

**Application of Deep Sea Water (DSW) for Nutrient Supplement in Hydroponics  
Cultivation of Tomato : Effect of supplemented DSW at Different EC Levels on Fruit Properties**

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**ABSTRACT**

Deep sea water (DSW) has the potential characteristics for nutrient supplement in hydroponics cultivation. This experiment was carried out to evaluate the application of DSW as a nutrient supplement for tomato cultivation in hydroponics system. Tomatoes were grown on 4 beds in nutrient film technique (NFT) system circulated with 1.5 dS m<sup>-1</sup> (control), 10 dS m<sup>-1</sup>, 15 dS m<sup>-1</sup> and 20 dS m<sup>-1</sup> of nutrient solution, respectively. DSW was supplemented into nutrient solution of control to obtain high EC level. Fresh weight of fruits decreased varied from 10-20% by increasing DSW concentration in nutrient solution, but the effect of the treatment was not found on size of 3<sup>rd</sup> truss fruits. The density of fruits increased as the DSW concentration increased in nutrient solution. Tomato stiffness of treated plants had almost the same value among EC levels although different among 3 trusses. Fruit quality parameters increased by increasing the DSW concentration in nutrient solution. Treated plants circulated with EC 20 dS m<sup>-1</sup> supplemented nutrient solution for 2 weeks produced tomatoes with highest soluble solids, 8.0% Brix or increased 30% of control (1<sup>st</sup> truss). However there were no significant effect on fruits of 2<sup>nd</sup> and 3<sup>rd</sup> trusses. DSW could be used as nutrient supplement for hydroponics cultivation of tomato.

Key words : Deep sea water, fruit quality, electrical conductivity, tomato

**INTRODUCTION**

Deep sea water (DSW), accounting for 95% of all the sea water, generally refers to sea water from a depth of more than 200 m. DSW has cold temperature, abundant nutrients, and good water quality that is pathogen-free and stable. DSW contains a lot of minerals such as Na<sup>+</sup>, Mg<sup>2+</sup>, K<sup>+</sup>, and Ca<sup>2+</sup>. When DSW is supplemented into nutrient solution for hydroponics it increases electrical conductivity (EC) of the nutrient solution (Fallah, 2005).

Previous studies have shown that parameters of fruit quality such as soluble solids content, titratable acidity and dry matter increased by increasing EC level of nutrient solution from 2 to 10 dS m<sup>-1</sup> (Soria and Cuartero, 1998; Eltez *et al.*, 2002; Ling Li *et al.*, 2001; Okano *et al.*, 2002). However, the higher quality of tomato fruits that was obtained in high EC level of nutrient solution is often adversely affected by the appearance of blossom end rot (BER) and the yield is decreased by 5.1 % per dS m<sup>-1</sup> above 2 dS m<sup>-1</sup> (Ling Li *et al.*, 2001). In previous study, salinity was obtained by adding sodium chloride (NaCl), or concentrated nutrition to obtain varied EC level of 2 – 9.5 mS m<sup>-1</sup> (Schwarz and Kuchenbuch, 1998; Ling Li *et al.*, 2001;

Eltez *et al.*, 2002; Okano *et al.*, 2002; Katerji *et al.*, 2003). It was reported that under higher EC level of nutrient solution, treated plants produced fruits in smaller size (Eltez *et al.*, 2002; Okano *et al.*, 2002). It was reported that in single-truss tomato cultivation, there was a high rate of occurrence of blossom-end rot when salinity was applied 3 days after pollination (Okano *et al.*, 2002). Therefore, EC of the nutrient solution should be maintained at the right level not only for high quality of tomato fruit but also for preventing BER.

In this experiment, DSW that pumped from DSW station located at Muroto, Kochi prefecture, was added at different levels into nutrient solution in hydroponics cultivation of tomato plants to increase EC level of nutrient solution. This experiment was carried out to study the effect of different concentration of DSW in nutrient solution on fruit properties.

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**MATERIALS AND METHODS**

*Cultivation*

Tomatoes (*Lycopersicon esculentum* cv House Momotaro) were sown on rock wool on October 24, 2002. Tomatoes were grown on nutrient film technique (NFT) system starting from December 28, 2002 until May 10, 2003 in greenhouse of Kochi University Japan. The NFT system contained 4 beds in which each bed had length 10 m and slope 1 %. These beds contained 40 plants per bed and nutrient solution was circulated from 100 L tank solution through bed with flow rate 3 L min<sup>-1</sup>.

