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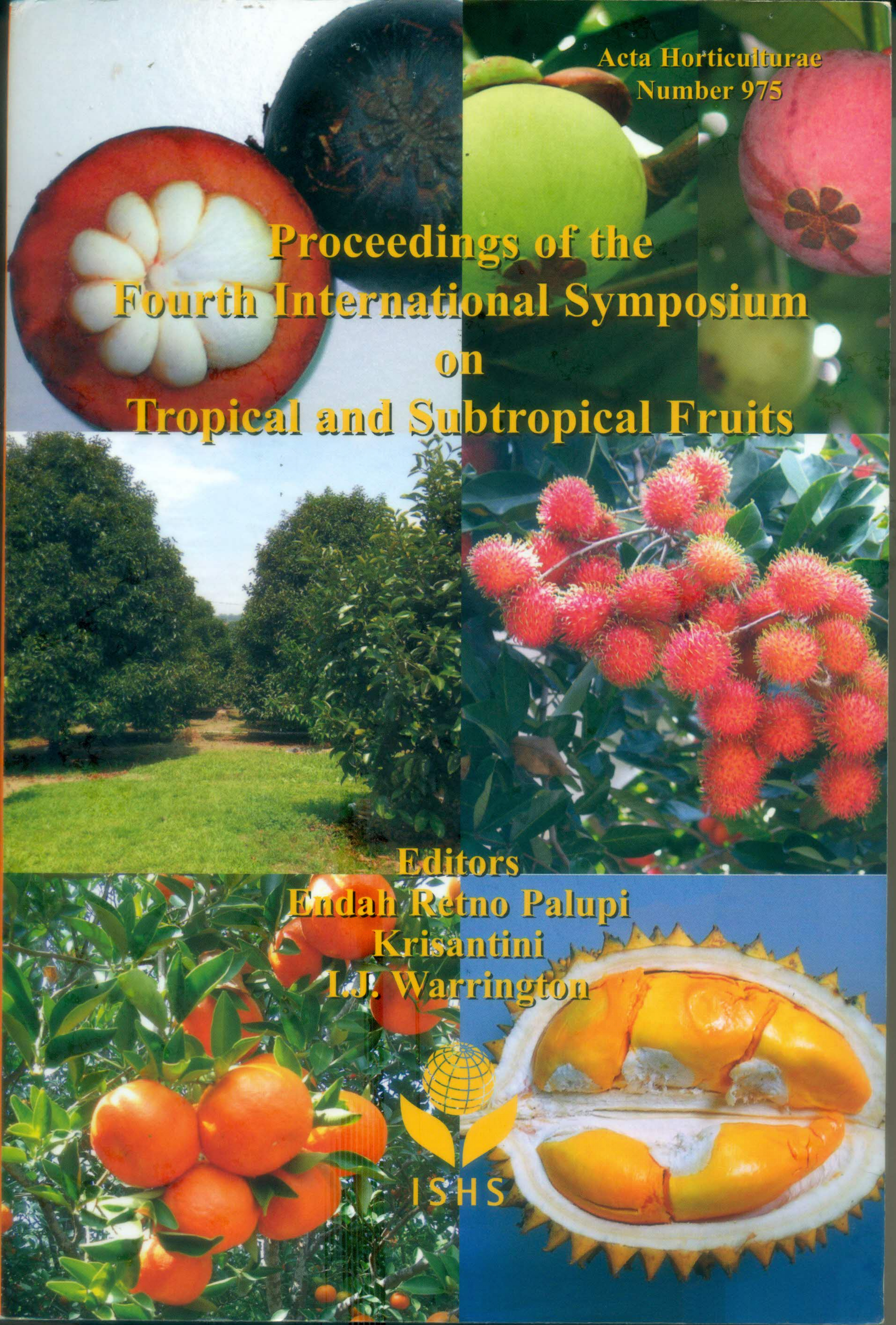

Editors
Endah Retno Palupi
Krisantini
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Photographs on the front cover:

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1. An opened mangosteen fruit showing its white segments and reddish-pink rind (by courtesy of M. Reza Tirtawinata).
2. A maturing green and a ripe maroon mangosteen fruit (by courtesy of M. Reza Tirtawinata).
3. Mangosteen tree (by courtesy of R. Poerwanto).
4. Rambutan 'Lebak Bulus' – ripened fruit bunch (by courtesy of M. Reza Tirtawinata).
5. Jeruk Soe, East Nusa Tenggara (by courtesy of R. Poerwanto).
6. Opened fruit of Durian Lai showing its golden flesh edible arillus (by courtesy of M. Reza Tirtawinata).

