

Effect of Soft Rock Amendment on Soil Moisture and Water Storage in Mu Us Sandy Land

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Abstract. Effect of soft rock as soil amendment on soil moisture and water storage was investigated in a field experiment in a sandy soil in Mu Us Sandy Land of China in 2012-2014. Treatments includes four rates of soft rock to sandy soil in volume (0:1, 1:1, 1:2 and 1:5) were applied only in the first year. Adding soft rock amendments increased soil moisture and soil water storage. The treatment with rate of 1:1 (soft rock to sandy soil in volume) had the greatest effect on soil moisture and water storage averaged over the three years. Soft rock amendments showed promise for improving soil moisture and water storage in Mu Us Sandy Land.

1. Introduction

Desertification is one of the most critical types of land degradation and is being widely recognized as a serious threat to arid and semiarid environments worldwide (Veron et al., 2006; Li et al., 2018). Mu Us Sandy Land (also called Mu Us Desert) is one of China's four major sandy land with the area of 3.98×10^6 ha (Han et al., 2012), which is located in south eastern Ordos region in Inner Mongolia and northern Shaanxi Loess Plateau. Due to the long-time grazing, unreasonable land reclamation for agriculture (Liu et al., 2010), fuel wood collection and fossil fuel exploitation, land desertification and low productivity were taken place in the Mu Us region (Liu et al., 2014; Han et al., 2015). The region is mainly a sandy agro-pastoral land embedded with desert patches. Nevertheless, drought and lack of water resource are the main limiting factors in agriculture production in this region. Therefore, improving the ability of soil to store water from limited precipitation, reducing evapotranspiration, and increasing water use efficiency, are essential strategies for sustainable development of rainfed agriculture. The objective of this study was to evaluate the effect of different rates of soft rock amendments on spatial and temporal distribution of soil moisture and soil water storage in Mu Us Sandy Land.

2. Materials and methods

2.1. Experimental site and design

The experimental field is located in Dahanji village ($38^{\circ}27'53''$ N, $109^{\circ}28'58''$ E) of Yuyang district, Yulin city, Mu Us Sandy Land of China. The location is in northern Shaanxi, with an altitude of 1210 m and a typical warm temperate monsoon climate. The mean annual temperature (1990-2014) is 8.1°C , annual sunshine is 2879 h, annual total radiation is $145.2 \text{ kcal cm}^{-2}$, frost-free period is 150 d each year,



annual precipitation is 414 mm (65% of which occurs from June to September). It represents the climate characteristics of a warm moist summer and a cool dry winter with annual precipitation of 300-500 mm and annual cumulative temperature ($>10^{\circ}\text{C}$) of 2200-3400 $^{\circ}\text{C}$ in most of Mu Us Sandy Land (Han et al., 2015).

The field experiment was conducted from 2012 to 2014, inclusive. The experimental design consisted of four ratios of soft rock to sandy soil in volume: 0:1 (CK), 1:1 (T1), 1:2 (T2) and 1:5 (T3) at 0-30 depth. This experiment was a randomized complete block factorial design with three replications. Each plot was 10 m wide by 12 m long, with a 2 m buffer zone between the plots. The diameter less than about 5 cm of soft rock was selected and applied in the treatments, and larger particles were crushed by machine. The soft rock was applied only one time in the middle of March, 2012 for all treatments; air-dried fine sandy soil samples were thoroughly mixed with soft rock to obtain three different contents of soft rock. The surface was covered with a 30 cm deep compound soil with different ratios of soft rock to sand in each plot. Below 30 cm was local sand and the soil of 30-100 cm profile was homogeneous (Wang et al., 2013).

2.2. Experimental protocol

Aeolian sandy soil and soft rock are the two typical soils in Mu Us Sandy Land (Chen and Wang, 2012). Aeolian sandy soil is a frigid, Typic Haplustoll with sandy loam texture that has been formed from aeolian deposits. Soft rock is a type of loose rock that is specifically identified as an interceded sandstone composed of thick layers of sandstone, sandy shale and shale that formed from fluvial clastic deposits and shales developed in the Jurassic, Triassic and Cretaceous periods (Mišćević and Vlastelica, 2017; Vlastelica, et al., 2016), it is composed of quartz ($70.5\pm 1.0\%$), feldspar ($16.4\pm 0.5\%$), muscovite ($12.9\pm 1.1\%$) and hematite ($0.2\pm 0.05\%$).

