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Efficiency of rice straw mulch as a soil amendment to reduce splash erosion

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Abstract Splash erosion is caused by the impact of raindrops on the soil surface. Raindrops detach soil particles, alter soil structure and increase soil erosion. Therefore, strategies are required to control the runoff and soil erosion through the control of splash erosion. The most effective measures for reducing soil splash are the use of amendments to improve and reinforce soil aggregates and/or to deploy physical barriers to minimize raindrop impacts. Straw mulch is a natural amendment that reinforces soil aggregates and reduces soil erosion. The present study examines the efficiency of straw mulch to reduce splash erosion and was conducted using silt-loam soils collected from summer rangeland in the Alborz Mountains, northern Iran. Rainfall simulators were used in the laboratory on 6 m^2 plots to test the utility of soil amendments to reduce erosion. Data from nine splash cups placed on three replicates for each treatment (treated *vs* bare soil) showed that the straw mulch reduced splash erosion in all directions.

Key words Alborz Mountains, Iran; erosion control; mulch; natural amendment; splash erosion

INTRODUCTION

Soil erosion and sediment yield from catchments are key limitations for achieving sustainable land use and maintaining water quality in streams, lakes and other water bodies (Mutua & Klik, 2006). There are several stages/types of water erosion, including splash, sheet, interrill, rill, gully and stream bank erosion. The extent of splash erosion, as in other forms of soil erosion, is a function of raindrop impact energy and of aggregate stability (Kukal & Sarkar, 2010). A variety of soil conservation methods have been tested with variable results (Lal, 2005). Various natural and organic mulches have been tested to soil erosion conservation. These include different kinds of crop residues, leaf litter, woodchips, bark chips and gravel or crushed stone (Gilley *et al.*, 1986; Ruy, 2006; Ruiz-Sinoga *et al.*, 2010; Smets *et al.*, 2011). The effectiveness of mulch for reducing runoff and soil erosion depends on factors that include rainfall erosivity, soil type, steepness and length of slope, and the rate and type of mulch application (e.g. Amimoto, 1981; Cogo *et al.*, 1984). The most effective soil splash reduction measures are the use of amendments for improvement and reinforcement of soil aggregates and/or the deployment of physical barriers to minimize raindrop impacts (Kukal & Sarkar, 2010).

Several studies have shown the importance of soil organic matter content in soil loss and soil erosion control (Morgan, 1995; Auerswald *et al.*, 2003). Straw mulch has been found to be very effective in preventing soil erosion (Center for Watershed Protection, 2001) because it absorbs the impact energy of raindrops (Das & Agrawal, 2002; Kukal & Sarkar, 2010). Mulch reduces splash erosion in addition to increasing soil organic matter and improving surface aggregation (Sur & Ghuman, 1994). Loch & Donnoll (1988) studied the effects of the amount of stubble mulch on erosion of a cracking clay soil under simulated rain. They found that rain-flow erosion decreased with increasing amounts of stubble. DeHaan (1996) tested the erosion control effectiveness of various mulching treatments using rainfall simulators. They reported that runoff rates were 13 times lower on mulched land compared to land that was left bare after harvest. Groen & Woods (2008) studied the effectiveness of aerial seeding and straw mulch on reducing post-wildfire erosion in northwestern Montana, USA, to compare the erosion and runoff rates from adjacent 0.5 m^2 treated plots. The results showed a significant increase in ground cover and reduction in erosion rate compared to control conditions. Kukal & Sarkar (2010) studied the effect of wheat straw mulch and polyvinyl alcoholon on splash erosion and infiltration rate in two soils under simulated rainfall in semi-arid tropics. They showed that mulch and polyvinyl alcoholon decreased splash and increased infiltration more effectively in sandy loam than in silt loam. Recently, Scholten *et al.* (2011) used Tübingen splash cups to measure the kinetic energy of rainfall. The splash cups were calibrated in combination with a laser disdrometer using a linear regression function.

A review of the literature demonstrates the variable behaviour and effectiveness of different mulches under different conditions. The present study examines the splash erosion reduction potential of straw mulch amendments on silt-loam soils collected from summer rangeland, Alborz Mountains, northern Iran using a simulated rainfall intensity of 90 mm/h and slope of 30%.

MATERIALS AND METHODS

Erosion plots and rainfall simulator

The laboratory experiments were conducted using three 6 m × 1 m erosion plots with a depth of 0.5 m and slope of 30% (Fig. 1). The rainfall simulator consisted of a 4000-L water reservoir and 27 pre-calibrated nozzles located on three parallel lines designed to simulate an average raindrop size of 1.3 mm. The simulator was placed at a constant height of 4 m from the highest plot level which produced an average fall velocity of 4–5.5 m s^{-1} (around 80–95% of their terminal velocity depending upon the size).

