EFFECT OF N, P, K CONCENTRATIONS ON YIELD AND FRUIT QUALITY OF TOMATO (SOLANUM LYCOPERSICUM L.) IN TUFF CULTURE

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ABSTRACT

This study concluded that high concentration of N, P and K in the nutrient solution gave higher total yield and tomato fruit weight than the control nutrient solution in tuff culture grown tomato. High phosphorus concentration (100 ppm) in the nutrient solution gave the highest total and marketable yield, number of marketable fruits and yield per plant, while low phosphorus concentration (20 ppm) gave the highest total soluble solids and titratable acids content in tuff culture grown tomato. The control nutrient solution gave the least total soluble solids, titratable acidity content and the highest pH of tomato juice.

Keywords: Tomato, tuff, open soilless, macronutrients, yield, fruit quality.

INTRODUCTION

Pest and disease accumulation in soil and water availability have always been a problem in protected cultivation. Production is maintained by practicing soil sterilization. The use of methyl bromide, which is the most common soil fumigant, will be banned in the future. Therefore, the use of soilless culture can be one of the alternatives to overcome soil problems and to increase water use efficiency. However, the main disadvantage of soilless culture is the high initial cost of establishment [4,8,12,25].

There are three main types of soilless cultivation: organic substrates (e.g. peatmoss), inorganic substrates (e.g. tuff) and no substrates (e.g. NFT). Nutrient solution can be applied either in open or closed system. In closed system the drained nutrient solution is recirculated but not in the open system [8,13,26]. Jordan has nearly 1500 ha greenhouse area, of which mostly is used for vegetables grown in soil. Soilless cultivation is being practiced only on a very small scale; farmers are using the closed soilless culture where tuff substrate is used to produce crops such as cut flowers. Jordan has good deposits of black tuff with attractive physical and chemical properties for agriculture [5,6,7,17,22,23].

Plant nutritional status affects yield, fruit quality and susceptibility to pathogens. Hence it is essential to have a good knowledge of the plant's mineral requirements in order to ensure a good yield and to avoid nutrient wastage. This may decrease production costs and reduce the risk of water pollution [9]. Several works were conducted to study the effects of macronutrient concentrations on vegetables grown in soilless culture. No significant differences were observed among four N:K ratios of nutrient solutions, however, the 3:1 ratio produced the highest optimal and marketable pepper yields [16]. Schon et al. [20] found more fruits and total marketable fruit weight for pepper plants grown with N at 175 ppm than other treatments, and a trend toward higher yield with N at 175 ppm rather than 120 ppm but the differences were not significant. However, a higher rose yield was obtained by 200 ppm N, also, a significant positive response to K was detected when 200 ppm K was increased to 300 ppm K [11]. When decreasing concentrations of N, K and Ca were used in tomato soilless cultivation, differences were observed in total yield, fruit size, titratable acidity and sugar content [3].

High nitrogen level (275 ppm) had little effect at first but ultimately reduced tomato yield, fruit size and root growth in NFT, and at low nitrogen concentration (35 ppm) was sufficient for plant growth, while low concentration of nitrogen and potassium (10 and 20 ppm respectively) proved to be deficient [25]. Tomato plants grown under four phosphorus concentrations (5, 10, 50, 200 ppm), a fully satisfactory growth of tomato plant was noticed at 5-10 ppm, and no significant differences in yield resulted over the range tested [18]. According to Spensley et al. [21], a typical nutrient solution for tomato production has the following composition: N: 150-200 ppm, P: 30-40 ppm, K: 200-300 ppm, Mg: 40-50 ppm, Ca: 150-200 ppm and Fe: 5 ppm.

This study was carried out to evaluate the effects of different concentrations of N, P and K in the nutrient solution (with lower and higher concentrations of the control nutrient solution) on tomato yield and fruit quality growing in a non-circulating open tuff culture under plastic houses.

MATERIALS AND METHODS

This research was conducted during the 2004 season at Wadi Al-Rayyan northern Jordan Valley (latitude 24º32'N, longitude 35º35'E, altitude 200m below sea level). Three unheated plastic houses were used to grow tomato under a non-circulating open soilless culture. Each plastic house represented one replicate and was divided into four rows. Six treatments of different concentrations of N, P and K with lower and higher concentrations than the control nutrient solution were randomly distributed according to Randomized Complete Block Design with three replicates. Treatments were: 100 and 300 ppm Nitrogen, 20 and 100 ppm Phosphorus, and 0 and 450 ppm Potassium. A complete Hoagland's nutrient solution was used as the control treatment [14] consisted of 200 ppm Nitrogen, 60 ppm Phosphorus and 300 ppm Potassium (Table 1). For all treatments, Ca, Mg and micronutrients concentrations were kept constant.