Editors

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Effect of Intermittent Method of Deep Sea Water Treatment on Fruit Properties in Multi-Trusses Cultivation of Tomato

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Keywords: deep sea water, fruit properties, intermittent treatment, multi-trusses cultivation, nutrient film technique, *Lycopersicon esculentum*

Abstract

Deep sea water (DSW), that has cold temperature, abundant nutrients, good quality and is pathogen-free, has been used for high quality tomato production. It had both advantageous and deleterious effects on tomato fruit properties. In this experiment, DSW treatment was applied both intermittently and continuously during fruit growth. The objective was to obtain an effective method for DSW treatment in multi-truss cultivation to obtain high quality tomatoes while minimizing any reduction of yield. The results of the study showed that in the intermittent treatment, a longer treatment interval ($2W_{EC10}1W_{EC1}$) produced tomatoes with higher soluble solids concentration and higher acidity than a shorter treatment interval ($1W_{EC10}1W_{EC1}$). Intermittent treatments produced tomatoes larger than from the $continue_{EC10}$ treatment but fruit density was lower. The enlargement of fruits from the intermittent treatment was greater than from the $continue_{EC10}$ treatment – thus the volume of these intermittent treatment fruits were greater. Increasing dissolved oxygen in the nutrient solution could reduce blossom end rot in the tomatoes.

INTRODUCTION

Previous studies have shown that deep sea water (DSW) treatment could increase quality parameters such as soluble solids concentration, acidity, and dry matter (Chadirin et al., 2007). These fruit quality parameters increased both in response to increasing DSW concentration in the nutrient solution and to treatment duration. However, yield decreased in DSW treatments because of small fruits and physiological disorders, like blossom end rot (BER) (Chadirin et al., 2008). The increment of gain in fruit quality parameters tended to decline from the 1st to the 3rd truss. Thus, it is necessary to investigate a method of DSW treatment to obtain high fruit quality from all of trusses while minimizing any reductions in yield.

In this experiment, DSW treatment was applied both intermittently and continuously during fruit growth. The objective was to obtain an effective method of DSW treatment in multi-truss cultivation to obtain high quality tomatoes while minimizing any reduction in yield.

MATERIALS AND METHODS

Tomatoes (*Lycopersicon esculentum* 'House momotaro'), were grown on a nutrient film technique (NFT) system with beds 10 m long and a slope of 1%. These beds each contained 47 plants and nutrient solution was circulated from a 100-L tank through the bed with flow rate of 3 L min^{-1}. Nutrient solution of the control (1.0 dS m^{-1}), was made from Otsuka Solution and DSW was supplemented into the control nutrient solution to reach 10.0 dS m^{-1}.

All of cultivation beds were circulated with standard nutrient solution with electrical conductivity (EC) 1.0 dS m^{-1} after transplantation. When fruits of the 1st truss were at 21 days after pollination, all beds were treated with supplemented nutrient solution with EC 5.0 dS m^{-1} for 3 days following which the DSW treatments were started. Bed 1 ($2W_{EC10}1W_{EC1}$) was treated intermittently with supplemented nutrient solution (EC 10.0 dS m^{-1}) for 2 weeks followed with standard nutrient solution (EC 1.0 dS m^{-1}) for

1 week. This cycle was continued until the end of cultivation. Bed 2 ($1W_{EC10}1W_{EC1}$) was circulated with supplemented nutrient (10.0 dS m^{-1}) continuously for 1 week and then with standard nutrient solution (1.0 dS m^{-1}) for 1 week. This cycle was also continued until the end of cultivation.

