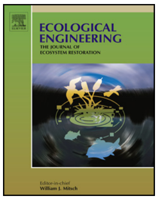
Ecological Engineering 102 (2017) 270–279

Contents lists available at ScienceDirect

Ecological Engineering

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



# The effect of super absorbent polymers on soil and water conservation on the terraces of the loess plateau

Yuanbo Cao[a], Baitian Wang[a,*], Hongyan Guo[a], Huijie Xiao[a], Tingting Wei[b]

[a] College of Soil and Water Conservation, Beijing Forestry University, Beijing 100083, PR China
[b] China National Gold Group Corporation, Beijing 100011, PR China

ARTICLE INFO

*Article history:*
Received 21 October 2016
Received in revised form 15 February 2017
Accepted 18 February 2017
Available online 24 February 2017

*Keywords:*
SAPs
Artificial rainfall
Soil and water conservation
Soil physical and chemical properties
Loess plateau

ABSTRACT

The loess plateau of northern China has always been severely affected by drought and rainfall, impacting ecological integrity and sustainable development in particular. Super-absorbent polymers (SAPs) can relieve the pressure of water shortages and change the process of rainfall-runoff. In this study, SAPs were mixed with soil in percentages(weight ratio) of 0, 0.25%, 0.5%, 0.75%, 1% and 2%; then, these mixtures were applied in 5 cm depth layers in runoff plots of 5 m × 4 m for every treatment (T1, T2, T3, T4, T5). Artificial rainfall intensity was controlled at 40 mm/h, and the rainfall duration was 0.5 h when the soil physical and chemical properties were surveyed. With SAPs, the initial runoff time of different treatments increased by 21.5-102.7%; the amount of surface runoff decreased remarkably; the SAPs could reduce the loss of soil and water: the runoff reduction effect was 24.6% (T1), 41.5% (T2), 46.5% (T3), 50.7% (T4), and 60.6% (T5); the sediment reduction effect was very significant at 58.8% (T1), 74.1% (T2), 85.6% (T3), 80.9% (T4), and 75% (T5); and the lowest losses of total nitrogen (TN 0.09 kg), total phosphorus (TP 5.02 g) and total potassium (TK 0.08 kg) were measured in T3,with 14.9%, 14.2% and 13.1% that of the control (CK), respectively. The soil moisture content increased by 19.2%, 32.5%, 33.5% and 31.3% compared to CK in the different soil layers; SAPs could raise the soil temperature by 0.72 °C (T5) and lower the soil temperature by 0.53 °C (T5) in September and July, respectively. The aboveground biomass and underground biomass of the treatments increased by a maximum value of 84.4% in T3, which was 38% greater than CK, and the vegetation in T3 (44 kinds) was the most abundant and it was 69.2% more than CK (26 kinds). The effect was not always positively correlated with the percentage of SAPs. The application of SAPs in this study showed a comprehensive utility (soil erosion prevention, redistribution of soil water and temperature, maintenance of fertility and the synergy between SAPs and plants), which suggest that the most basic goal, to ensure socio-economic and ecological sustainability in dryland systems, is obtained.

## 1. Introduction

The Chinese loess plateau is one of the most seriously eroded areas, with some of the worst water quality and highest fertilizer use rates in the world, which are becoming major issues that restrict agriculture (Fu, 1989; Wang et al., 2002; Hamilton and Luk, 1993; Edwards, 1996). It is vital to improve water use efficiency, soil moisture conservation, and water-saving technologies to reasonably develop the Chinese loess plateau (Cao et al., 2009; Feng et al., 2006). Traditionally, terraces and other projects are universal measures used to improve the cultivation environment in the region (Catt, 2001), but due to the uneven seasonal rainfall, this is not a very effective way to conserve water and soil and to maintain land fertility (Fu et al., 2011). Furthermore, the soils in the area are mostly characterized by low water-holding capacity, a high evapotranspiration rate and excessive leaching of the scant rainfall, leading to poor water use and fertilizer efficiency in crops (Fu et al., 2011; Gao et al., 2013). Therefore, reducing soil erosion and improving soil is urgently needed to ensure the socio-economic and ecological sustainability of dryland systems (König et al., 2013). Super absorbent polymers (SAPs) may provide a new way to conserve water and soil and to maintain land fertility (Barrios, 2007; Bai et al., 2010; Keren and Ben-Hur, 1997).

