The Influence of Saline Water Drip Irrigation and Root temperature Zone on Tomato Yield under Soilless Cultivation

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Abstract

A field experiment was carried out during winter seasons at 2016, on a private farm at the Department of Horticultural Science, Ferdowsi University of Mashhad. To evaluate the saline water drip irrigation (SWDI) (0, 1.5, 3 and 6) ds.m^{-1} in nutrient solution on tomato plants (*Solanum Lycopersicum* L Cv. Memory) under high (30°C), low (20°C) and medium (25°C) root zone temperature (RZT), an experiment was carried out as split –plot based on completely randomized design. High of the yield of a plant, total fruit and experimental were under SWDI (3) ds.m^{-1} compared to control, but lowest fruit diameter was under high SWDI (6) ds.m^{-1}. SWDI 6 ds.m^{-1} increased firmness fruit. High RZT 30°C decreased average fruit of weight compared to RZT 25 °C. Yield of the plant, fruit diameter and experimental had not significant by RZT. RZT 25°C decreased total fruit number /plant. Firmness fruit increased under RZT 25 °C compared to low RZT 20 °C. Interactions between RZT and SWDI were significant for all traits studied in the experiment.

Keywords: Salt Stress, Hydroponic, Greenhouse, Tomato Yield, Root Temperature

Introduction

Mechanisms of plants towards salt stress appear by restricting the entry of salt into the plant (especially minimizing the accumulation of salt in photosynthetic tissues and cytoplasm)[1]. The plant follows two main adaptive strategies towards high environment salinity stress, firstly to avoid tolerance due to various physical and physiological barriers; secondly enhancing the adaptive mechanisms internally that will enable successful survival. Therefore, the Na^+ uptake and its transport regulation across the plasma membranes and tonoplast are one of the key factors that establish the plant cell response to salinity stress [2]. Under conditions of high soil salinity, many plants, including tomato, are susceptible and decreased yields. To alleviate the deleterious impact of salt stress, the measures such as the reclamation of salinized lands, the improvement of irrigation with saline water and the cultivation of salinity variety have been applied and as well as the application of root zone heating [3]. The temperature at the root-zone also effects the growth and yield of many plants [4, 5]. In strawberry plants, root zone heating of cultivation media increased the development of flower bud initiation during the low temperature season and finally enhanced from fruit yield [6]. Cooling of the nutrient solution gives rise to in the reduction of fruit biomass production. Conversely, the fruit set was enhanced by low heating treatment of supplied water[7]. In addition, the determination of the precise heating of the root cells is difficult, as methods of thermoregulation are not applied directly to the roots. Therefore, we examined the effect of root temperature zone and electrical conductivityon the yield of tomato plants using a hydroponic system that could directly transduce the thermal effect on the roots, under a controlled light and air temperature inside greenhouse.

Material and Methods

Study site. The experiment was carried out for a period of 180 days from 1 January to 30 July 2016 at the greenhouse, Department of Horticulture Faculty Agricultural, Ferdowsi University of Mashhad. The greenhouse was well protected and had well-locked door system. In addition, it was a clean and dry place. That is why this place was selected for the experiment.

Plant material and culture conditions. F1 tomato seeds (Memory) were first sown in 2×2×2 cm sponge cubes, then covered with a thin layer of vermiculite on first January 2016 and germinated under greenhouse at Department of Horticulture, Ferdowsi University of Mashhad. The nutrient solution was based on half strength culture solution, 30 days after sowing; the seedlings were transferred to a soilless system with the distance of 25 cm apart. For conducting transactions on plants, a special system was used, in which a plastic container with the height and length of 30 and 50 cm, respectively, was prepared. Root zone temperature in the experiment was set by putting very transparent plastic cylinder with the height and diameter of 25 and 20 cm inside the container, then the cylinder filled with water and heater electrical aquarium was placed in water for setting root zone temperature, and finally the plastic cylinder was closed by special cover to prevent or reduce evaporation process. Thereafter, plastic container was filled with perlite and coco peat at the ratio of 50:50. Temperature transferred from water in cylinder plastic to growth medium by heat exchange 48 hours after warming water. Root zone temperature in the growth medium was measured by using a digital thermometer. It was found that temperatures in the agricultural medium were similar to the hot water in the plastic cylinder. Root zone temperature was set at three levels of 20, 25 and 30 ± 2 $^{\circ}$C.

