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Tomato Hydroponics in Korea

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ABSTRACT

Hydroponics is ideal for improving tomato quality, increasing yields, and escaping insects and/or disease. From a view point of these advantages, a tomato hydroponic system is highly recommended. Fertilizer application dosage and methods affect plant growth, yield and tomato quality. Potassium accelerates lycopene accumulation, and selenium increases fruit firmness. Chlorine and silicon increase soluble solid contents. Tomatoes contain various food functional substances such as lycopene, β-carotene, ascorbic acid, tocopherol, etc. The kinds of salts and their concentration in nutrient solution affect fruit texture, the amount of minerals, lycopene, and food functionality. Food functionality of tomatoes is well known to consumers, having antioxidants that prevent cancer and heart disease. In this manuscript we review the benefits of hydroponics on tomato quality, with a focus on Korea.

Keywords: functional food, nutriculture, soilless culture

CONTENTS

INTRODUCTION

Tomato cultivation area by hydroponics is 222 ha in Korea, accounting for 27.5% of the total hydroponic culture area (RDA 2003). Early hydroponic systems used sand and gravel, and about 38% have used perlite of late. Peatmoss was used in the late 1960s in hydroponics and rockwool substrates were developed by Grodan, Denmark in 1968. Rockwool was universally used until the late 1970s in Europe (Lee 1988). The ideal substrates for good quality tomatoes in bag culture were developed by Lee *et al*. (1993). The highest marketable yield was obtained with a mixture of peatmoss, vermiculite and granular rockwool at a 3:3:1 ratio (v/v). Total fruit yield and average fruit weight of 'Katinka' tomato was the highest in a single perlite treatment, followed by perlite mixed with rice hull and carbonized rice hull (Chung *et al*. 1996). Adding perlite to peatmoss, rice hull and carbonized rice hull resulted in higher fruit yield and high soluble solid contents.

A deeper transplanting depth resulted in an increased number of harvested fruit at first truss, increasing first fruit size, and accelerated harvest time (Vavrina *et al*. 1996). In a separate study, the number of marketable fruits of 'Momotaro T-93' was not influenced by transplanting depth (Lee and Kim 1999), and was the most in the 60 day-old seedling plot.

Predicting plant differentiation and development of 'VF-134-19' was primarily researched by integrated temperature (Wolf *et al*. 1986), but Kim (1994) showed that there were high correlations between external quality, namely lengthwise growth of fruits harmonized with lateral growth. The volume and/or weight of fruit could be non-destructively estimated by length and width of fruit. Volume = $0.071 \times (\text{length} + \text{width})^3 + 0.451$, Fresh weight = $0.072 \times (\text{length} + \text{width})^3 + 0.542$. These models were used to accurately evaluate fruits harvested in 1994.

Received: 28 February, 2007. Accepted: 7 October, 2007.

Invited Mini-Review

IMPROVEMENT OF SOLUBLE SOLID CONTENT

Control of nutrient solution supply and bioceramic

Increasing methods of soluble solid contents have been researched. These are represented by reducing water content in fruit and control of nutrient composition by reducing nitrogen and by increasing carbohydrate. Schiavi *et al.* (1995) and Kaith and Awsathi (1996) attempted to increase potassium ion in nutrient solution and reduce water content in fruit by increasing the salinity of the nutrient solution (Cho and Jung 1997). Li *et al.* (2001) investigated the effects of nutrient solution supplying frequency on 'Momotaro T-93' tomato quality. By supplying 0.9 L·plant^{-1} 8 times a day appeared to produce high soluble solid tomato, while 16 times a day supply of 1.8 L·plant^{-1} gave a higher yield of tomato fruit in ash ball culture. The reducing sugar content decreased with frequent irrigation and their differences increased as high as the cluster in polyurethane culture (Kim and Kim 1998). The reducing sugar content in polyurethane culture was higher than in perlite culture and their differences increased in proportion to the growth of the plant when the percentage of drainage was 25%.

Bioceramic forms, such as bioceramic balls, bioceramic pads, and bioceramic powder, affected plant growth and development differently (Chung *et al.* 1992). Cumulative fruit fresh and dry weight of 'Seokwang' tomato were reduced when 0.02% of bioceramic powder was treated into nutrient solution but 0.2% of bioceramic foliar spray produced more cumulative fruit fresh and dry weight than the control (Lee *et al.* 1996). It was shown that treatment of bioceramic powder into the nutrient solution and foliar spray could improve soluble solid content without reducing yields. Bioceramic treatment on roots or aerial parts increased the vitality of plant cell and growth (Jeong *et al.* 1992). Lee *et al.* (1995) assumed that the growth promotion effect of bioceramic was caused by micronutrients in bioceramic, and by far infrared ray radiation.

