THE EFFECT OF DIFFERENT IRRIGATION APPLICATIONS ON THE BLOSSOM-END ROT IN TREATED WASTEWATER-IRRIGATED TOMATOES (*LYCOPERSICON ESCULENTUM*)

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Abstract. The study investigates the effect of water deficit conditions on blossom-end rot (BER) in tomato. Drip irrigation was used in irrigation. Therefore, experiment was conducted as a randomized complete block design (three replicates), in a 2 × 5 factorial arrangement, corresponding to two different water resources [treated wastewater (TWW) and freshwater (FW)] and five different irrigation practices. The irrigation strategies comprised full irrigation (100%), deficit irrigation, which involves the use of 75% and 50% of the water used in full irrigation, and partial root drying (PRD). According to the study results, in the full irrigation applications, blossom-end rot according to the fruit number values were 10.85% in fresh water irrigation while it was the lowest with 8.57% for treated wastewater. Also, in full irrigation applications, blossom-end rot values according to fruit weight were found to be lower compared to those in other applications. It was determined that there was a negative relation between blossom-end rot and Ca value. The lowest blossom-end rot incidence was observed in the full irrigation applications, while it was lower in the PRD applications than in the D applications. In the production of marketable tomato, the PRD applications can be more advantageous than the D applications under water shortage conditions.
Keywords: *BER, wastewater, tomato, PRD, deficit irrigation*

Introduction

The gap between water supply and demand is growing with the increasing global population and has reached life-threatening levels in certain regions of the world (Hussain et al., 2002). Moreover, although water of higher quality is suitable for household use, lower-quality waters are used in agricultural irrigation due to increasing demand for water in arid and semi-arid regions (Kızıloğlu et al., 2008). Thus, the need for the re-use of treated wastewaters is increasing. Today, according to recent estimates, 20 million hectares of agricultural land are irrigated with raw, processed or partially-diluted wastewaters worldwide (Drechsel et al., 2010). In agricultural irrigation, water saving-oriented applications are also used in addition to the use of wastewaters to protect surface and underground water resources. Deficit irrigation and partial root drying methods are examples of these applications. The studies have shown that deficit irrigation and partial root drying yielded positive results in the reduction of agricultural water use (Doğan Demir, 2016). Partial root drying and deficit irrigation are fundamentally similar to each other but in the partial root drying method, a portion of the root remains dry while the rest is wetted depending on alternating wetting (Stikic et al., 2003).

Various plant species are irrigated using wastewater with partial root drying and deficit irrigation. High yields can be achieved with the irrigation of tomato plants with partial root drying and deficit irrigation either using clean water or wastewater and there are various studies investigating this subject (Al-Lahham et al., 2007; Li et al., 2007; Ekici, 2002; Alrajhi et al., 2015; Zegbe et al., 2007), but certain diseases may develop and cause yield losses due to applications. In tomatoes, blossom-end rot is the most common issue with these applications. Blossom-end rot in tomato has been described as a physical disorder for more than a century (Selby, 1896; Spurr, 1959; Saure, 2001; Ho and White, 2005; Taylor and Locascio, 2004). Although low calcium content has generally been reported to be the cause of blossom-end rot in tomato, various factors including acidic growing media, high N content, high soil salinity, low soil moisture and soil dryness have also been reported to affect the development of blossom-end rot (Selby, 1896; Shaykewich et al., 1971; Pill and Lambeth, 1980; Winsor and Adams, 1987; Ikeda and Osawa, 1988; Ho et al., 1999; Saure, 2001; Taylor and Locascio, 2004; Zhai et al., 2015).

There is limited information about the effects of water deficit and water stress on plant nutrition. In general, the nitrogen concentration in plant tissues increases with water stress. On the other hand, the phosphorus concentration in plants has been reported to decrease with decreasing water (Reichman and Grunes, 1966; Greenway et al., 1966; Thorup, 1969). The relationship between moisture deficit in soils and plant nutrition affects blossom-end rot development in tomatoes (Shaykewich et al., 1971; Bost, 2010). Tan and Dhanvantari (1985) reported that blossom-end rot development in tomatoes was reduced with irrigation. The water stress in plants increases under water deficit conditions, which results in blossom-end rot (Shaykewich et al., 1971; Ward, 1973).

