

Research Article

The Comprehensive Effects of the Subsurface Drainage on Greenhouse Saline Soil, Tomato Yield and Quality

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Abstract: The aim of this study is to understand the effect of subsurface drainage on salts of greenhouse soils, tomato yield and quality. Different layout schemes with various pipe depth (0.6 and 0.8 m) and space (6, 8 and 10 m) were designed, the Electrical Conductivity (EC) of topsoil soil during different periods, the tomato yield and the main quality indexes (soluble solids, total acid, vitamin C, sugar/acid ratio) were observed. The results showed that: the topsoil EC values showed a fluctuating decline trend, D2S1 treatment obtained the best results of topsoil salt removing, with the removal rate of 50.87%; the tomato yield of D2S3 was the highest, which reached 128.33 t/hm²; the smaller buried depth and space of drainage pipes increased the concentration of the main nutrients of tomato. If the reduction of greenhouse soil salts were served as the main purpose, the drainage scheme with 0.8 m buried depth and 6 m space could be considered.

Keywords: Quality, saline soil, subsurface drainage, tomato, yield

INTRODUCTION

The development of protected agriculture in China is rapid, the cultivation area of protected agriculture accounted for 11.6% of the total agricultural area. Tomato is an important economic crop in China and is the main variety of greenhouse cultivation (Maomao *et al.*, 2014). However, due to the shortage of rainwater leaching and strong evaporation (Bezborodov *et al.*, 2010; Li *et al.*, 2015), the soil environment gradually worsening, among these environmental factors, the negative effects of high salinity on tomato economic yield and quality should not be ignored.

At present, the improvement methods of saline soil include soil replacement, biological organic fertilizer, improved the high-temperature stuffy shed. As an effective salt reducing method, the subsurface drainage have been widely used in the improvement of saline soils and obtain satisfactory results (Mastrocicco *et al.*, 2013; Mathew *et al.*, 2001). However, subsurface drainage had not been widely applied in improving greenhouse saline soils, the effects of different layout schemes of drainage pipes on greenhouse saline soils, crop yield and quality was scarcer. In this study, different schemes with various buried depth and space of drainage pipes were designed, the effect of different drainage treatments on greenhouse saline soils, tomato

quality and yield were explored, in order to provide theoretical and practical basis for the wider application of subsurface drainage.

MATERIALS AND METHODS

Experimental site: The experiment was conducted from May to September of 2014 at the Modern Agricultural Garden in Wuxi, Jiangsu province, China. Wuxi belongs to north subtropical humid monsoon climate zone, with four clear seasons, abundant rainfalls and sufficient heat. The perennial (1981~2010, 30 years statistics) average temperature of Wuxi was 16.2°C, the average precipitation was 1121.7 mm, the rainy time was 123 days, the sunshine hours were 1924.3 h and the sunshine percentage was 43%. The experimental soil type was yellow brown soil, with a pH of 6.03, available N content 104.56 mg/kg, available phosphorus content of 9.45 mg/kg, available potassium content of 188.87 mg/kg, 0-20 cm, 20-40 cm and 40-60 cm soil EC value of 5.17 ms/cm, 3.23 ms/cm and 2.31 ms/cm, respectively.

Experimental design: According to the reality of soil characters and groundwater level, we set 2 buried depths and 3 spaces of drainage pipes, there were 6 treatments in total, each treatment made 3 replications.

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Table 1: Experimental design

Treatment	D1S1	D1S2	D1S3	D2S1	D2S2	D2S3
Depth (m)	0.6	0.6	0.6	0.8	0.8	0.8
Space (m)	6	8	10	6	8	10

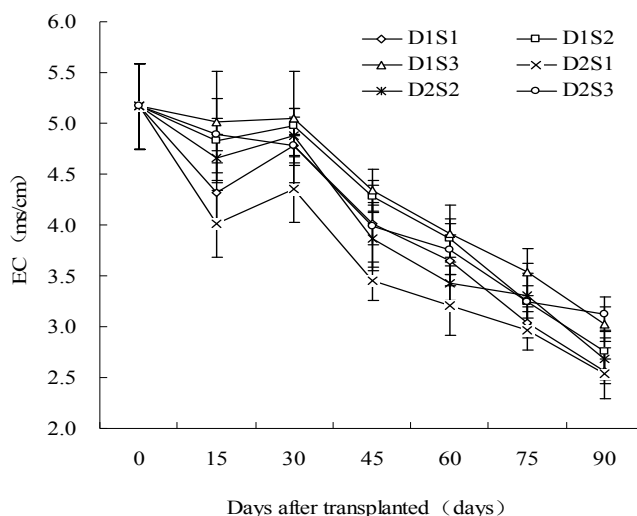


Fig. 1: Dynamic change of surface soil EC

The buried depths were 0.6 m (D1) and 0.8 m (D2) and the spaces were 6 m (S1), 8 m (S2) and 10 m (S3), respectively. Detailed experimental design was shown as Table 1. The type of drainage pipes were plastic corrugated pipes, which covered with non-woven fabric. Drainage pools were excavated at the side of each treatment in order to collect the waters discharged by the drainage pipes and the pump was used to extract the waters in the pools.

The plant material was the tomato type “Ying Shi Da Hong”, the young seedlings were cultivated in the seedling plates and were transplanted to the soils with the treatment of subsurface drainage. After transplanting, the conventional field management was conducted and each treatment was applied with the same amount of fertilizer. The tomato plant was toppling after growing with the third inflorescence fruit. The fields were irrigated following the needs of tomato growth according to the local planting experience.

