall, 1982). Dry matter content of tomato fruit increased with potassium concentration in the nutrient solution increase up to 800 mg K/liter (Adams and Grimmett, 1986).

2.10 Specific gravity and juice yield

Specific gravity and juice yield were reported as quality parameters, which have high heritability and genetic advance (Kasrawi and Amr, 1990). Tomatone treatment reduced fruit specific gravity due to puffiness which resulted from empty or partially filled locules (Maslamani and Suwwan, 1987). Plant density did not affect tomato fruit specific gravity (Shibli and Suwwan, 1987). Differences in specific gravity of tomato fruits were found between those harvested early and late in the growing season (Nettels, 1950). Significant differences among some cultivars tested for specific gravity were reported (Suwwan, 1989, Suwwan and Abu-baker, 1986).

3. Materials and Methods

3.1 Location

This experiment was conducted during the growing seasons of 1997 and 1998 at the University of Jordan Research Station located in the central region of Jordan Valley, 32N latitude, 35-30 longitude and 250 meter below sea level.

3.2 Experimental design

A split-plot arrangement in a randomized complete block design with three replicates was used. Potassium applied as K_2SO_4 in four levels of 0, 50, 100 and 150 kg K_2SO_4/ hectare were assigned as the main plots, and three processing tomato hybrids 'Faridah', 'Wafa' and 'Guardian' were used as subplots. These cultivars are widely planted in Jordan . Seeds of these hybrids were obtained from Eastern Company, Jordan Valley Company and Agricultural Material Company, respectively. Potassium fertilizer was added as potassium sulfate through the drip irrigation system. Fertilizer added in four times at fifteen days interval starting from flowering time.

3.3 Land selection

There were three fields in the research station. To select one of the lowest potassium content, six soil samples were taken, two from each field. Samples were taken from two depths: 0-15 and 15-30 cm. The field with the lowest potassium content was chosen for the experiment and has the following characteristics:

Soil texture: Loamy sand (sand 75% , silt 12.5% , clay 12.5%)

P : 50 ppm , $CaCO_3$:16.4% , pH: 7.5 , E.C. : 2.21 mmhos/cm

Organic matter :0.324 % , available potassium: 139 ppm.

3.4 Land preparation

The land was plowed by moldboard then harrowed by chisel plow. Raised beds at a width of one meter in the year 1997 and half meter in the year 1998 were prepared. Diammonium phosphate (20-45-0) was added at the rate of 500 kg/hectare before planting. Drip irrigation lines and black plastic mulch were applied on the raised beds.

On January 5th 1997, the seeds were sown in the speedling trays, then transplanted to the field in February 20th with plant spacing of 1.5m between rows and 0.35m between plants within a row. In the year 1998 the seeds were sown in the speedling trays in December 20th 1997, then transplanted to the field in February 4th, 1998 with plant spacing of 0.75m between rows and 0.35m between plants within rows.

3.5 Cultural practices

Irrigation was applied depending on the climatic conditions and total water amount added was about 10000 m^3/ ha. Nitrogen fertilizer was applied as urea at a rate of 270 Kg/ha during the season. 'Tachgaren'(Hymexazol), 'Rimiltin'(Cymoxanil, Copper and Mancozeb) and 'Evesect'(Thiocyclam) pesticides were used to control fusarium welt, blights and white fly, respectively. Weed control was done manually when needed.

3.6 Measurements

-Soil analysis

From each subplot, two soil samples were taken, one from 0-15 cm and the other from 15-30 cm soil depth before planting in the 1997 season and before and after planting in the 1998 season. 100 ml of 1N ammonium acetate were added to five grams air dry soil, then shacked for 30 minutes and then the suspension was filtrated and the potassium concentration was measured by flamephotometer (Page *et al.*, 1982).

Hand harvesting was carried out when the fruits were at the red ripe stage. Fruits in good condition with uniform ripening were used for tomato quality evaluation. The evaluation was carried out one time during 1997 season and three times during 1998 season at two weeks interval.

Fruit sampling was done by taking one fruit from each of the fifteen different plants in the 1997 season and by taking two Kg from the harvested fruits of each plot in the 1998 season. The following parameters were recorded:

- Early and total yield:

Every experimental unit was harvested separately and early yield was recorded as the production of the first week.

-Specific gravity of the fruit:

Known weight fruits were placed in a beaker and their volumes were determined by water displacement method. Specific gravity was obtained by dividing the weight (g) by the volume of replaced water (ml) (Kramer and Twigg, 1973).

-Juice yield:

Fruits of known weight were cut into quarters mixed in a blender, then pressed by a cloth. The juice was collected, and weighed and the residues were discarded. Juice yield (as % of the fruits) was obtained by dividing the weight of the juice by the weight of the whole fruits from which it was extracted.

- Total soluble solids:

A drop of the juice was placed on the stage of a refractometer and the total soluble solids were read directly (Kramer and Twigg, 1973).

-Juice pH:

Ten grams of the juice were placed in a beaker and the pH was read directly from the pH meter (Kramer and Twigg, 1973).

-Titrable acidity:

Ten grams of the juice and few drops of phenolphthalein were titrated against 0.1 N NaOH solution, considering the first turning to pink color as the end point. Titrable acidity was expressed as percent citric acid (Kramer and Twigg, 1973).

-Color of the juice:

The color of the juice was determined using a Gardener colorimeter (Kramer and Twigg, 1973).

-Leaf and fruit potassium content:

Leaf and fruit potassium contents were determined at 110 days plant age in the year 1997, while in the year 1998, leaf potassium content was determined at 80, 105 and 120 days plant age and fruit potassium content was determined at 105 and 120 day plant age.

Fruit and leaf samples were oven dried at 70° C for 72 hours. Grinded subsamples were wet digested, then potassium was determined by flamephotometer according to Jackson (1958).

-Firmness:

In the first year, a penetrometer was used to determine the firmness (Alan and Paden 1994). It gives the readings 0-30 mm and the higher the reading the softest the fruit. In the second year pressure tester (lb/in^2) was used (Kramer and Twigg, 1973).

-Dry weight percentage:

The fruits were cut in halves and dried in the oven for 72 hr at 70° C, and the percentage was calculated by dry weight / fresh weight.

Table 1 Main effects of potassium fertilizer and cultivar on early and total fruit yield (1997); total yield and fruit number per plant (1998) of tomato plants grown in the Jordan Valley.