Although partial root drying is a variation of deficit irrigation, deficit irrigation has been reported to aggravate blossom-end rot development in tomatoes (Adams and Ho, 1992; Obreza et al., 1996; Taylor et al., 2004; Sun, 2013). The irrigation method also affects the development of blossom-end rot (Carrijo et al., 1983).

For the detection of blossom-end rot (BER), total fruit number and rotten fruit number were determined. The number of the fruits with a rotten blossom-end were divided by the total fruit number and the blossom-end rot was given in percentages in the calculations. Furthermore, blossom-end rot value was also determined in percentages with respect to fruit weight. For this purpose, the weights of the fruits with a rotten blossom-end were measured and divided by the total weight of the fruits (Koral, 2006).

Studies have reported that the ratio of K/Ca was a more deterministic indicator of blossom-end rot in tomato than Ca content and the ratio between K and Ca and Ca content were related with each other (Gerard and Hipp, 1968; DeKock et al., 1982; Nukaya et al., 1994). Thus, this study also investigates the relationships between the Ca, K/Ca and K+Mg/Ca contents of the leaves and upper 30 cm of the soil and blossom-end rot. Moreover, the study examines the relationship between blossom-end rot and nitrogen and salinity values, which are thought to affect blossom-end rot.

The study investigates the effects of partial root drying (PRD) and deficit irrigation (D) on blossom-end rot (BER) in the tomato plants irrigated with treated wastewater.

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Materials and methods

The mean elevation of the study area (*Fig. 1*) from sea level was 1030 m and the study area is located at latitude 38°53’01.91” - 38°53’01.52” N and longitude 40°32’57.82” - 40°32’56.73” E.

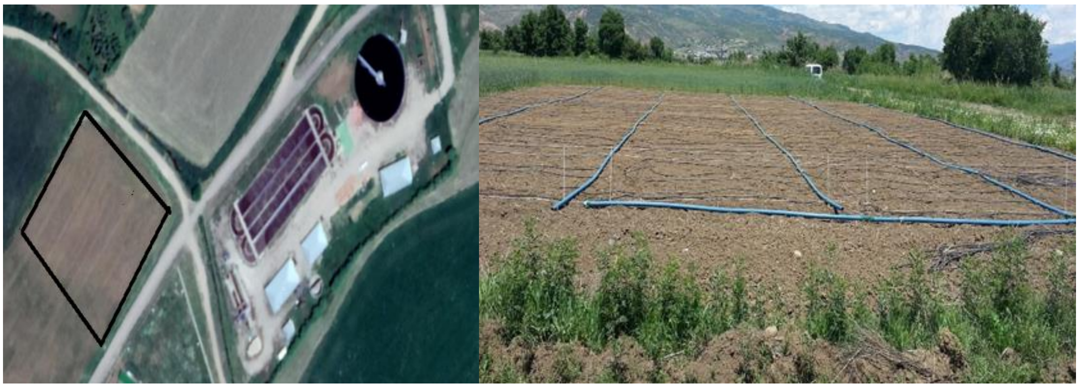

Figure 1. *Study area*

Table 1 shows the long-term average climatic data and climatic data for the study year in Bingöl, Turkey, as obtained from the meteorology station.

Table 1. *The long term average climatic data and climatic data for the study year in Bingöl, Turkey*

Year	Month	Temperature (°C)	Relative humidity (%)	Wind speed (m/s^{-1})	Daily sunshine (h)	Evaporation (mm)	Precipitation (mm)
Long term (1960-2013)	May	16.3	55.8	1.9	7.31	116.5	75.1
	June	22.1	43.5	2.1	9.40	179.1	20.6
	July	26.7	35.9	2.2	9.54	231.2	5.7
	August	26.4	35.1	2.1	9.24	221.7	3.3
	September	21.1	41.0	1.9	8.31	158.2	10.4
2013	May	18.7	47.8	0.87	7.20	12	7.0
	June	22.8	33.3	1.04	8.84	181	6.2
	July	27.2	26.4	1.28	9.39	278	-
	August	26.4	26.2	1.08	9.19	255	-
	September	20.3	34.5	0.83	7.95	111	10.9

[&]Includes the vegetation period in May and September of 2013
*The precipitation and evaporation values for 2013 were measured using a rain gauge and an A-class evaporation pan installed in the study area.