Measurement:

EC: The EC values were measured by HH2/WET Soil Parameters Analyzer (produced by Delta-T Company, UK). The determination location is surface soil right above the drainage pipes. From the beginning of tomato transplanting, the EC values were measured every 15 days, each measurement repeated 3 times (Shao *et al.*, 2012).

Tomato yield: At maturity, the tomato yields were calculated by the fruit numbers and the average weight of single fruit.

Tomato quality: At maturity, 6 tomato plants were selected randomly for tomato quality measurements. The single fruit volume was measured by the replacement method; the soluble solid was measured by the ACT-1E digital refractometer produced by ATAGO Company, Japan; the total sugar was measured by the Fehling titration method; the total acid was measured by the NaOH titration method; the Vitamin C content was measured by the 2, 6-dichloroindophenol titrimetric method (Maggio *et al.*, 2004; Wang *et al.*, 2011).

Data analysis: The data were analyzed by SPSS 17.0 software.

RESULTS AND ANALYSIS

Effects of subsurface drainage on surface soil EC:

Figure 1 showed the dynamic changes of surface soil EC. As was shown in Fig. 1, surface soil EC presented a fluctuating decline trend, the decline regularity of each treatment was similar. During 0~30 d after transplanted, EC changed not significantly and was slightly increased during 15~30 d. This was probably because that the tomato leaves grew slowly during this period, resulting in a relatively smaller leaf area index and a larger soil bared area, thus the soil evaporation and resalinization was strong. During 30~90 d after transplanted, surface soil EC reduced obviously and reached the lowest level at 90 d. Among the different treatments, the decline range of D2S1 was the greatest, reaching 50.87%. In general, in this experiment, the EC

Table 2: Effects of different treatments on the main quality index of tomato

Treatment	Density (g/cm ³)	Volume (cm ³)	Soluble solid (%)	Total acid (g/100 g)	Vc (mg/100 g)	Sugar/acid ratio
D1S1	0.929 a	125.22 b	7.32 a	0.643 a	14.08 a	9.38 a
D1S2	0.933 a	128.98 ab	7.21 a	0.622 ab	14.21 a	8.87 a
D1S3	0.917 a	134.53 a	6.78 ab	0.589 b	13.02 b	8.56 ab
D2S1	0.931 a	130.66 ab	6.88 ab	0.604 b	12.98 b	8.91 a
D2S2	0.929 a	129.18 ab	6.42 b	0.588 b	12.34 bc	8.29 b
D2S3	0.913 a	137.22 a	6.26 b	0.523 c	11.99 c	8.21 b

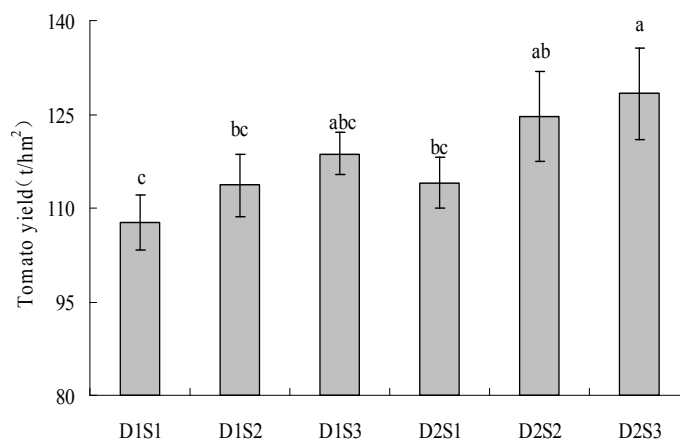


Fig. 2: The tomato yield treated with different subsurface drainage

declined as the buried depth of drainage pipes increased or the space decreased. This was similar to Shao's (Shao *et al.*, 2012) and Retzema's (Ritzema *et al.*, 2006) study conclusions.

Effects of subsurface drainage on tomato yield:

Figure 2 displayed the effects of subsurface drainage on the tomato yield. As was shown in Fig. 2, D2S3 obtained the highest tomato yield of 128.33 t/hm²; followed by D2S2, the tomato yield was 124.67 t/hm²; the tomato yield of D1S1 was the lowest, which was only 107.67 t/hm², significantly (p<0.05) lower than that of D2S2 and D2S3. Under different buried depth, the tomato yield increased with larger space of pipes; while under different space, the tomato yield increased with deeper buried depth of pipes. This mainly due to that when the pipes were buried shallower and closer, the drainage was smoother and the soil moisture was decreased, thus negatively affected the tomato yield.

Effects of subsurface drainage on tomato quality:

Table 2 showed the effects of subsurface drainage on tomato quality. The differences of tomato density among drainage treatments were not significant (p>0.05). The single fruit volume was positively related with the buried depth and space. The soluble solid, total acid, Vc content and sugar/acid ratio generally increased as the depth and space decreased, this mainly because in this experiment, a shallower and closer layout of pipes was beneficial for draining the soil waters, thus increasing the concentration of main quality index of tomatoes.

CONCLUSION

According to the above analysis, the conclusions could be obtained as follows:

- Under different layout schemes of drainage pipes, the topsoil EC values showed a fluctuating decline trend. After one season tomato cultivation, D2S1 treatment obtained the best results of topsoil salt removing, with the removal rate of 50.87%.
- In this experiment, the tomato yield generally increased with a larger depth and space. The tomato yield of D2S3 (0.8 m depth combined with 10 m space) was the highest, which reached 128.33 t/hm².
- The smaller buried depth and space of drainage pipes increased the concentration of the main nutrients of tomato, but which had no significant effects on the tomato density.

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