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Reducing runoff and soil loss using corn stalk juice at plot scale

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ABSTRACT

Soil erosion control is the most essential principle for the sound utilization of soil and water. Application of soil amendments is considered as an appropriate and new strategy for soil erosion control. Despite the application of different amendments used for soil and water conservation, effects of corn stalk juice to control erosion and reduce runoff have not been considered yet. Corn stalk juice is a byproduct differentially utilized for green biomass, for example, as an energy source or a natural fiber material. The present study was conducted to evaluate the performance of the application of corn stalk juice on the runoff and erosion control of Crosby-Miami complex Alfisol packed in small-sized plots with three replicates. The study was performed under laboratory conditions using rainfall simulation and four small plots with 5% slope. Experiments were then set up as one control and six different treated plots (named as T1, T2, T3, T4, T5 and T6) with two volumes of 0.4, 0.8 L and three concentrations of 25%, 50%, 75% and subjected to simulated rainfall, respectively. The results showed that the corn stalk juice had positive effects on runoff and erosion control. The effects of the high volume and concentration of corn stalk juice on runoff and erosion were both better than those of the low ones. The high corn stalk juice concentration was more effective on runoff and erosion reduction compared with the low corn stalk juice concentration under the same corn stalk juice volume, and vice versa. Runoff reduction benefit was 32%, 35%, 39%, 56%, 63% and 76%, respectively, for T1, T2, T3, T4, T5 and T6 treatments. Erosion reduction benefit was 38%, 42%, 65%, 77%, 89% and 96%, respectively, for T1, T2, T3, T4, T5 and T6 treatments. The effect of corn stalk juice on erosion was more obvious than that on runoff when the corn stalk juice concentrations and volumes both were the same. The present study provides insight into the development of corn stalk juice as a useful soil amendment.

1. Introduction

Soil erosion by water is one of the most widespread and major ecological and environmental problems worldwide which results in reduced agricultural productivity, increased water pollution, and affects sustainable development (Novara et al., 2011; Palacio et al., 2014; Adugna et al., 2015; Prosdocimi et al., 2016a). In many cases, water erosion causes a nearly irreversible decline in soil productivity and other soil functions, resulting in environmental damage. Accordingly, the prevention and control of soil erosion by water is of paramount importance for the management and conservation of natural resources (Tejada and Gonzalez, 2006; Cerdà et al., 2009; Liu et al., 2011; Keesstra et al., 2016a,b) and has been paid much attention (Asselman et al., 2003; Weltzin et al., 2003; Singer and Shainberg, 2004; Nearing et al., 2005; Jin et al., 2008; Sun et al., 2014; Ngetich et al., 2014).

Towards this attempt, application of different wastes as soil amendments is therefore one of the effective methods in order to control soil erosion as well as to manage large amounts of wastes potentially produced worldwide to fulfill human needs (Smets et al., 2008; Sadeghi et al., 2015a,b, 2016; Yazdanpanah et al., 2016). The application of organic wastes, such as sewage sludge (Tejada and Gonzalez, 2007; Singh and Agrawal, 2008; Pengcheng et al., 2008; Hueso-González et al., 2014; Hu et al., 2015), crop residues (Jiang et al., 2011; Li et al., 2011; Fernández et al., 2012; Liu et al., 2012; Gholami et al., 2012, 2013; Shi et al., 2013; Fernández and Vega, 2014; Moreno-Ramón et al., 2014; Sadeghi et al., 2015a,b, 2016; Peng et al., 2016), compost manure (Ramos and Martínez-

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Casasnovas, 2006; Tejada and Gonzalez, 2007; Lentz and Lehrsch, 2014; Doan et al., 2015; Peng et al., 2016), byproducts with a high organic matter content (Tejada and Gonzalez, 2007; Larney and Angers, 2012; Jiménez et al., 2015; Hazbavi and Sadeghi, 2016; Prosdocimi et al., 2016b) and synthetic organic polymers, i.e., polyacrylamides (PAMs) (Flanagan and Canady, 2006; Teo et al., 2006; Mamedov et al., 2010; Lee et al., 2011; Tümsava and Kara, 2011; Liu et al., 2014; Inbar et al., 2015; Doan et al., 2015; Wang et al., 2015), to soils has become increasingly common in an attempt to maintain soil organic matter, reclaim degraded soils and supply plant materials. Previous studies have been conducted about application of soil amendments to improve soil structure (e.g., Karami et al., 2012; Brevik et al., 2015), change soil and water behavior (e.g., Huang et al., 2014) and reduce runoff and soil erosion in recent years (e.g., Prats et al., 2014; Rodrigo Comino et al., 2016). Although different soil amendments have been tested to protect soil, improve soil quality, and to reduce runoff and control soil erosion throughout the globe, there is still a need to seek natural products that may provide the same soil and water conservation benefits (Gholami et al., 2012).

In the process of developing green biomass utilization, such as fiber extraction, the plant juice becomes a natural byproduct because only water is used in the extraction. Harvesting green biomass may cause soil conservation challenges due to the reduced amount of organic materials left on the soil surface. One possible trade-off is to return the plant juice back to the soil as an amendment. The review of the scientific literature published about amendments in soil and water conservation shows us that the use of corn stalk juice, a kind of plant juice, as a soil amendment has not been investigated and reported yet.