Main effects	1997		1998	
Fertilizer level (Kg/ha)	Early yield (ton/ha)	Total yield (ton/ha)	Total yield (ton/ha)	Fruit number per plant
0	15.84 b	57.91 b	87.72 b	23.6 a
50	17.14 b	60.27 b	100.10 a	23.4 a
100	17.28 b	64.33 a	105.93 a	24.8 a
150	20.38 a	67.00 a	100.14 a	24.2 a
Cultivar				
Faridah	17.82 a	62.28 a	95.11 b	23.6 a
Wafa	17.26 a	60.92 a	99.12 a	23.0 a
Guardian	17.90 a	63.93 a	101.19 a	25.5 a

Means within columns for each main effect with same letter are not significantly different at 5% level according to LSD.

deficiency stages by an increased dark respiration rate (Brady *et. al.*, 1968). The enzyme NO_3 reductase activity was stimulated by an increased supply of potassium nutrient medium, indicating that if plants are not adequately supplied with potassium, NO_3 reduction may be affected and hence also the nitrogen nutrition of the plant (Kirkby *et al.*, 1981). This importance of potassium in photosynthesis, respiration, root development, photosynthate translocation and NO_3 transport may explain the increase of early and total fruit yield.

On the other hand, the highest rate of potassium fertilizer showed a significant decrease in 'Wafa' total fruit yield and insignificant decrease in the other two cultivars in the year 1998. This decrease in 'Wafa' total yield at the highest rate may be due to antagonism between positive charged nutrients. Kolota and Orlowski (1984) reported antagonism between potassium and magnesium at high potassium rates more than 400 mg / liter in the nutrient solution where at these high rates the yield and vegetative growth of tomato adversely affected.

The difference between the year 1997 and 1998 may be resulted form different spacing, date of transplanting and the different environmental conditions between the years.

Insignificant differences between cultivars might be related to the selection of these cultivars which is usually depend upon the preference of farmers. Farmers preference usually depends on yield performance.

'Faridah' has the lower production where it doesn't affected by potassium fertilizer application, but it has a slight increase by potassium fertilization increase. On the contrary 'Wafa' was severely affected when no potassium fertilizer applied and has a sharp increase in production with potassium fertilization increase, also there is a significant depression with the highest potassium fertilization level. 'Guardian' gave the best production and stability sense it does not severely affected by the high and low potassium fertilization levels. 'Wafa', 'Guardian' gave the higher production than 'Faridah'.

4.2 Fruit number per plant

Fruit number was taken in the season 1998 only. Averaged over cultivars, there were no significant differences in fruit number per plant between fertilization levels (Table 1). No significant differences in fruit number per plant among cultivars in 1998 season and also no significant interaction between cultivars and fertilizer level in fruit number per plant.

This result disagreed with Eid (1991) who showed that the highest fruit number per plant was obtained with the highest level of NPK fertilizer added. Same finding was reported by (Eid *et al.*. 1992). This disagreement may be due to the late time of application (flowering time) or to the different fertilizers applied. The cultivars did not differ among each other indicating same ability to set fruit in all cultivars.

4.3 Leaf Potassium Content :

Averaged over cultivars, in 1997, application of potassium at 50 Kg/ha had no significant effect on leaf potassium content compared to zero. Application of potassium at 100 Kg/ha significantly increased leaf potassium content compared to zero, but did not differ from 50 Kg / ha. Application of potassium at 150 Kg/ha significantly increased leaf potassium content compared to zero and 50 Kg/ha (Table 3).

In 1998, in date 1 application of potassium at 50 Kg / ha had no significant increase in leaf potassium content. Application of potassium at 100 and 150 Kg / ha significantly increased leaf potassium content compared to zero, but did not differ significantly from 50 Kg / ha application. In date 2, application of zero, 50 and 100 Kg/ha did not differ significantly from each other in leaf potassium content. Application of potassium at 150 Kg/ha significantly increased leaf potassium content compared to zero and 50 Kg / ha, but did not significantly differ from 100

Table 3 Main effects of potassium and cultivar on leaf potassium content (%) of tomato plants grown in the Jordan valley in 1997 and 1998 seasons.

Main effect	1997	1998			
Fertilizer level Kg/ha	Leaf K content	Leaf K content in date 1	Leaf K content in date 2	Leaf K content in date 3	Leaf K content mean
0	1.49 c	2.19 b	1.56 b	1.31 a	1.67 b
50	1.77 bc	2.44 ab	1.63 b	1.28 a	1.77 b
100	2.00 ab	2.62 a	1.80 ab	1.50 a	1.95 a
150	2.19 a	2.60 a	2.05 a	1.45 a	2.02 a
Cultivar					
Faridah	1.74 a	2.32 b	1.69 b	1.38 a	1.78 b
Wafa	1.74 a	2.47 ab	1.54 b	1.36 a	1.77 b
Guardian	2.10 a	2.61 a	2.04 a	1.41 a	2.00 a

Means within columns for each main effect with same letter are not significantly different at 5% level according to LSD.

Date 1 at 110 day plant age in 1997.

Date 1, date 2 and date 3 at 75, 105 and 120 day plant age, respectively in 1998.

Kg / ha. In date 3, no significant effect of potassium application on leaf potassium content. In the mean of three dates, application of potassium at 50 Kg / ha had no significant effect on leaf potassium content. Application of 100 and 150 Kg / ha significantly increased leaf potassium content compared to zero and 50 Kg / ha (Table 3).

In 1997, no significant difference in leaf potassium content between cultivars was obtained. In 1998, in date 1 'Guardian' was significantly higher than 'Faridah' in leaf potassium content. 'Wafa' did not differ significantly from both cultivars. In date 2, 'Guardian' was significantly higher than 'Faridah' and 'Wafa' in leaf potassium content. In date 3, no significant difference between the cultivars in leaf potassium content was obtained. In the mean of three dates, 'Guardian' was significantly higher than 'Faridah' and 'Wafa' in leaf potassium content. No significant interaction between potassium fertilizer and cultivar in leaf potassium content was obtained (Table 3). Orphanos and Papadopuolos (1980) reported that potassium fertilization increased the concentration of potassium in the leaves. Potassium content of petioles increased with increasing concentration of potassium to 10 meq / liter in the nutrient solution (Trudel and Ozbun, 1971).