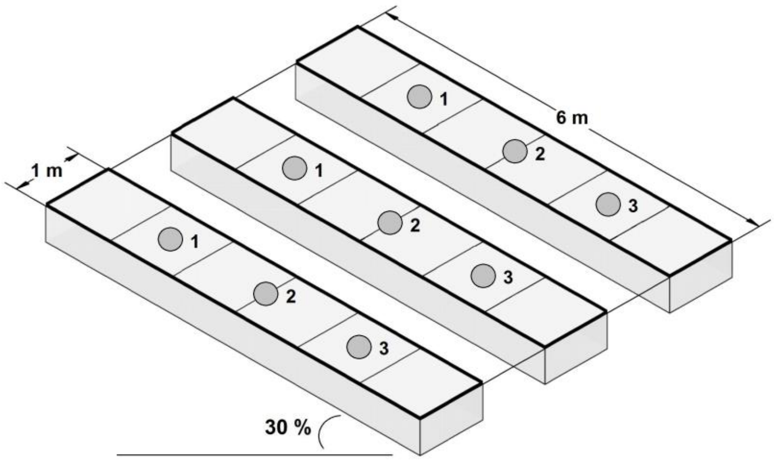

Fig. 1 Experimental plots and placement of splash cups for each plot.

Soil type

A sandy-loam soil (14% clay, 24% silt and 62% sand) was collected from the top 20 cm of soils during summer in the rangelands of the Alborz Mountains in northern Iran (Kukal & Sarkar, 2010). The soil was then prepared for application of laboratory condition using previously reported methods (Thompson & Beckmann, 1959; Loch & Donnollan, 1988; Kukal & Sarkar, 2011). A soil depth of 15 cm was compacted by concrete roller to a bulk density of 1.376 g cm^{-3} to achieve the desired bulk density similar to field conditions. Three layers of mineral pumice grains with different sizes and total thickness of 15 cm were used as a filter layer under the experimental soil. Based on the annual average soil moisture content, the soils were treated to produce a moisture content of 30%. The pH, electrical conductivity (EC) and organic matter content of the soil were 7.95, 75.5 µmohs cm^{-1} and 2.167%, respectively.

Straw mulch

The air-dry rice straw mulch was selected and tested in the laboratory experiments (Fig. 1) and spread on the soil surface 5 days before treatments with a cover, depth and dry weight of about

90% (Das & Agrawal 2002; Kukal & Sarkar, 2010), 5–8 cm and 0.5 kg m^{-2}, respectively. The purpose of applying the mulch 5 days before treatments was to increase the stability of straw mulch layer on the soil surface.

Fig. 2 Treated plots with rice straw mulch in the laboratory.

Laboratory measurements

The initial studies of rainfall characteristics in the area from which the soil was collected showed the highest probable rainfall intensity with a return period of 1 year was about 90 mm h^{-1} and the duration about 10–15 minutes. In this study, three splash cups (Morgan, 1978) were used to measure splash erosion in each plot (Fig. 2). Splashed sediment samples were collected from the upward and downward segments of the cups in each treated and control plot for 10 minute after the runoff threshold was reached. The splash sediments were then measured using a decantation procedure and oven drying at 105°C for 24 h before weighing on high-precision scales (0.001 g) (Sadeghi & Saeidi, 2011).

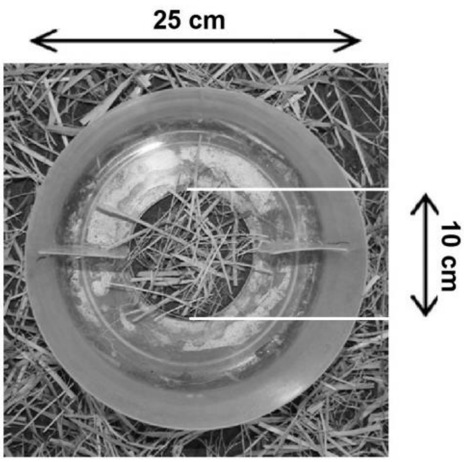

Fig. 3 An example of a splash cup installed in the treated plot with rice straw mulch.

RESULTS AND DISCUSSION

The splash erosion results for three plots before and after mulching are shown in Table 1 and show that the rice straw mulch reduces splash erosion from 52.07% to 89.23%, with an average reduction of some 70.29%. The average amounts of splash erosion before and after straw mulch spreading were 236.09 and 70.15 g m^{-2}, respectively. A significant reduction (t-test, $p = 0.001$) in splash erosion was observed with straw mulch amendments. The results also verified that straw mulch as a soil amendment can play an effective role on reducing splash erosion in even a short period (5 days) after spreading. Faust (2008) reported that the rice straw mulch was effective in a short period too.

The results show that straw mulch application protects soil aggregates from the direct impact energy of raindrops and reduces soil detachment. Although the structure of soil aggregates was visually conserved after application of the straw mulch, further studies are recommended to evaluate the stability of soil aggregates resulting from straw mulch use and so allow more comprehensive conclusions.

Table 1 Splash erosion (g m^{-2}) resulted from treated control conditions.

Plots	Cup no.	Before mulching	After mulching	Conservation ratio (%)
1	1	204.84	85.10	58.46
	2	253.25	74.65	70.52
	3	307.64	38.34	87.54
2	1	173.76	71.59	58.80
	2	334.65	36.05	89.23
	3	225.73	102.93	54.40
3	1	200.38	96.05	52.07
	2	182.17	72.87	60.00
	3	242.42	53.76	77.82
Average		236.09	70.15	70.29

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