SAPs are hydrophilic networks polymers with a super-high capacity for water absorption, water retention and slow water release (Devine and Higginbotham, 2005; Omidian et al., 2005). Previous researchers (Devine and Higginbotham, 2005; Omidian et al., 2005; Karimi et al., 2009) have found SAPs that can improve the

---

* Corresponding author.
*E-mail address:* wbaitian@bjfu.edu.cn (B. Wang).

http://dx.doi.org/10.1016/j.ecoleng.2017.02.043
0925-8574/

soil water holding capacity and stabilize the soil structure, which reduces water loss, soil nutrient loss, and soil erosion in furrow-irrigated fields. SAPs incorporation into soil is considered to be an efficient means of cultivation (Goebel et al., 2005) because these polymers retain large quantities of water and nutrients, which are released as the plants need them; therefore, they have been widely used for agricultural water saving and ecological recovery. During the last several decades, SAPs have been intensively studied, and many studies (Bai et al., 2010; Devine and Higginbotham, 2005; Li et al., 2004; Busscher et al., 2009) have focused on the comparison and evaluation of soil physicochemical properties after applying SAPs. Johnson (Johnson, 1984) reported an increase of 171–402% in water retention capacity when SAPs were incorporated into coarse sand. Research has shown that SAPs amendments can reduce soil penetration resistance (John et al., 2005), increase soil aggregation, and aid the protection of soil organic matter (Goebel et al., 2005; John et al., 2005). This finding seems to suggest that the soil structure is optimized and more stable after applying SAPs; consequently, soil corrosion stability can increase. This has a positive effect on retaining nutrients (Juntunen et al., 2002) due to lower soil loss and more water retention. Similarly, the influence of SAPs on soil temperature is remarkable (Giller et al., 2009). SAPs also contribute to yield enhancement and increased seed germination and emergence (Yazdani et al., 2007; Bai et al., 2013), in the fields of both agriculture and forestry (Han et al., 2005; Zohuriaan-Mehr and Kabiri, 2008). When polymers are incorporated into the soil, they retain large quantities of water and nutrients, which are released as the plants require. In the agricultural and horticultural industry, SAPs are applied in the form of seed additives, seed coatings, and root dips (Zohuriaan-Mehr and Kabiri, 2008; Han et al., 2010), which have direct and indirect effects on plant growth. When the weight ratio (SAP/soil) was 0.5%–1%, it had obvious effect on retention fertilizer and water (Bres and Weston, 1993; Griffiths et al., 1998), and it was the optimal content for seedling growth (Tang, 2003). The weight ratio of 0.1%–0.3% could improve maize production 3% (Feng et al., 1993). At the same, the corn ear length and thousand seed weight were significantly increased (Zhao et al., 2006). However, little information on the effects of SAPs on soil and water conservation on the terraces of the loess plateau has been published.

This study is one of a few investigations that use an in situ experiment to use SAPs and simulated artificial rainfall to evaluate the effects of different percentages of SAPs on soil and water conservation on the terraces of the loess plateau. Furthermore, we studied the effect of SAPs on runoff and nutrient losses and the effect of SAPs on soil moisture and soil temperature, as well as the effect of SAPs on plants in different treatments. These test results may provide a reference for similar areas for soil and water conservation management.