The response of leaf potassium content to potassium application decreased with plant age. Potassium is translocated from leaves to the fruits and so, in the last date the differences disappeared among fertilization levels.

On the other hand, the ability of cultivar 'Guardian' to higher potassium uptake gave the higher leaf potassium content. This result may explain the steady increase in yield for this cultivar and did not severely affected by the absence of potassium fertilizer. On the contrary, 'Faridah' (which showed lower ability for potassium uptake) yield did not significantly affected by potassium application.

The different response in both seasons of experiment may resulted from different distribution way of potassium fertilizer. In 1998 season, there was higher plant density with same amount of fertilizer in addition to the different environmental conditions.

4.4 Fruit Potassium Content :

Averaged over cultivars, in 1997, application of 50 Kg / ha had no significant effect on fruit potassium content. Potassium application at 100 and 150 Kg / ha significantly increased fruit potassium content compared to zero and 50 Kg / ha.. Potassium application increase from 100 to 150 Kg / ha had no significant increase in fruit potassium content. In 1998, application of potassium significantly increased fruit potassium content, but increasing the level of application had no significant effect on fruit potassium content (Table 4).

In 1997, fruit potassium content did not differ significantly between cultivars. In 1998, in date 1 and the two dates mean, 'Guardian' was significantly higher than 'Faridah', but 'Wafa' did not differ from both cultivars. In date 2, no significant difference between cultivars and no significant interaction between potassium fertilizer and cultivar in fruit potassium content was obtained (Table 4).

This increase of fruit potassium content due to potassium fertilization was reported by many researchers (Adams *et al.*, 1978; Trudel and Ozbun, 1971; Picha and Hall, 1981)

Similar to leaf potassium content, fruit potassium content differ in response to potassium fertilizer in both years which may resulted from the differences in potassium distribution in addition to the different environmental conditions in both years.

'Guardian' which has the highest leaf potassium content also has the higher fruit potassium content that prove the higher ability to potassium uptake. On the contrary, 'Faridah' which has the lower leaf potassium content also has the lower fruit potassium content. There were significant correlations obtained between leaf potassium content and fruit potassium content in date 1 and between leaf potassium content in and fruit potassium content in date 2.

Table 4 Main effects of potassium and cultivar on fruit potassium content (%) of tomato plants grown in the Jordan valley in 1997 and 1998 seasons.

Main effect	1997	1998		
Fertilizer level Kg/ha	Date 1	Date 1	Date 2	Mean
0	3.262 b	3.10 b	3.04 b	3.07 b
50	3.406 b	3.52 a	3.38 a	3.45 a
100	3.624 a	3.59 a	3.56 a	3.56 a
150	3.724 a	3.56 a	3.57 a	3.58 a
Cultivar				
Faridah	3.48 a	3.32 b	3.36 a	3.34 b
Wafa	3.49 a	3.43 ab	3.29 a	3.36 ab
Guardian	3.55 a	3.58 a	3.51 a	3.55 a

Means within columns for each main effect with same letter are not significantly different at 5% level according to LSD.

Date 1 at 110 day plant age in 1997.

Date 1 and date 2 at 105 and 120 day plant age, respectively in 1998.

4.5 Total Soluble Solids:

Averaged over cultivars, total soluble solids was increased significantly by the application of potassium fertilizer, but increasing the level of potassium application had no significant effect on total soluble solids content in both years of experiment except the last date in 1997 (Table 5). There was 6.6% -7.5% increase in soluble solids content when potassium fertilization applied at rates of 50 - 150 Kg / ha compared to the control (Table 5).

No significant difference in total soluble solids content among cultivars except the mean of the three dates in 1998, where 'Faridah' was significantly lower than 'Guardian'. No significant interaction between potassium fertilizer and cultivars was obtained in total soluble solids content (Table 5).

The differences in soluble solids in the first date of the season disappeared at the second date of the season (last harvest) in 1997 and all treatments became significantly equal in total soluble solids content. In 1998, the differences were appeared to the end of season. This difference may be resulted from senescence which led to low water uptake which concomitant to high temperature at the end of season and reduced fruit water accumulation and increased fruit soluble solids. This did not

Table 5 Main effects of potassium and cultivar on total soluble solids content (%) of tomato plants grown in the Jordan valley in 1997 and 1998 seasons.

Main effects	1997			1998			
Fertilizer level (Kg/ha)	Date 1	Date 2	Mean	Date 1	Date 2	Date 3	Mean
0	4.41 b	5.01 a	4.73 b	5.06 b	4.52 b	4.42 b	4.67 b
50	4.70 a	5.33 a	5.06 a	5.53 a	5.42 a	4.88 a	5.27 a
100	4.71 a	5.22 a	4.97 ab	5.74 a	5.37 a	4.90 a	5.33 a
150	4.74 a	5.25 a	4.99 a	5.65 a	5.31 a	4.90 a	5.28 a
Cultivar							
Faridah	4.66 a	5.15 a	4.90 a	5.44 a	5.04 a	4.71 a	5.06 b
Wafa	4.66 a	5.21 a	4.93 a	5.48 a	5.09 a	4.83 a	5.13 ab
Guardian	4.60 a	5.29 a	4.94 a	5.57 a	5.34 a	4.79 a	5.23 a

Means within columns for each main effect with same letter are not significantly different at 5% level according to LSD.

Date 1, date 2 at 110 and 125 day plant age, respectively in 1997

Date 1, date 2 and date 3 at 90, 105 and 120 day plant age, respectively in 1998.

happen in the second season due to the earlier planting date which escaped the hot period in June. Deficit irrigation reduced fruit water accumulation but increased fruit soluble solids (Mitchel *et al.*, 1991). Picha and Hall (1982) reported that soluble solids increased with higher rates of potassium from 0 - 93 Kg/ha but no further significant increase occurred with higher potassium rates.