Soilless beds (40 cm wide, 30 cm deep and 10 m long) were made in soil with cement blocks and the ground was zero leveled. Each bed was lined with a 400-µ black polyethylene sheet to preserve the nutrient solution. Acid-washed black tuff was placed in the beds in two layers; 5 cm of coarse tuff (8-16 mm in diameter) below and 15 cm of fine tuff (0-4 mm in diameter) above. The upper side of beds was covered with black plastic mulch, and an empty space was made at the end of soilless beds to monitor and control the nutrient solution. The nutrient solutions were consisted of four stock solutions: Complex A: contains potassium nitrate, calcium nitrate, Complex B: contains mono-ammonium phosphate, and magnesium sulphate, Micronutrient solution: contains $CuSO_4$, $MnCl_2$, Mo acid, Bo acid, $ZnSO_4$, and Fe solution which added weekly. The nutrient solutions were delivered to beds with a drip irrigation system two times a day, and daily monitored for electrical conductivity (EC) and pH and adjusted to

Table 1. Treatments and concentrations used in the study

Treatment	Nitrogen (N) ppm	Phosphorus (P) ppm	Potassium (K) ppm
Control	200	60	300
T1 (- Nitrogen)	100	60	300
T2 (+ Nitrogen)	300	60	300
T3 (- Phosphorus)	200	20	300
T4 (+ Phosphorus)	200	100	300
T5 (- Potassium)	200	60	0
T6 (+Potassium)	200	60	450

2.0 – 2.5 dS/m, and 5.5 – 6.0; respectively.

Tomato (Solanum lycopersicum L.) c.v. 'Hana' seedlings were planted on the October 15th at 7.0 plants/m^2 in double row distribution [10]. At each harvest, fruits were collected, counted and weighed to determine total and marketable yield (fruit weight ≥ 60 g), yield per plant and average marketable fruit weight. Ten red stage fruits from each treatment were randomly selected and cut into pieces, then juice was extracted with fruit juicer and filtered to exclude precipitates. Total soluble solids (TSS) content was measured by Fisher® refractometer (Fisher Scientific Co.). For titratable acidity measurement, 10 ml of filtrate was dispensed and supplied for titration by 0.1N NaOH until pH 8.1. The amount of NaOH in ml was recorded to calculate titratable acidity which is expressed as the amount of citric acid (mg) in 100 ml of fruit juice [2]. Juice pH was measured by pH meter (HANNA® Instruments).

Treatments were randomly assigned the experimental units in a Randomized Complete Block Design with three replications per treatment. Collected data were statistically analyzed using MSTAT software (version 4.0, 1985) and mean separation was performed according to the Least Significant Difference (LSD) method, P≤0.05.

RESULTS AND DISCUSSION

Total and marketable yields and marketable fruit number were significantly highest with the higher phosphorus concentration (100 ppm) when compared with the control nutrient solution. The higher concentrations of N, P and K in the nutrient solution gave significantly higher results than the control nutrient solution. For all treatments, the smallest total and marketable yields and marketable fruit number were noticed at low potassium concentration (0 ppm) (Table 2). These results agree with Zekri and Obreza [27] who stated that lower concentrations of N, P and K may limit plant growth, flower and fruit production due to their effects in many aspects of plant growth and development including photosynthesis and carbohydrate production, consequently, yield and marketable fruits will be reduced. In addition, potassium is known to help in vigorous tomato growth and stimulates early flowering and fruit setting, thereby, its deficiency will result in slow stunted growth and reduction in yield and marketable fruits [15, 24]. Moreover, Winsor and Massey [25] noticed that yield of tomato fruit was reduced significantly by low potassium concentration which was observed in our study. Meanwhile, Nitrogen deficiency can result in stunted growth and decrease fruit number and size, whereas high nitrogen level can stimulate excessive vegetative growth which can delay fruit setting and maturation [19]. On the contrary to our results, Winsor and Massey [25] found that the highest nitrogen treatment (275 ppm) reduced the yield and the proportion of high grade tomato fruit. Also, low nitrogen concentration increased the high grade fruits and the fruit size, whereas, low potassium decreased it [25].

The highest yield per plant was recorded at high phosphorus concentration (100 ppm) with an increase about 31% compared with the control nutrient solution. Compared with control, the higher concentrations of N, P and K gave significantly more yields per plant. On the other hand, lower potassium concentration (0 ppm) in the nutrient solution resulted in significantly smaller yield per plant and fruit weight (Table 3). According to Abd-Alla et al. [1] and Sainju et al. [19], phosphorous has a positive role in stimulating healthy root growth which helps in better utilization of water and nutrients. This will eventually promote a strong stem and foliage growth, producing large number of flower and early fruit setting. As a result, phosphorus increases the number and production of tomato fruits. In addition, N, P and K are needed for plant growth, flower and fruit formation; therefore, their low concentrations will lower the yield of plant [27].