Nutrient solution was made based on Otsuka Solution. Control bed was circulated with nutrient solution at electrical conductivity (EC) level of 1.5 dS m<sup>-1</sup>. Treated beds were circulated with nutrient solution that was made by supplementing DSW into nutrient solution control until reaching designed EC levels. To obtain the effect of EC level on fruit properties, the experiment was set up for 4 beds cultivation with EC 1.5 (control), 10.0, 15.0, 20.0 dS m<sup>-1</sup>, respectively. This treatment was conducted for 2 weeks. After 2 weeks treatment, all beds were circulated with nutrient solution EC 1.5 dS m<sup>-1</sup>.

Tomatoes were maintained on 5 fruits per truss and 3 trusses per plant. For analysis of fruit properties, fruit samples were taken from 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> truss. Fruits of 1<sup>st</sup> truss were pollinated on January 20, 2003. Fruits of 2<sup>nd</sup> truss were pollinated on February 5, 2003 and fruits of 3<sup>rd</sup> truss were pollinated on February 21, 2003. DSW treatment was started on February 21, 2003 at 06.00 p.m. At that time, 1<sup>st</sup> truss, 2<sup>nd</sup> truss and 3<sup>rd</sup> truss were respectively 30 days, 16 days and 1 day after pollination. After DSW treatment was released, nutrient solution was maintained at 1.5 dS m<sup>-1</sup> for all treated beds, same with control.

*Analysis of Fruit Properties*

Tomatoes were harvested at full ripe stage. Seven tomatoes from each bed and each truss were taken randomly for analysis of fruit properties. Tomatoes were weighed and their color was evaluated by color reader Minolta, CR-10. Density and volume of fruits were evaluated, as follows:

$$V = \frac{(W_a - W_l)}{(\rho_l - \rho_a)g} \times 10^3 \dots\dots\dots (1)$$

And then density of tomatoes can be calculated by :

$$\rho = \frac{M}{V} = \frac{W_a + V\rho_a g}{W_a - W} (\rho_l - \rho_a) \times 10^{-3} \dots\dots\dots (2)$$

$$\rho = \frac{W_a}{W_a - W} (\rho_l - \rho_a) + \rho_a \dots\dots\dots (3)$$

W<sub>a</sub> : weight of fruit in air, (N)

W<sub>l</sub> : weight of fruit in liquid, (N)

M : mass of fruit, (kg)

g : gravitation, (m s<sup>-2</sup>)

V : volume of fruit, (L)

ρ : density of tomato, (kg m<sup>-3</sup>)

ρ<sub>a</sub> : density of air, (kg m<sup>-3</sup>)

ρ<sub>l</sub> : density of liquid, (kg m<sup>-3</sup>)

After density of fruits was evaluated, stiffness of tomato was measured using rheometer, “Shimadzu EZtest”. For measuring the stiffness of tomato its force-displacement curve was obtained by conducting compression test using rheometer. The fruits were positioned with their stem horizontal and the load was applied perpendicular to fruit using a 3 mm cylindrical stainless steel probe with a flat end and the test speed was 2 mm min<sup>-1</sup>. The force-displacement test was performed until 2 mm displacement. The rheometer “Shimadzu EZtest” was connected into personal computer for recording and displaying the results. Stiffness or rigidity is indicated by the slope of straight line portion of the force-displacement curve. An initial tangent was drawn to this curve at 0.5-1.5 mm displacement. At this interval, curve was being straight. Slope was measured as surface stiffness. Stiffness value was obtained by averaging data from 4 positions of measurement.

Tomato sample was divided into 4 pieces by slicing vertically and horizontally. Two pieces were juiced using hand mixer and then filtered using filter paper meanwhile the other pieces were evaluated for dry matter. This puree was measured for soluble solids content and acidity. Soluble solids content of tomato was measured in term % of Bricks by using digital refractometer (Atago, model PR-101, Japan). Acidity (% w/v) was measured by an acid meter (Sourty, Model Sou-1, Shimadzu, Japan) supplied with a standard reagent. Another two pieces of the tomato sample were dried by using oven at 70 °C temperature until the weight is constant.

