AGRICULTURAL WATER MANAGEMENT 95 (2008) 869–876

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/agwat

Effects of water application intensity, drop size and water application amount on the characteristics of topsoil pores under sprinkler irrigation

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ARTICLE INFO

Article history:
Received 16 August 2007
Accepted 18 February 2008
Published on line 15 April 2008

Keywords:
Sprinkler irrigation
Total soil porosity
Capillary porosity
Air-space porosity
Soil pore shape

ABSTRACT

Field experiments were carried out to study the effects of sprinkler irrigation on the characteristics of topsoil pores. Total soil porosity, capillary porosity, air-space porosity and porosities of different pore shapes were analyzed using images analysis of thin sections of soil samples. The experimental treatments included five water application intensities (5.3, 7.7, 11.0, 15.0 and 20.7 mm/h), five drop diameters (0.76, 1.28, 1.92, 3.18, 4.19 mm) and five water application amounts (9.0, 23.6, 37.5, 49.6, 59.4 mm). The compounding sprinkler system was used in the experiments of water application intensity and single sprinkler was used in the experiments of drop size and water application amount. The total porosity, air-space porosity and porosities of elongated pores have the similar decreasing tendency and pattern when water application intensity, drop diameter or water application amount increase. Capillary porosity, porosities of round and irregular pores have no obvious changing tendency. The decreasing porosities of the elongated pores and macropores are the main reasons for the decreasing of total porosity under sprinkler irrigation. To maintain soil structure in good conditions, the reasonable parameters would be considered for water application intensity, drop diameter and water application amount.

1. Introduction

Soil structure is the arrangement of primary particles into peds and the size, shape and arrangement of peds and voids or pore spaces that separate particles and peds (White, 2006). It is a key factor in the influence of soil on soil water movement and retention, erosion, crusting, nutrient recycling, root penetration and crop yields (Bronick and Lal, 2005). Furthermore, the pore system is an important aspect of soil structure for transporting water, solutes and air; determined by interlinked pores and their size and geometry (Pagliai et al., 1983; Connolly, 1998).

Different sizes of soil pores have different functions on water transport and water holding. Greenland (1977) indicated that pores ranging from 0.5 to 50 μm in equivalent pore diameter are storage pores, which provide the water reservoir for plants and microorganisms, while pores ranging from 50 to 500 μm are the most important in maintaining good soil structure conditions. Pores more than 50 μm in diameter determine the type of soil structure (Pagliai et al., 2004). Soil pore systems have been studied by many researchers under agricultural practices. Compared with conventional tillage, total soil porosity is significantly lower and the proportion of pores ranging from 30 to 500 μm is higher under no-tilled plots

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0378-3774/$ – see front matter
doi:10.1016/j.agwat.2008.02.011

(Pagliai et al., 1983). Diameter between 150 and 250 μm are the most frequent in some Hapludalfs and most pores between 0.1 and 1 mm have been produced by root (Tippkötter, 1983). Soil pore system under conventional tillage with higher contribution of large flow-active pores compares to reduce and no tillage treatments enhance infiltration and water storage capacity (Lipiec et al., 2006). Lin et al. (1999) reported that 10% of macropores (>0.5 mm) and mesopores (0.06–0.5 mm) contributed about 89% of the total water flux. The distribution of pore shapes is also an important factor for soil water transport as round pores are less effective in transmitting water than irregular and elongated pores (Valentin, 1991; Fox et al., 2004). Tillage causes an increase in large planar voids (elongated pores) and has little influence on non-planar voids as they occur in the aggregates and they are not destroyed by cultivation (Mermut et al., 1992; Pachepsky et al., 1996). The macroporosity in soils under alternative tillage is higher than under conventional tillage due to a larger number of elongated transmission pores (Pagliai et al., 2004). Under simulated rainstorms, the porosity reduction is mainly due to a decrease in size of elongated pores and is associated with an increase in runoff rate especially in the bare soil (Panini et al., 1997). The values of saturated hydraulic conductivity along the cultivated profile show the same trend of the elongated transmission pores (Pagliai et al., 2004).

Irrigation practices also affect strongly on soil structure. Sprinkler irrigation is one of the advanced irrigation technology used worldwide. Some investigators have found that raindrops of sprinklers break down aggregates and compact thin surface layers and lead to seal or crust formation and hardsetting (Ragab, 1983; Tarchitzky et al., 1984; Adeoye, 1986). Larger sprinkler intensity produced greater changes and influenced deeper soil layers on properties of soil structure (Bertand and Sor, 1962; Sor and Bertand, 1962). However, soil structure is damaged very slightly when drops are very fine. When drop size distribution is near that of natural rain and rainfall intensity is 20 mm/h, there is no difference in pore size distribution between initial aggregates and prewetted aggregates after 90 min rainfall (Le Bissonnais et al., 1989). Laboratory experiment found that the percentage of volume of pores in the sealed surface decreased as impact energy increased (Ragab, 1983). When the raindrop size (>5 mm) is big, soil structure is affected strongly due to soil splash and the formation of surface crust. The released fine material is partly washed into the underlying soil, reducing its porosity (McIntyre, 1958). Practices found that the topsoil in sprinkler irrigation fields was looser than that in border irrigation fields, which means that sprinkler irrigation may provide less damage on soil pore system in top soil than border irrigation (Sun, 2006). The results of experiments and practices are not agreed with each other by some researchers. Generally, simulated intensity of rainfall is bigger than that of the sprinkler irrigation in practices. The drop sizes are also different.

For the purpose to understand more detail about the effect of sprinkler irrigation on topsoil pore system, field experiments were carried out. The objective of this research was to study the influence of sprinkler irrigation on the amount, size and shape of topsoil pores under different parameters: (1) water application intensity, (2) water drop size and (3) water application amount.

2. Materials and methods

2.1. Experimental site

Field experiments were conducted at Tongzhou Experimental Base (TEB) for Water-Saving Irrigation Research, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences. TEB is located in Tongzhou District, Beijing (longitude 116°48′E, latitude 39°36′N; 20 m above sea level). It is a temperate, semi-humid monsoon climate. The main physical and chemical properties of experimental soil are listed in Table 1.

2.2. Experimental design

The field experiments included three parts: (1) the experiments for water application intensity of sprinkler irrigation; (2) the experiments for drop size of sprinkler irrigation; (3) the experiments for water application amount of sprinkler irrigation.

Part 1: Five experimental plots were selected and the area of each plot was 8 m × 8 m. A small sprinkler irrigation system with four impact sprinklers (Elgo 80B2, made in Israel) was installed in each experimental plot. The four sprinklers were deployed in a square pattern with a spacing of 8 m between sprinklers. The sprinklers were mounted at a 130 cm high riser. A water meter (LXS-20C, made in China) was installed in the main pipe to measure sprinkler water amount in each experimental plot. To exclude the effects of drop sizes and water application amount, soil samples were collected at the similar points in each experimental plot and the same water application amount was used in each experimental plot.

Part 2: A sprinkler (CYH-II, made in China) with single nozzle and wetted radius of 18 m was used. The size of the drops of sprinkler irrigation was different along the spraying radius. Five points with distances of 1.5, 5.0, 9.0, 13.0 and 16 m from the sprinkler were selected to present five drop sizes. If any observation point had

Table 1 – The main physical and chemical properties of experimental soil

Soil grain distribution (%)			K_s (m/d)	O.M. (mg/kg)	pH
>0.05 mm	0.05–0.002 mm	<0.002 mm			
20	54	26	0.190	13.1	7.59