The positive effect of potassium on total soluble solids was reported by other researchers. Eid (1991) reported that increasing NPK fertilizer up to 200 Kg N+ 64 Kg P_2O_5+ 72 Kg K_2O / Faddan (Faddan = 4.2 dunum) increased soluble solids in tomato juice. On the other hand potassium affected total soluble solids directly where total soluble solids mainly contain, sugar, which affected by photosynthesis and photosynthate translocation (Brady *et al.*, 1962). They mentioned that when plants are deficient in potassium, the lower leaves are very poor source of photosynthate and that potassium deficiency retards the movement of compounds in plants. Although potassium affect total soluble solids indirectly, where Kirkby *et al.* (1981) reported that potassium facilitates the upward movement of NO_3 from root to shoot in tomatoes. Nitrogen application increased soluble solids in tomatoes (Wright and Harris, 1985). Labeled CO_2 assimilation was increased significantly by increasing potassium application increase from 1.25 to

10.0 g / plant. However, potassium applied appears to be uptaked by the plant (Table 3) and its effect appear on total soluble solids. The differences between cultivars did not appear clearly. This result may due to suitability of cultivars for processing, which require high total soluble solids content.

4.6 Dry Weight Percentage of Fruits:

Averaged over cultivars in 1997, dry weight of fruit was significantly increased by the application of potassium, but increasing the level of potassium application had no significant effect on fruit dry weight. In 1998, potassium application had no significant effect on fruit dry weight (Table 6). No significant difference between cultivars in fruit dry weight was obtained in both years of experiment. Also, interaction between fertilizer and cultivar was not significant for fruit dry weight percentage.

Picha and Hall (1982) reported that application of potassium at 372 and 744 Kg / ha significantly increased the fruit dry weight compared to zero and 93 Kg / ha. The dry matter content of the fruit increased with potassium concentration increase in the feed solution (Adams and Grimitt, 1986). Hutte *et al.* (1986) reported that reducing potassium fertilizer concentration from 3.26 mM to 0.62 mM reduced fruit dry weight significantly from 5.82% to 5.47% . This effect may became

Table 6 Main effects of potassium and cultivar on fruit dry weight percentage of tomato plants grown in the Jordan valley in 1997 and 1998 seasons.

Main effect	1997	1998		
Fertilizer level	Date 1	Date 1	Date 2	Mean
0	5.29 b	4.92 a	4.81 a	4.87 a
50	5.97 a	5.21 a	4.76 a	4.98 a
100	5.86 a	5.15 a	4.78 a	4.96 a
150	5.91 a	5.00 a	5.03 a	5.01 a
Cultivar				
Faridah	5.73 a	4.95 a	4.86 a	4.90 a
Wafa	5.79 a	5.02 a	4.84 a	4.93 a
Guardian	5.75 a	5.24 a	4.84 a	5.04 a

Means within columns for each main effect with same letter are not significantly different at 5% level according to LSD.

Date 1 at 110 day plant age in 1997.

Date 1 and date 2 at 105 and 120 day plant age, respectively in 1998.

through the activation of krebs cycle enzyme by potassium (Lacatus *et al.*, 1994).

Dry weight differed in both seasons. There was a response to potassium application in 1997, but in 1998 was not affected. This difference may be resulted from different environmental conditions in both years including earlier planting date and closer spacing in 1998. Cultivars did not differ from each other showing similar ability to accumulate dry matter.

4.7 Titratable Acidity

Averaged over cultivars, titratable acidity in the fruits was increased significantly by the application of potassium, but increasing the level of potassium application had no significant effect on titratable acidity in both years of experiment (Table 7). In 1997, 'Faridah' significantly gave higher titratable acidity than 'Guardian', but 'Wafa' did not significantly differ from both cultivars. In 1998, all cultivars did not differ significantly from each other, except in the second date where 'Guardian' gave significantly higher in titratable acidity than the other two cultivars (Table 7). No significant interaction between potassium application and cultivar was obtained for fruit titratable acidity (Table 7).

These results agreed with those of Picha and Hall (1982) who reported that pericarp titratable acidity was increased with increasing

Table 7 Main effects of potassium and cultivar on tomato juice titratable acidity (%) of tomato plants grown in the Jordan valley in 1997 and 1998 seasons.

Main effect	1997	1998			
Fertilizer level Kg/ha	Date 1	Date 1	Date 2	Date 3	Mean
0	0.308 b	0.361 b	0.341 b	0.348 b	0.350 b
50	0.355 a	0.433 a	0.412 a	0.467 a	0.437 a
100	0.355 a	0.425 a	0.413 a	0.455 a	0.431 a
150	0.360 a	0.447 a	0.430 a	0.455 a	0.444 a
Cultivar					
Faridah	0.357 a	0.407 a	0.385 b	0.424 a	0.407 a
Wafa	0.341 ab	0.409 a	0.389 b	0.438 a	0.412 a
Guardian	0.335 b	0.434 a	0.424 a	0.434 a	0.430 a

Means within columns for each main effect with same letter are not significantly different at 5% level according to LSD.

Date 1 at 110 day plant age in 1997.

Date 1, date 2 and date 3 at 90, 105 and 120 day plant age, respectively in 1998 potassium fertilizer up to 744 Kg / ha. Adames *et al.* (1978) reported that increasing potassium concentration from 100 ppm to 300 ppm in the nutrient solution increased titratable acidity in tomato fruit juice. Mahakun *et al.* (1979) reported that there is a positive correlation between titratable acidity and fruit potassium content. Potassium application significantly increased fruit potassium content in the current experiment (Table 4).The increase in titratable acidity due to potassium could be explained by potassium activation of krebs cycle enzymes (Lacatus *et al* ., 1994). The different response in cultivars between both years of experiment may resulted from the different spacing and environmental conditions between the two years.

4.8 Juice pH:

In 1997, potassium application had no significant effect on juice pH, while in 1998, as cultivars average pH was significantly decreased by potassium application, but increasing the level of potassium application had no significant effect on juice pH (Table 8).

There was significant differences between cultivars in juice pH in 1997. 'Faridah' (which has higher titrable acidity) has the lower juice pH and on the contrary 'Guardian' (which has the lower titrable acidity) has the higher juice pH. 'Wafa' did not differ significantly from 'Faridah' and

Table 8 Main effects of potassium and cultivar on fruit juice pH of tomato plants grown in the Jordan valley in 1997 and 1998 seasons.