**RESULTS AND DISCUSSION**

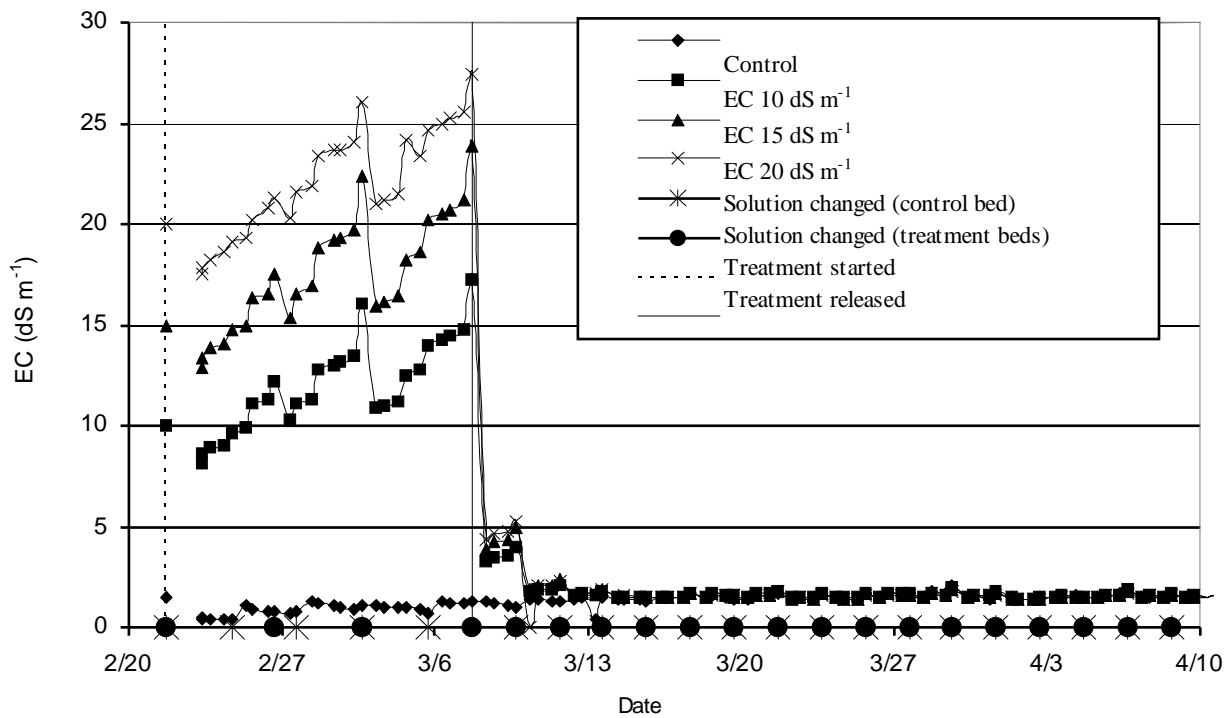
**Results**

*Environmental Condition*

Figure 1 shows time course of EC of nutrient solution during growth. During DSW treatment, EC of nutrient solution of treated bed increased from the initial level by time course. This increment was faster at fine days than that in cloudy or rainy days because of higher evapotranspiration during fine days. The nutrient solution was changed with new one when the EC reach 5.0 dS m<sup>-1</sup> above initial level. After this, The EC of nutrient solution was maintained at initial level.

Concentration of DSW in nutrient solution influenced the EC level of nutrient solution, that is higher DSW concentration resulted in higher EC level

of nutrient solution. Water uptake decreased by increasing EC level of nutrient solution.



[Figure 1. Time course of electrical conductivity of nutrient solution]

*Fruit Properties*

High EC level of nutrient solution caused a decrease in fruit size. For 1<sup>st</sup> truss, average fruit size from bed with EC level of 1.5 (control), 10.0, 15.0 and 20.0 dS m<sup>-1</sup> were 67.4, 65.8, 64.2 and 62.7 mm, respectively. When the size of treated tomatoes was compared to the control tomatoes, the highest decrement was obtained from bed with highest EC level 20.0 dS m<sup>-1</sup>. It was 7% for 1<sup>st</sup> truss fruits. For the 2<sup>nd</sup> truss, fruits size were 68.8, 65.9, 65.6 and 64.0 mm, respectively. Third truss produced bigger tomatoes than fruits of 1<sup>st</sup> and 2<sup>nd</sup> truss for both treated and control beds as the effect of stopping DSW treatment. (Table 1).

DSW treatment affected final size of harvested tomatoes. Average of fresh weight was decreased by duration of treatment for 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> truss (Table 1). Fresh weight of 1<sup>st</sup> truss fruits were 143.14, 133.47, 130.27, 117.80 g fruit<sup>-1</sup>, respectively from control to 20

mS m<sup>-1</sup> of EC treatment. In the same plants, fresh weight increased from 1<sup>st</sup> truss to 3<sup>rd</sup> truss.

Both treated and control plants produced tomatoes with volume below 0.200 L for 1<sup>st</sup> and 2<sup>nd</sup> truss and above 0.200 L for 3<sup>rd</sup> truss (Table 1). The smallest volume was obtained from bed with the highest EC level of nutrient solution (20.0 dS m<sup>-1</sup>). For 1<sup>st</sup> truss, the fruit volume was 0.118 L, while the control tomatoes were 0.148 L. These values imply that the EC level of 20.0 dS m<sup>-1</sup> decreased fruit volume 20%. The effect of high EC level was not found on fruit volume for 3<sup>rd</sup> truss (only 1 day influence).

