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Effects of soil managements on surface runoff and soil water content in jujube orchard under simulated rainfalls

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ABSTRACT

Inappropriate soil management on the Chinese Loess plateau has induced significant soil erosion, and improvements were obtained with cover crops, whereas few studies were reported about orchard soil management. This study investigated effects of five soil management (SM) practices on surface runoff and soil water content, which were (i) full ground mulching with jujube branches (BM), (ii) strip tillage only (ST), (iii) jujube branch mulch + strip tillage (BMT), (iv) jujube branch mulch + strip white clover (*Trifolium repens* L.) cover (BMWC), and (v) no cover (NC) as a control. Six microplots (with a length of 200 cm, width of 80 cm and depth of 80 cm) were subjected to artificial rain during the growing seasons from 2011 to 2013. The variables about runoff and sediment evolution as well as soil water content were studied. Results showed that: (i) the time to runoff initiation was significantly shorter under NC than in other treatments, and the runoff plateau, total runoff volume and sediment yield were highest under NC. Compared with NC, there was over 60% reduction in runoff and 80% reduction in sediment load under other treatments, (ii) runoff and sediment discharge increased linearly under NC before reaching the peak value, while it increased step-wise in the other treatments, (iii) soil water content (θ) and soil water storage increase (*SWI*) were significantly greater under BM than others; The 2-year (growing season of 2011 and 2012) mean θ and *SWI* were the lowest under NC, (iv) overall, BM increased soil water content, and decreased runoff and sediment yield, and thus could potentially solve water shortage and soil erosion problems in rainfed jujube orchards on Chinese Loess Plateau.

1. Introduction

Soil and water conservation has been an important topic since the 20th century in the USA (Helms, 2010). Soil management including ground cover and tillage has been regarded as an essential way to control soil and water losses as well as to modify the soil water content in arid and semiarid regions (Brevik et al., 2015). Since the initiation of the Grain for Green project in 1999, jujube trees have been extensively planted on the Chinese Loess Plateau (Wu et al., 2008, 2009), and the jujube orchard area will likely increase continuously in the future (Shao et al., 2004). Most jujube orchards are cultivated under rainfed conditions, and jujube orchards will suffer from severe drought due to limited water resource. Moreover, most jujube orchards were managed with traditional cultivation (clear cultivation), where growers remove plant residues from the soil surface. The traditional cultivation can induce more bare soil surface, higher evaporation, and severe soil degradation (Bravo-Espinosa et al., 2012; Ochoa-Cueva et al., 2013; Prokop and Poręba, 2012).

Alternative soil managements, such as residual crop mulch and tillage reduce bulk density, increase soil organic matter, and improve soil water conditions by altering soil structure and the physical, chemical, and biological processes (Bhattacharyya et al., 2008; Brevik et al., 2015; Huang et al., 2014a,b; Xu et al., 2012). Various soil managements help in increasing water infiltration and soil water content (Aboudrare et al., 2006; Giménez-Morera et al., 2010; Hulugalle et al., 2010), and regulate surface runoff and soil erosion (Lee et al., 2013; Moreno-Ramón et al., 2014). Soil surface managements also reduced the impact of the

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kinetic energy of rain drops, and increased rainfall interception and storage. These beneficial effects are closely related to mulch application rates and diversity of materials (Adekalu et al., 2007; Jordán et al., 2010; Yang et al., 2012). Montenegro et al. (2013) conducted a simulated rainfall experiment by using 3 surface covers with different mulching applications, and observed 51% reduction in runoff peak value under a mulch cover of 4 t ha^{-1}. In addition, high mulch rates increased soil water content and moderate soil temperature. The time to runoff initiation was also dramatically delayed and the runoff rate decreased with increased mulch weight (García-Moreno et al., 2013; Sadeghi et al., 2015). While low ground cover decreased most soil losses on a sloping field (Cerdà et al., 2009a), and Döring et al. (2005) noted that soil loss could be decreased by >97% on a potato field by using only 20% crop coverage.

Soil surface features also play a great role in runoff generation and soil erosion. Previous studies on interactions of surface mulching and other soil management techniques reported the decrease in soil erosion following tillage abandonment without mulching change (Mchunu et al., 2011). The reduced water loss by soil management also attributed to decreased soil evaporation and moderated soil temperature (Austin, 2011). It is shown that increased water loss and more serious soil erosion occurred under adverse tillage as it facilitated evaporation demand and weakened soil structure (Dahiya et al., 2007; Moret and Arrúe, 2007; Xu et al., 2013).

Vegetation cover is another popular soil management technique to control runoff and erosion, minimize leaching of nutrients and increase soil productivity (Durán Zuazo and Rodríguez Pleguezuelo, 2008; Podwojewski et al., 2011) by: (i) increasing hydraulic roughness, canopy and surface storage, (ii) improving soil profile storage capacity, and (iii) changing macropore geometry. Use of cover crops in California was suggested to increase infiltration, reduce runoff, and enhance the soil water-holding capacity in the root zone (Joyce et al., 2002). Cover crops can decrease nutrient leaching losses by transpiring water and depleting nutrients (Dabney, 1998).

