

Effects of Drip Irrigation Volumes on Plant Growth and Yield of Tomato Grown in Perlite

Doo Han Kim¹, Md Rayhan Ahmed Shawon², Jin Hee An¹, Hyoun Jin Lee¹, Yun-Jae Lee¹,
Minkyung Kim¹, Yong-Beom Lee³, and Ki Young Choi^{4,5*}

¹Student, Department of Agriculture and Industries, Kangwon National University Graduate School, Chuncheon 24341, Korea

²Postdoctoral Researcher, Division of Future Agriculture Convergence, Department of Controlled Agriculture, Kangwon National University, Chuncheon 24341, Korea

³Director, International Horticulture Institute, Seoul 02024, Korea

⁴Professor, Department of Agriculture and Industries, Kangwon National University Graduate School, Chuncheon 24341, Korea

⁵Professor, Division of Future Agriculture Convergence, Department of Controlled Agriculture, Kangwon National University, Chuncheon 24341, Korea

Abstract. The objective of this experiment was to investigate the effect of drip irrigation volume on tomatoes (*Solanum lycopersicum* L.) grown in a greenhouse using perlite medium. Plants were treated by three different irrigation treatment I₀, I₂₅, and I₅₀ (where irrigation volume of I₂₅ and I₅₀ was 25% and 50% higher than I₀, having limited or no leaching). Growth characteristics of plants, yield and water use efficiency were measured. The result showed that plant height, leaf length and leaf width were lowest in the I₀ treated plants. However, these parameters were not statistically significant differences between the plants that were grown in the I₂₅ and I₅₀ treatment. Soluble solids content, acidity and dry matter of 111th, 132nd, and 143rd days harvested tomato were higher in the plants irrigated with lowest volume (I₀) than the higher volume (I₂₅ or I₅₀). In addition, water content was lower in the 111th and 132nd days of harvested tomatoes from the I₀ treatment. The number of big-size tomatoes (>180 g) was significantly higher in the I₂₅ irrigated plants. There was no significant difference in the total number of harvested fruits among the treatments. The average fruit weight and total yield of harvested tomatoes were lowest in the I₀ treated plants. The water consumption of tomato was not significantly different amongst the treatments but water use efficiency was lowest in the I₀ treatment. Principal component analysis revealed that total soluble solid and acidity of tomato showed a positive correlation between each other. These results suggest that I₂₅ was the optimum irrigation treatment for tomato based on its measured growth characteristics, yield and water use efficiency.

Additional key words: plant height, fruit weight, fruit number, soluble solids content, acidity, correlation, water use efficiency

Introduction

Irrigation is one of the most important factors for the production of horticultural crops. The optimal supply of irrigation water is a key feature for high horticultural productivity with efficient water use, and the reduction of negative impact due to the percolation and leaching of excess water (Zou et al., 2013; Seidel et al., 2017). The drip irrigation method is considered a possible solution to facing water scarcity problems and increasing water use efficiencies in crop production (Van der Kooij et al., 2013; Ortega-Reig et al., 2017). Tomato is a horticultural crop, having a large

production volume globally. The cultivated area of tomatoes in Korea was 6,058 hectare (ha) which was the second-largest cultivated area among horticultural crops in the greenhouse, and the total production was 388,657 tons (MAFRA, 2020). Notably, tomato cultivation in Korea was 100% converted into controlled agriculture from traditional methods in 2010. After conversion, the average production of tomato per hectare is around 65 tons (61.6 to 70.7 tons), showing a difference depending on the year. Nowadays, growers need a stable production system including irrigation management in the protected greenhouse to increase the quality and yield of tomatoes.

Different solid substrates are adequate as a growing medium providing the necessary support for plant root structure. Substrate culture has advantages, for example,

*Corresponding author: choiky@kangwon.ac.kr
Received September 13, 2022; Revised October 4, 2022;
Accepted October 4, 2022

controlling the root environment and facilitating the stable production of high-quality vegetables and fruits (Arancon et al., 2015; Lim et al., 2020; Majid et al., 2021). In 2018, the total cultivated area of controlled agriculture in Korea was 3,409 ha with 87.7% using substrate culture (MAFRA, 2020). Furthermore, the irrigation method is non-circulating in substrate culture, requiring a continuous water supply with nutrients (Arancon et al., 2019). Sometimes, NaCl, KCl, or seawater are applied to control the EC of the growing medium (Park and Kim, 2002; Seo and Kim, 2004; Choi et al., 2017). Moreover, after water consumption by plants, discharge drainage causes environmental pollution because of its chemical features (Grewal et al., 2011; Kumar and Choi, 2014). For this reason, irrigation management is crucial to control the root environment as well as the physical and chemical properties of the growing substrate (Rouphael et al., 2006).