Inversely with effect of high EC level on the fruit volume, density of fruit increased by EC level. Control tomatoes had density below 1000.00 kg m<sup>-3</sup> while treated tomatoes had density above 1000.00 kg m<sup>-3</sup> (Table 1).

Table 1. The effect of DSW concentration in nutrient solution on fruit properties of tomato.

EC level (dS m <sup>-1</sup> )	Fresh weight (g fruit <sup>-1</sup> )		Diameter (mm)		Volume (L)		Density (kg m <sup>-3</sup> )	
<b>Truss 1</b>								
1.5 (control)	143.14	(100)	67.4	(100)	0.148	(100)	973.75	(100)
10	133.47	(93)	65.8	(98)	0.133	(90)	1001.37	(103)
15	130.27	(91)	64.2	(95)	0.129	(87)	1008.95	(104)
20	117.80	(82)	62.7	(93)	0.118	(80)	999.12	(103)
<b>Truss 2</b>								
1.5 (control)	163.23	(100)	68.8	(100)	0.165	(100)	991.33	(100)
10	149.00	(91)	65.9	(96)	0.148	(90)	1009.98	(102)
15	139.21	(85)	65.6	(95)	0.138	(84)	1010.34	(102)
20	145.46	(89)	64.0	(93)	0.095	(58)	1010.44	(102)
<b>Truss 3</b>								
1.5 (control)	216.90	(100)	75.4	(100)	0.218	(100)	995.16	(100)
10	245.20	(113)	78.2	(104)	0.245	(112)	1002.80	(101)
15	243.30	(112)	77.0	(102)	0.240	(110)	1012.92	(102)
20	213.13	(98)	74.2	(98)	0.212	(97)	1003.62	(101)

Values are mean of seven samples

Number in parantheses is relative values from control

In contrast with fresh weight per fruit which increased from 1<sup>st</sup> truss to 3<sup>rd</sup> truss, stiffness of whole fruit decreased from 1<sup>st</sup> truss to 3<sup>rd</sup> truss. The highest fruit stiffness was 4.06 N mm<sup>-1</sup> that was obtained from 1<sup>st</sup> truss with EC level of nutrient solution of 20.0 dS m<sup>-1</sup> and the lowest was 2.03 N mm<sup>-1</sup>, that was obtained from 3<sup>rd</sup> truss with EC of 10.0 dS m<sup>-1</sup> (Figure 2).

Increasing EC level of nutrient solution had increased the parameter of fruit quality such as soluble solids content, acidity and flavor of tomatoes fruit. Treated plants produced tomatoes with higher soluble solids content than that of control tomatoes (Figure 3). The highest soluble solids content was 8.0 % Brix that was showed by 1<sup>st</sup> truss fruits with highest EC level of nutrient solution of 20.0 dS m<sup>-1</sup>. The lowest soluble solids content was 6.7 % Brix. It was obtained from 1<sup>st</sup> truss fruit of control bed. This value meant that nutrient solution with 20.0 dS m<sup>-1</sup> EC could increase soluble solids content of treated tomatoes by 30 % than that of control tomatoes in winter cultivation. This increment tended to decline from 1<sup>st</sup> truss to 3<sup>rd</sup> truss.

Treated tomatoes had acidity slightly higher than that of control tomatoes. The highest acidity was 0.44 % w/v that was obtained from 1<sup>st</sup> truss fruits with EC level of 10.0 dS m<sup>-1</sup> while acidity of control tomatoes was 0.37 % w/v. It means increasing EC level of nutrient solution increased acidity of fruits by 17 %. In the same beds, acidity of tomato fruits tends to descend from 1<sup>st</sup> truss to 3<sup>rd</sup> truss (Figure 4).

Almost 80 % of dry matter content of tomato is soluble solids content. Thus similar to the increasing of soluble solids content and acidity, the dry matter content of tomatoes also increased by EC level of nutrient solution (Figure 5). The lowest dry matter content of fruit was 4.62 % w/w that was obtained from 1<sup>st</sup> truss of control tomatoes and the highest was 5.82 % w/w that was obtained from treated plants with nutrient of 20.0 dS m<sup>-1</sup>. It means that 20.0 dS m<sup>-1</sup> nutrient solution could increase dry matter content of treated tomatoes by 26 % than its control. Although dry matter content of tomato fruits showed a tendency of increasing with the increasing EC level of nutrient, the increments declined from 1<sup>st</sup> truss to 3<sup>rd</sup> truss.

