

Effect of Soft Rock Amendment on Soil Hydraulic Parameters in Mu Us Sandy Land

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Abstract. Effect of soft rock as soil amendment on soil saturated hydraulic conductivity and water holding capacity 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 water hold water holding capacity; decreased soil saturated hydraulic conductivity. The treatment with rate of 1:1 (soft rock to sandy soil in volume) had the greatest effect on soil saturated hydraulic conductivity and water holding capacity averaged over the three years. Soft rock amendments showed promise for improving soil hydraulic parameters in Mu Us Sandy Land

1. Introduction

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 southeastern Ordos region in Inner Mongolia and northern Shaanxi Loess Plateau. In this region, there is an area of more than 1.67×10^6 ha covered by a kind of special soft rocks (also called Pisha sandstone or Feldspathic Sandstone) (Ni et al., 2008). The soft rocks composed of mudstone, thick layer sandstone and arenaceous shale (Bazhenov et al., 1993; Martin et al., 1999), which is a kind of loosely bound sedimentary rock formed during the Permian (approximately 250 million years ago), Mesozoic Triassic, Jurassic and Cretaceous period (Zhang et al., 2009). It is normally associated with sand and widely distributes in the Mu Us Sandy Land.

Sandy land soil with little or no structure is highly permeable under both wet and dry conditions and it retains little or no water (She et al., 2014). However, soft rock had high content of silt and clay with high water retention capacity. Soft rock is also highly subject to weathering and rapidly expands when it comes into contact with water (Mišćević and Vlastelica, 2014). Reports of soft rock used in agriculture are relatively few, and information about the quantitative effects of soft rock addition in sandy soil on crop yield in the compound soil is still inadequate in this region. The objective of this study was to evaluate the effect of different rates of soft rock amendments on spatial and temporal distribution of soil saturated hydraulic conductivity and water holding capacity in Mu Us Sandy Land.



2. Materials and methods

2.1. Experimental site and design

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.

2.2. Field and laboratory measurements

Soil water holding capacity and saturated hydraulic conductivity was measured at harvest time in each year with the gravimetric method (Mohamed et al., 2016) and the constant-head method (Reynolds, 2006), respectively. Undisturbed soil samples were collected from each plot from three random positions with a 10 cm diameter by 5 cm high cutting ring, at 0-10, 10-20, 20-30 and 30-40 cm depths. For water holding capacity, soil samples were saturated with deionized water and the top was covered by a plastic wrap to prevent the loss of water by evaporation. The samples were drained for 48 h at room temperature (Dugan et al., 2010; Koide et al., 2014). Then samples were taken after 48 h, weighed, oven dried at 105°C until constant weight and reweighed. Water holding capacity was determined by the difference between the mass of the wet and dry sample. For soil saturated hydraulic conductivity, a perforated bottom was placed underneath the cutting ring to stabilize the soil, and a second 5 cm high ring was placed on top of the cutting ring and sealed with tape to prevent water leakage. The cutting rings were placed over a beaker. Water was added in the upper ring and kept at 5 cm head using the height of the upper ring as a guide. Leachate was periodically measured by dumping the beaker into a graduated cylinder. Soil saturated hydraulic conductivity was determined by the flow rate for steady state conditions.

2.3. Data analysis

Saturated hydraulic conductivity was calculated by Eq. (1):

$$K_{sat} = V \cdot d / (T \cdot A \cdot h) \quad (1)$$

where V is the volume of water (m^3), d is the soil thickness (m), T is the time of infiltration (s), A is the area of the ring (m^2) and h is the water head (m).

3. Results

The soft rock amendments led to a significant decrease ($P < 0.05$) in soil saturated hydraulic conductivity compared with the control with no soft rock (Table 1). The amendment effect on saturated hydraulic conductivity was different in different soil layers with the greatest difference among all soft rock amendment treatments occurring in the 0-10, 10-20 and 20-30 cm layers in 2012, 2013 and 2014, respectively. The respective decrease in saturated hydraulic conductivity for 0-10, 10-20, 20-30 and 30-40 cm soil layers over that for the control with no soft rock ranged from 77 to 96%, 76-96%, 73-97% and 4-20% in 2012, 74-96%, 75-95%, 73-96% and 1-22% in 2013, and 76-96%, 76-96%, 70-96% and 2-24% in 2014. For all the soil layers, the T1 treatment had the greatest effect in 2012, 2013 and 2014. The amendments listed in descending order of effect on soil saturated hydraulic conductivity were $T1 > T2 > T3 > CK$.

All three soft rock treatments had a significant increase ($P < 0.05$) on water holding capacity over that for the control treatment, except for the layer 30-40 cm in 2012, where only T1 treatment had a significant increase (Fig. 1). There was a similar pattern of soft rock effect on water holding capacity in the four soil layers in 2012, 2013 and 2014: the soft rock listed in descending order of effect on soil

water holding capacity was $T1 > T2 > T3 > CK$. The improvement in water holding capacity ranged from 75.0-225.5%, 60.0-150.0% and 50.0-180.0% for the 0-10 cm; 41.7-133.3%, 38.5-107.7% and 83.3-150.0% for the 10-20 cm; 35.7-92.9%, 33.3-80.0% and 18.8-75.0% for the 20-30 cm; 6.7-40.0%, 6.7-46.7% and 20.0-53.3% for 30-40 cm in 2012, 2013 and 2014, respectively.