Culture Processes. All agricultural operations conducted by the methods used in the production tomato plants in greenhouses, where has been tinkering with the plants seedlings similar after seven days of agriculture has also been conducting the processes of irrigation by drip irrigation system, has also been cultivated plant breeding on one leg and then wiring the plants by cotton threads on wiring located above each sector has also been added compound fertilizer NPK 20: 20: 20 spraying on the leaves in the third and fifth week in quantities of 50 g per 100 liters of water, this has been sprayed several plants workshops and preventive disease and insect resistance as spraying Abannlit a concentration of 2 g /L after two weeks from the date of agriculture, and to prevent wilt plants sprayed with pesticide systemic fungal Albastin concentration of 1 ml /L. Also, tomato plants were fed throughout the planting period with the nutrient solutions shown in (Table 1) by drip irrigation.

Training system. The basic principles of training the plants to uniformities distribute the foliage throughout the entire greenhouse so that the leaves can intercept maximum light. Single crop wires were placed 3 m above the ground over each row of plants. The strings for plants were then tied alternately to the overhead wires so that the plants were inclined away from the row on each side.

Pruning. Plants were trained to be overhead wire and the growing point was removed tell 500 mm for plants, a small loop of string was tied to the wire and the main stem below the top leaf to prevent the plant from slipping down the string, all side shoots were cut after producing one fruit at an early stage. Three or four leaves have been selected when the main stem reached the top of the wire, then other 2 branches were allowed to grow down. Only the laterals were topped when necessary (when they touch the ground).

Table 1: Nutrient solution composition for ‘tomato plants grown in stirred solution culture for 28 weeks, with full strength modified Hoagland's nutrient solution.

Cations Nutrient	Concentration mg L^{-1}
H2KO4P	130
KNO3	500
Ca (NO3)2	1180
Mn So4	490
Iron Chelate	25 cc
Micronutrient Stock	4 cc

Measurements of yield characteristics

1- **Total fruit number/plant:** Counting the number of fruits from the beginning of harvest until the last fairy extracted rate for each experimental unit on according to the following equation: Total fruit number /plant = $\frac{\textit{Fruit number in experimental unit}}{\textit{Plant number in experimental}}$

2- **Fruit weight (g)**: During harvesting time, the tomato was weighed by using an electric balance. The weight of each tomato was recorded in a notebook. Average fruit weight (g), it was calculated according to the following equation:

$$= \frac{\textit{Experimental unit yield}\,(g)}{\textit{Fruit number in experimental unit}}$$

3- **Fruit diameter (mm):** Recorded by caliper for 10 fruits from the experimental unit, and take the of average.

4- **Plant yield**: Plant yield (Kg). It was calculated according to the following equation:

$$= \frac{\textit{Experimental unit yield}\ (Kg)}{\textit{Plant number in experimental unite}}$$

5- **Experimental yield: Plant yield (Kg).** It was calculated according to the following equation: $= \frac{\textit{Experimental unit yield}\ (Kg)}{\textit{Plant number in experimental unite}}$

6- **Fruit firmness:** Fruit firmness was recorded using a penetrometer (tomato Fruit Firmness Tester model FT-327). Data was recorded on day one.

Experimental design and statistical analysis. The experiment was performed as split – plot design in a completely randomized design (RCD) with four replications and two factors. The first factor was three Root Zone Temperatures (RZT) (20±2, 25±2 as control [8] and 30±2°C), and the second factor was four levels of saline water drip irrigation in nutrition solution (0, 1.5, 3 and 6 ds.m^{-1}).