Korean farms use different solid substrates for plant cultivation such as coir (35.1%), perlite (29.1%), rock wool (10.0%) and other (20.9%) (MAFRA, 2020). As a growing medium, perlite takes the attention of the growers because of its high permeability, low buffering capacity, and ease to control plant's root zone environment (Lee et al., 2010; Silber et al., 2010). In addition, perlite adsorbs fewer inorganic ions, and growers are able to use it for a long time compared to coir and rock wool medium (Asaduzzaman et al., 2013). The amount of water present in the root zone of a plant is a vital factor for the plant's development. Excess and deficiency of water adversely affected plant physiological activities which lead to decreased plant growth and productivity (Danso et al., 2015; Phukan et al., 2016). Researchers showed that the fruit setting on different horticultural crops greatly reduced under water scarcity and water logging conditions, and fruit drop was increased (Williams, 2012; Khattab et al., 2012; Klein et al., 2015; Zhen et al., 2020). Fruit quality also highly depends on water availability in the root zone in terms of total ascorbic acid, soluble solid, acidity and color index (Suárez et al., 2010; Nangare et al., 2016; Rasheed et al., 2018; Ren et al., 2021).

Tomato is a nutritious food with soluble solids content, which is one of the main features of its quality (Beckles, 2012; Sagor et al., 2016). Soluble solids content in tomatoes

highly depends on variety and cultivation method, including intercultural operation and moisture content in the root zone (Nuruddin et al., 2003; Ripoll et al., 2016; Bertin and Genard, 2018). The amount of irrigation affects fruit yield, color, flavor, and soluble acid content in tomatoes (Gao et al., 2019). In substrate medium, minimizing the volume of irrigation is an effective technique to improve the soluble solids content of fruits (Li et al., 2001; Choi et al., 2018). However, previous studies reported that the improvement of soluble solids content in fruits by reducing the amount of irrigation sometimes suppressed plant water absorption, increased blossom-end rot, and decreased water use efficiency (Park and Kim 2002; Li et al., 2001; Kang et al., 2006). So, proper management of irrigation volume in tomato plants is very crucial for the growers to get profitable production from a substrate culture. But related information is still limited in Korea and globally. For this reason, this experiment was conducted to investigate the effect of irrigation volume on plant growth characteristics, yield, and soluble solids content of tomatoes grown in the substrate using perlite.

Materials and Methods

1. Growing conditions

This experiment was conducted in a greenhouse (width 12.5 m × length 70 m × height 460 cm, covered by transparent plastic sheet) located in Sinbuk-eup, Chuncheon-si, Korea. Large size tomato (*Solanum lycopersicum* L.) seeds (cv. Saekomi, Boonong Seed Company, Korea) were sown on 24 October 2019. Seedlings were grafted with rootstock 'Tank' (Boonong Seed Company, Korea) on 7 December 2019. Healthy grafted seedlings (plant height 20 – 23 cm, around 10 leaves) were transplanted into growing beds on 4 January 2020 for cultivation in 100% perlite medium where 80% were large sized (2.5 – 5.0 mm) and 20% were small-sized (1.2 – 2.0 mm). Seedlings were planted in the beds (Fig. 1) at 30 cm of intervals and grown until 6 June 2020. Each bed length was 45 m and the width was 30 cm. The height of the growing bed was 20 cm. Heating and chilling hoses (set at the bottom of the bed) were used for temperature regulation in the growing bed. Light, temperature, and humidity in the greenhouse were measured using a data logger (WatchDog

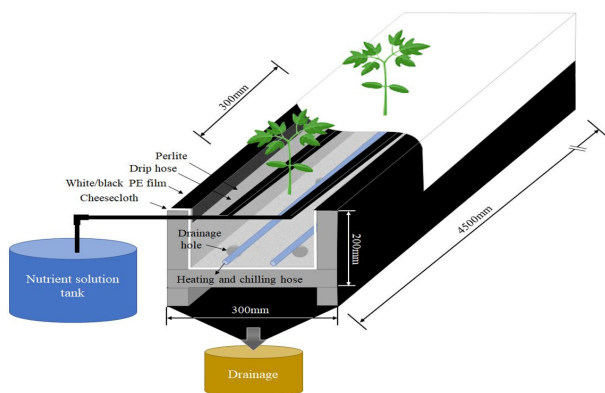


Fig. 1. Schematic diagram of the growing bed where tomato plants were grown and using perlite as a growing medium with heating and chilling facilities.