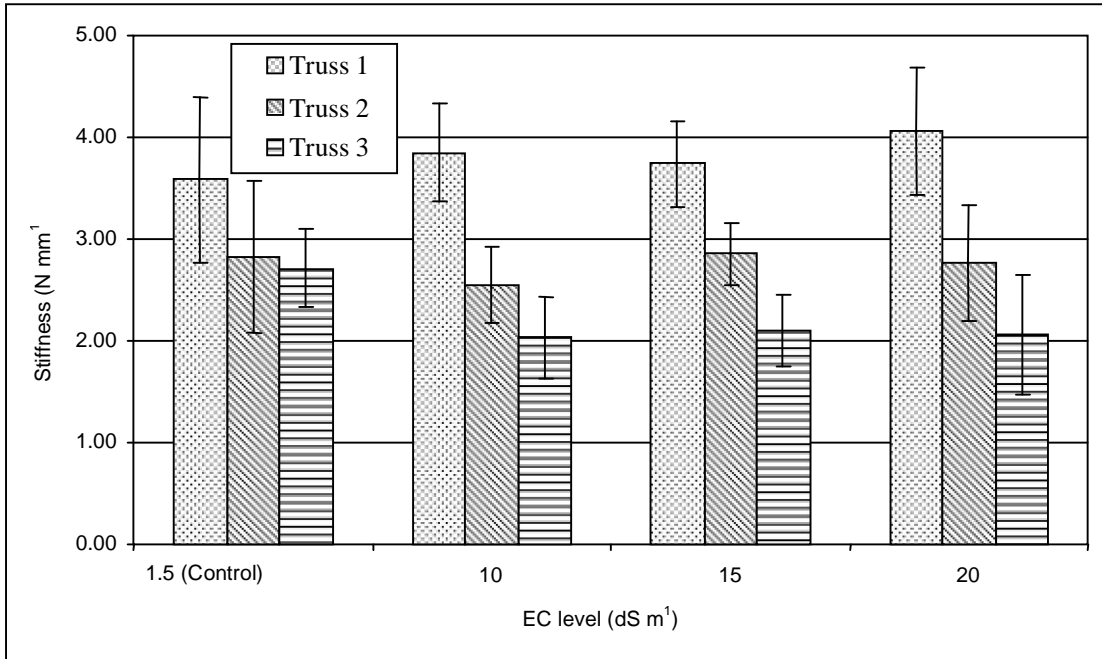


Figure 2. The effect of DSW application to the nutrient solution on the stiffness of tomato fruits

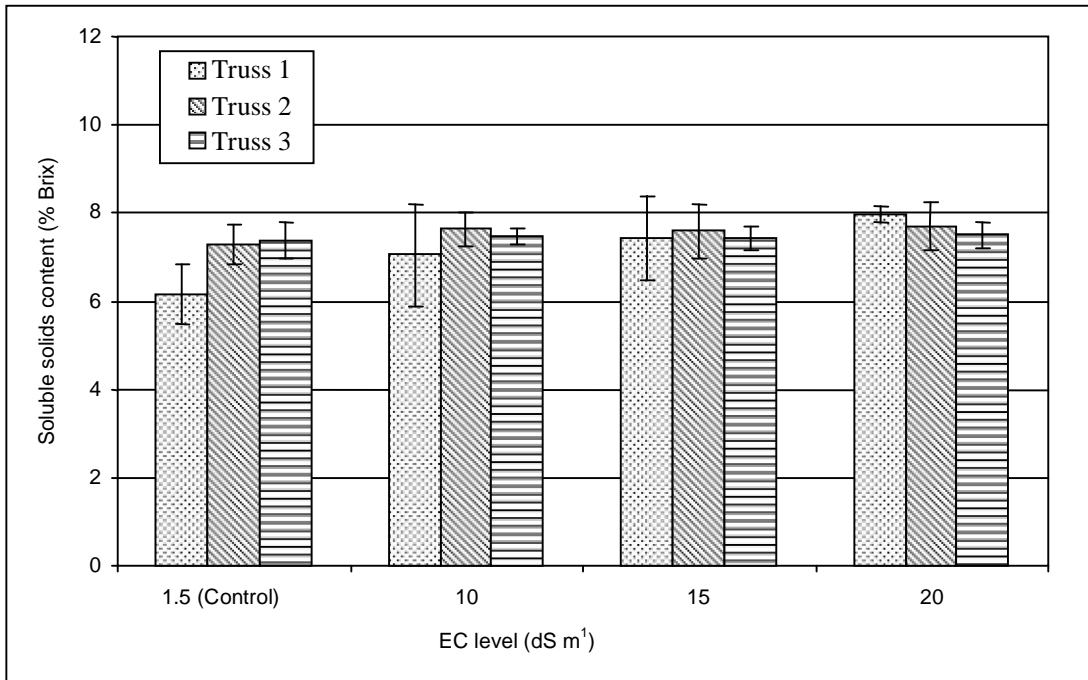


Figure 3. The effect of DSW application to the nutrient solution on the soluble solids content of tomato fruits

