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DISTRIBUTION CHARACTERISTICS AND STABILITY OF SOIL AGGREGATES AS COMPOUNDED BY SOFT ROCK AND SAND UNDER DIFFERENT PLANTING YEARS OF CORN IN MU US SANDY LAND IN CHINA

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Abstract

Field plot experiments of compound soil mixing with soft rock and sand with ratios of 1 : 1, 1 : 2 and 1 : 5 during 2010-2018 years of corn cultivation in Mu Us Sandy Land in china., was carried out to observe the change characteristics of composition, distribution and mean weight diameter (MWD) of compound soil water stable aggregate (WSA) under different corn planting years. The results showed that with the increase of planting years, the content of WSA in composite soils of three portions with a particle size of < 0.25 mm gradually decreased, and WSA with a particle size of > 0.25 mm showed a continuous increasing trend. The WSA with a particle size of 0.25 - 0.5 mm accounted high for the maximum ratio, which plays an important role in the agglomeration of the compound soil. After 9 years of planting, the MWD of 1 : 1, 1 : 2 and 1 : 5 compound soil WSA increased by 1.13, 1.85 and 1.58 times, respectively, and t 1:2 compound soil WSA with particle size > 0.25 mm and MWD increase at a faster rate, which lead to a higher soil agglomeration and stability. The interaction between the mixture ratio of soft rock to sand and the planting years of corn has a significant impact on the formation and stability of WSA in the compound soil. With the increase of planting years of corn, the agglomeration effect of compound soil in different proportions was found to enhance, and the development of soil structure improve continuously.

Introduction

The amount particle size distribution and stability of soil aggregates are important indicators for the good development of soil structure (Das *et al*. 2014), especially the content of WSA has a significant impact on the physical, chemical, and biological properties of the soil (Hartley *et al*. 2016, Qu *et al*. 2019), which is crucial to retain water and fertilizer, coordinate soil water, fertilizer and air heat for crop growth. It is also the basic condition for crop growth, development, high yield and stable yield (Wang *et al*. 2014, Chaplot and Cooper 2015). Therefore, the composition and stability of soil WSA can be used to measure the degree of soil structural development and sustainable utilization (Mao *et al.* 2018, Li *et al.* 2019). The MWD is a common method to evaluate the characteristics and stability of soil aggregates. The larger the MWD value the higher the degree of soil agglomeration. The more stable soil structure, the better the soil development status (Darapuneni *et al.* 2021).

As two different materials, soft rock and sand in the Mu Us sandy land, Han *et al.* (2012) found that the two have complementary characteristics, and they were combined to form a reconstituted soil. The compound soil of soft rock and sand has the basic physical and chemical

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properties of agricultural production. In the process of agricultural utilization, there are not only material accumulation and dynamic processes that promote soil agglomeration, but also dispersion risks and mechanisms. She *et al.* (2014) pointed out that the addition of soft rock can effectively improve the water and fertilizer retention capacity of aeolian sandy soil, and reduce the nutrient loss and water infiltration rate of aeolian sandy soil. Sun and Han (2018) found through moisture model analysis that the addition of soft rock can effectively improve the hydraulic parameters of aeolian sandy soil, which can significantly increase crop yields. Li *et al*. (2017) pointed out that the optimal combination ratio of soft rock and sand under the guidance of sand fixation is 1 : 1 ~ 1 : 5, which has the strongest water retention and water holding performance. Previous studies were mostly based on the aspects of compound soil nutrients and water, but there are no reports on long-term soil structure studies. Therefore, it is necessary to carry out a series of studies on the agglomeration process and state of compounded soils, which will help to understand the structural development status and quality change trend of the newly created compound soil. Thus this study was aimed to analyze the composition, distribution and MWD of the three proportions of compound soil WSA under different planting years to characterize the stability of the soil WSA and the development of the soil structure. This finding will provide a theoretical basis for the scientific value and effect of using soft rock to improve aeolian sandy soil in the Mu Us Sandy Land.