1450, Spectrum Technologies, Aurora, IL, USA) at 50 cm height. During the cultivation period, the daily average amount of light in the greenhouse was $836.1 \text{ J}\cdot\text{cm}^{-2}\cdot\text{d}^{-1}$, the average daily temperature was $20\pm 2 \text{ }^\circ\text{C}$ and the relative humidity was $65\pm 3\%$. Plants were grown by one stem training, and after the 7th flower cluster bloomed (April 10), the top three leaves were left and pinched.

2. Irrigation treatment

We applied irrigation water mixed with nutrients, preparing and using the Yamazaki tomato nutrient solution (N-P-K-Ca-Mg = 7.7-2.0-4.0-3.0-2.0 $\text{me}\cdot\text{L}^{-1}$, Mie, Japan). Irrigation operation was done with drip-hose lines (diameter 13 mm, Netafim, Korea) on the bed to supply water with nutrients in a non-circulating way. Applications consisted of three- different irrigation treatments: I_0 , I_{25} and I_{50} (Fig. 2A). The I_0 treatment was selected to ensure no or limited drainage (Fig. 2B). Compared to the I_0 treatment, the 25% and 50% larger amounts of irrigation were followed up corresponding to the I_{25} and I_{50} treatments (Fig. 2A). The number of two, three and four drip hose lines were used for controlling irrigation intensity in I_0 , I_{25} and I_{50} treatments respectively. Every bed has fifteen plants. We monitored the water volume for irrigation in a timer-controlled manner (up to 130 mL for one drip hose line at 40 – 60 min intervals based on weather during the day 8 am to 5 pm) adjusting the EC and pH levels of irrigation with the nutrient solution control system (Netaplex, Netafim, Korea). EC level of irrigation water at the beginning of transplanted was 2.5 – 2.6

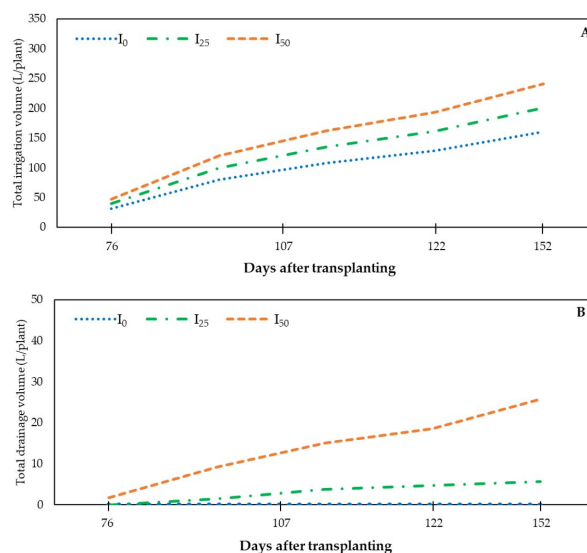


Fig. 2. The irrigation volume (A) and drainage volume (B) in I_0 , I_{25} , and I_{50} treatment during the treatment period.

$\text{dS}\cdot\text{m}^{-1}$, and from 20 May 2020, gradually decreased to $2.2 \text{ dS}\cdot\text{m}^{-1}$, adjusting the pH value of the irrigation water to 5.9 – 6.1 for the entire period. Drainage water from every bed was collected by using a pipe in the bottom of the bed and stored in a container through a funnel (Fig. 1).

3. Measurement of plant growth parameters

At the vegetative stage of the plant (80 days after treatment), we measured plant growth characteristics. Plant height, leaf length, and leaf width were measured using a ruler. We measured the chlorophyll concentration in the upper- leaves of the plant (three fully opened, healthy leaves were selected from a plant and made an average, and each leaf obtained was the average of 3 readings from the upper side of the leaf blade) with a chlorophyll meter (SPAD 502, Minolta, Japan). Measures of stem diameter were at 30 cm from the base of the plant using a digital caliper 117 (CD-20APX; Mitutoyo Corp., Kanagawa, Japan).