The data obtained for each parameter were analyzed using statistical JMP٨ software, and the related graphs were drawn by using excel software; one–way analysis of variance (ANOVA) was used for determining the difference among treatments; means comparison was performed using the least significant difference (LSD) at 5% level of probability.

Results and Discussion

Yield characterize

Effects of saline water drip irrigation (SWDI) and root zone temperature (RZT) on tomato plants yield

Average of fruit weight (g). (Table 2 and 3) shows that average fruit weight was affected by SWDI and RZT. High SWDI treatment increased average fruit weight so that fruit weight under high SWDI treatment was 0.184 mg compared to fruit weight 0.172 mg in control treatment. Average fruit weight at SWDI 6 ds.m^{-1} was not significantly but higher than that of control treatment. A similar effect of high SWDI on average fruit weight was reported by [9]. As explained the highest general average fruit weight was for those treatments with 1.5 and 2.5 mS cm^{-1} EC. The highest monthly average fruit weight reported in plants grown with 2.5 mS cm^{-1} EC nutrient solution. Furthermore, based on (Table 3) root zone temperature had a significant effect on average fruit weight, where average fruit weight 0.202 mg was obtained in RZT 25°C compared to average fruit weight 0.166 and 0.162 mg in root zone temperature 20 and 30°C,similar results were observed by [10] as showed individual fruit size and total yield were higher than in the control due to a higher total dry weight in the heating treatment. Data in the (Fig 1) showed that interaction between RZT and SWDI caused significant differences in average fruit weight. Treatment of the interaction between SWDI 0 ds.m^{-1} and RZT 25 $^{\circ}$C showed the highest average fruit weight (0.225 mg) in comparison with the combination of 0 ds.m^{-1} and RZT 20 $^{\circ}$C, reached (0.141 mg) and 1.5 ds.m^{-1} with 20°C.

Table 2. The main effect of different saline water drip irrigation on some characteristics of tomato

SWDI ds.m^{-1}	Average fruit weight (g)	Yield of plant (kg)	Total Fruit number /plant	Experimental unit yield (kg)
Control	0.173 a	1.481 b	19.08 c	3.260 b
1.5	0.174 a	1.791 a	21.25 ab	3.541 ab
3	0.177 a	1.865 a	21.75 a	3.793 a
6	0.185 a	1.818 a	19.91 bc	3.679 ab

Within a column means followed by the same letter are not significantly different at P < 5% according to least significant different test.

Table 3. The main effect of different temperature of root zone on some yield characteristics of tomato

RZT (°**C**)	Average fruit weight (g)	Yield of plant (kg)	Total Fruit number /plant	Experimental unit yield (kg)
20	0.166 b	1.739 a	21.87 a	3.723 a
25	0.202 a	1.777 a	19.18 c	3.459 a
30	0.163 b	1.701 a	20.43 b	3.522 a

Within a column means followed by the same letter are not significantly different at P < 5% according to least significant different test. Low temperature (20°C), optimum temperature (25°C) and high temperature stress (30°C).