A profile was dug to determine the soil properties in the study area and disturbed and undisturbed soil samples were collected from the depths of 0-30, 30-60 and 60- 90 cm of the soil profile, followed by the analyses of the physical, chemical and hydraulic properties of the soil samples (*Table 2*).

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Table 2. *Basal properties of experimental field soil prior to trial*

Parameter	**Soil layer (cm)**		
	0-30	**30-60**	**60-90**
Texture	Clay	Clay	Clay
Bulk density (mg m^{-3})	1.30	1.31	1.36
Field capacity (% of weight)	28.5	30.3	30.8
Wilting point (% of weight)	17.2	18.1	18.4
pH	8.01	7.94	7.92
EC (dS m^{-})	0.528	0.509	0.450
Organic matter (%)	1.6	1.3	1.1
$CaCO_3$ (%)	4.60	3.40	2.10
Total N (%)	0.08	0.07	0.05
P_2O (kg da^{-})	8.30	5.7	1.5
K_2O (kg da^{-})	71.3	66.2	58.8
Ca (cmol kg^{-})	25.1	28.7	29.4
Mg (cmol kg^{-})	5.60	4.63	4.84
Na (cmol kg^{-})	0.50	0.40	0.40
B (mg kg^{-})	0.57	0.51	0.54
Fe (mg kg^{-})	14.5	15.7	15.0
Zn (mg kg^{-})	0.60	0.80	0.40
Cu (mg kg^{-})	0.60	0.80	0.80
Mn (mg kg^{-})	13.2	11.3	12.7
Cd (mg kg^{-})	0.20	0.30	0.30
Ni (mg kg^{-})	1.90	1.40	0.90
Pb (mg kg^{-})	0.09	0.09	0.05

The Joker-F_1 (*Lycopersicon esculentum*) variety was used in the study. In the trials, Joker F1 tomato variety was chosen due to the fact that it is a very strong variety that can cover the fruit, it is more resistant to diseases, it has can highly adapt to the region, it yields a hard fruit with a long shelf-life and it is suitable for temporary and long-term harvest. The seedlings were planted in the field on May 20. Prior to planting, plough cultivation was applied, large clods were crushed and field surface was smoothed to prepare the conditions for planting. The plants were planted in 5 rows with an inter-row spacing of 100 cm and intra-row spacing of 50 cm. Weeding was carried out manually through hoeing three times until the first harvest. Nitrogenous, phosphorous and potassium fertilizers were used in fertilization. Prior to planting, compound Diammonium Phosphate (DAP) (20:20:0) was applied in the dose of 50 kg per decare. Equal fertilization to each plant was carried out until reaching a cover level of 30% and irrigation conditions were met; after planting, in each irrigation, the NPK 15:15:15 and potassium nitrate 13-0-46 fertilizers were applied in the amount of 10 kg (50 kg in total) using a drip irrigation system. To control the more cricket population, the Korban-4 insecticide was used after planting. The experiments were carried out using waters of two different qualities in the applications, i.e. freshwater (FW) and treated wastewater (TWW). The quality result of each parameter in the *Table 3* shows the three sampling periods (June, July, and August). The clean water was obtained from the open irrigation channel at the entrance of the field and the wastewater was obtained from the exit of the wastewater treatment plant of Bingöl. *Table 3* shows the properties of the irrigation waters.

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Table 3. *The quality of the irrigation waters*