Materials and Methods

The experimental area is located in Yuyang District, Yulin City, Mu Us Sandy Land. There is a big difference in temperature between winter and summer in this area. The average temperature in winter (January) is -9.5~-12°C, and the average temperature in summer (July) is 24 ± 2°C. The rainfall during the year is almost concentrated in autumn (especially in August), which is about 60 to 75% of the annual precipitation. The inter-annual precipitation shows a significant difference, that is, the wet year is 2 to 4 times the precipitation of the dry year. The area has sufficient sunlight and shallow groundwater burial, which can meet the irrigation and growth of the local main crop corn. The experimental area is mainly distributed in aeolian sand soil and soft rock, which are alternately distributed. The sand particles are in a state of dispersion without agglomeration, with poor structure, loose soil, and poor water retention. There are abundant secondary clay minerals in soft rock, which can promote soil agglomeration and has good water holding capacity.

The field plot experiment for the compound soil of soft rock and sand was established in 2010, and three repeated experiments were set up with the volume mixing ratio of soft rock and sand at 1 : 1, 1 : 2, and 1 : 5. Each plot experiment is 12 m long × 5 m wide. A total of 9 plots was set up to carry out long-term monitoring experiments on the quality of compound soil. According to the experimental design, the surface layer (0~30 cm) of aeolian sandy soil in the study area was covered with the compound soil in the ratio of 1 : 1, 1 : 2, 1 : 5 volumetric ratio of soft rock to sand. Then the two materials were thoroughly mixed by mechanical raking. Spring corn, the main local agricultural crop, is sown at early May each year. Compound fertilizer (90 kg N/ha, 40 kg P/ha, 75 kg K/ha) was applied 1-2 days before planting, and urea was applied at 187 kg N/ha once at the jointing stage of corn.

The experiment adopted the "S" sampling method after the corn harvest every year (Bao 2000). The soil aggregates were collected using aluminum boxes to get the undisturbed soil samples of the 0 - 20 cm surface soil under each treatment. Soils were collected from three points for each treatment, sealed and brought to the laboratory. The composition of WSA was determined by the wet sieve method (Zhao *et al*. 2013, David and María 2019). The 50 g of air-dried soil samples were mixed and the WSA content of each particle size of > 2, 2-1, 1 - 0.5, 0.5 - 0.25 and <

0.25 mm was determined using an agglomerate analyzer. Due to the unstable structure of the compound soil, the test method was slightly modified, which was set at 25 times/min and shook for 3 min. Finally, the aggregate soil samples with different particle sizes on the sieve were placed in an aluminum box and dried (105°C) to calculate the content of > 0.25 mm WSA.

The parameters of > 0.25mm particle size WSA and MWD were used to measure the stability of aggregates (Zhou *et al.* 2020), and the calculation formula is as follows:

$$WSAC = \sum_{i=1}^{n} (W_i) \tag{2.1}$$

$$MWD = \sum_{i=1}^{n} (\overline{X_i} \times W_i) \tag{2.2}$$

Where, W_i represents the content of agglomerates in the i-th particle size (g); X_i represents the MWD of the agglomerates in the i-th particle size (mm).

Results and Discussion

Before planting, < 0.25 mm WSA in the three proportions of compound soil accounted for the largest proportion (Table 1), with a range of 84.2 to 86.3%. With the development of the experiment, the content of < 0.25 mm WSA in the 1 : 1, 1 : 2 and 1 : 5 compound soils decreased significantly, compared with before planting, the content decreased by 53.9, 67.9 and 60.7% after nine years of planting, with a range of 33.6 to 38.8%.

Table 1. Composition of WSA in compound soil under different planting years of corn.