Many studies concerning mulching or tillage have been conducted on the Chinese Loess Plateau. These studies have contributed greatly to our understanding of soil management effects on soil properties, soil water content and nutrient status in croplands (Gao et al., 2011; Zhao et al., 2013a,b). However, there is limited information about surface runoff, and soil erosion under varying soil management in such orchards. In addition, there have been several studies based on effects of soil conservation managements on soil and water loss in orange, citrus, apricot and olive orchards (Abrisqueta et al., 2007; Cerdà et al., 2009a, b). However, it is still unknown if these management techniques also would be beneficial in rainfed jujube orchard for long-term production in Chinese Loess Plateau. Therefore, we conducted a rainfall simulation experiment to quantitatively study the effects of different soil management types on (i) surface runoff and sediment yield, both of which are severe environmental issues on the Chinese Loess Plateau, and (ii) soil water dynamics and distribution under simulated rainfall.

2. Materials and methods

2.1. Test soil and soil bins

The test loess soil was collected from farmland in Qingjian County (E 109°52′, N 37°03′), Yulin city in Shaanxi Province, China. The soil was passed through a sieve with 10 mm × 10 mm openings and then air-dried to about 6% of water content in mass. Finally, it was thoroughly mixed to minimize variability and packed into soil bins in seven 10-cm deep layers to achieve a natural bulk density of around 1.35 g cm^{-3}. Each layer was lightly raked before packing the next layer to minimize discontinuities between layers. Table 1 gives selected physical properties of the test soil.

The soil bins in this experiment measured 200 cm × 80 cm × 80 cm with four wheels to facilitate transportation (Fig. 1A). According to previous studies the roots of 3-year-old jujube trees are distributed mainly in the 0–60 cm soil layer (Ma et al., 2012a,b). Apertures were drilled on the bottom of the soil bins to allow drainage. The slope gradient was set at 26.7%, which is typical for jujube plots on the Loess Plateau (Niu, 2009).

Table 1
Selected physical properties of the studied soil.

Soil properties	Texture	Values: Content (%)
Soil particle	Sand (2–0.02 mm)	17.6 (1.3)
	Silt (0.02–0.002 mm)	64.3 (1.8)
	Clay (<0.002 mm)	18.1 (2.6)
Saturated hydraulic conductivity (mm min^{-1})		0.99 (0.15)
Saturated moisture (cm^3 cm^{-3})		0.537 (0.019)
Field capacity (cm^3 cm^{-3})		0.294 (0.009)
Wilting point (cm^3 cm^{-3})		0.084 (0.013)

2.2. Treatments

The study evaluated 5 treatments, each of which was applied to a 3-year-old jujube tree (cv. Lizao on *Ziziphus* rootstock) planted in the

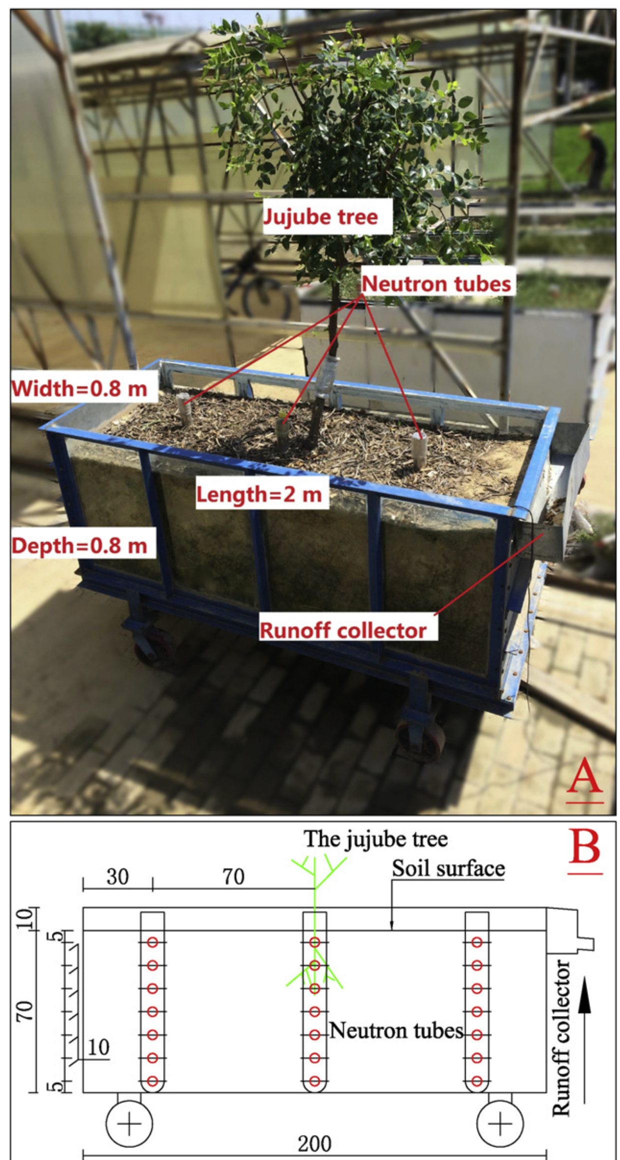

Fig. 1. The soil bin setup showing the size and the location of runoff collector (A) and the distribution of neutron tubes (B).