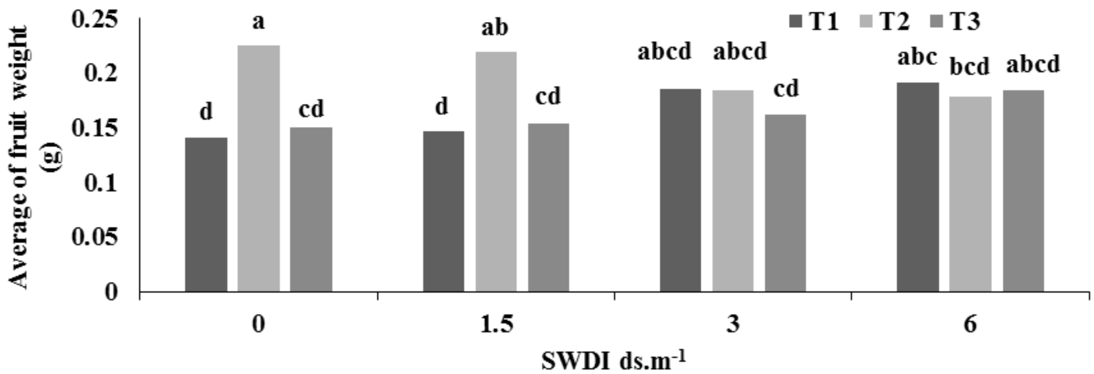

Fig. 1. The interaction effect of root zone temperature and different levels of saline water drip irrigation on the **Average fruit weight**. Low temperature (T1 = 20°C), optimum temperature (T2 = 25°C), and high temperature stress (T3 = 30°C).

Total fruits number/plant, yield plant, and experimental unit yield. That tomato yield is decreased under salinity above threshold values condition is an unquestioned fact [11] had reported that the total yield of tomato (*Lycopersicon esculentum* M. cv. Durinta F1) is significantly decreased at salinity equal and above 5 dS m^{-1}, and a 7.2% yield reduction per unit increase in salinity. In addition [12] also reported that tomato (*Lycopersicon esculentum* Mill) total and marketable fresh fruit yield reduced significantly with increasing salinity. [13] had proposed that tomato (Solanum Lycopersicum L.) growth and yield reduction affected by salinity could be the reasons for variation in photosynthetic products translocation toward the root, reduced of plant top especially leaves, partial or total enclosed of stomata, the direct effect of salt stress on photosynthesis system and ion balance. In the present study number of fruits, plant yield and experimental unit yield increased in SWDI level of 3 ds.m^{-1} compared to the treatment containing saline water drip irrigation at 0 and 6 ds.m^{-1} level (Table 2). Saline water drip irrigation may be decreased the production of yield by overturning water and nutritional balance of plant and loss of photosynthetic capacity, the latter is limiting factor to the supply of carbohydrate for plant growth [14]. Salt stress could also decrease shoot and root development by reducing turgor in growing plant parts as a result of limited water potential in root growth medium [15]. RZT is important in plant growth and development because it affects the physiological process in roots such as mineral nutrients and uptake of water[16]. RZT may also be critical for plant survival, because roots have a lower temperature optimum and are less adapted to extreme fluctuation than shoots, under controlled conditions root growth increase nearly laniary with increased RZT from a minimum to an optimum temperature [17]. Results in (Table 3) showed total fruit number/plant was significantly affected by RZT. Low RZT 20°C treatment increased total fruit number / plant and experimental unit yield so that total fruit number/plant and experimental unit yield under RZT 25°C treatment were 19.187 and 3.522 compared to total fruit number/plant and experimental unit yield under root zone 20°C were 21.875 and 3.723 respectively. But the yield of plant increased by RZT 20 and 25°C treatments reached 1.739 and 1.777 so that 1.701 respectively under root zone temperature 30°C (Table 3). These results agree with other authors [18] and [19] showing not any effect of root temperatures between 15 and 20°C on tomato production. However, other authors testing the same root zone temperatures have shown that heating roots at 20°C increased the production [20]. We found root-zone temperature had no effect on the yield of plant and experiment unit yield while root zone temperature 20°C had effect significantly on the total fruit number/plant per plant, similarly with [20]. Interaction effect of SWDI and RZT, the results in (Fig 3) showed that the interaction between SWDI and RZT, caused an increase in total fruit number/plant, the greatest total fruit number/plant was observed in (SWDI levels of 3 $ds.m^{-1}$ and RZT of 30 °C, while the lowest amount was seen SWDI 0 $ds.m^{-1}$ and RZT 25°C. The results also showed that combination of SWDI of 6 $ds.m^{-1}$ and RZT 20°C increased experimental unit yield/plant, while combination of SWDI levels of 0 $ds.m^{-1}$ and RZT 25°C had the lowest experimental unit/plant table (Fig 4). As seen in the (Fig 5) the highest yield of the plant was observed in SWDI levels of 3 $ds.m^{-1}$ and RZT of 30°C, whereas that lowest yield of the plant was due to a saline water drip irrigation level of 0 $ds.m^{-1}$ and root zone temperature 20°C.