Using some salts: KCl, NaCl and SiO_2

'Seokwang' tomato plant height, after supplementing NaCl treatment in nutrient solution, increased in the plot of EC 2 and 3 dS·m^{-1} at 21 days after transplanting (Cho *et al.* 1996). However, plant height at 68 days after transplanting decreased with an increase in NaCl concentration in nutrient solution. Top fresh and dry weight were not influenced by salinity, however, root fresh and dry weight tended to increase at 21 days after transplanting. Blossom-end rot and puffy fruit were not influenced by NaCl treatment in nutrient solution at the seedling stage. The occurrence of puffy fruit was about 30% in NaCl-treated plots. Total fresh weight and dry weight of fruit decreased as the salinity level increased in the tomato seedling stage. However, when the salinity level of nutrient solution was increased to EC 3 dS·m^{-1}, total fresh and dry weight of fruit were almost the same level as the control. Fruit quality in terms of soluble solid content was improved when NaCl was added in nutrient solution. Gough and Hobson (1990) showed that saline adaptability of cherry tomato differed depending on the cultivar.

A higher concentration and earlier supplement of KCl and NaCl to the solution resulted in greater fruit quality improvement of 'House Momotaro' (Rhee *et al.* 2001a). However, a proportional reduction in yield accompanied this result. The concentration of KCl and NaCl, which improve fruit quality without a significant yield reduction were 20 and 25 mM, respectively. The proper time to supplement KCl or NaCl to the solution was 20 days after anthesis of the first truss flowers. Rhee *et al.* (2001b) reported that 20 mM of KCl and 25 mM of NaCl supplement in 'House Momotaro' and 'Seokwang' tomato nutrient solution promoted the conversion of starch to sucrose, and the content of starch greatly decreased, while that of reduced carbohydrates greatly increased at 32 days after anthesis and later. At this time, the activity of invertase was high, while that of sucrose synthase was low. The number of stomata increased, while the size of stomata decreased when 20 mM KCl and 25 mM NaCl were supplemented in Yamazaki's standard tomato solution compared to the control (Rhee *et al.* 2001c).

Kim *et al.* (2003a) investigated the effects of silicate application on fruit quality of 'Momotaro Yoku' tomato. The soluble solid content was increased to 6.9 °Brix in 4 ton·ha^{-1} as opposed to 6.3 °Brix in the control, but the extent of titratable acidity was not significant among the treatments. The fruits containing more soluble silicon had a greater lycopene content. Fruit hardness increased with increasing silicon application.

Silicon dioxide content of leaves was higher in silicate treatment than the control, and in lower leaves than upper ones. Soluble silicon content of 'Momotaro Yoku' fruit was higher in silicate treatment than control, and was 6-9 times higher in lower fruits than upper ones (Kim *et al.* 2002). The activities of sucrose phosphate synthase and sucrose synthase in tomato fruits also showed a maximum value at 34 days after fruit setting. Silicate application in perlite medium also resulted in a positive correlation with the silicon content of tomato fruit and the content was closely related to the enzymes' activities (Kim *et al.* 2003b).

IMPROVEMENT OF FRUIT QUALITY

Functional tomato: Lycopene, selenium and calcium

Fertilizer application dosage and methods affect plant growth, yield and product quality such as texture, minerals, pigments, etc. The effect of selenium forms on selenium uptake of hydroponically-grown tomato was investigated (Lee *et al.* 2005). Growth characteristics, viz. plant height, number of leaves, leaf area and chlorophyll content, increased significantly in the plot of foliar application of selenium, and in the plot of foliar application plus drenching of chelated-selenium than in any other plot. Transport of selenium into the tomato fruits was as high as 3.03 ppm in the plot of foliar application plus drenching than in plots of foliar application or drenching in both selenium and chelated-selenium treatments. Foliar application and drenching of organic chelated-selenium were effective to produce functional tomato fruits.