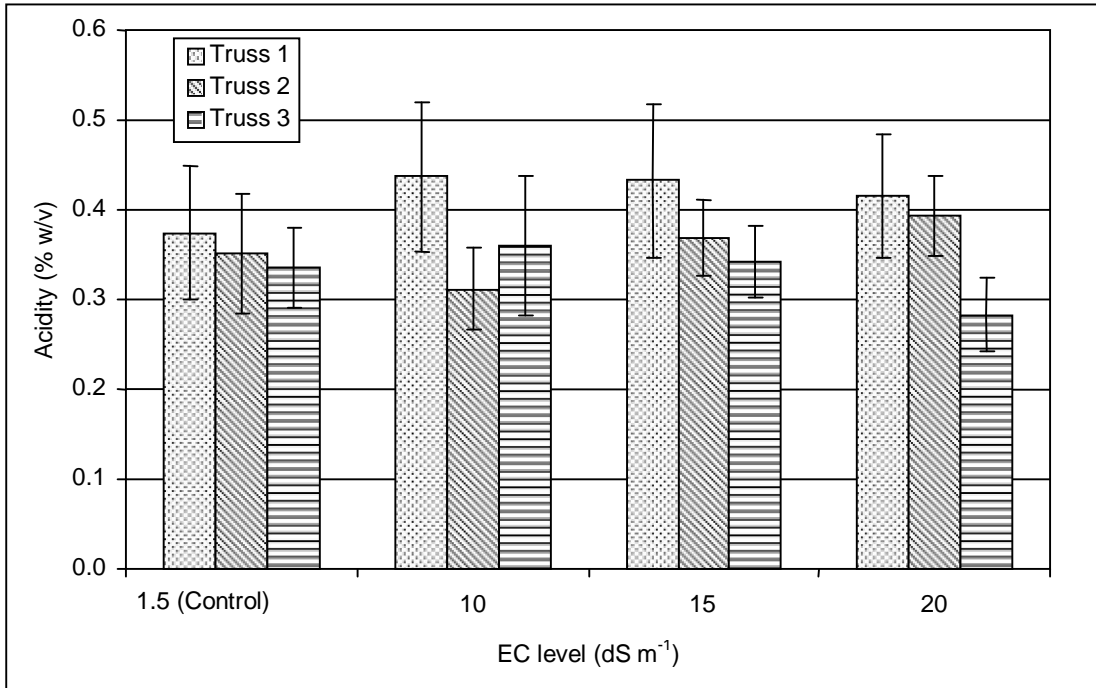


Figure 4. The effect of DSW application to the nutrient solution on the acidity of tomato fruits