Concurrently with beds 1 and 2 being treated with intermittent applications, beds 3 and 4 were circulated with supplemented nutrient solution (EC 10.0 dS m^{-1}) from 24 days after pollination until fruits were harvested. Supplementation of O_2 into the nutrient solution was carried out for bed 3 ($continue_{EC10+O2}$) to investigate its use for control of BER in the tomatoes while bed 4 ($continue_{EC10}$) was not supplemented with O_2. Supplementation of O_2 was carried by using a dissolved oxygen machine running for 10 min every hour. During cultivation, tomatoes were maintained at 5 fruits per truss and 4 trusses per plant.

Ten fruits were selected randomly from each truss and from each bed and diameter of fruit was measured by caliper every 3 days during fruit growth until fruits were harvested in the ripe condition. Fruit volume (V) was estimated by following the equation of Okano et al. (2002).

Full ripe tomatoes were harvested from each bed and 5 fruits were selected randomly from each bed and each truss for measurement of fruit properties including weight, size, density, volume, soluble solids concentration and acidity (Chadirin et al., 2008).

RESULTS AND DISCUSSION

Figure 1 shows the changes in fruit volume during growth. The DSW treatment does not seem to have affected the fruits on the 1st truss. These fruits were 21 days after pollination and had volume 60 cm^3 when the treatment was started. They had a final size of 140 cm^3 and developed normally even during treatment. Fruits of the 2nd and 3rd trusses were 13 and 3 days after pollination and fruits of the 4th truss were pollinated 3 days after the DSW was started. Among the 2nd, 3rd and 4th trusses, the enlargement of fruits from intermittent treatment was greater than in the $continue_{EC10}$ treatment – thus, the volumes of these fruits were greater.

Intermittent treatments produced tomatoes that were larger than fruit from the $continue_{EC10}$ treatment with fresh weight above 70.00 g per fruit, while $continue_{EC10}$ treatment produced tomatoes with fresh weight below 65.00 g per fruit for the 2nd, 3rd, and 4th trusses (Table 1). Plants that were treated with the short interval treatment ($1W_{EC10}1W_{EC1}$) produced tomatoes that were heavier than those from the longer interval treatment ($2W_{EC10}1W_{EC1}$).

Plants that were treated by intermittent treatments produced tomatoes which had a larger volume than those from the $continue_{EC10}$ treatment. Both of intermittent treatments produced tomatoes where the volume of fruits was above 0.070 L, while $continue_{EC10}$ treatments produced tomatoes with a fruit volume lower than 0.065 L (Table 1). In intermittent treatments, the volumes of fruit from the $1W_{EC10}1W_{EC1}$ treatment were greater than those from the $2W_{EC10}1W_{EC1}$ treatment.

In contrast, intermittent treatments produced tomatoes which had a density which was lower than those from the $continue_{EC10}$ treatment. The $2W_{EC10}1W_{EC1}$ treatment produced tomatoes that had density of fruit was higher than the $1W_{EC10}1W_{EC1}$ treatment. The longer treatment interval produced tomatoes which had a higher density of fruit (Chadirin et al., 2008).

Supplemented O_2 in the nutrient solution did not impact on the puncture strength of tomato skin (data not shown).

All treatments produced tomato fruit with a soluble solids concentration higher than 6.0°Brix. Soluble solids concentration increased from the 1st to the 3rd truss and then slightly decreased at the 4th truss (Fig. 2). The highest value of soluble solids concentration was obtained from the 3rd truss of $continue_{EC10+O2}$ treatments (9.9°Brix).

Acidity of fruit increased from the 1st to the 4th truss within each treatment. The $continue_{EC10}$ treatments produced fruit with acidity which was higher than fruit from the intermittent treatments and the intermittent treatment, $2W_{EC10}1W_{EC1}$, produced higher acidity than the $1W_{EC10}1W_{EC1}$ treatment.

The highest of yield was obtained from the intermittent treatment ($1W_{EC10}1W_{EC1}$). (Fig. 3). Intermittent treatments produced yields that were 27-31% higher than the $continue_{EC10}$ treatment. Small fruit size and BER caused low yields in the $continue_{EC10}$ treatment.