Parameter	June		July		August	
	TWW	**FW**	**TWW**	**FW**	**TWW**	**FW**
pH -	7.08	7.75	8.15	8.49	8.05	8.22
EC (dS m^{-})	0.480	0.172	0.529	0.159	0.533	0.158
TSS (mg l^{-})	20.3	21.2	16.0	17.8	28.0	21.3
Total N (mg l^{-})	14.9	-	13.0	-	13.41	-
Total P (mg l^{-})	1.95	-	2.00	-	1.86	-
CO_3 (me l^{-})	0	0	0	0	0.10	0.03
HCO_3 (me l^{-})	0.30	0.27	0.51	0.34	0.29	0.22
SO_4 (me l^{-})	3.90	1.20	2.85	1.43	2.89	1.41
Cl (me l^{-})	0.50	0.65	1.30	0.45	1.92	0.23
Ca (me l^{-})	1.59	1.16	2.58	1.23	2.11	0.91
Mg (me l^{-})	0.99	0.77	1.09	0.83	1.88	0.74
Na (me l^{-})	2.02	0.16	0.54	0.13	0.95	0.23
K (me l^{-})	0.14	0.07	0.41	0.04	0.49	0.05
B (mg l^{-})	0.19	0.03	0.54	0.34	0.57	0.39
Fe (mg l^{-})	0.46	0.23	0.09	0.06	0.15	0.10
Cu (mg l^{-})	0.13	0.09	0.05	0.03	0.09	0.04
Ni (mg l^{-})	0.03	0.04	0.05	0.05	0.05	0.04
Cd (mg l^{-})	0.07	0.05	0.11	0.07	0	0
Mn (mg l^{-})	0.11	0.06	0.09	0.03	0.02	0.01
Zn (mg l^{-})	0.05	0.04	0.04	0.04	0.08	0.04
Pb (mg l^{-})	0.02	0.02	0.09	0.07	0.08	0.05
Cr (mg l^{-})	0.35	0.25	0.46	0.42	0.41	0.37
Co (mg l^{-})	0.19	0.17	0.20	0.16	0.19	0.17
BOD_5 (mg l^{-})	24.0	-	25.0	-	36.0	-
COD (mg l^{-})	67.2	-	63.8	-	96.0	-
%Na (%)	42.62	20.22	11.69	5.30	17.49	9.50
SAR -	1.77	0.54	0.40	0.12	0.67	0.22
RSC (me l^{-})	-2.28	-1.87	-3.16	-1.94	-3.60	-1.89

TWW treated wastewater, *FW* freshwater, *EC* electrical conductivity, *TSS* total suspended solids, *BOD_5* 5-day biochemical oxygen demand, *COD* chemical oxygen demand, *SAR* sodium adsorption ratio, *RSC* residual sodium carbonate

Drip irrigation was used in irrigation. Therefore, experiment was conducted as a randomized complete block design (three replicates), in a 2 × 5 factorial arrangement, corresponding to two different water resources [treated wastewater (TWW) and freshwater (FW)] and five different irrigation practices. The irrigation strategies comprised full irrigation (100%), deficit irrigation, which involves the use of 75% and 50% of the water used in full irrigation, and partial root drying (PRD). In all applications, waters of two different qualities (clean water and wastewater) were used. In each parcel, 6 lateral pipes were installed in the middle of each plant row pair with a spacing of 100 cm; the irrigation water was applied from all lateral pipes in full and deficit irrigation applications, while the irrigation water was alternately applied in the partial root drying method [from no. 1-3-5 lateral pipes in odd-number irrigations; from

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no. 2-4-6 lateral pipes in even-number irrigations]. The amount of irrigation water were equal in wastewater and clean water applications and adjusted in accordance with the control application in which 100% full irrigation was applied. The irrigations were commenced immediately after planting and finalized on September 29, when the growing season ended. *Table 4* shows the total and monthly irrigation water amounts in different applications. A total of 640.2 mm irrigation water was used in the 100% full irrigation application to tomato plants. The lowest irrigation water amount was 338.3 mm and applied in the 50% D and 50% PRD applications (*Table 4*).

Table 4. *The amounts of monthly and seasonal irrigation water applications to tomato plants in different irrigation applications (mm)*

Application	Months					
	May	**June**	**July**	**August**	**September**	**Total**
% 100	10.6	37.0	219	207.6	166.1	640.2
% 75 D	10.6	34.2	164.3	155.7	124.6	489.3
% 50 D	10.6	31.4	109.5	103.8	83.1	338.3
% 75 PRD	10.6	34.2	164.3	155.7	124.6	489.3
% 50 PRD	10.6	31.4	109.5	103.8	83.1	338.3

%100 full irrigation, *75D* and *50D* 75 and 50% deficit irrigation, *75PRD* and *50PRD* 75 and 50% deficit irrigation with PRD

Irrigation quantities in the scheduled irrigation period were corrected using a coefficient of 0.50 for the 50D and 50 PRD treatments and using a coefficient of 0.75 for the 75D and 75PRD treatments (*Table 4*).