Tillage consisted of spring ploughing at about 30 cm depth. Seeds of the corn were planted manually at the middle of May in each of the three years (2012-2014). In 2012, about 60 days of rock application to soil, seeds were sown. The corn variety was XianYu335, the seeding depth was about 5 cm, the row spacing was 60 cm, and the planting density was 65,000 plants ha $^{-1}$. The Xian Yu335 was widely used in local corn production with moderate sensitive to water deficit. Compound fertilizer (90 kg N ha $^{-1}$, 40 kg P ha $^{-1}$, and 75 kg K ha $^{-1}$) was applied into 20 cm deep furrows and covered with soil using a fertilizer applicator when seeding. Urea was applied at 187 kg N ha $^{-1}$ at the corn jointing stage as the local applied levels of fertilizer management. Weed control was by manual hoeing when required. Harvest was in the late September approximately 130 days after sowing.

2.3. Field and laboratory measurements

Soil samples for gravimetric soil moisture content were obtained manually at three random positions in each plot with a soil auger, at depths of 0-10, 10-20, 20-40, 40-60, 60-80 and 80-100 cm at 1 d before sowing and 10, 30, 50, 70, 90, 110 and 130 d after sowing. The samples from each plot at same depth were mixed and the composite samples were packed in aluminium boxes and oven-dried at 105 $^{\circ}\text{C}$ until constant weight.

2.4. Data analysis

Soil water storage (SW, mm) was calculated by Eq. (1):

$$SW = d \times c \times \frac{\rho_s}{\rho_w} \quad (1)$$

Where d is soil depth (mm), c is gravimetric soil moisture content, ρ_s is soil bulk density and ρ_w is water density.

We normalized soil water storage data using Eq. (2):

$$N_{ij} = \frac{SW_{ij}}{CW_{ij}} \quad (2)$$

Where i and j is referred to year and days after sowing respectively. N_{ij} is normalized soil water storage, SW_{ij} is the mean soil water storage of each soil amendment treatment, CW_{ij} is the mean control soil water storage.

An analysis of variance (ANOVA) was performed using SAS Ver. 9.0 software (SAS Institute Inc., Cary, NC, USA). Tests of significant use the least significant difference (LSD) at $P \leq 0.05$. Mean values were reported in the tables and figures.

3. Results

The soil amendment treatment and soil layer had a significant effect ($P < 0.05$) on soil moisture in 2012, 2013 and 2014 (Table 1). The interaction between treatment and soil layer had a significant effect ($P < 0.05$) on soil moisture in all three years except at 130 d after sowing in 2012. Normalized soil water storage is plotted against days after sowing in all three years (Fig.1). The normalization process forced all soil amendment treatments to start unity at planting in 2012, as the entire field was at approximately the same soil moisture content at the beginning of the experiment. The effect of amendment treatments clearly increased water storage when the control water storage was low, reaching a maximum of 1.45 at 110 d after sowing in 2014. The amendments listed in descending order of effect on soil water storage were $T1 > T2 > T3 > CK$. The T1 treatment always had the greatest increase relative soil water storage at each measurement time in all of 2012, 2013 and 2014, but there was some variability in effectiveness of the other soil amendment treatments. There was little difference of normalized soil water storage when the control water storage was high as a result of adequate precipitation.

Table 1. ANOVA of effect of soft rock treatments and soil layer on the soil moisture in 2012-2014

Year	Factors	DF	Days after sowing (d)						
			10	30	50	70	90	110	130
2012	T	3	*	***	***	**	***	**	***
	L	5	***	***	***	***	***	***	***
	T*L	15	*	*	***	***	*	***	NS
2013	T	3	*	**	***	**	***	***	***
	L	5	***	***	***	***	***	**	***
	T*L	15	***	***	***	***	***	***	***
2014	T	3	**	**	***	***	***	***	***
	L	5	***	***	***	***	***	***	***
	T*L	15	**	***	***	***	***	***	***

T and L represent soft rock amendment treatment and soil layer respectively. *, ** and *** significant at 0.05, 0.01 and 0.001 probability levels. NS means not significant.