Lee *et al.* (2005b) applied selenium in nutrient solution to increase selenium content in tomato fruits. There was no difference in plant height among the treatments, and the lightest fruits were produced in the 4.0 mg·L^{-1} selenium treatment. The heaviest weight and the greatest number of fruit formed when 0.5 mg·L^{-1} selenium was applied. Fruit firmness tended to increase with increasing selenium concentration. There was no regular trend between soluble solid content and selenium dosage in nutrient solution. The soluble solid content was not affected by the supply of selenium. The free sugar content tended to decrease as selenium concentration increased. Titrable acidity in the control was higher than in all other treatments. Selenium and lycopene content in tomato fruit tended to increase with an increase in selenium treatment.

Lee *et al.* (2005a) investigated the effects of K/N ratios in the standard nutrient solution for increasing the lycopene content of 'Super Momotaro'. Plant height of the 2nd truss-limited grown tomato was depressed when potassium was added, but there was no significant difference among the treatments. Fruit weight per plant was highest when the K/N ratio was 5.0:7 (in mg·L^{-1}). The soluble solid content in fruits of the 5.5:7 K/N treatment was higher than that of fruit from other treatments. Lycopene content was higher in the 4.5:7 plot (62.7 μg·g^{-1}) and in the 5.0:7 plot (58.2 μg·g^{-1}) than from other treatments. The electrical conductivity of fruit increased with high K/N ratios in nutrient solution, however, there was no significant statistical difference in growth and chlorophyll content.

To re-enforced calcium in tomato production, the addition of Ca-gluconate from 0.3 to 0.9 me·L^{-1} in nutrient solution of 'Super Momotaro' was investigated by Lee *et al*. (2005c). Plant height did not differ among treatments. The soluble solid content was not statistically different among the treatments, but glucose increased in the 0.9 me·L^{-1} Ca-gluconate treatment. There was an irregular trend in fruit firmness and soluble solid content. Fruit weight and average fruit weight per fruit decreased with high Ca-gluconate treatments. Cation content, such as Ca, K, Mg, and Na, in fruit increased when Ca-gluconate was added. A high lycopene content was found in the 0.6 me·L^{-1} Ca-gluconate treatment.

Inhibition of blossom-end rot incidence

It is well known that the occurrence of blossomed-end rot (BER) is caused by calcium uptake deficiency in tomato plants. The concentration of Ca ions is significantly lower in fruits than in stems, leaves, and roots. Ca-deficiency in fruits may not be the direct cause of occurrence of BER in tomato plants, but might rather be related to gene-regulated metabolic disorder under stress conditions (Nonami *et al*. 1995). The incidence of BER becomes higher with an increase in the K/Ca ratio (Nukaya *et. al*. 1995); K uptake is also affected by the K/Ca ratio, but to a lesser extent than Ca uptake. Considering growth, yield, and the incidence of BER, the optimum K/Ca ratio as a milliequivalent unit in a nutrient solution for perlite culture of tomatoes in the hot season is 4/5 (Kim *et al*. 1999).

Even though excess copper ions allowed for the growth of tomato plants, when Ca-zeolite was added to the nutrient solution, the recovery of tomato growth was observed and BER could be drastically reduced (Fukuyama *et al*. 1995). When zeolite as a buffering agent is added to a solution, zeolite has cation exchange capacity, and the solution increases buffering capacity against changes in pH and cation concentration.

Extending shelf-life

When 3 different calcium concentrations were tested in 'Sekye' tomato during hydroponics, a rise in the calcium ion content of the fruit retarded ripening and could be measured by the inhibition of color changes, softening, and ethylene production (Hong *et al*. 1995). The ripening process of treated fruits was not affected after the breaker stage. More cell wall components were detected in fruit treated with higher levels of calcium at the mature green stage but slightly fewer than in fruit treated with a lower calcium level as ripening progressed. Chelated soluble pectin level was high in tomato at the red stage, whereas water-soluble pectin was high in green mature fruit. Calcium treatment delayed the degradation of water-soluble pectin and increased the chelated soluble pectin ratio during ripening. Ripening, including pectin degradation and softening, may in part be controlled by the presence and amount of calcium in tomato fruit.

NUTRIENT SOLUTION

Development of optimal nutrient solution

The nutrient solution composition is diverse, depending on cultivation region or system, the kind of medium, growth stage, weather, method of supplying nutrient solution, etc. A feature of Korean tomato hydroponics is its use of perlite medium or rockwool (RDA 2003). The development of optimal nutrient solution focuses on perlite hydroponics. The National Horticulture Research Institute (NHRI) in Korea developed a nutrient solution for tomato based on perlite medium. Its N-P-K-Ca-Mg composition was 9-2-5-4-2 (me·L^{-1}). Most tomato growers in Korea now use NHRI nutrient solution in perlite medium.

