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Agricultural Water Management 74 (2005) 47–55
Agricultural water management
www.elsevier.com/locate/agwat

Influence of the thickness and grain size of tephra mulch on soil water evaporation

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Accepted 27 October 2004

Abstract

On the island of Lanzarote (Canary Islands, Spain), under extremely arid conditions – including annual rainfall of below 150 mm – a system for dry farming has evolved based on the use of volcanic mulch. This paper presents the results of the laboratory experiments conducted to assess the influence of two parameters of the mulch – thickness and grain size – on soil water evaporation. A soil typical of the zone, a silty clay Haplocambids, was chosen for the experiment. The mulch cover consisted of medium-grain basaltic tephra in layers 2, 5 and 10 cm thick. A 5 cm thick layer was also studied for fine, medium and coarse basaltic tephra. The soil was saturated and drained until the water content accounted for approximately 50% of weight and it was then subjected to evaporation for 31 days. The evaporation rate was maintained at between 9.1 and 11.5 mm per day, in keeping with an arid climate. The accumulated evaporation in the covered soils, irrespective of the mulch thickness and grain size, was significantly lower than in the uncovered soil. The reduction in accumulated evaporation varied with the mulch thickness: 10 cm of mulch produced a 92% reduction, 5 cm a 83% reduction and 2 cm a reduction of 52%. The 5 and 10 cm coverings provided adequate soil insulation, unlike the 2 cm thickness, which was less effective as a barrier preventing loss through evaporation. All grain sizes reduced evaporation by 81–85%.

Keywords: Evaporation losses; Dry farming; Volcanic mulch; Arid regions; Canary Islands; Traditional farming

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0378-3774/$ – see front matter
doi:10.1016/j.agwat.2004.10.011

1. Introduction

In arid regions with very little rainfall, evaporation causes major soil water loss, which restrict farming of annual crops. Despite this circumstance, throughout history man has developed farming practices aimed at reducing the amount of water lost. One such practice is the use of mulch, which can consist of a variety of materials. Inorganic mulch includes sand and rock fragments (Modaihsh et al., 1985; Groenevelt et al., 1989; Kemper et al., 1994; van Wesemael et al., 1996; Nachtergaele et al., 1998; Mellouli et al., 2000).

On the volcanic island of Lanzarote (Canary Islands, Spain), one of the most arid parts of the European Union given its annual rainfall of less than 150 mm, the long-standing tradition of using basaltic tephra mulch has made a certain amount of dry farming possible. The abundance of volcanic pyroclasts, the proximity of quarries and the duration of the system (effective for 20–25 years, after which the covering has to be replaced) make for an economically feasible farming practice, which is currently used in approximately 7000 ha. In previous works we have demonstrated the importance of this traditional practice for soil water conservation (Tejedor et al., 2003a) and for the rehabilitation of saline-sodic soils (Tejedor et al., 2003b), and we have also discussed the modifications caused in the soil classification (Tejedor et al., 2002a). The objective of this paper is to investigate the influence of the thickness and grain size of the tephra mulch on soil water evaporation. Three grain sizes (fine, medium and coarse) and three thickness of medium-grain tephra (2, 5 and 10 cm) were used for the laboratory experiment.

2. Materials and methods

The soil used in the study was 46% clay, 43% silt and 11% sand. It was taken in the area where the mulch is habitually used. The tephra was typical of that used in the traditional farming method. Of the parameters given in the literature for characterising the grain size of materials of this type (Folk, 1966; Prothero and Schwab, 1996; Bures, 1997) we used the median particle size (D_{50} or Φ_{50}) to differentiate the three types of tephra: fine ($1\ \text{mm} \leq D_{50} < 2\ \text{mm}$), medium ($2\ \text{mm} \leq D_{50} < 4\ \text{mm}$) and coarse ($D_{50} \geq 4\ \text{mm}$). The median particle size – the mesh size allowing 50% of the particles to pass through – reflects the most abundant grain size in the sample (Corey and Kemper, 1968). The grain size dispersion (σ) is calculated as $\sigma = ((\Phi_{84} - \Phi_{16})/4) + ((\Phi_{95} - \Phi_5)/6.6)$, where Φ_{84}, Φ_{16}, Φ_{95} and Φ_5 correspond, respectively, to the grain diameter below which small particles represent 84, 16, 95 and 5%. The soil surfaces were covered separately with tephra mulch as follows: (a) 5 cm of tephra of fine, medium and coarse grain and (b) 2, 5 and 10 cm of medium-grain tephra.

In order to simulate evaporation, we used metacrylate columns with heights of 30 cm (uncovered soil) and 32, 35 and 40 cm (for 2, 5 and 10 cm mulched soil, respectively). The columns were 8.4 cm inner diameter, provided with a drainage system. The soil was air-dried, 5 mm-sieved and placed in the columns, with a bulk density of 1.1 mg m^{-3}. It was saturated by capillary rise for 2 days and excess water was drained off for a further 2 days. The columns were covered with plastic to prevent loss. The weight of each was recorded (water content accounted for approximately 50% of the weight). Column bases were