Analyzing the Sand-fixing Effect of Feldspatic Sandstone from the Texture Characteristics

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Abstract. The purpose of this research was aimed to study the sand fixing effect of feldspatic sandstone in Mu Us Sandy Land, to provide a scientific basis for desertification control, soil and water conservation and development of farming there. Methods of mixing feldspatic sandstone and aeolian sandy soil according to 1: 0, 1: 1, 1: 2, 1: 5, and 0: 1 mass ratios, the graded composition and characteristics were studied with laser particle size analyzer. The result showed that these features of sand-based, loosely structured, easy to wind erosion of aeolian sandy soil were changed before feldspatic sandstone and aeolian sandy soil compounding. The <0.05 mm particle mass increased with feldspatic sandstone mass increasing. The texture presented this kind of change from sand to sandy loam to loam to silt loam. The small particle size distribution, good homogeneity and other features of aeolian sandy soil were improved to a certain degree, and the particle size distribution became broad before feldspatic sandstone and aeolian sandy soil compounding. The particle grading was continuous, and the grading characteristic was good when m(F): m(S) was 1: 2 (Cu was 76.21, Cc was 1.12) or when m(F): m(S) was 1: 5 (Cu was 54.71 and Cc was 2.54). The conclusion is that feldspatic sandstone has sand-fixing effect in texture characteristics, which heightens with feldspatic sandstone mass increasing, and when the mass ratio of feldspatic sandstone: aeolian sandy soil is 1: 2 or 1: 5 which compound better.

1. Introduction
Mu Us Sandy Land which is poor soil, lack of water and very fragile ecological environment, therefore where is one of the most serious areas of desertification in northern China. These traditional water conservation measures such as aerial seeding in sand [1], seal sand to cultivate forest and grass [2], ecological water conservancy restoration [3-4] were huge in cost, and did not reverse the momentum of exacerbating desertification in Mu Us Sandy Land. The cognition to the mechanism of wind and water erosion of soil and the practice of sand governance showed that there was a close correlation between erosion and topsoil size distribution characteristics [5-7], therefore we made the best of local conditions, the use of local widely distributed feldspatic sandstone that a kind of rock
interbed of dry hard as stone, water soft as mud to research the sand-fixation effect [8]. This study about water-holding capacity, nutrient conditions, crop yields and so on of feldspathic sandstone and aeolian sandy soil compound soil has made some progress at present [9-21], however, the sand-fixation effect of feldspathic sandstone from texture feature to analyze has not been reported. In this study, we used the “tight and loose” feature with texture structure of feldspathic sandstone and aeolian sandy soil in Mu Us Sandy Land to analyze the texture characteristics and differences of feldspathic sandstone and aeolian sandy soil in different mass ratios, which provided more adequate scientific basis to compensate for the inherent defects of aeolian sandy soil in texture structure, to make feldspathic sandstone applied in soil and water management and development of agricultural planting in Mu Us Sandy Land.

2. Materials and Methods

2.1. Experimental Zone Overview
The study area lies in Dajihan village of Xiaojihan township in Yulin city Yuyang of northern Shaanxi, locates in E109°28′38″~109°30′10″, N38°27′53″~38°28′23″, where is in northern Shaanxi, southern edge of the Mu Us Desert, Wuding River middle reaches, whose elevation is 1206~1215 m. Here is typical semi-arid temperate semi-arid continental monsoon climate zone, uneven spatial and temporal distribution of precipitation, dry climate, long winter and short summer, four distinctive seasons, abundant sunshine, arid and windy in spring, cool and moist in autumn. The average annual temperature is 8.1 °C, ≥10°C accumulated temperature is 3307.5 °C and continuous days for 168d. The annual average frost-free period is 154d, annual precipitation is 250 mm~440 mm, annual average rainfall is 413.9 mm and whose 60.9% concentrates in July to September, rain and heat over the same period, the annual extreme maximum rainfall is 695.4 mm, the minimum is 159.6 mm, the daily maximum rainfall is 141.7 mm. Here, the annual average sunshine time is 2879 h, the sunshine percentage 65%, the annual total amount of radiation is 145.2 kCal/cm2, the dryness is 1.0~2.5, the sand-driving wind with wind speed greater than 5 m·s⁻¹ appear at 220~580 times a year, the dune height is 10 m or less [22].

2.2. Experimental Design and Methods
We sampled local purple feldspathic sandstone and aeolian sandy soil in April 2014, then which were dried, ground and sieved with 2 mm aperture. Feldspathic sandstone (F) and aeolian sandy soil (S) were thorough mixed according to five kinds of different mass ratios (mF): m(S)=1: 0, 1: 1, 1: 2, 1: 5, 0: 1), then standby application.