BER were calculated using the below equations (*Eqs. 1–2;* Koral, 2006):

$$BER = \frac{Nf}{Ntf} x100 \quad \text{(Eq.1)}$$

where *BER* is the blossom-end rot (%), *Nf* number of rotten fruits, *Ntf* total number of fruits.

$$BER = \frac{Mf}{Mtf} x100 \quad \text{(Eq.2)}$$

where *BER* is the blossom-end rot (%), *Mf* rotten fruits weight (kg), *Mtf* total fruit weight (kg).

The changes in soil moisture were measured before the irrigations and showed that moisture did not drop to the wilting point in any of the applications throughout the growing season and the available water was reduced about 40% in the full irrigation application. A growing period of minumum 30% was provided and water was given equal to each plant until irrigation issues started. In general, the soil moisture values in the 75% PRD and 50% PRD applications were the closest values to the wilting point according to the soil moisture values. The changes in soil moisture during the growing season were close to each other in all applications (*Table 5*.)

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Table 5. *The changes in soil moisture in different irrigation applications in the study year (%)*

FW	100%	%50 D	%50 PRD	%75 D	%75 PRD	TWW	100%	%50 D	%50 PRD	%75 D	%75 PRD
Irrigation1	24.79	24.79	24.79	24.79	24.79	**Irrigation1**	24.79	24.79	24.79	24.79	24.79
Irrigation2	25.29	25.29	25.29	25.29	25.29	**Irrigation2**	25.29	25.29	25.29	25.29	25.29
Irrigation3	25.25	25.25	25.25	25.25	25.25	**Irrigation3**	25.25	25.25	25.25	25.25	25.25
Irrigation4	23.89	23.89	23.89	23.89	23.89	**Irrigation4**	23.89	23.89	23.89	23.89	23.89
Irrigation5	25.37	25.37	25.37	25.37	25.37	**Irrigation5**	25.37	25.37	25.37	25.37	25.37
Irrigation5	23.57	23.57	23.57	23.57	23.57	**Irrigation5**	23.57	23.57	23.57	23.57	23.57
Irrigation6	24.97	24.97	24.97	24.97	24.97	**Irrigation6**	24.97	24.97	24.97	24.97	24.97
Irrigation7	24.02	24.02	24.02	24.02	24.02	**Irrigation7**	24.02	24.02	24.02	24.02	24.02
Irrigation8	24.79	22.98	21.88	23.54	22.42	**Irrigation8**	24.91	22.07	21.01	23.92	23.28
Irrigation9	24.37	22.10	21.08	23.83	21.91	**Irrigation9**	24.89	20.92	22.86	23.91	23.39
Irrigation10	24.86	23.26	20.85	23.59	22.08	**Irrigation10**	24.72	22.75	24.08	23.72	22.97
Irrigation11	24.80	21.22	20.64	23.94	21.70	**Irrigation11**	24.99	22.40	23.63	23.81	22.32
Irrigation12	24.64	22.38	20.51	23.77	21.45	**Irrigation12**	24.69	22.47	23.44	23.63	22.81
Irrigation13	24.96	22.78	20.94	23.17	21.70	**Irrigation13**	25.02	22.94	21.04	23.14	21.64
Irrigation14	24.37	21.66	21.21	23.39	21.59	**Irrigation14**	25.07	22.76	21.66	23.63	22.58
Irrigation15	24.92	22.82	21.68	23.23	22.28	**Irrigation15**	24.98	22.82	21.16	23.32	21.88
Irrigation16	25.01	22.07	20.91	23.54	22.11	**Irrigation16**	24.93	22.46	21.19	23.76	22.59
Irrgitaion17	25.06	21.88	21.16	23.73	21.60	**Irrgitaion17**	25.11	22.01	21.62	23.69	22.51
Irrigation18	24.87	23.25	21.58	23.85	21.62	**Irrigation18**	24.96	22.18	21.23	23.72	22.57
Irrigation19	25.04	22.51	21.49	23.45	22.00	**Irrigation19**	25.01	22.31	21.63	23.74	22.50
Irrigation20	24.69	23.04	21.39	23.91	21.66	**Irrigation20**	24.86	22.39	22.01	23.84	22.80
Irrigation21	25.08	24.01	23.66	24.19	23.97	**Irrigation21**	25.16	24.31	23.84	24.31	24.04
Irrigation22	24.97	23.19	21.61	24.09	21.03	**Irrigation22**	25.34	23.61	22.46	24.19	22.53
Irrigation23	18.79	13.97	12.80	15.75	14.12	**Irrigation23**	20.93	18.11	17.75	19.98	19.04