Most of the BER affected tomatoes were obtained from the longest treatment ($continue_{EC10}$) (Fig. 4). Supplemental O_2 in the nutrient solution reduced BER tomatoes. Occurrence of cracking in tomato in the intermittent treatments was higher than in the $continue_{EC10}$ treatment (data not shown). Water flux into fruit was changed when plants were subjected to intermittent treatments.

CONCLUSIONS

When plants were grown with supplemented nutrient solution, fruit growth and cell enlargement of plant tissues were decreased because of the low water potential of the nutrient solution caused by the increased EC level. Thus when a supplementary treatment was stopped and the plant was circulated with standard nutrient solution, water potential of the nutrient solution increased and it likely increased of water uptake. Thus cell enlargement and plant growth were slightly increased. Intermittent treatments produced tomatoes that were bigger than those from the $continue_{EC10}$ treatment but soluble solids, acidity and dry matter content were lower. Intermittent treatment had higher yield because fruit size was greater.

In the $continue_{EC10}$ treatment, plants were circulated with nutrient solution where the EC was 10 dS m^{-1} from when the treatment was started until fruits were harvested. Thus plants were grown in a low water potential and had reduced water uptake for a prolonged time. Reduced water flux into the fruit decreased fruit growth (Schwarz and Kuchenbuch, 1998). Then final size of fruit was small and the volume of fruit was low. However, these fruit had a high soluble solids concentration as a consequence of the DSW treatment.

In intermittent treatments, a longer treatment interval ($2W_{EC10}1W_{EC1}$) produced tomatoes with soluble solids concentration, acidity and dry matter which were higher than fruit from the shorter treatment interval ($1W_{EC10}1W_{EC1}$). This result was in agreement with previous experiments where the effect of DSW was increased by increasing treatment duration (Chadirin et al., 2008).

DSW treatment applied as an intermittent method could improve yield by 28% compared to a continuous DSW treatment. Blossom end rot (BER) occurrence could be reduced from 65 to 23% by O_2 supplementation in the nutrient solution. Soffer (1988) indicated that dissolved oxygen is essential to root formation and root growth. Oxygen affected the timing of rooting, rooting percentage, number of roots, and root length. In this experiment, we assumed that dissolved oxygen improved root performance and thus Ca^{2+} uptake by roots was increased so reducing the occurrence of BER.

The intermittent method of DSW treatment can be suggested for high quality tomato production when optimum yield is sought in multi-truss cultivation. The incidence of cracking in tomatoes should be considered when the intermittent method of DSW treatment is applied under hot and humid climatic conditions.

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Tables

Table 1. Effect of intermittent method of DSW treatment on fruit properties of tomato.

Treatment	Fresh weight (g fruit^{-1})	Diameter (mm)	Volume (L)	Density (kg m^{-3})	Acidity (% w/v)
			Truss 1		
$2_{WEC10}1_{WEC1}$	130.28(5.67)	64.8(2.1)	**0.132(0.006)**	**989.9(8.5)**	**0.43(0.23)**
$1_{WEC10}1_{WEC1}$	137.17(6.52)	**65.9(1.3)**	**0.137(0.006)**	**1003.8(4.1)**	**0.49(0.24)**
$Continue_{EC10}$	126.03(11.93)	**65.3(2.6)**	**0.077(0.007)**	**988.6(28.6)**	**0.51(0.25)**
			Truss 2		
$2_{WEC10}1_{WEC1}$	70.69(8.99)	**52.1(2.3)**	**0.070(0.010)**	**1011.4(7.2)**	**0.56(0.22)**
$1_{WEC10}1_{WEC1}$	81.37(9.25)	55.3(1.7)	**0.081(0.009)**	**1001.1(13.0)**	**0.50(0.16)**
$Continue_{EC10}$	62.30(4.59)	**49.6(1.1)**	**0.061(0.004)**	**1022.7(10.6)**	**0.71(0.44)**
			Truss 3		
$2_{WEC10}1_{WEC1}$	73.50(7.58)	**53.4(1.5)**	**0.073(0.007)**	**1004.7(18.8)**	**0.59(0.46)**
$1_{WEC10}1_{WEC1}$	95.44(10.37)	59.4(1.4)	**0.098(0.008)**	**976.2(41.9)**	**0.59(0.30)**
$Continue_{EC10}$	62.73(2.76)	49.3(0.7)	**0.062(0.003)**	**1019.2(2.5)**	**0.93(0.32)**
			Truss 4		
$2_{WEC10}1_{WEC1}$	71.70(13.76)	**51.8(3.5)**	**0.072(0.014)**	**999.3(7.2)**	**0.71(0.25)**
$1_{WEC10}1_{WEC1}$	**81.66(4.41)**	**53.9(0.5)**	**0.082(0.004)**	**995.4(11.7)**	**0.59(0.31)**
$Continue_{EC10}$	53.79(4.60)	**47.2(1.6)**	0.053(0.006)	**1021.9(26.5)**	**0.83(0.30)**