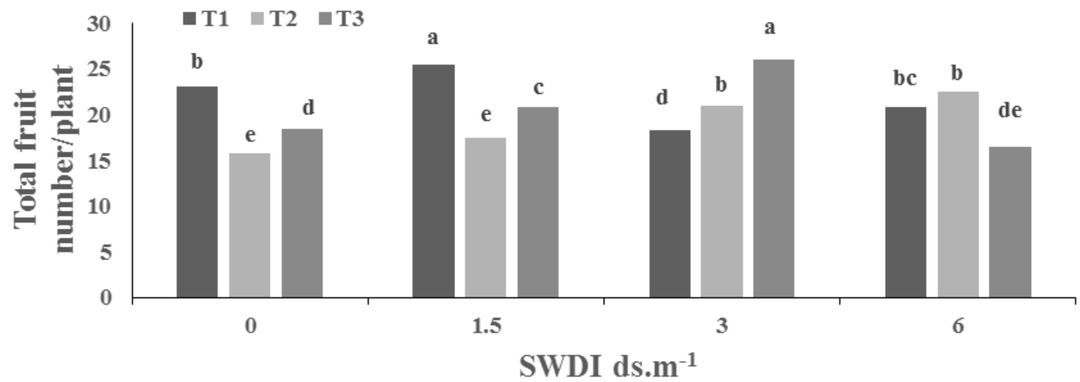

Fig.2. The interaction effect of root zone temperature and different levels of saline water drip irrigation on the **Total fruit number/plant (kg).** Low temperature (T1 = 20°C), optimum temperature (T2 = 25°C), and high temperature stress (T3 = 30°C).

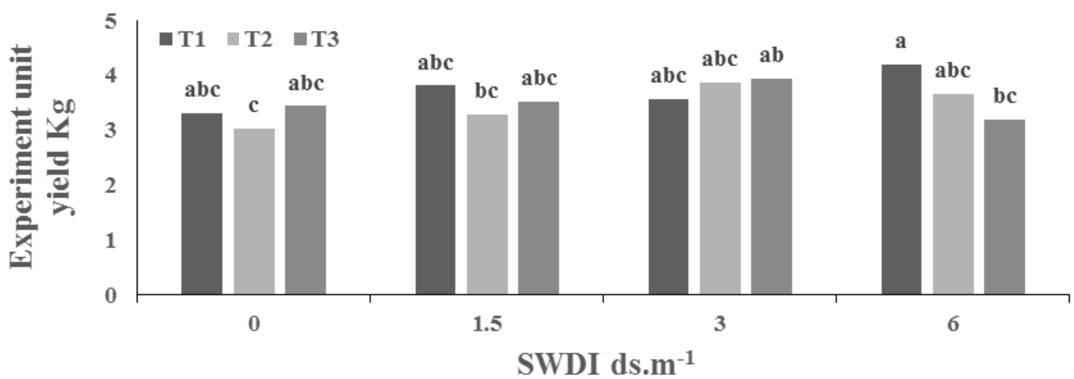

Fig.3. The interaction effect of root zone temperature and different levels of saline water drip irrigation on the **Experiment unit yield (kg).** Low temperature (T1 = 20°C), optimum temperature (T2 = 25°C), and high temperature stress (T3 = 30°C).