FW freshwater, *TWW* treated wastewater, *%100* full irrigation, *75D* and *50D* 75 and 50% deficit irrigation, *75PRD* and *50PRD* 75 and 50% deficit irrigation with PRD

The variance analyses were carried out using the SAS software (SAS, 2000) and the Duncan multiple comparison test of the Minitab software was used to compare the significant averages (Kesici and Kocabaş, 2007).

Results and discussion

Tables 6 and *7* show the effects of PRD and D applications on the blossom-end rot in tomato. According to *Table 6*, blossom-end rot incidences with respect to fruit number varied between 8.57% and 33.22%. The highest blossom-end rot incidence was obtained in the 50% D freshwater applications. The differences between the averages obtained for water resources were statistically not significant, while the differences between the applications were significant. The lowest blossom-end rot incidence was obtained in the 100% full irrigation applications, while the highest blossom-end rot incidence was obtained in the 50% D applications. The PRD applications had less effect

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on blossom-end rot than the deficit irrigation applications. In their study, Zegbe et al. (2007) reported that the highest blossom-end rot was obtained in the D (37%) and PRD (22%) applications and determined that blossom-end rot was higher in the deficit irrigation application than in the partial root drying application. Obreza et al. (1996) found that blossom-end rot was five times higher in the 30% deficit irrigation application than in the full irrigation application. In the same vein, Dorji et al. (2005) determined that the highest blossom-end rot incidences were obtained in the deficit irrigation and partial root drying applications. The increased blossom-end rot incidences in deficit irrigation and partial root drying applications are attributable to the water deficit-induced decrease in the calcium content of the fruits (Adams and Ho, 1992).

Table 6. *Blossom-end rot incidences with respect to fruit number (%)*

Applications	**% 100**	**% 75 D**	**% 50 D**	**% 75 PRD**	**% 50 PRD**	***Means***
FW	10.85^{cd}	18.18^{bcd}	33.22^{a}	18.42^{bcd}	21.30^{bc}	18.71
TWW	8.57^{d}	21.59^{bc}	24.61^{ab}	19.39^{bcd}	19.42^{bcd}	20.39
Means	9.71**C**	19.88**B**	28.91**A**	18.90**B**	20.36**B**	

FW freshwater, *TWW* treated wastewater, *%100* full irrigation, *75D* and *50D* 75 and 50% deficit irrigation, *75PRD* and *50PRD* 75 and 50% deficit irrigation with PRD, $p<0.01$

Table 7. *Blossom-end rot incidences with respect to fruit weight (%)*

Applications	**% 100**	**% 75 D**	**% 50 D**	**% 75 PRD**	**% 50 PRD**	***Means***
FW	26.28	22.71	30.41	16.96	27.68	24.81
TWW	19.96	30.96	23.43	26.83	25.11	23.93
Means	19.79	26.83	26.92	21.90	26.39	

FW freshwater, *TWW* treated wastewater, *%100* full irrigation, *75D* and *50D* 75 and 50% deficit irrigation, *75PRD* and *50PRD* 75 and 50% deficit irrigation with PRD

According to *Table 7*, the blossom-end rot values with respect to fruit weight varied between 16.96 and 30.96%. The differences between the applications in the ratios of the weight of fruits with blossom-end rot to total fruit weight were not statistically significant.