Number in parentheses is the standard deviation.

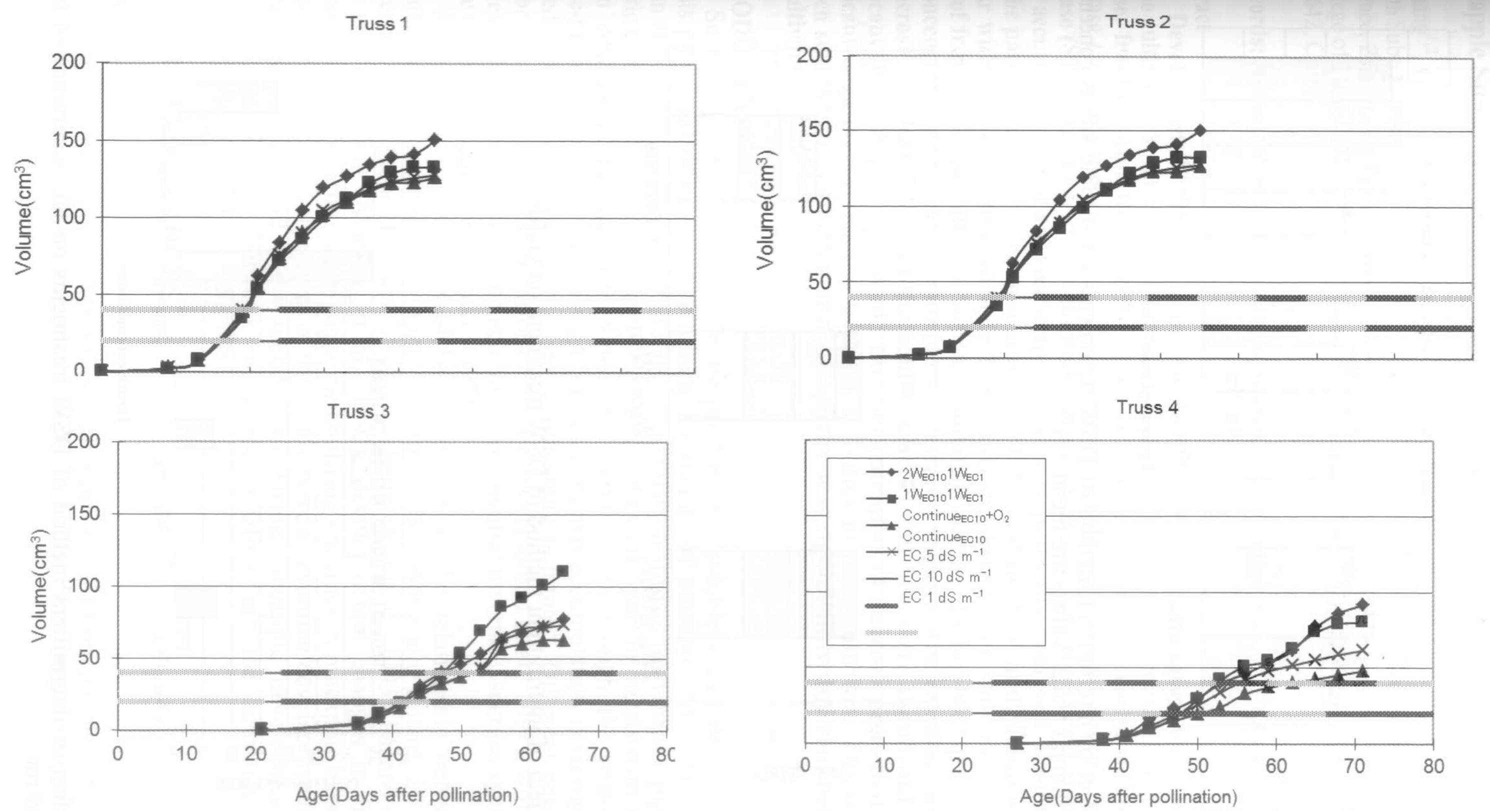

Fig. 1. Changes in volume of fruit on 1st, 2nd, 3rd and 4th truss plants grown in each treatment.

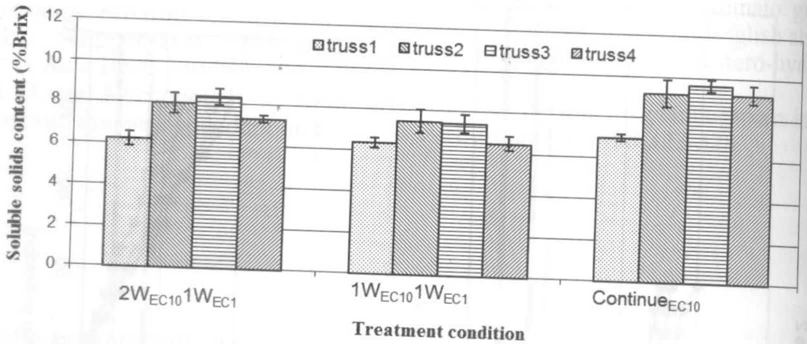

Fig. 2. Effect of intermittent method of DSW treatments on soluble