Won-Kwang University (WU) also developed a tomato nutrient solution (Yu and Bae 2005; Yu *et al*. 2006). WU nutrient solution has two uses, one for tomato, the other for cherry tomato.

The utilization of $NH_4H_2PO_4$ to stabilize pH in a deep-flow culture system using tap water, and the optimal range of $NH_4H_2PO_4$ in culture solution was researched by Lee *et al*. (1995a). The highest soluble solid content was obtained in 5/3-6/3 me·L^{-1} $NH_4H_2PO_4$. Ammonium toxicity symptoms appeared at 8/3 me·L^{-1} $NH_4H_2PO_4$. $NH_4H_2PO_4$ at 2/3 me·L^{-1} was good before the harvest stage and 5/3-6/3 me·L^{-1} $NH_4H_2PO_4$ at the harvest stage.

Ionic strength

Chung and Lee (1997b) found that plant height, leaf area and total dry weight increased with increasing ionic strength of nutrient solution of aeroponically grown 'Seokwang' tomato. Fruit dry weight per plant was the highest in double strength and the lowest in quarter strength solution. Stomatal resistance was inversely related to transpiration. In double and standard strength solution NAR decreased by increasing leaf area in the early growth stage. In half and quarter strength solution, changes in leaf area were similar. In half and quarter strength solution, leaves thickened at an early growth stage, while in standard and double strength solutions a thickening pattern appeared only in later growth stages. According to the change pattern of the T/R ratio, dry matter was partitioned more to the shoot region at an early stage and then later to the root region.

When the growth of aeroponically grown tomato was divided into four stages, the initial ionic strength affected the T/R ratio and total dry weight in later stages (Chung and Lee 1997a). Total fruit yield and leaf area were the highest in the 2→1/4 →1/2→1 me·L^{-1} plot. Fruit yield was highly affected by the growth stage.

Diurnal alternation of nutrient solution and dissolved oxygen

Kim *et al*. (2006) reported that plants were shortest at a high nutrient concentration during the day (6/1 me·L^{-1}, day/night). Yield decreased with an increase in the nutrient concentration. Yield was higher at a lower concentration (4/1 me·L^{-1}) at night compared to the same concentration (4/4 me·L^{-1}) during the day, and at night yield of the inverse concentration (1/4 me·L^{-1}) was similar to that of the control (Perlite culture). Yield was greatly reduced by a higher nutrient concentration during the day than at night, and the decrease in yield was alleviated by a lower concentration at night. By increasing the concentration of nutrient solution during the day, the sugar content of tomato fruit increased, but yield decreased. The Ca content of leaves and the sugar content of fruit increased by supplying $Ca(NO_2)_2$ solution during the day more than at night, but plant growth was greatly suppressed by supplying $Ca(NO_3)_2$ solution at 4 me·L^{-1} (4/4^{ca} me·L^{-1}) at night.

Yang *et al*. (1991) investigated the optimal oxygen concentration of nutrient solution of tomato. The growth of shoots were better in the 10 and 20 mg·L^{-1} treatments than in the 5 or 40 mg·L^{-1}. The number of flower buds was greater in the 10 and 20 mg·L^{-1} treatments, and also the cluster of flowers were heavier in those treatments. Primary and total roots were longer in the 10 and 20 mg·L^{-1} treatments than those at 5 or 10 mg·L^{-1}. The pH and EC of the nutrient solution gradually increased excepting at 5 mg·L^{-1}. Stomatal resistance was higher in the leaves grown at 5 or 40 mg·L^{-1} of oxygen, and the photosynthetic activity and the root respiration improved with an increase in oxygen concentration.

Nutrient diagnosis

A non-destructive nutrient diagnosis method for nitrogen was developed in tomato leaves by Lee *et al*. (1995b) using a specific color difference sensor (SCDS) in tomato nutrient film technique system. As the SCDS value of tomato leaf increased, so the CO_2 assimilation rate increased linearly but the total average fruit weight and marketable yield increased quadratically. The CO_2 assimilation rate increased largely in the 0-3% range of leaf nitrogen content, but photosynthetic saturation was shown at 3.3-3.5%. The leaf nitrogen content was closely related to the SCDS value of tomato leaf. Considering physiological activity, growth and yield of tomato, the optimum range of leaf nitrogen content was found to be 3.0-3.8% and the SCDS values equivalent for that range was 40.0-52.2.