Soft rock: sand	Years	Percentage of WSA (%)				
		>2mm	2-1mm	1-0.5mm	0.5-0.25mm	<0.25mm
1:1	0	1.4±0.07d	2.1±0.11d	2.7±0.08e	9.6±0.42e	84.2±9.71a
	1	1.9±0.12d	3.3±0.12d	3.4±0.27d	14.1±0.54d	77.3±7.94ba
	3	3.2±0.30c	4.7±0.23cd	6.5±0.34c	18.9±1.26c	66.7±5.35b
	5	4.8±0.44b	6.4±0.49b	9.9±0.52b	26.1±2.73b	52.8±7.48b
	7	6.1±0.61a	8.2±0.47a	10.4±1.29a	32.6±1.96a	42.7±5.72c
	9	6.9±0.35a	9.3±0.61a	9.6±0.77a	35.4±3.19a	38.8±3.55c
1:2	0	1.1±0.15d	1.9±0.05e	3.2±0.27e	7.5±1.07e	86.3±7.07a
	1	1.7±0.31d	3.5±0.17d	3.8±0.31e	12.1±0.63d	78.9±6.74a
	3	3.9±0.47c	5.2±0.39c	4.3±0.44de	17.1±1.82c	69.5±10.16b
	5	5.4±0.43c	8.1±0.42b	7.4±0.62c	23.6±1.41b	55.5±2.75c
	7	8.5±0.56b	12.6±0.72a	10.3±1.35b	36.8±3.17a	31.8±4.49d
	9	10.1±0.37a	13.4±1.68a	11.6±1.16a	37.2±2.35a	27.7±2.87e
1:5	0	0.8±0.08d	1.2±0.07e	4.3±0.63cd	8.1±2.51f	85.6±5.26a
	1	1.4±0.13d	2.9±0.25d	4.7±0.45c	11.2±1.29e	79.8±6.87b
	3	2.8±0.19c	4.4±0.61c	3.3±0.59d	18.0±0.83d	71.5±5.09c
	5	3.7±0.22c	6.3±0.36b	5.2±0.37c	25.4±1.75c	59.4±4.72d
	7	5.9±0.47b	10.7±0.82a	7.5±0.94b	31.4±2.24b	44.5±2.45e
	9	7.8±0.39a	11.1±0.79a	12.3±1.15a	35.2±3.48a	33.6±3.58f

Correspondingly, the content of > 0.25 mm WSA in the 1:1, 1:2, and 1:5 compound soils showed an overall increasing trend, and the content of WSA with a particle size of 0.25-0.5 mm increased by 2.69, 3.96, 3.34 times, respectively, the content of WSA with a particle size of 1-0.5 mm increased by 2.56, 2.63 and 1.86 times, respectively; the content of WSA with a particle size of 2-1 mm increased by 3.43, 6.05 and 8.25 times, respectively; the content of >2 mm WSA increased by 3.93, 8.18 and 8.75 times, respectively, and the soil structure continued to develop in the direction of agglomeration.

Results showed that the planting years has a significant impact on the newly-created soil aggregates. With the development of the experiment, the content of aggregates with a particle size of < 0.25 mm gradually decreased, and the content of aggregates with a particle size of > 0.25 mm increased, and the compound soil showed continuous agglomeration trends. This is mainly because the interaction between the planting years of corn and the mixing ratio of soft rock and sand promoted the formation of WSA in the compound soil, and improved the quality of the aggregates to a certain extent, especially enhanced the agglomeration effect of 1:2 and 1:5 compound soil.

Before planting, the content of WSA with a particle size of 0.25 - 2 mm was 1 : 1 > 1: 5 > 1 : 2, and the range of change was 14.4~12.6%, and there was no significant difference among different proportions ($p > 0.05$) (Fig. 1). With the development of the experiment, the composition of WSA in the three proportions of compound soil gradually changed from < 0.25 mm particle size to mainly 0.25 - 2 mm fine and large aggregates. Compared with before planting, after nine years of planting, the WSA content of 0.25-2 mm particle size in 1:1, 1:2 and 1:5 compound soil increased by 2.77, 3.94 and 3.31 times, respectively. The aggregate content in this particle size range was 1 : 2 > 1 : 5 > 1 : 1, with a range of 54.3~62.2%, and there was a significant difference among different proportions ($p < 0.05$).