## 2. Materials and methods

### 2.1. Site description

This study was performed in *Daiju Village, in Fangshan County, Shanxi Province* (37° 59′ N, 111° 31′ E) (Fig. 1), which is located on the central part of the loess plateau, which is a typical loess gully and hilly area with an average elevation of 1057.2 m (Cao et al., 2016). This catchment has a total area of 2.02 $km^2$, with a gully density of 2.74 km $km^{-2}$, and with slope gradients ranging from 10 to 30°. The experimental field has a semi-arid continental climate with a mean annual precipitation of 562 mm and a mean air temperature of 8.6 °C over the past 20 years. The rainfall is concentrated mainly between June and September and has large inter-annual variation. The growing season for most deciduous plant species ranges from April to October. The soil in the study area is derived mainly from loess material and has a depth of 50–200 m, depending on the topography of the exact location. The loess in this area is usually composed of more than 50% silt (0.002–0.05 mm) and less than 20% clay (<0.002 mm), with a porosity of approximately 50%. The gravimetric field capacity and soil water content at the wilting point are 20–35% and 3–6%, respectively. The county averaged erosion is 6800 t $km^{-2}$ $a^{-1}$, and the water and soil loss area (879 $km^2$) includes 61% of the total area of the county, with 5.97 million tons of soil loss. The areas of severe, intensive, moderate and slight erosion classes are 202.1 $km^2$, 211 $km^2$, 290.1 $km^2$ and 175.8 $km^2$, respectively. The dominant land use type before the experiment at the site was bench terracing (cornfield), and the soil physical and chemical properties are shown in Table 1.

### 2.2. Experimental materials

Super absorbent polymer (polyacrylamide-acrylic superabsorbent resin) was provided by the Beijing Hanlimiao New Technology co., LTD. The parameter characteristics of the super absorbent polymer are shown in Table 2.

The rainfall simulator had an independent design that consisted of four electric sprayers and a portable artificial rainfall simulator with multiple nozzles, and simulated rainfall coverage was 100%. The average rainfall intensity was 40 mm/h with an error less than 10%. Four pieces of PolyVinyl Chloride (PVC) board were used: two were 500 cm × 30 cm × 1 cm and another two were 400 cm × 30 cm × 1 cm (one had openings for runoff outfall); the boards covered the simple rectangular runoff plot, and all of the boards could be removed and reused.

### 2.3. Field sampling and indoor testing

The SAPs particles were mixed with the soil at a weight ratio of 0 (CK), 0.25% (T1), 0.5% (T2), 0.75% (T3), 1% (T4) and 2% (T5); then, the mixture was applied to 5 cm soil layers on April 24th. Every treatment (runoff plots) was uniform 20 $m^2$ (5 m × 4 m) with three repeats (treatments partitioned by 50 cm). On July 16th, the rainfall simulator was calibrated, and the rainfall intensity was controlled at 40 mm/h before the runoff plots were constructed for each treatment. The simulated rainfall duration was accurately set at 0.5 h. During the rainfall process, the initial time of runoff and flow velocity were observed and recorded. The runoff water was collected with plastic buckets from the opening of the PVC board. After the simulated rainfall, the sediment concentration and soil erosion were calculated. From July 17th to July 24th, the soil temperature and soil moisture at depths of 5 cm, 10 cm, 15 cm and 20 cm were continuously acquired with a soil temperature and humidity meter (*DH8902, China*). Furthermore, the soil temperature was observed from May to October. On August 21st, for each of the sample plots, the aboveground biomass and underground biomass were collected and weighed, and the vegetation coverage and plant species were counted; the sampled areas were within the geometric center and four boundary areas of the 5 m × 4 m treatments, and the plots were established as 1 m × 1 m areas. Similarly, the soil profiles were dug from the geometric center of each treatment area to determine the soil bulk density, soil porosity and root density; the soil samples were collected from different depths (0 cm, 5 cm, 10 cm, 15 cm and 20 cm) with three replicates and the soil samples was obtain by cutting ring in the corresponding soil profiles, then the soil samples was transferred to valve bag.

A no-vacuum, fast-dripping pre-wetting method (Cantón et al., 2001) was used to measure the >0.5 mm water-stable aggregates. The Walkley-Black acid digestion method (State Forestry Administration, 1999) was used to measure the soil organic carbon; the semi-micro Kjeldahl method, molybdenum blue colorimetry