Average fruit weight in this study was increased significantly by the high concentrations of Nitrogen, Phosphorus and Potassium in the nutrient solution (+N, +P, +K treatments) with 8-10 % over the control nutrient solution which gave an intermediate fruit weight. Low concentrations of the three macronutrients negatively affected fruit weight (Table 3). These results are in agree with Imas [15] and Zekri and Obreza [27] who stated that

Table 2. Effect of N, P and K concentrations on total and marketable yield (kg/m^2) and on marketable fruit number of tomato cv. 'Hana'

Treatment	Total yield (kg/m^2)	Market. yield (kg/m^2)	Marketable fruit number
Control	8.1[1] d	7.7 d	417 d
T1 (- Nitrogen)	6.7 e	6.4 e	379 e
T2 (+ Nitrogen)	10.5 b	10.3 b	499 b
T3 (- Phosphorus)	6.8 e	6.4 e	393 d
T4 (+ Phosphorus)	11. 9 a	11.6 a	550 a
T5 (- Potassium)	6.2 f	5.8 f	348 f
T6 (+Potassium)	9.8 c	9.6 c	457 c

[1]Mean separation at 5 % level (LSD), values that don't share the same letter are significantly different.

Table 3. Effect of N, P and K concentrations on yield per plant and average fruit weight (g) of tomato cv. 'Hana'

Treatment	Yield per plant (kg/plant)	Average fruit weight (g)
Control	1.51[1] d	82 b
T1 (- Nitrogen)	1.25 e	76 c
T2 (+ Nitrogen)	1.95 b	88 a
T3 (- Phosphorus)	1.26 e	74 c
T4 (+ Phosphorus)	2.20 a	90 a
T5 (- Potassium)	1.16 f	77 c
T6 (+Potassium)	1.82 c	90 a

[1]Mean separation at 5 % level (LSD), values that don't share the same letter are significantly different.

low concentrations of N, P and K will result in smaller fruit since the rate of photosynthetic activity of the plant will drop sharply, therefore, growth will be reduced and smaller fruits will be produced. On the contrary to our results, Winsor and Massey [25] found that high nitrogen concentration (275 ppm) reduced fruit size, whereas potassium was without effect.

The results showed that total soluble solids (TSS) content was significantly higher at the higher and lower concentrations of both Nitrogen and Phosphorus in the nutrient solution compared with the control solution. In addition, the higher concentrations of N, P and K resulted in more soluble solids compared with the control nutrient solution. However, Potassium at higher or lower concentrations than the control solution did not affect total soluble solids.

(Table 4). These results are in agreement with Zekri and Obreza [27] who noticed that plant grown at high nitrogen or at low phosphorus concentrations will result in fruits with high soluble solids content, however, potassium at high levels reduced fruit total soluble solids. On the contrary, Imas [15] and Sainju et al. [19] noticed that high potassium concentrations increased fruit total soluble solids of tomato fruit which was observed in this study. On the other hand, Abd-Alla et al. [1] and Sainju et al. [19] stated that high phosphorus concentration will increase fruit soluble solids content of tomato fruit.

High titratable acidity content was observed with low phosphorus concentration treatment (20 ppm) compared with all other treatments which were not significantly different among each other. However, the smallest titratable acidity content was observed in the control nutrient solution treatment (Table 4). These results agree with Abd-Alla et al. [1], Sainju et al. [19] and Zekri and Obreza [27] who stated that plant grown at low phosphorus concentration will produce fruits with high acidity. According to Imas [15], high K concentrations will increase fruit titratable acidity and citric acid content of tomato fruit which was observed in this study.

The highest juice pH recorded in this study was found in the control solution treatment which was significantly higher than other treatments. Other treatments did not differ significantly among each other, and among these higher potassium concentration (450 ppm) was the highest (Table 4). The least juice pH was recorded at low phosphorus concentration (20pmm). This agrees with Imas [15] and Zekri and Obreza [27] who noticed that low levels of phosphorus will increase acidity of fruit juice. On the other hand, Winsor and Massey [25] showed a progressive increase in acidity of tomato juices with increasing levels of nitrogen, whereas potassium had little effect which was not supported by our results.

Table 4. Effect of N, P and K concentrations on chemical fruit quality of tomato cv. 'Hana'

Treatment	TSS %	Titratable acidity (mg citric acid /100ml)	Juice pH
Control	5.6[1] c	430 b	4.39 a
T1 (- Nitrogen)	6.0 ab	468 b	4.25 b
T2 (+ Nitrogen)	6.3 a	462 b	4.24 b
T3 (- Phosphorus)	6.4 a	518 a	4.23 b
T4 (+ Phosphorus)	6.1 ab	470 b	4.25 b
T5 (- Potassium)	5.9 bc	470 b	4.23 b
T6 (+Potassium)	5.9 bc	455.0 b	4.27 b

[1]Mean separation at 5 % level (LSD), values that don't share the same letter are significantly different.

CONCLUSION

Plant nutritional status affects yield and fruit quality. Hence it is essential to have a good knowledge of the plant's mineral requirements to ensure a good yield and to avoid nutrient wastage, which will decrease production costs and reduce the risk of water pollution. This study concluded that increasing N, P and K concentrations in the nutrient solution over the control nutrient solution resulted in more total yield and the highest fruit weight. In addition, increasing the phosphorus concentration over the control solution resulted in the highest total and marketable yield, number of marketable fruits per treatment and the biggest yield per plant. However, decreasing phosphorus in the solution below the control solution resulted in the highest total soluble solids and titratable acidity contents. The control nutrient solution induced the smallest total soluble solids, titratable acidity contents and the highest pH in the juice of tomato fruit.

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