4. Measurement of fruit growth parameters

Every day we harvested the tomatoes from 23 March 2020 to 5 June 2020; the sequence of fruit harvest was at three different clusters during the treatment period for the analysis of fruit characteristics on the 111th, 132nd, and 143rd days after treatment. Fruit color reflected by tomato was measured by TES 135A colorimeter (TES Electrical Electronic Co.

Ltd., Taipei, Taiwan) and described in terms of hunter L , a , and b values. ' L ' denotes brightness, '+ a ' denotes red, '- a ' denotes green, '+ b ' denotes yellow, and '- b ' denotes blue. We measured the firmness of fruit with a digital fruit hardness tester FR-5105 (Lutron Electronic Enterprise Co. Ltd., Taipei, Taiwan). The above was done by compression with a three mm-diameter cylindrical probe, measuring the maximum compression force (just at the moment when the device penetrates the epicarp) in Newtons (N).

After measuring the firmness, every fruit were cut into eight pieces and made juice using mortar and pestle for measuring soluble solids content (°Brix) and acidity. Digital pocket refractometers ATAGO PAL-1 (Atago Co. Ltd., Tokyo, Japan) was used for measuring soluble solids content and PAL-BX/ACID1 (Atago Co. Ltd., Tokyo, Japan) was used for measuring acidity (%) in tomatoes.

The number of fruits and fruit weight were measured. Fruit yield was calculated (excluding those fruits that were less than 100 g and deformed). fruit yield per plant was computed by summing up the fruit weight (g) from each harvest of each plant and it is presented as the average of plants per treatment. The fresh weight of the fruit was measured using an electronic balance. The dry weight of the fruit was determined after drying the samples in an oven at 60°C to a constant weight.

The water content, dry matter percentage, water consumption and water use efficiency of fruit were calculated by the following formula:

$$\text{Water content (\%)} = \{(\text{fresh weight} - \text{dry weight}) / \text{fresh weight}\} \times 100$$

$$\text{Dry matter (\%)} = (\text{dry weight} / \text{fresh weight}) \times 100$$

$$\text{Water consumption of fruit (mL} \cdot \text{g}^{-1} \cdot \text{plant}^{-1}) = \text{applied irrigation volume (mL} \cdot \text{plant}^{-1}) / \text{total fruit weight (g} \cdot \text{plant}^{-1})$$

$$\text{Water use efficiency of fruit (g} \cdot \text{L}^{-1} \cdot \text{plant}^{-1}) = \text{total fruit weight (g} \cdot \text{plant}^{-1}) / \text{applied irrigation volume-leachate (L} \cdot \text{plant}^{-1}).$$

5. Statistical analysis

Effects of treatments were analyzed using SAS program (Statistical Analysis System, version 9.3, SAS Institute, Cary, NC, USA). Significant differences among the means were examined using ANOVA (Analysis of variance) followed by Duncan's multiple range test (DMRT) at $p \leq 0.05$. OriginLab 10.0 software (OriginLab, Northampton, MA, USA) was used for principal component analysis (PCA).

Results and Discussion

Different levels of irrigation treatments affected the plant growth characteristics of the tomato plant (Table 1). Plant height, leaf length, and leaf width were significantly higher in plants irrigated at 25% (I_{25}) or 50% (I_{50}) higher volume than in control (I_0). Furthermore, stem diameter and chlorophyll content did not reflect significant differences among treatments. Decreased plant height, leaf length, and leaf width in I_0 treatment may be an adaptive role of plants under limited water. Other studies (van Iersel and Nemali, 2004; Alvarez et al., 2009) showed that plant growth is generally decreased when the availability of soil water is limited. In addition, deficit irrigation greatly impacts on plant height compared to leaf width, resulting in a greater reduction in vertical growth than in horizontal growth. An et al. (2005) reported that a low drainage ratio is good for plant

Table 1. Effect of irrigation volume on plant growth characteristics of tomato at 80 days after treatment.