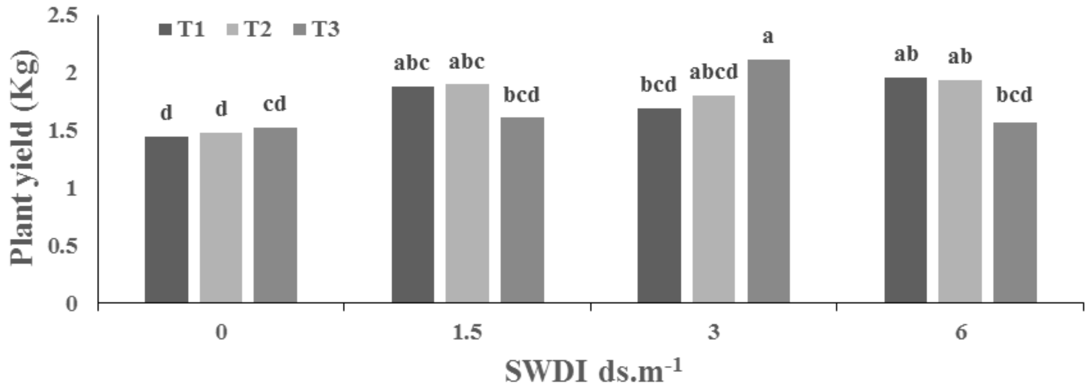

Fig.4. The interaction effect of root zone temperature and different levels of saline water drip irrigation on the **Plant yield (kg).** Low temperature (T1 = 20°C), optimum temperature (T2 = 25°C), and high temperature stress (T3 = 30°C).

Fruit Diameter. The diameter of individual tomato fruits varied significantly for the significantly for the different levels of SWDI (Table 4). The maximum fruit diameter 57.50 mm was recorded from control treatment, whereas the minimum 50.89 mm was found in 6 ds.m^{-1}. It was observed that SWDI decreased fruit size. Statically not significantly difference was observed for fruit diameter of tomato due to the application of difference levels of RZT (Table 5). SWDI and RZT levels significantly affected fruit diameter of tomato plants (Fig 5). The highest fruit diameter 58.01 mm of tomato was recorded from non – saline water drip irrigation condition with RZT 30°C treatment combination whereas the lowest 47.55 was found from 6 ds.m^{-1} with RZT 30 $^{\circ}$C application. It has been reported that excessive salt exposure decreased tomato fruit size [21].

Table 4. The main effect of different saline water drip irrigation on some characteristics of tomato

SWDI (ds.m^{-1})	Fruit diameter (mm)	Firmness fruit
Control	57.50 a	1.91 c
1.5	53.64 ab	2.34 b
3	52.87 ab	2.18 b
6	50.89 b	2.82 a

Within a column means followed by the same letter are not significantly different at P < 5% according to least significant different test.

Table 5. The main effect of different temperature of root zone on some characteristics of tomato

RZT (°C)	Fruit diameter (mm)	Firmness fruit
20	53.42 a	2.15 b
25	54.41 a	2.51 a
30	53.35 a	2.26 b

Within a column means followed by the same letter are not significantly different at P < 5% according to least significant different test. Low temperature (20°C), optimum temperature (25°C) and high temperature stress (30°C).