These size distribution characteristics of each sample were studied with Malvern laser particle size analyzer, Mastersizer 2000 (England) [23], and the method of wet manual measurement was used to analyze. The particle size distribution was based on Chinese grain size system grading, the mechanical composition was based on soil texture triangle system of USDA [24]. We used the data processing software of SigmatPlot 10.0 to analyze these data and plot.

3. Result and Analysis

3.1. The Texture Characteristics after Feldspathic sandstone and aeolian sandy soil compounding
The particle size range distribution of Feldspathic sandstone and aeolian sandy soil compound soil shown in figure 1, as can be seen from figure 1, when the full-time for the Feldspathic sandstone, the content of coarse silt (~0.01~0.05 mm) was the most abundant, followed by fine silt (~0.002~0.005 mm) and middle powder (~0.01~0.005 mm), whose content were fairly, coarse clay (~0.001~0.002 mm) and fine clay (<0.001 mm) were less, the kind of particles of >0.25 mm almost none. When the full-time for the aeolian sandy soil, the content of coarse sand (~0.25~1 mm) was at most, followed by fine sand (~0.05~0.25 mm), silt (~0.05~0.002 mm) was very small, only 4.05%, clay (<0.002 mm) was
less than 1%, therefore can be considered almost no clay in aeolian sandy soil. The content of coarse sand (0.25~1 mm) was maximum, secondly, fine sand (0.05~0.25 mm) and coarse silt (0.01~0.05 mm) of feldspathic sandstone and aeolian sandy soil compound soil in three kinds of mass ratios (m(F): m(S)=1: 1, 1: 2, 1: 5). To 0.05 mm for the sector that is the boundary between sand and silt of U.S. soil texture, the content of each particle size distribution was m(F): m(S)=1: 0>1: 1>1: 2>1: 5>0: 1 of feldspathic sandstone and aeolian sandy soil compound soil within <0.05 mm particle size composition range, which was m(F): m(S)=1: 0<1: 1<1: 2<1: 5<0: 1 when >0.05 mm, this was because that these content of >0.05 mm grain size composition in aeolian sandy soil and <0.05 mm in feldspathic sandstone were very high, which can be clearly seen from figure 1.

![Particle size distribution range of feldspathic sandstone (F) and aeolian sandy soil (S) compound soil](image)

**Fig. 1** The Particle size distribution range of feldspathic sandstone (F) and aeolian sandy soil (S) compound soil

Table 1 is mechanical composition and texture of feldspathic sandstone and aeolian sandy soil in each mass ratio prepared by USDA soil texture classification system standard. As can be seen from table 1, the content of critical grain size (silt and clay) gradually improved of structure occurrence in compound soil with the increase of feldspathic sandstone content, which showed linear growth, the relational expression of silt $y=69.04x+10.41$, $R^2 = 0.9630$, clay $y=13.37x+2.42$, $R^2 = 0.8873$(where $y$ is the percentage content of particles $x$ is percentage of the feldspathic sandstone), and the texture presented the change from sand to sandy loam to loam to silty loam, the texture conditions changed for the better, therefore the compound soil gradually showing certain structural properties. Joining feldspathic sandstone that made the coarse sand texture in aeolian sandy soil gradually improved, therefore feldspathic sandstone has some sand fixation effect at the texture.

| $M$ (F): $m$ (S) | Granulometric composition (%) | Texture       |
|------------------|-------------------------------|---------------|
|                  | Sand (2~0.05mm) | Silt (0.05~0.002mm) | Clay (<0.002mm) |               |
| 1: 0             | 10.43          | 75.31          | 14.26          | Silt loam    |
| 1: 1             | 39.57          | 49.38          | 11.05          | Loam         |
| 1: 2             | 52.74          | 38.88          | 8.38           | Sandy loam   |
| 1: 5             | 72.55          | 22.53          | 4.92           | Sandy loam   |
| 0: 1             | 95.73          | 4.05           | 0.21           | Sand         |
3.2. Granulartity Characteristics after Feldspatic Sandstone and Aeolian Sandy Soil Compounding