Main effect	1997	1998			
Fertilizer level Kg/ha	Date 1	Date 1	Date 2	Date 3	Mean
0	4.08 a	4.21 a	4.10 a	4.11 a	4.13 a
50	4.06 a	4.13 b	3.92 b	4.01 b	4.02 b
100	4.06 a	4.14 b	3.96 b	4.01 b	4.03 b
150	4.06 a	4.11 b	3.91 b	4.02 b	4.01 b
Cultivar					
Faridah	4.05 b	4.13 a	3.99 a	4.03 a	4.05 a
Wafa	4.06 b	4.18 a	3.96 a	4.05 a	4.06 a
Guardian	4.10 a	4.13 a	3.96 a	4.03 a	4.04 a

Means within columns for each main effect with same letter are not significantly different at 5% level according to LSD.

Date 1 at 105 day plant age in 1997.

Date 1, date 2 and date 3 at 90, 105 and 120 day plant age, respectively in 1998.

significantly lower than 'Guardian' in juice pH. In 1998 there were no significant differences among cultivars in juice pH (Table 8).

Pericarp pH did not change with increasing potassium fertilizer up to 186 kg / ha but decreased at potassium rate above 186 kg / ha (Picha and Hall, 1982). Similar results were found by (Kattan *et al.*, 1957).

The different pH response to potassium fertilizer in both seasons may resulted from different phosphorus application in both seasons. In 1998 season phosphorus was more even distributed than in 1997 season due to closer spacing and higher plant density. Phosphorous related to buffering activity in the tomato pericarp tissue and the entire fruit (Mahakun *et al.*, 1979). In 1998. potassium application resulted in increased titratable acidity and decreased juice pH. A negative correlation was obtained between titratable acidity and juice pH. This result agreed with those of Mahakun *et al.* (1979) who reported that juice pH showed negative correlation with total acidity.

4.9 Juice Color

Averaged over cultivars in 1997 season, application and increasing application rate caused a slight insignificant increase in juice color (Table 9). In 1998, juice color was not significantly affected by potassium application in the first date, while in the later two dates, potassium

Table 9 Main effects of potassium and cultivar on fruit juice color (red to yellow ratio) of tomato plants grown in the Jordan valley in 1997 and 1998 seasons.

Main effect	1997	1998			
Fertilizer level (Kg/ha)	Date 1	Date 1	Date 2	Date 3	Mean
0	1.29 a	1.53 a	1.51 b	0.91 b	1.31 b
50	1.45 a	1.66 a	1.77 ab	0.99 ab	1.47 a
100	1.47 a	1.61 a	1.82 a	1.27 a	1.57 a
150	1.52 a	1.60 a	1.82 a	1.25 a	1.56 a
Cultivar					
Faridah	1.49 a	1.57 a	1.78 a	1.06 a	1.47 a
Wafa	1.55 a	1.59 a	1.74 a	1.16 a	1.49 a
Guardian	1.25 b	1.65 a	1.67 a	1.09 a	1.47 a

Means within columns for each main effect with same letter are not significantly different at 5% level according to LSD.

Date 1 at 105 day plant age in 1997.

Date 1, date 2 and date 3 at 90, 105 and 120 day plant age, respectively in 1998.

application at 100 and 150 Kg / ha significantly increased juice color compared to zero and did not significantly differ from the application of 50 Kg / ha. In the mean of the three dates, application of potassium significantly increased juice color, but increasing the level had no significant effect on juice color (Table 9).

In 1997, cultivars significantly differed in juice color among each other. 'Guardian' was significantly lower in juice color than 'Faridah' and 'Wafa'. In 1998, cultivars did not differ significantly from each other. No significant interaction between potassium application and cultivar was obtained (Table 9).

Dick and Shattuck (1987) reported that potassium treatment markedly affects the incidence of tomato blotchy fruit (color disorder). Fruits from all cultivars had significantly less blotchy ripening with potassium fertilization in both seasons of the experiment (Picha and Hall, 1981). High nitrogen levels significantly increased the incidence and severity of blotchy ripening and potassium levels up to 8 meq / liter improved fruit color (Cotter, 1961). Although potassium increases lycopene content and improves the color, where Trudel and Ozbun (1971) reported that satisfactory pericarp color for whole pack production can only be obtained when the potassium fertilization regime exceeds 500 kg / ha. Then they found lycopene content rises sharply as the potassium level in the nutrient solution is increased with a maximum at 8 meq and a slight decrease at 10 meq K/liter. Trudel and Ozben (1971) mentioned that under the conditions of severe potassium deficiency lycopene syntheses enzyme level is lowered. This could lead to reduce rates of enzymatic reaction involved in carotenoid and precursor synthesis.

On the contrary, Hartz *et al.* (1996) reported that fruit color was unaffected by potassium fertilization up to 135 Kg / ha. Different treatments of potassium fertilizer up to 200 lb / acre (lb = 0.45 Kg, acre =4 dunums) did not affect fruit color (Kattan *et al.*, 1957).

From the field observations, 'Guardian' fruits were subjected more to direct sun radiation (due to its morphology and leaf distribution on the plant) than other cultivars where sun scald may developed especially at the end of season with high temperature and both where required for sun scald development which affected fruit color in 1997.

Earlier planting in 1998 gave the fruit more suitable environment for coloring by avoidance of hot weather and reducing occurrence of disorders especially sun scald. On the other hand, closer spacing in 1998 may reduced the direct sun light in the hot period. Consequently the disorder was reduced.

4.10 Firmness

Averaged over cultivars, application of potassium had no significant effect on fruit firmness in both years of experiment except the mean of three dates of 1998. Application of potassium fertilizer at 50 and 100 Kg K_2SO_4 / ha significantly increased fruit firmness, but the application of 150 K_2SO_4 Kg / ha did not differ significantly from all other treatments in the mean of three dates in 1998 (Table 10).

In 1997, Faridah was significantly firmer than 'Guardian' and 'Wafa', while in 1998, no significant differences between cultivars were obtained. No significant interaction between potassium fertilizer and cultivar was obtained in fruit firmness (Table 10).

Potassium has moderate effect on fruit firmness, where Kattan *et al.* (1957) found that different treatment of potassium fertilization up to 200 lb / acre (lb = 0.45 Kg, acre =4 dunums) did not affect fruit firmness. On the contrary, Hutte *et al.* (1986) reported that a significant interaction between nitrogen and potassium where a combination of 1.61 mM N with 0.65 mM K gave the softest tomato fruits and 16.14 mM N with 3.26 mM K gave the firmest fruits.

In the mean of season 1998, the application of potassium at 150 Kg / ha reduced fruit firmness. This result may be due to the deficiency of another positive charged nutrient like magnesium (Kolota and Orlowski, 1984).