Treatment	Plant height (cm)	Stem diameter (mm)	Leaf length (cm)	Leaf width (cm)	Chlorophyll content (SPAD value)
I_0	170.6 ^a b ^y	8.9 a	36.5 b	32.5 b	44.1 a
I_{25}	195.5 a	9.6 a	52.3 a	47.5 a	40.9 a
I_{50}	191.7 a	10.1 a	52.8 a	51.2 a	42.2 a

^aEach value is the means (n = 5).

^yMeans within columns sharing the same letter are not significantly different based on Duncan's multiple range test at $p \leq 0.05$.

growth; in contrast, long-term low drainage causes water stress conditions and inhibits nutrient absorption by roots, causing a decline in plant growth and development. Limited water decreases the plant growth of tomato plants by the reduction of transpiration (Imana et al., 2010).

Furthermore, plant height, leaf length, and leaf width were not significantly different between I₂₅ and I₅₀ treatments (Table 1). Moreover, irrigation and drainage volumes were lower in I₂₅-treated plants compared to I₅₀ treatment (Fig. 2). Kim et al. (2011) showed that tomatoes grown in perlite medium under different watering amounts in one-time irrigation using different drainage ratios affected the growth and development of plants. In addition, they reported high irrigation with a drainage ratio below 15% was favorable for the plant. In this experiment, the growth of the plant was comparatively better in the I₂₅ treatment than in others (Table 2) with a low drainage ratio (Fig. 2B). Furthermore, Kim et al. (2011) reported that root development and yield were highest when the drainage ratio was stable. Jeong et al. (2002) reported that the drainage ratio in a substrate culture was decreased when they applied the total amount of water by multiple irrigations (more frequent) compared to one irrigation (less frequent) in a day. Alvarez et al. (2009) noted that the application of proper irrigation saves water and

reduces unwanted excessive growth of plants. In this experiment, the total amount of supplied irrigation per plant was 160.9 L, 201.2 L, and 241.4 L for I₀, I₂₅ and I₅₀ treatments, respectively (Fig. 2). So, after the treatment period, the irrigated water difference per plant between I₀ and I₂₅ irrigation treatment, besides the I₂₅ and I₅₀ irrigation treatment, was around 40 L. In addition, around 80 L of irrigated water per plant was the difference between I₀ and I₅₀ irrigation treatment. This amount of difference is considered crucial to making cost-effective production by optimizing water use efficiency and irrigation cost.

The fruit characteristics of tomatoes were examined from three different harvesting clusters when harvesting was done on 111th, 132nd and 143rd days of treatment which correspond to 2nd and 3rd clusters, respectively in Table 2. It was observed that hunter value ‘a’ in 111th and 132nd days after treatment harvested tomatoes were significantly greater in the I₀ treated plants than in I₂₅ and I₅₀ treated plants (Table 2). However, there was no significant difference in hunter value ‘L’ and ‘b’ by the treatments. The hunter ‘L’, ‘a’ and ‘b’ values of tomato were used for color determination. Generally, tomatoes’ visual appearance and color strongly influence consumer opinion about the fruit quality. Hunter ‘L’ and ‘a’ indicate the lightness and redness of a fruit,

Table 2. Effect of irrigation volume on fruit characteristics of tomato in perlite hydroponics.

Treatment	Hunter value			Firmness (N/φ5 mm)	Dry matter (%)	Water content (%)
	L	a	b			
111 DAT						
I ₀	42.0 ^z a ^y	22.2 a	21.8 a	23.0 a	8.5 a	91.5 b
I ₂₅	41.2 a	22.8 a	18.6 a	16.9 b	6.1 b	93.9 a
I ₅₀	43.4 a	18.2 b	19.1 a	22.7 a	5.7 b	94.3 a
132 DAT						
I ₀	40.8 a	30.0 a	19.9 a	16.5 a	8.4 a	91.6 b
I ₂₅	38.5 a	26.4 b	14.8 a	12.1 a	6.5 b	93.6 a
I ₅₀	36.3 a	23.5 b	12.2 a	12.7 a	5.7 b	94.3 a
143 DAT						
I ₀	33.7 a	22.3 a	15.8 a	14.0 a	8.7 a	91.3 b
I ₂₅	36.4 a	22.5 a	13.8 a	13.2 a	7.1 b	92.9 a
I ₅₀	36.2 a	21.0 a	13.0 a	15.6 a	6.6 c	93.4 a

^zEach value is the means (n = 5).