ENVIRONMENT AND HYDROPONIC SYSTEM

Hydroponic system control

A closed hydroponic system can save 64% of water, 44% of nitrogen and 50% of potassium compared to an open system (Sonneveld 1993), but ions in the nutrient solution are easily unbalanced and accumulation of particular ions may occur over medium- to long-term cultivation. An unbalanced root environment can cause the deterioration of tomato yield and marketability. The main hydroponic production system of cherry tomato is deep flow culture (Park and Kim 1991). An appropriate hydroponic system depends on the weather, the grower's skill, the growing season, regional characteristics, etc. Kim (1993) investigated the appropriated hydroponic system in Korea, nutrient film technique and deep flow culture when 'Mini-Carol' cherry tomatoes were grown in summer. Although the first time to flower and fruit color per cluster did not differ among cultural systems, the marketable yields as number of tomatoes per cluster were higher (147.6) in deep flow culture than in NFT (116.2).

Hydroponics is good to regulate the nutrient solution strength and its composition, which needs to be regulated depending on the kind of crop, growth stage, growing method, climate, etc. Thus, regulation of the nutrient solution is a prime issue in hydroponics. Kim *et al*. (1995) developed using a programmable logic controller a facility to control the EC and pH automatically in nutriculture of tomato whose program was written in ladder diagram language. EC and pH levels of the nutrient solution could be maintained at 1.70-1.72 and 6.1-6.5, respectively, during the entire growing period. Better fruits and higher yield were obtained in the automatic plot (2,410 g per plant) than in the control plot (2,260 g per plant).

Modeling nutrient uptake of tomato for predicting the amount of nutrients in the drainage solution in closed perlite culture was developed by Kim and Kim (2001). A model for the amount of each inorganic ion absorbed was developed by using EC and the amount of nutrient solution absorbed per unit radiation ($mg \cdot MJ^{-1}$), which proved to be practical with a positive correlation ($p = 0.01$) between the developed model and practical values.

The fan and pad cooling method is very effective but expensive (Nelson 1991). Choi *et al*. (2000) found that the cooling method was not expensive, but that the marketable yield was lower (44.6 $ton \cdot ha^{-1}$) in the fan and shading (temperature control) method than in the fan treatment (53.2 $ton \cdot ha^{-1}$) due to a lack of light intensity, 89 W·J as 22% of outdoor radiation, with a long shading period. The fogging method, which uses 500 ml/min/100 m^2, with 50 µm droplets, requires expensive equipment and maintenance expenses must be taken into consideration. At present, the most effective cooling methods are considered to be an increase in the ventilation rate with a fan or the use of a fan and shading (radiation control).

Rhizosphere environments

Root zone temperature affects root activity, and water and nutrient absorption ability (Udagawa *et al*. 1991). High root zone temperature accelerated root elongation, root browning, root respiration, etc. Optimal root zone temperature of tomato was 25°C, and root growth was inhibited below 15°C (Fujishige *et al*. 1991). Rhee *et al*. (2001d) reported that by raising root zone temperature from 10°C to 25°C, except for 25°C, showed positive effects on plant height, leaf length, stem diameter, and plant fresh and dry weights, but not the T/R ratio which was greatest in the control (8.5°C) in truss-limited tomato hydroponics.

The misting intervals in an aeroponic system of 'Seokwang' tomatoes affected tomato growth and fruit yield (Chung *et al*. 1993). Leaf area, dry weight of each organ, the number of flowers or of fruits set, and the fruit dry weight were greater in the 30-sec spray every 10-min than 60-sec, and 10-sec spray in every 10-min treatments. Total dry weight and net assimilation rate (NAR) were closely related to the leaf area but differed slightly with the root environment, being affected by the misting intervals of the nutrient solution. Total dry weight was higher in the order of 30-sec spray every 10-min, continuous plot, 10-sec spray every 10-min, and 60-sec spray every 10-min. NAR of continuous plot and 30-sec spray every 10-min treatments were higher (6.3- and 6.25 $g \cdot m^{-2} \cdot day^{-1}$, respectively) than those of 60-sec and 10-sec spray every 10-min treatments (5.6- and 5.7 $g \cdot m^{-2} \cdot day^{-1}$, respectively). When specific leaf area (SLA) was high, NAR was low. However SLA and NAR could be altered by adjusting the misting interval of the nutrient solution. Leaf dry weight and total dry weight were also closely related to the fruit dry weight. But total dry weight and fruit dry weight in 30-sec spray every 10-min misting interval treatment of nutrient solution were higher (267.1 g and 51.3 g per plant, respectively) than those of 60-sec, and 10-sec spray every 10-min. But total dry weight and fruit dry weight showed significant differences. Oxygen absorption rate of tomato roots was higher from the atmosphere than from dissolved oxygen in nutrient solution (Yang 1988).

