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Research Paper

Effects of saline water irrigation on soil salinity and yield of summer maize (*Zea mays* L.) in subsurface drainage system

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ABSTRACT

Sustainable development of saline water irrigation was restricted by salt accumulation in the soil profile without appropriate salt discharging measures. A two year study was conducted in 2014 and 2015 to identify the effect of saline water irrigation on soil salt and maize yield under subsurface drainage system. The treatments of this study comprised three levels of water salinity with 0.78, 3.75, and 6.25 dS m^{-1} (S1–S3) and three levels of subsurface drainage depth with no subsurface drainage, drain depth of 0.8 m and 1.2 m (D0–D2). Results indicated that the average salt content within the root zone was in the order of D0 > D2 > D1. No salt accumulation occurred during the two growing seasons under D1, but there was salt accumulation under D2S3. Soil desalinization efficiency reduced with the increasing of irrigation water salinity, and the average desalinization efficiency for D1 was higher than that of D0 and D2. Maize yield and water use efficiency decreased with the increase of water salinity. The yield decreased by 2.08–3.01% for every 1 dS m^{-1} increase in salinity level of irrigation water under D1, and 3.53–3.93% for every 1 dS m^{-1} under D2. The effects of water salinity and drainage depth on maize yield and WUE were significant ($p < 0.05$) in the two growing seasons. From the view points of relative yield and soil salt balance, it can be recognized even as the salinity level of irrigation water is as high as 6.25 dS m^{-1}, saline water can be applied to irrigate maize under drain depth of 0.8 m.

1. Introduction

Increasing agricultural production has become an urgent requirement for the expanding population (Wan et al., 2007; Singh et al., 2001; Chen et al., 2015). However, scarcity of fresh water is a constraint to irrigation throughout the world (Mantell et al., 1985; Beltran, 1999). Meanwhile, saline water is in plentiful supply in the world (Mantell et al., 1985), it is regarded as an important resource to maintain agricultural irrigation (Jang et al., 2013; Arslan, 2012; Ali et al., 2007). Saline water irrigation has been used more prevalently for the plants such as wheat and oleic sunflower which is moderately tolerant of salinity (Francois, 1996; Mass and Grattan, 1999). In China, irrigation constitutes the primary source of water for agricultural development. Although fresh water sources are scarce, shallow saline groundwater resources are abundant in China in coastal and fresh water-deficient areas (Wang et al., 2015).

Summer maize, as one of the most widely consumed cereals, is grown in wide range of climatic zone, which is classified as a mild salt-tolerant crop (Mass and Grattan, 1999). Several researchers (Russo and Bakker, 1987; Sun et al., 2010) studied the use of saline water in maize through field or pot experiments. Kang (Kang et al., 2010) expounded that the decreasing rate of the fresh ear yield for every 1 dS m^{-1} increase in salinity of irrigation water was about 0.4–3.3%. Amer working with furrow irrigated maize found that maximum yield of 9.12 Mg hm^{-2} was achieved by 325 mm adequate irrigation quantity (Amer 2010). Dooronbos and Pruitt. W.O. (Dooronbos and Kassam, 1979) considered that maize yield decrease under increasing soil salinity is: 0% at ECe 1.7 dS m^{-1}, 10% at 2.5 dS m^{-1}, 25% at 3.8 dS m^{-1}, 50% at 5.9 dS m^{-1}, and 100% at EC_e 10 dS m^{-1}. Xue indicated that, under conjunctive use of saline and non-saline irrigation water for irrigation, the annual average yield and water productivity of spring maize were changed by 5.3% and 2.6%, respectively, compared with non-saline water irrigation (Xue and Ren, 2017). However, these studies primarily focused on