^yMeans within columns sharing the same letter are not significantly different based on Duncan’s multiple range test at $p \leq 0.05$.

DAT = Days after treatment.

respectively. The degree of redness in a tomato is mainly attributed by the accumulation of lycopene pigments (Nisha et al., 2011). Lycopene concentration in tomatoes is an indicator of quality and is beneficial for consumers because lycopene has antioxidant properties (Shi et al., 2007).

Dry matter of tomatoes was highest in all clusters of tomatoes treated with I_0 treatment (Table 2). Boas et al. (2017) reported that water deficit reduced the yield of tomatoes but increased their dry matter content. However, the moisture content of 111th and 132nd days after treatment harvested tomatoes was lower in I_0 -treated plants than in other treatments (Table 2).

Furthermore, the soluble solids content was significantly higher in all harvested clusters of tomatoes in I_0 -treated plants compared to those grown in I_{25} and I_{50} treatments (Fig. 3A). Sugar accumulation in fruit is associated with enzyme activities, specifically sucrose-metabolizing enzymes (Zhang et al., 2012). Ripoll et al. (2014) reviewed that water deficit stimulates secondary metabolism and enzymatic activities of plants to enhance plant defense mechanism and resulted in soluble solids content increased in fruit. Maybe the lower irrigation is a reason for greater soluble solids content in I_0 -treated plants (Figs. 2A, 3A). Choi et al. (2016) showed that low irrigation with a low drainage ratio increased the soluble solids content in tomatoes. The acidity of tomatoes was significantly higher in I_0 -treated plants than those grown in I_{25} and I_{50} treatments in all harvested clusters (Fig. 3B). Low irrigation in I_0 treatment may be the reason for high acidity in I_0 -treated tomatoes. Subramanian et al. (2006) showed that the acidity of tomatoes was increased under water deficit conditions compared to well-watered

when plants are grown in soil. High soluble solids content and acidity in I_0 -treated tomatoes may be related to each other. Huang et al. (2022) reported that the acidity and soluble solids content of apples were increased under deficit irrigation. Furthermore, the soluble solids content and acidity accumulation of tomatoes both showed a similar trend when plants were grown in a soilless system at different potassium levels (Caretto et al., 2008).

The number of big-size fruits (greater than 180 g) was lower but small-size fruits (<100 g) was higher in I_0 -treated plants than in those grown in other treatments (Table 3). On the other hand, the number of big size fruits was highest and the number of small size fruits was lowest in plants those were grown in I_{25} treatment. There was no significant difference in the total number of harvested fruits among different irrigation I_0 , I_{25} and I_{50} .

The average weight of fruits was lowest in those plants treated with the I_0 treatment (Fig. 4). In addition, the total yield reflected the lowest value in I_0 treated plants. Nevertheless, our results suggest that the observed average weight

Table 3. Effect of irrigation volume on number of fruits per plant grown in perlite medium.

Treatment	Number of fruits per plant			
	<100 g	101–180 g	>180 g	Total
I_0	6.2 ^z a ^y	20.6 a	6.8 c	33.6 a
I_{25}	1.0 c	15.6 b	17.6 a	34.2 a
I_{50}	4.2 b	18.8 a	12.4 b	35.4 a

^zEach value is the means (n = 5).

^yMeans within columns sharing the same letter are not significantly different based on Duncan's multiple range test at $p \leq 0.05$.

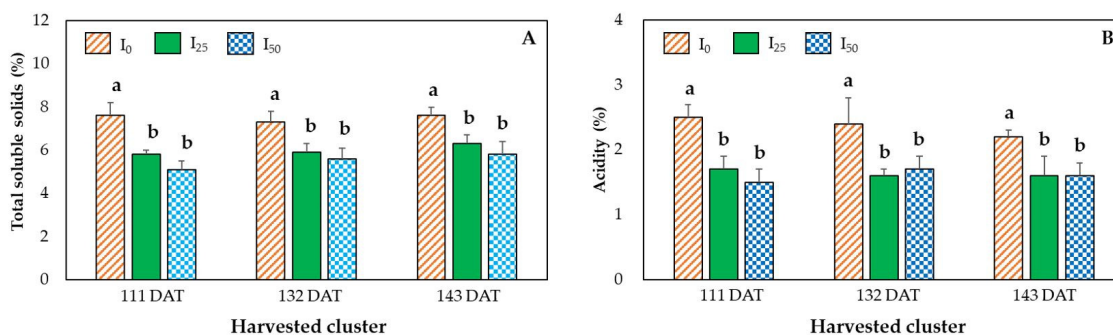


Fig. 3. Effect of irrigation volume on soluble solids content (A) and acidity (B) of fruits. Lines above the bar represent the standard deviation of the mean (n = 5). Means above each bar followed by the same letters are not significantly different by Duncan's multiple range test (DMRT) at $p \leq 0.05$. DAT = Days after treatment.