In addition, the most widely used method to study the effects of soil amendments on soil erosion has been to apply simulated rainfall under laboratory conditions on disturbed soils because they are more rapid, efficient, controlled and adaptable than natural rainfall research (Moreno-Ramón et al., 2014; Lassu et al., 2015).

Consequently, in the present study, we hypothesized that the addition of corn stalk juice to the soil can be an effective method to reduce runoff and control soil erosion. A rainfall simulator was employed in the laboratory. The objective of this study, therefore, was to evaluate the effects of corn stalk juice on runoff and soil erosion reduction under simulated rainfall in the lab.

2. Materials and methods

2.1. Test materials

The surface soil materials were obtained from a Crosby-Miami complex Alfisol containing 20% clay, 66% silt and 14% sand from the Purdue Animal Science Research and Education Center (a typical region with hills and erosion), West Lafayette, Indiana, USA, located at a latitude of 40°29′24″N, longitude of 87°00′54″W. The soil was collected from the top layer of 0–10 cm of the profile. The test soil was air-dried, crushed and subsequently passed through an 8-mm sieve to obtain maximum similarity with the soil natural conditions (Defersha et al., 2011; Ziadat and Taimeh, 2013; Khaledi Darvishan et al., 2014; Sadeghi et al., 2015b) after pebbles and plant residues had been removed. The corn stalk juice used in the present study was extracted from field corn plants grown at the Purdue Agronomy Farm in West Lafayette, Indiana. The general properties of the extracted corn stalk juice are shown in Table 1.

Table 1
Physical and chemical properties of corn stalk juice in the experiment.

Parameter	Unit	As received basis	Dry basis
Moisture	%	88.26	
Dry Matter	%	11.74	
Nitrogen	%	0.29	2.44
Crude Protein	%	1.83	15.25
Calcium (Ca)	%	0.09	0.78
Potassium (K)	%	0.56	4.78
Magnesium (Mg)	%	0.05	0.46
Sodium (Na)	%	0.01	0.06
Phosphorus (P)	%	0.04	0.35
Sulfur (S)	%	0.02	0.19
Aluminum (Al)	ppm	3	13
Boron (B)	ppm	1	10
Copper (Cu)	ppm	3	14
Iron (Fe)	ppm	3	26
Manganese (Mn)	ppm	2	9
Zinc (Zn)	ppm	3	23

2.2. Experiment layout and treatments

The laboratory experiments were conducted at the USDA-ARS National Soil Erosion Research Lab in West Lafayette, Indiana. Four 0.5-m-long, 0.2-m-wide and 0.1-m-deep soil boxes with runoff collecting troughs at the outlet end were fabricated. The designed soil box slope was 5%. At the bottom of the soil box, three rows of holes with 0.05-m spacing per row and three drainage holes per row were drilled for water drainage from the box. Before filling the soil box, a small sponge was inserted into each bottom drainage hole. A 0.02-m layer of sand was laid at the bottom of the soil box in order to simulate natural drainage condition and decreasing plot weight (Defersha et al., 2011; Khaledi Darvishan et al., 2014). A 0.05-m thick test soil layer was then placed on the top and separated from the sand by a sheet of landscape fabric (Defersha et al., 2011; Khaledi Darvishan et al., 2014). The soil was ultimately compacted by a wood block to achieve the bulk density of 1.3 g cm^{-3} almost equal to that measured for the soil under natural conditions (Sadeghi et al., 2015b). Before packing, the gravimetric water content of the soil was adjusted to 12%, the typical level during the flood season in this area when most erosion occurs. After the soil was packed, corn stalk juice by volume concentration of 25%, 50% and 75% was prepared in 0.4 and 0.8 L, respectively, and uniformly applied on the surface of the plots from a perforated plastic bottle. After corn stalk juice application, the soil surface was dried thoroughly for one week prior to rainfall simulation.

The corn stalk juice treatments involved three application concentrations (25%, 50% and 75%) and two application volumes (0.4 and 0.8 L). One control (CK, 0.4 L deionized water) and six experimental treatments (T1, 0.1 L corn stalk juice mixed with 0.3 L deionized water, T2, 0.2 L corn stalk juice mixed with 0.2 L deionized water, T3, 0.3 L corn stalk juice mixed with 0.1 L deionized water, T4, 0.2 L corn stalk juice mixed with 0.6 L deionized water, T5, 0.4 L corn stalk juice mixed with 0.4 L deionized water, T6, 0.6 L corn stalk juice mixed with 0.2 L deionized water) were designed and three replicates per treatment, totalizing 21 experimental units.

2.3. Rainfall simulation and measurements

After one-week air drying, the treated soil box was subjected to the rainfall simulation run. The soil box was placed under two programmable rainfall simulators equipped with oscillating VeeJet nozzles (Part no. 80100, Spraying Systems Co., Wheaton, IL). Two boxes were under the simulation at a time. The distance between the upslope end of the soil box and the rainfall nozzle was approximately 2.45 m. The rainfall simulator was programmed to produce rainfalls at 25, 50, 75 and 100 mm h^{-1}.