The higher incidences of blossom-end rot in the deficit irrigation applications is attributable to the activation of the self-defense mechanisms of the plants in response to water stress. Moreover, irregular irrigation and saline water conditions have been reported to be the most common causes of blossom-end rot (Cuartero and Fernandez-Munoz, 1999; Franco et al., 1999; Zhai et al., 2015). The decrease in the soil moisture in the D and PRD applications can contribute to the increase in blossom-end rot incidences. According to *Table 6*, the highest incidence of blossom-end rot was observed in the deficit irrigation applications due to decreased soil moisture (*Tables 4* and *5*). In their study, Shaykewich et al. (1971) reported that blossom-end rot increased in soils with decreased moisture content. Pill and Mambeth (1980) observed that hardness and blossom-end rot increased in tomatoes under conditions of low NH_4 fertilization and soil water potential. It has also been reported that low Ca content in the fruit and deficit irrigation application affected the development of blossom-end rot (Adams and Ho, 1993; Taylor et al., 2004; Ho and White, 2005). Researchers have

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noted that the PRD method is a variation of the deficit irrigation applications and one of its negative effects on the tomato plants is blossom-end rot development (Obreza et al., 1996; Zegbe et al., 2004). In their study in which the effects of PRD and D applications on tomato were investigated, Sun et al. (2013) reported that the PRD applications had a lesser effect on the development of blossom-end rot than the D applications and associated it with the increase in the abscisic acid concentration and the subsequent increase in stomatal conductivity leading to increased calcium uptake and, thus, decreased blossom-end rot development.

There was a statistically significant relationship between blossom-end rot and Ca contents of the fruit and leaves (*Table 8*). The first studies about the issue generally reported that blossom-end rot occurred under conditions of Ca deficiency (Hamner et al., 1942; Ward, 1973; Bradfield and Guttridge, 1984; Adams and Ho, 1992). However, blossom-end rot is not only affected by Ca deficiency but also affected by high Mg, Na, K and NH_4 concentrations, rapid growth, irrigation amount, low Ca content in soil and high or low transpiration (Geraldson, 1955; Kirby and Pilbeam, 1984; De Kreij, 1996; Paiva et al., 1998; Marcelis and Ho, 1999; Franco et al., 1999; Saure, 2001; Taylor and Locascio, 2004). The K and N contents of the fruits were also determined to have statistically significant effects on blossom-end rot while in soil, only the effects of K+Mg/Ca and EC on blossom-end rot were statistically significant. The results indicated that various factors affected blossom-end rot in addition to Ca deficiency.

Table 8. *The linear correlation between BER and Ca, K, N, K/Ca K+Mg/Ca and EC*

	Fruit	**Leaf**	**Soil**
Ca	-0.557**	-0.691**	-0.055
K	-0.407*	-0.280	-0.480
N	-0.399*	-0.300	-0.160
K/Ca	-0.264	0.380*	-0.040
K+Mg/Ca	-0.290	0.465**	0.396*
EC	-0.002	-	-0.535**

**p < 0.01, *p < 0.05

There was a significant negative relationship between blossom-end rot and the potassium content of the fruits, while the relationship between blossom-end rot and the potassium contents of leaves and soil was not statistically significant. Moreover, there was a significant negative relationship between the nitrogen content of the fruits and BER. There was a significant positive relationship between the K/Ca and K+Mg/Ca ratios in leaves and BER. BER had a significant positive relationship with the K+Mg/Ca ratio in soil, while it had a significant negative relationship with EC (*Table 8*). DeKock et al. (1982) reported that the ratio of K/Ca was a better determinant of blossom-end rot than the Ca content. However, Wada et al. (1996) and Bar-Tal and Pressman (1996) argued that the relationship between K/Ca and blossom-end rot did not have a predictive value. Albahou (1999) reported that high salinity contributed to the decrease in the blossom-end rot incidences. However, various researchers are of the opinion that blossom-end rot increases with increasing salinity and NH_4 content (Pill and Lambeth, 1980; Nonami et al., 1995; Saure, 2014).

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Conclusion

In the study in which the effects of the D and PRD methods on blossom-end rot were investigated, the lowest blossom end-rot incidence was observed in the 100% full irrigation applications. The D application had the highest effect on blossom-end rot development. The PRD method had a lower effect than the deficit irrigation application. The lower incidence of blossom-end rot in the PRD applications compared with the D applications was associated with increased abscisic acid concentration in the xylem, decreased stomatal conductivity and the more effective use of water leading to increased Ca uptake and reduced blossom-end rot development. Therefore, the PRD can be a promising method for water saving under water deficit conditions and reduction of blossom-end rot development in tomatoes.

The results indicated that blossom-end rot was affected by various factors in addition to Ca deficiency. Furthermore, the results showed that in the production of marketable tomato, the PRD method is more advantageous than the D method under water shortage conditions where full irrigation is limited.

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