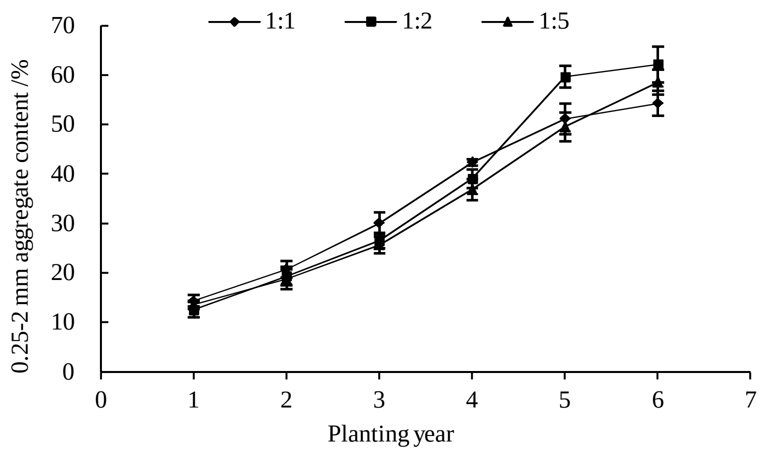

Fig. 1. Interannual variation of 0.25-2 mm WSA in different proportions of compound soil.

Before planting, the content of > 2 mm WSA in the three proportions of compound soil was 1 : 1 > 1 : 2 > 1 : 5 (Fig. 2), and the variation range was 0.8~1.4%, which is relatively small, and there was no significant difference among all proportions ($p > 0.05$). With the development of the experiment, the content of > 2 mm WSA in 1 : 1, 1 : 2 and 1 : 5 compound soils showed a continuous increase. After 9 years of planting, aggregate content increased by 3.93, 8.18 and 8.75 times and the mass percentage of aggregates varied from 6.9 to 10.1%.

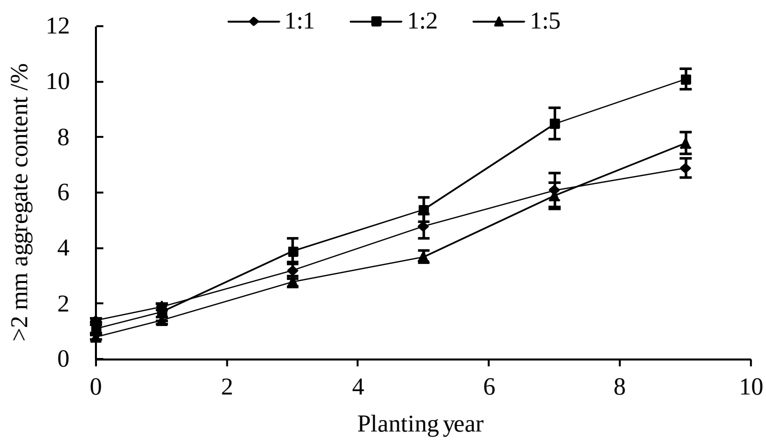

Fig. 2. Interannual variation of >2 mm WSA in different proportions of compound soil.

With the increase of corn planting years, the content of WSA with a particle size of 0.25 - 0.5 mm accounted for the largest proportion, which is the main component of aggregates with a particle size of > 0.25 mm. This might be due to the root system and its exudates which can consolidate and aggregate soil particles to form a stable aggregate structure. Crop planting has changed the material basis of compound soil agglomeration (Meng *et al.* 2014), making the < 0.25 mm micro-aggregates transform into 0.25 - 0.5 mm small and medium-sized aggregates, and the compound soil agglomeration is enhanced, and there is a trend of further agglomeration.