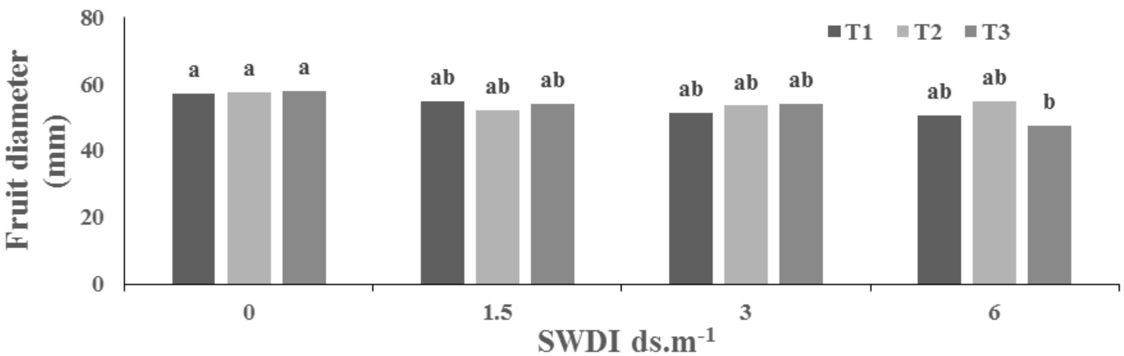

Fig.5

. The interaction effect of root zone temperature and different levels of saline water drip irrigation on the **Fruit number**. Low temperature (T1 = 20°C), optimum temperature (T2 = 25°C), and high temperature stress (T3 = 30°C).

Firmness Fruit. Was highly significantly ($P< 0.05$) affected by SWDI levels (Table 4). Various SWDI levels significantly affected the fruit firmness, maximum fruit firmness 2.82 was recorded in 6 ds.m^{-1} fellow by 1.5, 3 and 0 ds.m^{-1} (2.34, 2.18 and 1.90) recpectivally. Fruit firmness also was significantly influenced by RZT (Table 5). Root zone temperature 25°C enhanced fruit firmness by about 2.51, while the RZT 20°C treatment showed lowest values by 2.15. As shown in (Fig 6) activities of fruit firmness was enhanced by SWDI and RZT and the highest activities were recorded in combined stressed plants (6 ds.m^{-1} with 30°C) and the lowest levels was recorded combined stressed plant (3 ds.m^{-1} with 20 °C). The enhancing effects of saline water drip irrigation on the firmness of fruit are in agreement with reports of other investigators [22, 23] reported the saline water drip irrigation enhanced further the fruit firmness. Attributed the enhancing total soluble solids in tomato fruit with increased salinity to concentration effects originating from reduced fruit water content due to the adaptation of the plant to salinity. Nevertheless, in terms of consumer quality, the relevant criterion is the composition of the fresh fruit.

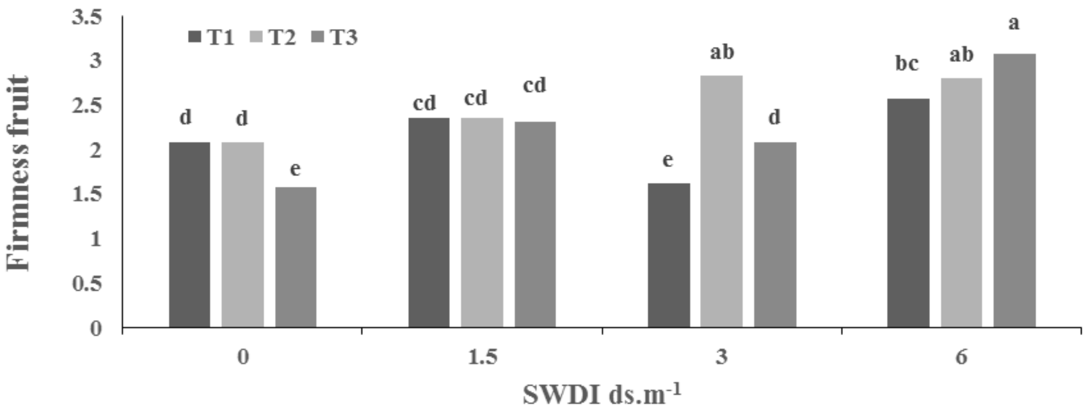

Fig.6. The interaction effect of root zone temperature and different levels of saline water drip irrigation on **Firmness fruit**. Low temperature (T1 = 20°C), optimum temperature (T2 = 25°C), and high temperature stress (T3 = 30°C).

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