Table 1. Soil saturated hydraulic conductivity (cm min^{-1}) with different soft rock treatments and soil layers in 2012, 2013 and 2014

Year	Soil layer (cm)	CK	T1	T2	T3
2012	0-10	7.1 a	0.26 d	0.49 c	1.61 b
	10-20	8.13 a	0.34 d	0.78 c	1.93 b
	20-30	6.71 a	0.23 d	0.61 c	1.78 b
	30-40	6.40 a	5.12 c	5.87 b	6.13 ab
2013	0-10	6.70 a	0.24 d	0.51 c	1.72 b
	10-20	7.84 a	0.36 d	0.84 c	1.98 b
	20-30	7.45 a	0.28 d	0.91 c	1.99 b
	30-40	6.51 a	5.07 c	5.74 b	6.45 a
2014	0-10	7.03 a	0.28 d	0.62 c	1.68 b
	10-20	8.45 a	0.33 d	0.77 c	2.01 b
	20-30	7.01 a	0.31 d	0.78 c	2.13 b
	30-40	6.58 a	4.98 c	5.34 b	6.48 a

Mean values in the table, and rows within the same soil layer and with the same letters are not significantly different at $P < 0.05$ according to a protected LSD test.

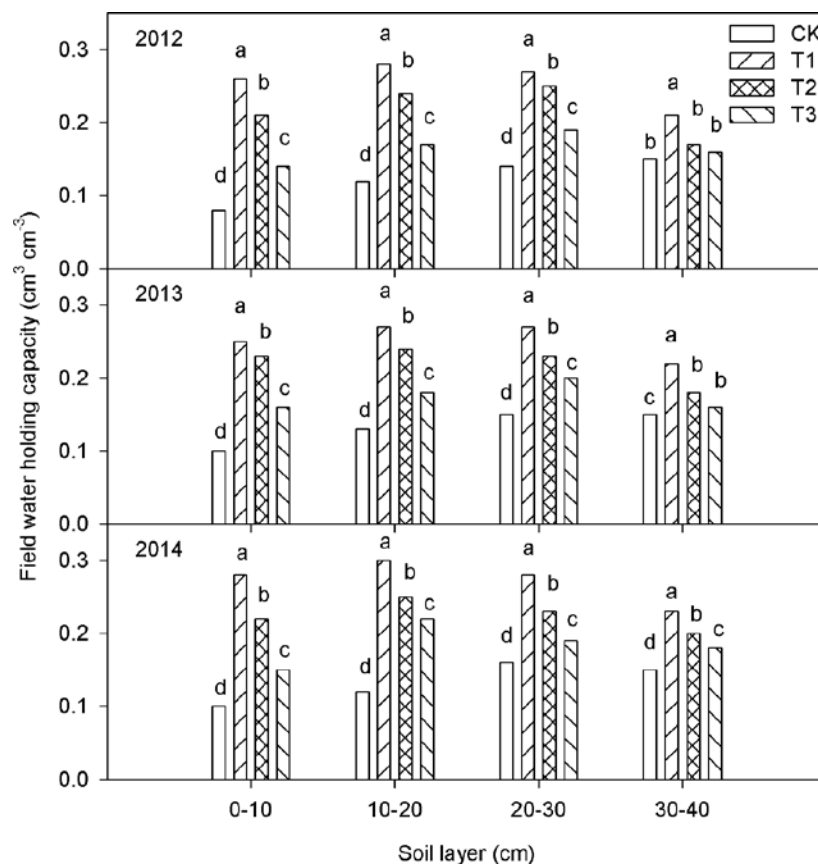


Figure 1. Water holding capacity with soil amendments in 2012, 2013 and 2014. Treatment code: CK, no soft rock control; T1, soft rock to sandy soil in volume 1:1; T2, 1:2; T3, 1:5. Small bar shows

standard deviation. Columns within the same year and with the same letters are not significantly different at $P < 0.05$ according to a protected LSD test.

4. Discussion

Our data showed that water holding capacity was significantly ($P < 0.05$) higher in all soil layers in plots receiving water absorbing soil amendments than in control plots, where no amendments were applied (Fig. 1). This was consistent with Farrell et al., (2013) who reported improved water holding capacity with hydrogel and montmorillonite. Soft rock was usually fine grained and its grading sizes were widely distributed, with about 32.9% of silt-sized (0.002-0.05 mm diameter) and 47.5% of clay-sized (< 0.002 mm) and 19.6% of sand-sized (0.05-2 mm) grains. Sandy soils have lower water holding capacity than finer textured soil because they contain mainly large pores (Tahir and Marschner, 2016). The majority of pores in soft rock are small leading to high water holding capacity. Consequently, the addition of soft rock to sandy soil increased water holding capacity in the present study with a greater increase in T1 treatment than T2 and T3 treatments (Fig. 1). Soft rock decreased saturated hydraulic conductivity in all of 0-40 cm soil layers, with the largest effect in the 0-30 cm layer in the three years (Table 1). The sandy soils was dominated by large pores, therefore, the movement of soil water through sandy soil was relatively unhindered and fast. This behavior was less noticeable in all soft rock addition treatments.

5. Conclusions

Soft rock as a soil amendment decreased soil saturated hydraulic conductivity, especially in 0-30 cm soil layers. 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 and yield have increased up to a certain level of soft rock application rate to the sandy soil is complex. The further research into the long-term effect of soft rock on soil chemical, biological properties and soil microbial community structure is required to gain a better understanding of the mechanism of soft rock as amendment for increasing crop yield in Mu Us Sandy Land, China.

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7. References

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