Table 10 Main effects of potassium and cultivar on fruit firmness (mm) in 1997 and (lb/in^2)in 1998 of tomato plants grown in the Jordan valley.

Main effect	1997	1998			
Fertilizer level Kg/ha	Date 1	Date 1	Date 2	Date 3	Mean
0	9.30 a	6.21 a	7.32 a	7.39 a	6.97 b
50	9.82 a	6.32 a	7.20 a	7.91 a	7.14 a
100	9.35 a	6.45 a	7.46 a	7.63 a	7.20 a
150	9.63 a	6.38 a	7.29 a	7.62 a	7.09 ab
Cultivar					
Faridah	8.39 b	6.47 a	7.24 a	7.60 a	7.09 a
Wafa	9.97 a	6.35 a	7.46 a	7.83 a	7.21 a
Guardian	10.22 a	6.28 a	7.25 a	7.48 a	7.00 a

Means within columns for each main effect with same letter are not significantly different at 5% level according to LSD.

Date 1 at 105 day plant age in 1997.

Date 1, date 2 and date 3 at 90, 105 and 120 day plant age, respectively in 1998.

The morphology of 'Guardian' play a role in firmness where 'Guardian' gave softer fruits. Experiments in the two different years showed different response in firmness that may resulted from the different environmental conditions in both years.

4.11 Specific Gravity and Juice Yield

Averaged over cultivars, application of potassium had no significant effect on specific gravity in both years of experiment (Table 11).

No significant differences in specific gravity among cultivars in both years of experiment except the mean of the three dates in 1998 where 'Faridah' was significantly higher than 'Wafa'. 'Guardian' did not significantly differ from 'Faridah' and 'Wafa'. No significant interaction between potassium fertilizer and cultivar was obtained in specific gravity (Table 11)

This quality parameter appeared to be genetically dependent more than the effect of environmental conditions. Many experiments carried out and fail to affect tomato fruit specific gravity as the results found by Shibli and Suwwan (1987).

Averaged over cultivars, application of potassium had no significant effect on tomato fruit juice yield (Table 12).

In 1997, 'Faridah' and 'Wafa' were significantly higher in juice yield than 'Guardian', while in 1998, no significant difference was obtained between cultivars except the last date where 'Faridah' significantly gave higher juice yield than 'Wafa' and 'Guardian'. No significant interaction between potassium fertilizer and cultivar was obtained in juice yield (Table 12).

Potassium application failed to affect tomato fruit juice yield. This parameter appeared to be genetically controlled more than environmentally affected and similar to the specific gravity. However, Kasrawi and Amr (1990) found that tomato juice yield heritability was about 79-82% in the population used, which indicate the high genetic effect over environmental effect.

Table 11 Main effects of potassium and cultivar on fruit specific gravity (gm / ml) of tomato plants grown in the Jordan valley in 1997 and 1998 seasons.

Main effect	1997	1998			
Fertilizer level (Kg/ha)	Date 1	Date 1	Date 2	Date 3	Mean
0	1.0063 a	0.9784 a	0.991 a	0.9898 a	0.985 a
50	1.0036 a	0.9961 a	1.0072 a	0.9984 a	1.00 a
100	1.0094 a	0.9778 a	0.9948 a	0.9906 a	0.987 a
150	1.0022 a	0.9956 a	0.9956 a	0.9907 a	0.988 a
Cultivar					
Faridah	1.0039 a	0.9895 a	1.0043 a	0.9983 a	0.996 a
Wafa	1.0044 a	0.9717 a	0.9959 a	0.9885 a	0.984 b
Guardian	1.0078 a	0.9883 a	0.9912 a	0.9903 a	0.989 ab

Means within columns for each main effect with same letter are not significantly different at 5% level according to LSD.

Date 1 at 105 day plant age in 1997.

Date 1, date 2 and date 3 at 90, 105 and 120 day plant age, respectively in 1998.

Table 12 Main effects of potassium and cultivar on fruit juice yield percentage of tomato plants grown in the Jordan valley in 1997 and 1998 seasons.

Main effect	1997	1998			
Fertilizer level Kg/ha	Juice yield	Juice yield in date 1	Juice yield in date 2	Juice yield in date 3	Juice yield mean
0	78.59 a	79.33 a	80.57 a	78.86 a	79.51 a
50	80.17 a	74.33 a	80.72 a	78.18 a	77.64 a
100	81.01 a	81.33 a	81.17 a	78.81 a	80.36 a
150	80.33 a	79.78 a	80.28 a	78.39 a	79.40 a
Cultivar					
Faridah	81.108 a	80.00 a	80.68 a	79.94 a	80.13 a
Wafa	80.239 a	78.33 a	80.63 a	77.92 b	78.85 a
Guardian	78.727 b	77.75 a	80.75 a	77.82 b	78.71 a

Means within columns for each main effect with same letter are not significantly different at 5% level according to LSD.

Date 1 at 105 day plant age in 1997.

Date 1, date 2 and date 3 at 90, 105 and 120 day plant age, respectively in 1998.

5. Conclusion and Recommendation

-Potassium as an important plant nutrient, its application increased early and total tomato yield and improved processing tomato total soluble solids, titrable acidity, juice pH, juice color and dry weight percentage.

-Under the prevailing conditions of the experiment, the best potassium application level was 100 Kg K_2SO_4 /ha which gave the best total yield and quality.

- 'Guardian' has the higher and stable production over all potassium levels, but 'Faridah' has better quality. 'Wafa' was intermediate position between the other two cultivars.

- Application of 50 Kg/ha potassium sulfate was adequate to improve processing tomato quality.

- Avoiding high rates of potassium application is recommended due to the expected reduction in yield.

Grown in Sand Culture. *Aust. J. Exp. Agric.* **26**:133-138.

-Jackson, M.L. 1958 *Soil Chemical Analysis* In: Black C.A. (Editor). *Methods of soil analysis P II Chemical and Microbiologecal Properties.* 1ed Agronomy Series No. 9.

-Jolly, V. D., Brown, J. C., Blaylock, M. J. and Camp, S. D. 1988. A Role for Potassium in the Use of Iron by Plants. *J. Plant. Nut.* **12**: 1159-1175.

-Kasrawi, M. A. and Amer, A. S. 1990 Genotypic Variation and Correlations for Quality Characteristics in Processing Tomatoes. *J. Gent. and Breed.* **44**:85-90.