Table 4. Effect of irrigation volume on average fruit weight, total fruit weight, water consumption and water use efficiency of tomato.

Treatment	Fruit weight (g·plant ⁻¹)	Total fruit weight (g·plant ⁻¹)	Water consumption (mL·g ⁻¹ ·plant ⁻¹)	Water use efficiency (g·L ⁻¹ ·plant ⁻¹)
I ₀	139 b	4484.9 b	40.2 a	25.4 b
I ₂₅	196 a	6658.2 a	34.7 a	30.7 a
I ₅₀	177 a	6839.2 a	38.8 a	31.7 a

²Each value is the means (n = 5).

³Means within columns sharing the same letter are not significantly different based on Duncan’s multiple range test at $p \leq 0.05$.

of fruit and fruit yield of tomatoes were not statistically different between the I₂₅ and I₅₀ treatments. Hwang et al. (2012) showed that the average weight of tomatoes decreased with a small amount of irrigation treatment than in the control treatment in hydroponic culture (rock wool medium). Kim et al. (2011) reported good growth of tomatoes in perlite medium when the drainage ratio was less than 15%. Our findings are in line with their findings. In this experiment, the average weight of I₂₅-treated fruits was slightly greater when compared to those grown in I₅₀ treatment (Table 4) with low drainage in I₂₅ treatment compared to I₅₀ because of lower irrigation.

The water consumption of plant was 40.2, 34.7, and 38.1 mL·g⁻¹·plant⁻¹ in I₀, I₂₅ and I₅₀ treatment, respectively (Table 4). In addition, the water use efficiency of plant was 25.4, 30.7, and 31.7 g·L⁻¹·plant⁻¹ in I₀, I₂₅ and I₅₀ treated plants. Notably, the water use efficiency of plant was lowest in the I₀ treatment. However, the water use efficiency of plant was not significantly different between the I₂₅ and I₅₀ treatments.

We applied a principal component analysis (PCA) to uncover the correlation of the different growth characteristics of plant and harvested fruits with the irrigation volume treatments (Fig. 4). The PCA is a multivariate data analysis to create implicit artificial variables by combining highly correlated variables. Due to the different units of measure between variables, variables with large variances can be interpreted as important variables (Kim et al., 2013). The PCA, however, best explains the variance of the entire data. The elements of PC1 and PC2 described 94.76% and 5.24% of the variability in the data, respectively. The PCA biplot illustrated a clear separation of the parameters. The result showed that soluble solids content and acidity were positively correlated, and their response is closer to the I₀ treatment than others. Other research also showed that

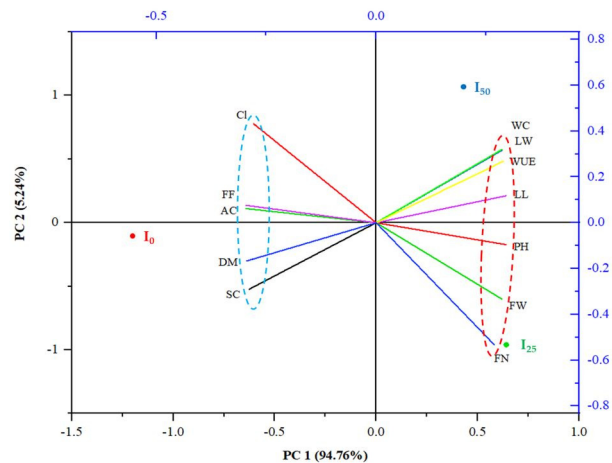


Fig. 4. Principal component analysis (PCA) to elucidate the variable treatment relationships among the three treatments. The lines starting from the central point of the biplots in the PCA have the attributes to display the negative or positive associations of the variables, and their proximity specifies the degree of correlation with specific treatment. PH, plant height; LL, leaf length; LW, leaf width; CL, chlorophyll content; FN, fruit number; FW, fruit weight; FF, fruit firmness; SC, soluble solids content; AC, acidity; DM, dry matter; WC, water content; WUE, water use efficiency.