Shin and Lee (1999) found that the automatic irrigation system using 'Seokwang' tomato stem diameter monitoring and the transpiration model for the determination, respectively, of irrigation timing and amount was designed and evaluated for its applicability in pot and field culture. In pot culture, the yield and quality of greenhouse tomato improved when irrigation was practiced based on the stem diameter monitoring and the respiration model as compared to the irrigation practice based on soil moisture monitoring.

The differences in root environment and in growth of 'Seokwang' tomato plants between aeroponics and nutrient film technique (NFT) were investigated by Yang *et al*. (1990a). Temperature fluctuation in the root environment was greater in aeroponics than in NFT, especially when the solution temperature was low. Under the same solution temperature of 25°C, the plant growth expressed by plant height, stem diameter, leaf number, leaf area, leaf length and the total root length was almost double in aeroponics than in NFT, but this difference became less significant as the solution temperature decreased.

The days to the first and last flowering were earlier in aeroponics than in NFT by 3 days and more flowers formed per plant in aeroponics. Fruit size in terms of height and diameter was not substantially affected by culture system or spraying interval, but the fruit yield was higher in aeroponics than in NFT, and in aeroponics with shorter spraying intervals. The supporting material which did not show any noticeable effects on the shoot growth significantly influenced root growth.

Cho *et al*. (1997) reported compositional differences of rhizosphere microorganisms among the substrates of cherry tomato in nutrition culture. The total number of microorganisms in the rhizosphere of cherry tomato was significantly less in substrate culture (10^3-10^5 $cfu \cdot g^{-1}$) than in soil (5.0×10^8 $cfu \cdot g^{-1}$). The total number of microorganisms was higher in the order of soil > rice hull > nutrient solution. Bacteria were the main microorganisms in the rhizosphere in substrates. *Actinomyces* composed 10% of the substrate such as rice hull, carbonized rice hull, and perlite. Colonization of rhizosphere microorganisms on root surfaces was much more in the upper and lower parts than in the middle parts, and ectorhizosphere microorganisms were much more than endorhizosphere microorganisms.

Physio-morphological characteristics of roots

The changes in morphological adaptation of tomato plants between aeroponics and NFT were studied by Yang *et al*. (1990b). Development, as judged by the amount of root hairs and the diameter of secondary roots, was better in aeroponics than in NFT. Anatomical observations also indicated that the root cap, epidermis and cortical layer were thicker, that there were more cell layers in the cortex, and that the zone of cell division was longer in the roots grown in aeroponics than those grown in NFT. Also, the intercellular spaces in the roots grown in aeroponics were larger than those grown in NFT.

There were marked differences in stomatal resistance, water potential of leaves and temperature of leaves, root surface and plant body between aeroponics and NFT (Yang *et al*. 1990c). The stomatal opening or leaf potential could be regulated by changing the temperature and ionic strength of the solution. Especially, the temperature fluctuation in the leaves and root surface within ± 1.5°C strongly indicated the possible establishment of an optimal environment. The photosynthetic activity as well as the leaf respiration was significantly higher in aeroponics than in NFT. The amount of root respiration was lower in NFT but higher in aeroponics; it was higher in the plots sprayed at shorter intervals among the aeroponic treatments. In the contents of endogenous growth hormones, GA_3 and zeatin riboside were higher in the plants grown in aeroponics, while ABA and IAA were higher in the plants grown in NFT. When the hormone contents were compared in organs, roots from aeroponics contained more GA_3 and zeatin but less ABA and IAA than those from NFT, while the leaves from aeroponics contained more zeatin only than those from NFT.

CONCLUSION

Hydroponics is ideal for improving tomato quality, increasing yield, and escaping insects and/or disease. Although the tomato hydroponic system is very strongly recommended, the nutrient solution needs to be strictly regulated depending on the growth stage, growing method, growing season, climate, etc. Thus, it is necessary to pay much attention to plant growth, physiological disorder or disease symptoms and environment factors when we grow tomatoes in hydroponics.

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