With the increase of planting years, the MWD of compound soil WSA with the three proportions showed an increasing trend (Fig. 3). The MWD of 1 : 1 compound soil WSA showed a slow increasing trend, and there were significant differences in MWD of 3, 5 and 7 years after planting ($p < 0.05$), and MWD gradually stabilized among different years after planting 7 years ($p > 0.05$). The 1 : 2 compound soil MWD before planting and 1 year after planting was not significantly different, after 3 years of planting, the MWD showed a significant increasing trend, and there were significant differences in MWD values between 3, 5, 7 and 9 years ($p < 0.05$). There was no significant difference in MWD value of 1 : 5 compound soil before planting, 1 year, 3 years, and 5 years ($p > 0.05$), but MWD value increased significantly after 5 years of planting and reached the maximum value after 9 years of planting. Compared with before planting, the MWD value of 1 : 1, 1 : 2 and 1:5 compound soil increased by 1.13, 1.85 and 1.58 times after 9 years of planting, of which 1 : 2 and 1:5 compound soil increased rate significantly higher than the 1:1 compound ratio.

MWD is an important indicator for evaluating the stability of soil aggregates (Liu *et al.* 2014). The interaction between soil parent material and corn planting years affects the formation and stability of compound soil aggregates. According to related research (Luo *et al.* 2013, Wang *et al.* 2017, Sun and Han 2018), the interaction of corn growth characteristics and the mixing ratio of soft rock and sand makes the clay and organic matter content of 1 : 2 compound soil higher than 1 : 1 and 1 : 5 compound ratio. However, the content of soil organic matter and clay directly affects the aggregation and cementation of soil particles. The higher the content of soil clay and organic matter, the stronger the soil agglomeration and the higher the soil stability (An *et al.* 2010).

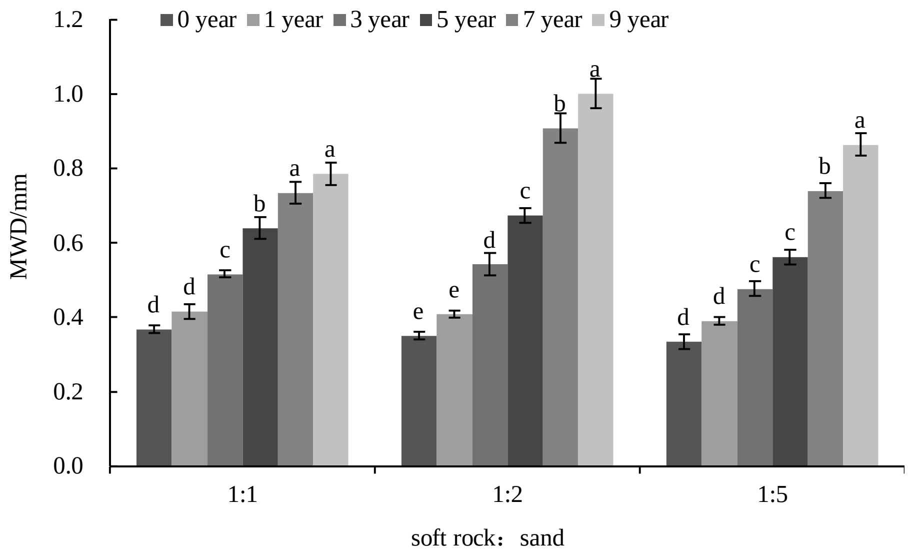

Fig. 3. MWD variation characteristics of compound soil WSA in different proportions.

With the development of the experiment, the WSA and MWD of > 0.25 mm particle size in the three proportions of compound soil showed a continuous increasing trend. After 9 years of planting, the main component of aggregates with a particle size of > 0.25 mm was 0.25 - 0.5 mm, and the soil agglomeration effect of 1 : 2 and 1 : 5 compound soil was significantly higher than that of 1 : 1 compound soil. With the increase of corn planting years, the agglomeration effect of compound soil with the three proportions is increased, and the stability of the aggregates is continuously improved. The soil is in a trend of continuous maturation and sustainable development, and it does not need to be compounded again after many years.

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