Figure 2 was particle accumulative curve of feldspatic sandstone and aeolian sandy soil compound soil, figure 3 was frequency distribution curve of compound soil. From figure 2 and figure 3 can be seen that the particle size distribution of feldspatic sandstone was wide range, whose frequency distribution of particle size had no obvious crest, and the particle accumulative curve had no apparent steep, therefore which belong to multiple decentralized cumulative curve, which described the homogeneity of feldspatic sandstone poor, no one particle gradation accounted advantage. The particle size of aeolian sandy soil mainly ranged from 0.05 mm to 1 mm in Mu Us Sandy Land, overall coarse particles, therefore whose frequency distribution curve had a very narrow peak distribution, whose particle accumulative curve had obvious steep, which belong to monodisperse cumulative curve, therefore aeolian sandy soil had good homogeneity and strong sorting. In three kinds of different mass ratios of feldspatic sandstone and aeolian sandy soil compound soil, whose frequency distribution curve was divided into two parts according to particle size of 0.05 mm, the small particle size content gradually increased with the increase in the quality of feldspatic sandstone in the first half. The coarse particle size decreased gradually with the increase in the quality of feldspatic sandstone in the second half. However, the particle accumulative curves of compound soil all showed a significant turning trend, which belong to multiple decentralized cumulative curve, but with the quality increase of feldspatic sandstone, these particle accumulative curves of compound soil and aeolian sandy soil had started showing some differences, and gradual transition to a multi-cumulative curve similar to the feldspatic sandstone, which presented that after adding feldspatic sandstone in aeolian sandy soil the homogeneous size composition of aeolian sandy soil was improved, the size composition of compound soil started showing this kind of status of thickness mixing, the particle size distribution scope enlarged.

![Graph](image-url)

**Fig. 2** The particle accumulative curve of feldspatic sandstone (F) and aeolian sandy soil (S) compound soil
The content of frequency distribution (%)

0 1 2 3 4 5 6 7 8 9

\( m(F): m(S) = 1:0 \)
\( m(F): m(S) = 1:1 \)
\( m(F): m(S) = 1:2 \)
\( m(F): m(S) = 1:5 \)
\( m(F): m(S) = 0:1 \)

**Fig. 3** The frequency distribution curve of feldspatic sandstone (F) and aeolian sandy soil (S) compound soil

Selecting uniformity coefficient (Cu) and curvature coefficient (Cc) evaluated the good or bad of compound soil gradation. Cu is a ratio of limit size that particle size when \( d(0.6) \) and effective size that particle size when \( d(0.1) \), where \( d(0.1) \) represents the size of particle cumulative percentage being 10%, the rest analogy, which is an important index to reflect soil particles uniformity. Cc is the index of reflecting the slope of soil particle size gradation accumulation curve whether continuous, where Cc equals to \( \frac{d(0.3) \times d(0.3)}{d(0.6) \times d(0.1)} \). Cu is generally greater than 1, the closer to 1, indicating that the soil samples are more uniform. The soil of Cu<5 is called uniform particle soil whose graduation is poor. The larger Cu showed that the more widely particle size distribution. The kind of soil samples of Cu>10 have well graduation, but too large Cu (generally greater than 100, an order of magnitude difference) indicates that the kind of soil has a potential lack of intermediate particle size, which is discontinuous graduation [25]. Therefore, Cu and Cc are needed simultaneously to evaluate the graduation characteristics after feldspatic sandstone and aeolian sandy soil compounding.

The graduation parameters of compound soil in different mass ratios were gained according to laser particle size analyzer and figure 2, as shown in table 2. As can be seen from table 2, the volume particle size and soil particle size under each accumulated content of compound soil showed a decreasing trend with the increase of feldspatic sandstone quality, which stated that joining feldspatic sandstone in aeolian sandy soil that improved the condition of coarse particle size of aeolian sandy soil, therefore the particle size composition of compound soil changed into thinner graduation. Feldspatic sandstone’s particle size was finer from these di values in table 2 can also be seen, which mainly concentrated in silt and clay segments. The Cu of feldspatic sandstone was 12.07, the Cc of feldspatic sandstone was 1.01. Experience has shown that a sample is well-graded soil while which meets the Cu>10 and Cc be 1 to 3[25], therefore feldspatic sandstone had wide particle size distribution from the point of view of particle size graduation. Feldspatic sandstone can be used with sand-fixing agent due to its continuous particle size graduation. From the di value of aeolian sandy soil in table 2 could be seen similarly that the particle size of aeolian sandy soil was coarser in Mu Us Sandy Land, and mainly concentrated in the section of sand. Cu of aeolian sandy soil was 3.32, Cc of aeolian sandy soil was 1.21, which illustrated the particle accumulative curve of aeolian sandy soil was continuous in Mu Us Sandy Land, whose soil particle size distribution was small, which was uniform grain soil and had poor graduation, which was consistent with the analysis to figure 2.
Aeolian sandy soil had no good mechanical properties, poor engineering properties. Although the particle size graduation of aeolian sandy soil was continuous in Mu Us Sandy Land, its Cu too low, the smaller particle size distribution, which led to the lack of small graduation particles, therefore which was this kind of soil of poor graduation. Calculation showed that when \( m(F) \) than \( m(S) \) was 1: 2, Cu was 78.21, Cc was 1.12. When \( m(F) \) than \( m(S) \) was 1: 5, Cu was 54.71 more than 10, Cc was 2.54 between 1 to 3, which could simultaneously met above two conditions, therefore when \( m(F) \) than \( m(S) \) was 1: 2 or 1: 5, compound soil could exhibit good particle graduation characteristics, whose the composition of coarse and fine particles were mixed [26]. From table 2 could also be seen that the Cu of feldspathic sandstone and aeolian sandy soil compound soil in different mass ratios was much larger than the Cu of feldspathic sandstone and the Cu of aeolian sandy soil, which showed that joining feldspathic sandstone in aeolian sandy soil could improve aeolian sandy soil’s defect of article size homogeneity, and the particle size composition and particle graduation of compound soil tended to be more benign.