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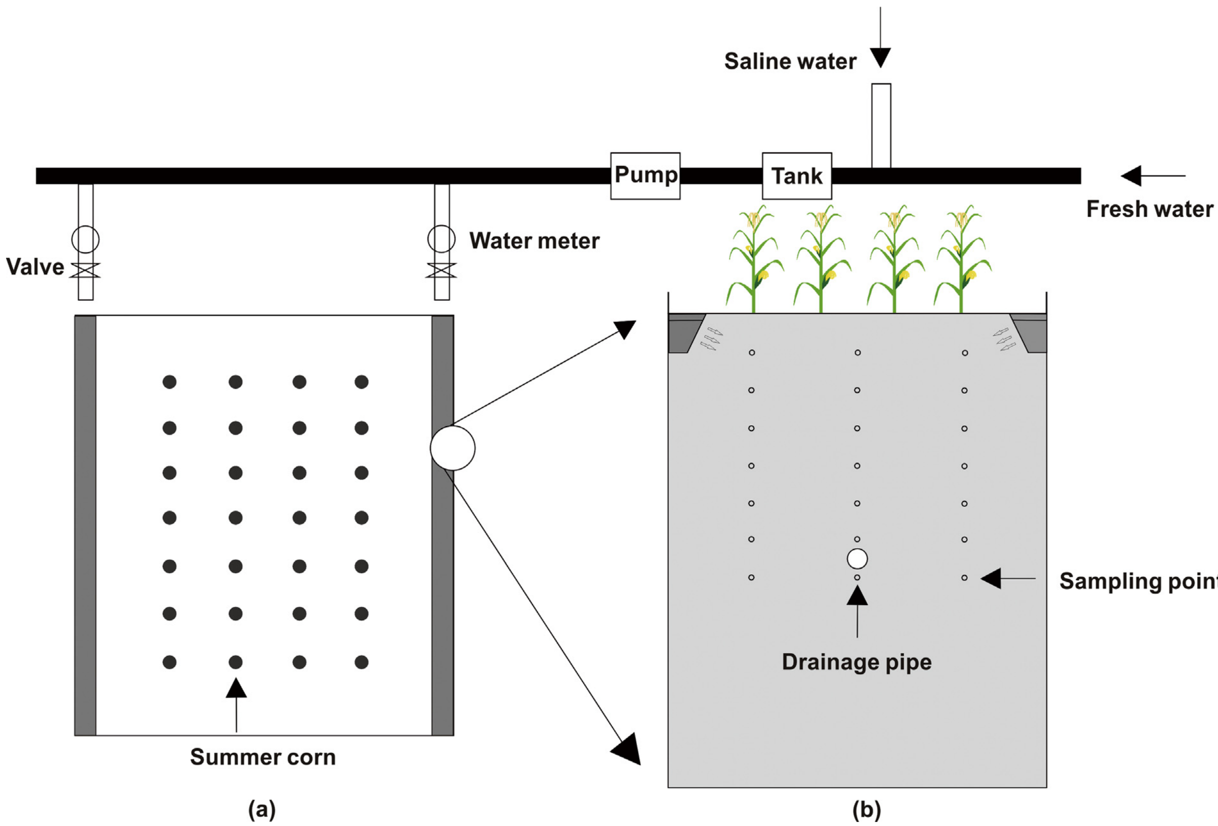

Fig. 1. (a) The layout of the lysimeter; (b) The profile map of the lysimeter.

Table 1
Basic physical properties of initial soil profile.

Depth (cm)	Soil texture	Mechanical composition/%			Soil bulk density/gcm-3	Field capacity/cm^{3}cm^{-3}
		Clay (<0.002 mm)	Silt (0.002–0.02 mm)	Sand (0.02–2 mm)		
0–20	Clay loam	24.15	45.41	30.44	1.37	0.39
20–40	Clay loam	30.28	48.15	21.57	1.41	0.38
40–80	Clay	38.27	27.68	34.05	1.48	0.36
80–140	Clay	39.55	28.05	32.40	1.56	0.25

the impacts of saline water on crop yield and water consumption, rather than its impacts on soil salinity.

When saline water was used for irrigation, salt was brought into soil together with water. Researches indicated that long-term use of saline water for irrigation without drainage or soil leaching measures would cause the risk of soil salinization (Malash et al., 2005; Minhas and Gupta, 1993). Wang indicated that irrigation with saline water at concentrations below 3 g/L will reduce the maize yield by no more than 10% compared with fresh water irrigation, but long-term saline water irrigationwill result in significant yield losses, even for low concentrations of salt (Wang et al., 2015). Therefore, applicable drainage measures should be taken into account when saline water was used instead of fresh water. Among which, subsurface drainage has been proved to be an effective technology for soil salt leaching and drainage of excess water (Moustafa, 2010; Singh et al., 2006). The need for subsurface drainage in the irrigated agricultural zones has been summarized by Smedema (Smedema et al., 2000). They estimated that less than one third of all the irrigated lands needing drainage have been drained, which was a concern because drainage was critical for salinity management to sustain arid irrigated agriculture. Subsurface drainage were widely used in different areas in China: field experiment in the eastern coastal saline area of Hebei Province suggested that subsurface drainage significantly prevented the rise of the groundwater table during melting of frozen soil water, and thus considerably reduced salinity across soil layers, especially in the 30 cm layer (Yu et al., 2016); He's research in Xinjiang arid reguon also indicated that subsurface drainage could leach salinity effectively (He et al., 2016); Zhang's research in soil salinization area in South China indicated that the subsurface drainage system decreased the soil salinity of different soil layers, especially the EC of soil which above the subsurface drainage. Meanwhile, the average yield of tomato was increased (Zhang et al., 2012). Drain depth was regarded as an important factor for the design of subsurface drainage system, Ayars and Meek (1994). indicated that deeper-placed laterals tend to have higher salinity water discharged which results in an increased salt load being discharged in the drainage water (Ayars and Meek, 1994). While, using SaltMod, Srinivasulu predicted that further deepening of the drains from the present depth of 1–1.4 m would not have any better influence on the reduction of the root zone salinity (Srinivasulu et al., 2004). Doering developed a shallow drainage system concept for arid irrigated areas, they found that deep drain placement resulted in excessive drainage losses and using a shallow drain placement conserved irrigation water (Doering et al., 1982). Thus, the effect