-Kasrawi, M. A., Snober, B. A. and Suwwan, M. A. 1981. Tomato Fruit Firmness for 17 Tomato Cultivars (*Lycopersecon esculentum*) Grown Under Rainfed and Irrigated Conditions of Jordan. *Dirasat* **8** :33-47.

-Kattan, A. A., Stark, F. C. and Kramer, A. 1957. Effect of Certain Preharvest Factors on Yield and Quality of Row and Processed Tomatoes. *Proc. Amer. Soc. Hort. Sci.* **69**:327-342.

-Kirkby, E. A., Armstrong, M. J. and Legget, J. E. 1981. Potassium Recalculation in Tomato Plant in Relation to Potassium Supply. *J. Plant Nutr.* **3**(6):955-966.

-Kolota, E. and Orlowski 1984. The Influence of Potassium and Magnesium Fertilization on Growth, Yield and Mineral Nutrition of

Greenhouse Tomato. *Bulletin Warzywiezy.* **27**:301-315.

-Kramer. A. and Twigg, B.A., 1973. *Quality Control for The Food Industry, 3ed edition.* AVI, Westport.

-Lacatus, V., Botez,C., Chelu, M., Mirghis, R. and Voican, V. 1994 The Influence of Organic and Mineral Fertilizers on Tomato Quality for Processing. *Acta Hort.* **376**:329-332.

-Mahakun, N., Leeper, P. W. and Burns, E. E. 1979. Acidic Constituents of Various Tomato Fruit Types. *J. Food Sci.* **44**:1241-1244.

-Mas, Y. 1983 *World Vegetables: Princeples, Production and Nutrition Values.* Ellis Horwood Limited Puplishers.

-Maslamani, H. K. and Suwwan, M. A. 1987. Effect of Plant Spacing, Clipping and Tomatone on Yield, Fruit Quality and Growth of Tomato Grown under Plastic House Conditions in the Jordan Valley. *Dirasat* **14**(11): 7-27.

-Mitchell. J. P.; Shennan, C.; Grattan, S. R. and May, D. M. 1991 Tomato Fruit Yields and Quality under Water Deficit and Salinity. *J. Amer. Soc. Hort. Sci.* **116**(2):215-221.

-Nettles, V. F. 1950. The Relationship of Specific Gravity of Tomato fruits to Their Stage of Maturity. *Proc. Amer. Soc. Hort. Sci.* **55**:343-345.

-Orphanos, P. I. and Papadopoulos, I. 1980. The Nitrogen, Phosphorus and Potassium Requirement of Tomatoes Grown in Pots and in

The Soil in Unheated Plastic Greenhouse in Cyprus. *J. Hort. Sci.* **55**(4) :415-423.

-Page, A.L., Miller, R.H. and Keeney, D.R. 1982 *Methods of Soil Analysis.* Amer. Soc. of Agron. Inc. and Soil Sci. Soc. of Amer. Inc.

-Papadopoulos, A. P. and Khosla, S. 1993. Limitation of The K:N Ratio in The Nutrient Feed of Drip-Irrigation Greenhouse Tomatoes as a Crop Management Tool. *Can. J. Plant Sci.* **73**: 289-296.

-Picha, D. H. and Hall, C. B. 1981. Influence Potassium, Cultivar, and Season on Tomato Graywall and Blotchy Ripening. *J. Amer. Soc. Hort. Sci.* **106**(6) : 704-708.

-Picha, D. H. and Hall, C. B. 1982. Effect of Potassium Fertilization and Season on Fresh Market Tomato Quality Characters. *HortSci.* **17**(4): 634-635.

-Rao, M. H. 1994. Growth Yield and Quality of Tomato, carrot and Cauliflower as Influenced by Levels and Sources of Potassium. *J. Potassium Res.* **10**(4): 402-406.

-Shibli, R. and Suwwan, M. A. 1987. Effect of Plant Population and Burst Application on Yield, Growth and Fruit Quality of Late Field Tomato in The Jordan Valley. *Dirasat* **14**(5): 55-72.

-Suwwan, M. A. 1989. Evaluation of Tomato Hybrids and Cultivars for Yield, Fruit Quality and Physiological Disorders. *Emir. J. Agric. Sci* **1**:

105-115.

-Suwwan, M. A. and Abu-Baker, S. M. 1986 Physical Properties of Tomato Fruits of Nine tomato Hybrids and Cultivars under Plastic House Conditions in the Jordan Valley. *Dirasat* **13**: 7-17.

-Szlek, M.; Miller, G. W. and Welkie, G. W. 1990. Potassium Effect on Iron Stress in Tomato I. The Effect on pH, Fe-Reductase and Chlorophyll. *J. Plant Nutr.* **13**(2): 215-229.

-Tisdale, S. L.; Nelson, W. L. and Beaton, J. D. 1985. *Soil Fertility and Fertilizers*. Macmillan Publishing Company New York.

-Trudel, M. J. and Ozbun, J. L. 1971. Influence of Potassium on Carotenoid Content of Tomato Fruit. *J. Amer. Soc. Hort. Sci.* **96**(6): 763-765.

-Tsikalas, P. E. and Manios, V. I. 1985. Nutrition of Tomatoes in Growing Bags in Greenhouses. I Effect on Productivity. *Georgike Erwna.* 9(2):279-289.

-Varis, S. and George, R. A. T. 1985. The Influence of Mineral Nutrition on Fruit Yield, Seed Yield and Quality in Tomato. *J. Hort. Sci.* **60**(3): 373-376.

-Vittum, M. T., Robinson, W. B. and Marx, G. A. 1962. Raw-Product Quality of Vine Ripened Processing Tomatoes as Influenced By Irrigation, Fertility Level and Variety. *Proc. Amer. Soc. Hort. Sci.* **80**: 535-543.

-Wright, D. H. and Harris, N. D. 1985. Effect of Nitrogen and Potassium Fertilization on Tomato Flavor. *J. Agric. and Food Chem.* **33**(3): 355-358.

Appendix(A) Analysis of variance for total and early yield in 1997 season.