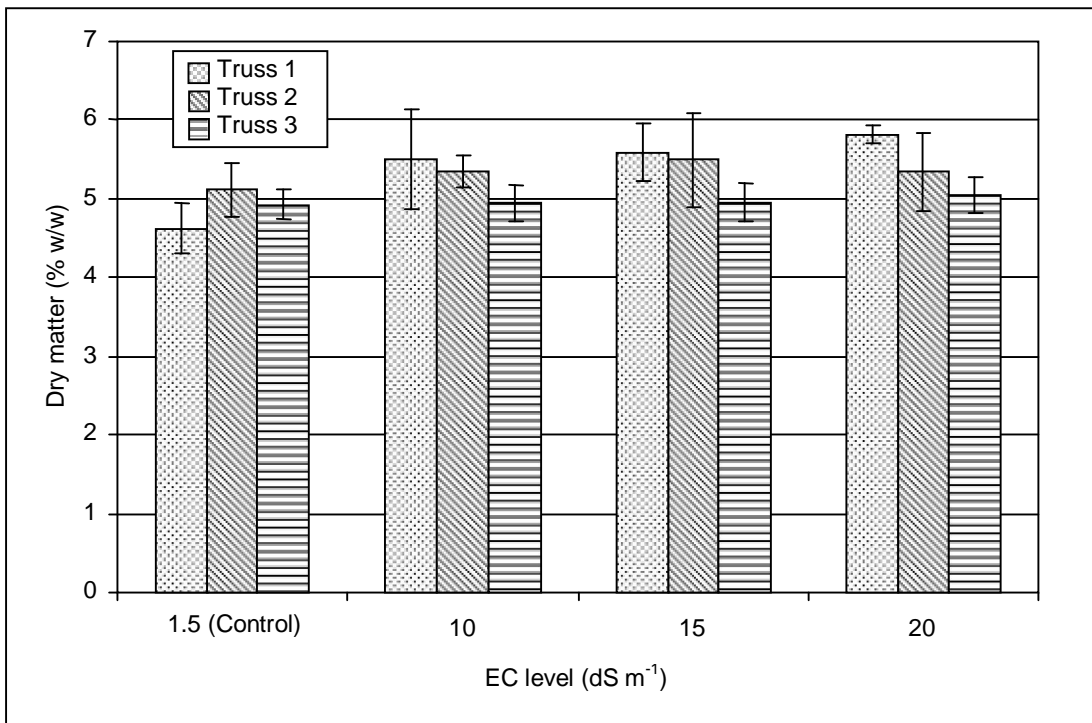


Figure 5. The effect of DSW application to the nutrient solution on the dry matter of tomato fruits

*Yields and Physical Disorder*

For 1<sup>st</sup> and 2<sup>nd</sup> truss, fruit yield decreased because of a reduction in fruit size. Figure 6 shows that the highest production of tomatoes was obtained from the

EC of 10.0 dS m<sup>-1</sup> and the lowest production was from EC of 20.0 dS m<sup>-1</sup>. EC level of 10.0 dS m<sup>-1</sup> produced the highest fruit number thus increased the fruit yield.

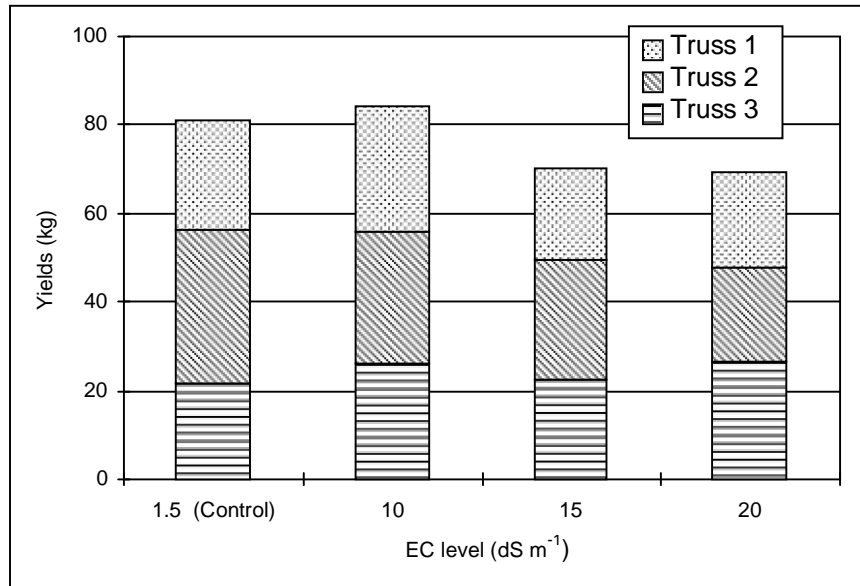


Figure 6. Effect of DSW application to the nutrient solution on the yield per bed

Physiological disorders like fruit cracking and BER were found. Generally, the number of BER fruits increased with the EC level of nutrient solution. Figure 7 shows that BER fruit was not found in control plants but the percentage increased from EC 10.0 dS m<sup>-1</sup> to 15.0 dS m<sup>-1</sup> and then afterward decreased in 20.0 dS m<sup>-1</sup>. The highest percentage of BER was obtained from 15.0 dS m<sup>-1</sup> EC level, that was 1%, 17% and 26%,

respectively for 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> truss. In the same bed, percentage of BER fruits tended to increase from 1<sup>st</sup> truss to the 3<sup>rd</sup> truss.

Fruit cracking occurred in both treated and control tomatoes. The percentage of cracking tomatoes were respectively 7%, 21%, 23% and 18% of the beds successively with EC of 1.5 (control), 10.0, 15.0, 20.0 dS m<sup>-1</sup>.