4. Discussion

In this study, the soft rock treatments had similar effects on the soil moisture and water storage in each year (Fig. 1). Soft rock had more effect on soil storage when there are more droughts in soil during a period of less rainfall, retained the limited rainfall and lowered evaporation losses and increased plant available water for crop growth (Wu et al., 2008; Agaba et al., 2010). In our experiment, the soil moisture and water storage were significantly better in the T1, T2 and T3 treatments relative to the CK treatment due to the higher field water holding capacity and lower soil saturated hydraulic conductivity. These results were consistent with Xu et al. (2015) who found that synthetic and natural water absorbent polymer additives could be used to improve water holding capacity in a semi-arid region. The mineralogical structure of soft rock allows it to absorb a large amount of water rapidly under sufficient water conditions, and slowly release water into the soil for crop uptake under drought conditions (Mi et al., 2017). The T1 treatment had greatest effect on soil moisture and water storage.

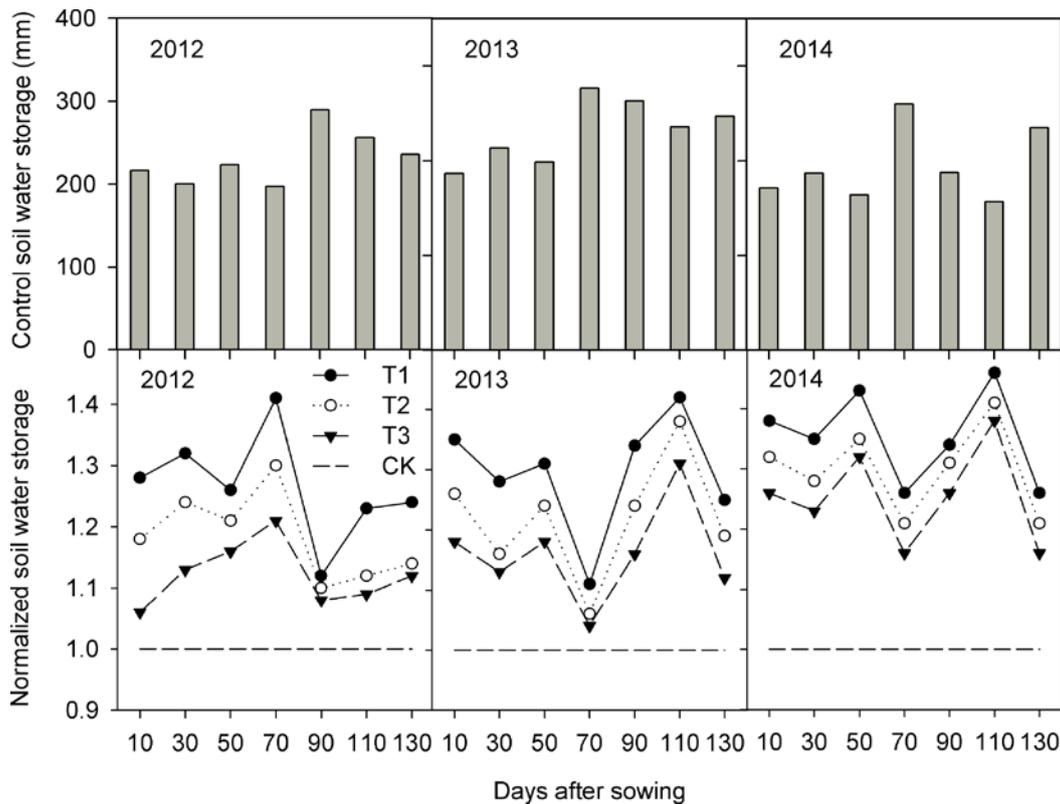


Figure 1. The temporal variation of normalized soil water storage and control soil water storage with soft rock in 2012, 2013 and 2014. Treatment code: CK, no soft rock control; T1, soft rock to sandy soil in volume 1:1; T2, 1:2; T3, 1:5.

5. Conclusions

Soft rock as a soil amendment increased soil moisture, soil water storage, especially in relatively droughty periods with low rainfall. This study showed the potential of soft rock as amendment on improving soil water properties in Mu Us Sandy Land. The mechanism of soil properties have increased up to a certain level of soft rock application rate to the sandy soil is complex.

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7. References

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