solids concentration of tomato fruits. Values are mean ± SD.

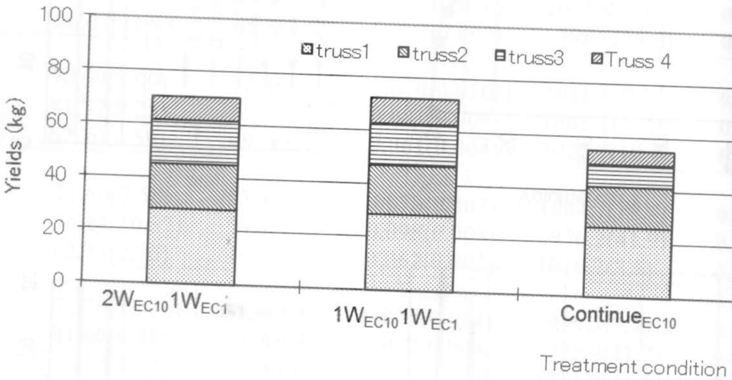

Fig. 3. Effect of intermittent method of DSW treatment on yields.

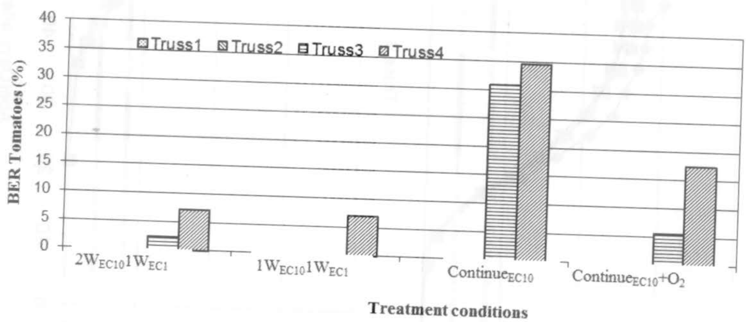

Fig. 4. Effect of intermittent method of DSW treatments on the occurrence of blossom end rot.