soluble solids content and acidity in fruits has a positive correlation (Anthon and Barrett, 2012; Quinet et al., 2019). In addition, there is a positive relation between dry matter and the soluble solids content of tomatoes (Table 4). In other studies, with fruits, the dry matter correlated positively with soluble solids content (Ścibisz et al., 2011; Turhan et al., 2011). Furthermore, the graph shows that plant height, fruit weight, fruit number have a positive correlation being closer to I₂₅ and I₅₀ treatments when compared to the I₀ treatment (Fig. 4). The biplot also showed that water content of fruits maintained a negative correlation with soluble solids content and acidity.

Conclusion

Although soluble solids content and acidity were higher in I₀-treated plants, it is not preferable for plant growth and yield of tomatoes. I₂₅ treatment was the most effective because growth characteristics, production of big fruit size, fruit yield, and water use efficiency were better and not significantly different compared to the I₅₀ treatment. In addition, approximately a 40 L irrigation difference per plant was between the I₂₅ and I₅₀ treated plants. So, considering the yield and quality of fruits and irrigation amount the I₂₅ treatment is more helpful to reduce water and nutrient usage than the I₅₀ treatment. In future research, we will investigate the irrigation effect on tomato plants grown in perlite and other growing mediums, as well as, their impact on physiological response and the bioactive compounds in fruits.

Acknowledgments

This research was supported by the Korea Smart Farm R&D Foundation of Korea (KoSFarm) (No. 421009-04), National Research Foundation of Korea (No. 2021R1F1A106428512), and the National Research Foundation of Korea (NRF) funded by the Korea government (MSIT) (No. 2021R1F1A1064285).

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펄라이트 재배에서 급액량이 토마토의 생육과 수량에 미치는 영향

김두한¹ · 라이한 샤원² · 안진희¹ · 이현진¹ · 이윤재¹ · 김민경¹ · 이용범³ · 최기영^{4,5*}

¹강원대학교 대학원 농산업학과 대학원생, ²강원대학교 미래농업융합학부 박사후 연구원, ³국제원예연구원 원장,

⁴강원대학교 미래농업융합학부 교수, ⁵강원대학교 대학원 농산업학과 교수

적 요. 본 실험은 펄라이트 수경재배에서 급액량이 토마토(*Solanum lycopersicum* L.)의 생육과 수량에 미치는 영향을 조사하기 위해 수행되었다. 급액 처리는 대조구인 I₀와 대조구보다 급액량이 각 25%, 50% 많은 I₂₅와 I₅₀로 세 수준 처리하였다. 처리기간 중 대조구 I₀ 처리구는 배액이 없었다. 조사항목으로 토마토 생육특성, 수량 및 수분이용 효율을 측정하였다 토마토의 초장, 엽장 및 엽폭이. I₀ 처리 가장 짧았고 I₂₅와 I₅₀ 처리에서는 통계적으로 차이가 없었다. 처리 후 111일, 132일 및 143일째에 측정된 토마토 과실의 당도, 산도 및 건물율은 관수량이 가장 적은 I₀가 관수량이 많은 I₂₅와 I₅₀ 보다 높았다. 그러나 처리 후 111일과 132일째 과실 내 수분함량은 I₀ 처리에서 가장 낮았다. 대과(>180g)의 수는 I₂₅에서 유의하게 더 많았으나 총 수확과 수는 처리 간 유의한 차이가 없었다. 과실의 평균 과중(g·plant⁻¹)과 총 수확량(g·plant⁻¹)은 I₀ 처리된 토마토에서 가장 낮았다. 수분 소비량은 처리 간 유의한 차이가 없었으나 수분이용효율은 I₀ 처리에서 가장 낮았다. 주성분 분석 결과 과실의 당도와 산도는 양의 상관관계가 있는 것으로 나타났다. 본 실험에서 토마토 생육, 과실 특성 및 수분이용효율을 토대로 얻은 결과는 I₂₅가 토마토 펄라이트 수경재배에서 다른 처리 보다 적절한 급액량임을 보여준다.

추가 주제어 : 초장, 과중, 과수, 당도, 산도, 상관관계, 수분이용효율