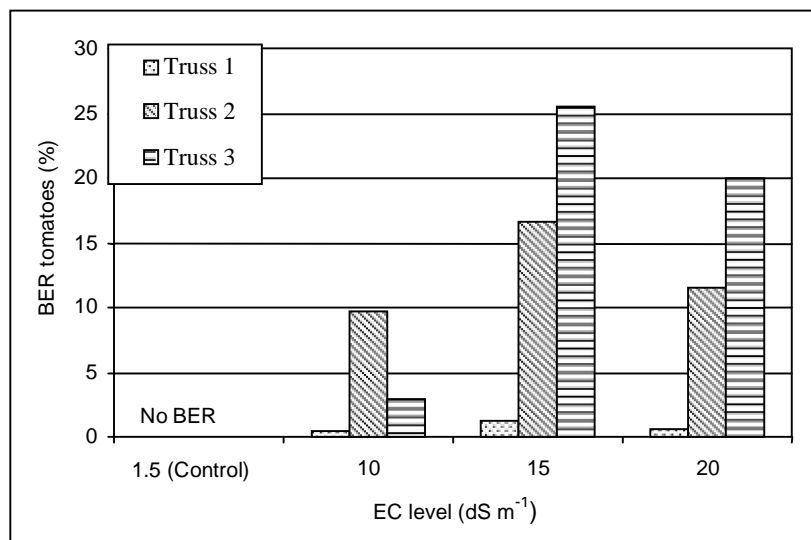


Figure 7. Effect of DSW application to the nutrient solution on BER occurrences

## Discussion

During DSW treatment in this experiment, fruits of 1<sup>st</sup> truss (28 days after pollination) and 2<sup>nd</sup> truss (16 days after pollination) were in period of rapid fruit expansion, meanwhile fruits 3<sup>rd</sup> truss (0 days after pollination) were in early growth stage. Because of the differences in growth stage, fruit size, fresh weight per fruit and volume of tomatoes decreased according to EC level of nutrient solution. Stronger effect was found on fruits which were in a period of rapid expansion than that in the early growth stage. Under high EC level, crop performance might be adversely affected by water deficit arising from the low water potential of nutrient solution (known as osmotic effect). Increasing EC level of nutrient solution decreases water availability and water uptake and thus reduces root pressure-driven xylem transport of water and water solute. Thus, it limits the cell expansion of plant cell. This phenomenon was suggested to be caused of the decreasing fruits size, fresh weight per fruit, volume of fruit but increased density of fruit (Ling Li *et al.*, 2001; Katerji *et al.*, 2003).

In this experiment, both treated and control plants produced tomatoes that tend to increase in size of fruit for 3<sup>rd</sup> truss. Increase in size of fruit caused increasing of fresh weight and volume per fruit. Fruits became bigger because water flow into the fruits increased after DSW treatment was stopped. Fruits of 3<sup>rd</sup> truss grew normally like the control tomatoes, while stiffness of whole fruit decreased from 1<sup>st</sup> truss to 3<sup>rd</sup> truss.

The highest increment of fruit quality parameters was obtained from fruits of 1<sup>st</sup> truss. This increment tended to decline from 1<sup>st</sup> truss to 3<sup>rd</sup> truss. It is supposed that the effect of treatment is stopped because 3<sup>rd</sup> truss fruits are in the earliest growth stage. These results are a coincidence with that reported by Eltez *et al.* (2002) who noted that parameters of fruit quality, such as soluble solids content and acidity, increased by increasing EC level of nutrient solution.

Quality of tomato obtained in high EC level of nutrient solution is often adversely affected by the appearance of BER. BER symptom begins as a slight browning at distal placental tissue which progressively invades the pericarp; beside the necrosis of the affected tissue, the fruits stop growing and start ripening too early. BER are caused by a local Ca<sup>2+</sup> deficiency at the distal placental fruit tissue (Cuartero and Munoz, 1999). Supplementation of DSW increased the salinity of nutrient solution, subsequently reduced the Ca<sup>2+</sup> uptake thus fruit contains less Ca<sup>2+</sup>. In winter, air humidity is low that cause an increase in transpiration. As a consequence, more Ca<sup>2+</sup> moved to leaves and less to the fruit, causing the BER in tomato plants occurred.

The yields reduction was mainly due the smaller fruit size, for 1<sup>st</sup> and 2<sup>nd</sup> truss. For 3<sup>rd</sup> truss, yields reduction was mainly due the number of fruits affected

by BER even though the fruits were bigger than fruits of 1<sup>st</sup> and 2<sup>nd</sup> truss. The EC level of 10.0 dS m<sup>-1</sup> had the highest yields due the higher fruits harvested.

Nowadays many farmers are growing tomato fruits in hydroponics cultivation in Indonesia. As islands country, Indonesia has great potential sea water to apply for cultivation to gain various advantages such cultivation under saline condition. However, the climate condition that characterized by hot and humid should be considered. Under high solar radiation, the saline condition will be affected on plant growth and fruit properties greater than low solar radiation.

## CONCLUSIONS

It was concluded that increasing EC level by supplemented DSW into nutrient solution for two weeks, decreased the tomato yields but could improve the taste and quality of fruits by increasing soluble solids content 21 %, acidity 16 %, and dry matter content of tomatoes 21 % respectively. However, the increment of soluble solids content acidity and dry matter of tomatoes tend to decline from 1<sup>st</sup> truss to 3<sup>rd</sup> truss. Thus, it is necessary to investigate the duration of treatment to maintain the increment of tomatoes quality in all trusses.

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