Source of variance	df	Total yield MS	Early yield MS
Rep	2	11221429 ns	759192 ns
Fertilizer	3	14864631*	33362245 *
Error (a)	6	11677557 ns	5227785 ns
Cultivar	2	27374945 ns	1454997 ns
Fert*cv	6	4944667 ns	4013272 ns
Error (b)	16	12534410	5824504

*Sinificant at 0.05 level

ns: not significant

Appendix (B) Analysis of variance for leaf and fruit potassium content in 1997 season.

Source of variance	df	K% in leaf MS	K% in fruit MS
Rep	2	0.0315 ns	0.0003 ns
Fertilizer	3	0.8283 *	0.3938 *
Error (a)	6	0.1067 ns	0.0164 ns
Cultivar	2	0.5317 ns	0.0162 ns
Fert*cv	6	0.0259 ns	0.0124 ns
Error (b)	16	0.2042	0.0578

*Sinificant at 0.05 level

ns: not significant

Appendix (C) Analysis of variance for total soluble solids in the med and the end of 1997 season.

Source of variance	df	TSS% in med season MS	TSS% in end season MS	TSS% mean
Rep	2	0.0039 ns	0.0226 ns	0.0052 ns
Fertilizer	3	0.2178 *	0.1221 ns	0.1570 *
Error (a)	6	0.0313 ns	0.1429 ns	0.0439 ns
Cultivar	2	0.0156 ns	0.0642 ns	0.0056 ns
Fert*cv	6	0.0451 ns	0.0041 ns	0.0141 ns
Error (b)	16	0.0261	0.1389	0.0379

*Sinificant at 0.05 level

ns: not significant

Appendix (D) Analysis of variance for titrable acidity and juice pH in 1997 season.

Source of variance	df	D.W MS	Titrable acidity MS	pH MS
Rep	2	0.0340 ns	0.00020 ns	0.00041 ns
Fertilizer	3	0.8886 **	0.00538 *	0.00095 ns
Error (a)	6	0.0756 ns	0.00091 ns	0.00113 ns
Cultivar	2	0.0113 ns	0.00164 *	0.00965 **
Fert*cv	6	0.0777 ns	0.00018 ns	0.00148 ns
Error (b)	16	0.0897	0.00042	0.00099

*Sinificant at 0.05 level

ns: not significant

Appendix (E) Analysis of variance for juice color and fruit firmness in 1997 season.

Source of variance	df	Juice color MS	Fruit firmness MS
Rep	2	0.0121 ns	1.5919 ns
Fertilizer	3	0.0897 ns	0.5297 ns
Error (a)	6	0.0407 ns	1.3889 ns
Cultivar	2	0.2953 *	11.7690 *
Fert*cv	6	0.0076 ns	3.1422 ns
Error (b)	16	0.0226	2.7084

*Sinificant at 0.05 level

ns: not significant

Appendix (F) Analysis of variance for specific gravity and juice yield in 1997 season.

Source of variance	df	Specific gravity MS	juice yield MS
Rep	2	9.1411 ns	6.4860 ns
Fertilizer	3	0.9219 ns	9.4015 ns
Error (a)	6	9.2507 ns	5.7611 ns
Cultivar	2	0.5453 ns	17.4309 *
Fert*cv	6	13.8271 ns	4.7598 ns
Error (b)	16	6.6375	2.4138

*Sinificant at 0.05 level

ns: not significant

Appendix (G) Analysis of variance for total soluble solids 1997 season.

Source of variance	df	TSS in date 1 MS	TSS in date 2 MS	TSS in date 3 MS	TSS mean MS
Rep	2	0.098 ns	0.057 ns	0.090 ns	0.0131 ns
Fertilizer	3	0.811 *	1.623 *	0.497 *	0.8966 *
Error (a)	6	0.042 ns	0.040 ns	0.096 ns	0.0116 ns
Cultivar	2	0.059 ns	0.319 ns	0.047 ns	0.0916 ns
Fert*cv	6	0.041 ns	0.298 ns	0.048 ns	0.0132 ns
Error (b)	16	0.120	0.158	0.075	0.0241

*Sinificant at 0.05 level

ns: not significant

Appendix (H) Analysis of variance for tomato juice titratable acidity (TA) 1998 season.

Source of variance	df	TA in date 1 MS	TA in date 2 MS	TA in date 3 MS	TA mean MS
Rep	2	0.177 ns	2.018 ns	0.006 ns	0.3329 ns
Fertilizer	3	3.187 *	3.429 *	6.889 *	4.2638 *
Error (a)	6	0.750 ns	0.414 ns	1.267 ns	0.2954 ns
Cultivar	2	0.670 ns	1.414 ns	0.158 ns	0.5126 ns
Fert*cv	6	0.352 ns	0.590 ns	1.367 ns	0.2139 ns
Error (b)	16	0.418	0.397	0.981	0.2516

*Sinificant at 0.05 level

ns: not significant

Appendix (I) Analysis of variance for tomato fruit juice pH 1998 season.

Source of variance	df	pH in date 1 MS	pH in date 2 MS	pH in date 3 MS	pH mean MS
Rep	2	0.0010 ns	0.0129 ns	0.0002 ns	0.0035 ns
Fertilizer	3	0.0152 *	0.0707 *	0.0200 *	0.0308 *
Error (a)	6	0.0019 ns	0.0094 ns	0.0048 ns	0.0028 ns
Cultivar	2	0.0072 ns	0.0028 ns	0.0021 ns	0.0016 ns
Fert*cv	6	0.0050 ns	0.0039 ns	0.0022 ns	0.0018 ns
Error (b)	16	0.0043	0.0044	0.0028	0.0022

*Sinificant at 0.05 level

ns: not significant

Appendix (J) Analysis of variance for tomato fruit color ratio 1998

season.

Source of variance	df	Color ratio date 1 MS	Color ratio date 2 MS	Color ratio date 3 MS	Color ratio mean MS
Rep	2	0.0258 ns	0.0156 ns	0.1162 ns	0.0387 ns
Fertilizer	3	0.0289 ns	0.1973 *	0.2950 *	0.1229 *
Error (a)	6	0.0868 ns	0.0541 ns	0.0619 ns	0.0172 ns
Cultivar	2	0.0219 ns	0.0356 ns	0.0299 ns	0.0022 ns
Fert*cv	6	0.0127 ns	0.0233 ns	0.0309 ns	0.0080 ns
Error (b)	16	0.0786	0.0224	0.0430	0.0180

*Sinificant at 0.05 level

ns: not significant