| \( M (F): m (S) \) | Volume average particle (mm) | \( d_i (mm) \) | Cu     | Cc   |
|-----------------|--------------------------|-------------|-------|-----|
|                 |                          | \( d_{10} \) | \( d_{30} \) | \( d_{50} \) |       |       |
| 1: 0            | 0.022                    | 0.0014      | 0.0049 | 0.0169 | 12.0714 | 1.0148 |
| 1: 1            | 0.133                    | 0.0023      | 0.0096 | 0.0528 | 23.0568 | 0.7622 |
| 1: 2            | 0.195                    | 0.0029      | 0.0268 | 0.2210 | 76.2069 | 1.1207 |
| 1: 5            | 0.267                    | 0.0068      | 0.0801 | 0.3720 | 54.7059 | 2.5364 |
| 0: 1            | 0.345                    | 0.1125      | 0.2250 | 0.3729 | 3.3156  | 1.2071 |

4. Discussion
The most lacking is clay for aeolian sandy soil, therefore which improved measures are that need to add clay or increase organic matter, and clay as “root-inducer” to improve aeolian sandy soil is early concerned at home and abroad [27-28]. We used local materials in Mu Us Sandy Land that is feldspathic sandstone as a kind of sand-fixing reagent, after joining in aeolian sandy soil, which is extremely important for the texture improvement of aeolian sandy soil and sand-fixing effect of feldspathic sandstone.

Aeolian sandy soil’s particle size is coarse in Mu Us Sandy Land, which mainly in the sand section. This result of aeolian sandy soil’s average particle size is similar to Zhi-pei Li et al study[29] that is the texture of feldspathic sandstone and aeolian sandy soil compound soil from sand to loam with the quality increase of feldspathic sandstone, which not only meet crop root ventilation needs, but also achieve to a certain fertilizer and water conservation effect[20], whose ability of anti-wind and water erosion gradually improved, therefore joining feldspathic sandstone in aeolian sandy soil is significant to enhance the role of sand-fixing in Mu Us Sandy Land. Felspathic sandstone has the effect of sand-fixing, contrary, aeolian sandy soil has some improvement to feldspathic sandstone of too high clay content easy to cause soil compaction [30]. After aeolian sandy soil be joined in feldspathic sandstone, the clay content of compound soil decreased, and this effect was obvious with the quality increase of aeolian sandy soil in compound soil, which indicated that aeolian sandy soil to improve the texture of compound soil can improve the soil hardening on account of too high clay content in feldspathic sandstone, therefore feldspathic sandstone and aeolian sandy soil can respectively make up for these deficiencies in each size distribution characteristics.

When \( m(F): m(S) \) was 1: 2 or 1: 5, Cu was greater than 10 and Cc was between 1 to 3, therefore which compound soil graduation characteristics was good and made for the shortcoming of aeolian sandy soil particle good diversity. But when \( m(F): m(S) \) was between 1: 2 to 1: 5, whether still has a good particle size distribution characteristic, remains to be further research.
5. Conclusion
From the texture characteristics, feldspatic sandstone can be used as a sand-fixing reagent to change the texture characteristics of aeolian sandy soil. With the quality increase of feldspatic sandstone in feldspatic sandstone and aeolian sandy soil compound soil, the small particle content of $<0.05$ mm increased, the large particle content of $>0.05$ mm reduced, sand content reduced, silt and clay content increased, the texture type changed for the better, and presented the change from sand to sandy loam to loam to silty loam. After adding feldspatic sandstone in aeolian sandy soil, changed these features of bad particle size distribution, homogeneous and single texture of aeolian sandy soil, and regarded this kind of mass ratio of m (F): m(S) was 1: 2 or 1: 5 as the best effect, whose particle size distribution become wide and particle graduation was continuous, whose Cu and Cc reached to the range of good particle graduation characteristics.

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