Effects of composite soil with feldspathic sandstone and sand on soil aggregates and organic carbon

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Abstract. The case was to study the effects of soils with different proportions of feldspathic sandstone and sand on soil stability and organic carbon at 0-30 cm soil depth with four different ratios (C1, C2, C3 and C4). They were used to prepare the composite soil in Fu Ping, Shaanxi Province of China, then the soil aggregates distribution, WASR, MWD, GMD, D value and organic carbon content were measured and analysed. The results showed: the soil stability of C1, C2 and C3 was better than C4, i.e., the composition could improve the soil stability. With the increasing of the planting years, the contents of soil aggregates with the size $\geq 0.25$ mm and MWD, GMD and SOC increased for each treatment at 0-30 cm soil depth, which was contrary to D values. WASR of C2 was significantly higher than others ($p<0.05$) after 3-year planting. The significant logarithmic relationships were found between the D values and the ratios in C1, C2 and C3. Besides C1 and C2 could increase the stability and content of large soil aggregates to improve soil structure; C2 could significantly increase the SOC than others at 0-30 cm soil depth.

1. Introduction

Mu Us Sandland is located between the southeast of Ordos Plateau and the north of Loess Plateau, China. Due to the improper agricultural reclamation and overgrazing, the region has encountered severe grassland degradation, desertification and productivity decrease [1,2,3]. Feldspathic sandstone and sand both are important composition in Mu Us Sandland. The bare feldspathic sandstone that weathered is easy to carry away with the wind and rain, which has been called the “cancer of environment” [4]. Chinese scientists and the local people studied the management of the Mu Us Sandland in a long time, and they mainly focused on the distribution, qualities and types of feldspathic
sandstone, the characteristics of water loss and soil erosion, control methods and ecological remediation. Han Liwen (2005) and Zheng Yuanrun (2006) reported that air seeding, afforestation and grass breeding in the sand area, and other integrated methods related to eco-system restoration and developing new models, which were all limited by the local natural conditions, resulting in innumerable measures with whatever physical or biological means merely had significant effects to reverse the desertification[5,6]. The ultimate reason could be the unstable soil structure, meaning that only by improving soil structure, can we rehabilitate the damage of desertification [7,8].

As the most basic soil structural element, soil aggregate has tremendous effects on soil physical and chemical characteristics, and thus its related parameters are very important to reflect the soil structure and stabilities [9,10]. Soil organic carbon is very important factor during the formation of soil aggregates. The close relationship between soil organic carbon and soil aggregates and maintaining soil organic carbon has been thought as a very vital strategy in releasing soil erosion, holding soil structure and improving soil grains condition[11,12]. The quantitative and dimensional distributions of soil aggregates in various sizes determine the distributions of soil pores and their continuity [13,14]. Among many different kinds of soil aggregates, water stable aggregate (WSA) is commonly used to evaluate the stability and anti-erosion ability of soil structure [15]. The characteristics of the distributions and stability of soil aggregates in a quantitative way was study in earlier time, but the study only focused on the soil grains’ proportions different sizes and the related parameters of soil aggregates in size over 0.25 mm (R0.25) .Then Van Bavel calculated the weighed sum of the data of soil aggregates in different sizes, and came up with the concept “mean weight diameter (MWD)”[16].The higher values of MWD means the larger proportion of soil aggregates and more stable of soil. Soil particles and their aggregates also have considerable characteristics of distribution, which could be analyzed by fractal dimension (D) method. Basically, higher D value means better soil aggregate structure and stability[17,18,19].

Generally, the structure of soil matrix could be improved by covering healthy soil on the local area. But Mu Us Sandland lacks loess soil, and the cost of long distance transportation is considerably high. From the perspective of resources, feldspathic sandstone and sand both are very important local natural resources. Feldspathic sandstone is in the form between soil and parent materials, but apt to rigidify during drying. So it affects the permeability of gas and water, and root extension. But feldspathic sandstone swells rapidly in water, becoming very good material to hold moisture. The sand, without solid structure, has very good permeability in both dry and wet conditions but is poor at water retention. It would be great if we could use their complementarity in texture and permeability to improve the local soil quality. Related study has been focusing on soil texture, parameters related to the variation of water and fertility under compositesoil with different proportions of feldspathic sandstone and sand. The object of this study was to explore the contents of soil aggregates in different sizes, the contents of R0.25, the stability of soil aggregates, the mean weight diameter (MWD), fractal dimension value, the contents of soil organic carbon and their variations under different composite artificial soil with different proportions of feldspathic sandstone and sand. Then the winter wheat was planted in the composite artificial soil, and the effects of different artificial soils on the wheat were compared.
2. Materials and methods

2.1 Site description
The experiment was carried out at Fu Ping Research Station at Zhe Yuan Village of Du Cong, Fu Ping County, City of Weinan, Shaanxi Province, China (109°11′N, 34°42′E, 492m above sea level). The area belongs to temperate semi-humid climate, the average annual rainfall capacity is 472.97 mm and 49% of it happens during July and September. The annual evaporation ranged from 1000 to 1300 mm, and frost-free period, average temperature, highest temperature in the summer, lowest temperature in the winter were 225 d, 13.4°C, 41.8°C, -2°C respectively and annual total energy from optical radiation were 123.9~127.8 kca/cm². All the parameters could satisfy the basic demand for crop growth.

2.2 Experimental design
The experiment was performed during September 2008 to June 2011. To simulate the soil composited by feldspathic sandstone and sand in situ in Mu Us Sandland the experimental plots were filled with 70 cm depth of parent materials using pure sand, and 30 cm of artificial soil, which were consisted of feldspathic sandstone and sand in different ratio in top layer. The feldspathic sandstone and sand was from Da Jihan Village, Xiaojihan Town, Yu Yang District, the City of Yulin, Shaanxi Province, which belongs to the typical Mu Us Sandland region. According to the study that the turning point of the decreasing rate of the hydraulic conductivity of composite soils appeared when 1:2 volume ratio of feldspathic sandstone to sand was used. Hence the volume ratio gradients of feldspathic sandstone to sand for the 4 treatments were 1:1(C1), 1:2(C2), 1:5(C3), and 1:2 (C3) for the C4, consisted of sand. The experiment measured the differences of soil aggregates and organic carbon between the each other treatment. Each plot had an area of 4 m² (ie., 2m × 2m), with three replicates. The whole experimental area laid out from the north to the south. The composition of composite soil in different treatments was showed in table 1 before planting.

Table 1. Different mixed ratio of feldspathic sandstone and sand on soil texture before planting.

| Treatments | Diameter of particles content (%) | Soil texture |
|------------|----------------------------------|--------------|
|            | Sand (%)                         | Silt (%)     | Clay (%)   |
| C1         | 39.57b                           | 49.38a       | 8.24a   | Loamy soil |
| C2         | 52.74ab                          | 38.88b       | 8.38a   | Sandy loam |
| C3         | 70.79a                           | 24.08b       | 5.13a   | Sandy loam |
| C4         | 94.07b                           | 3.20b        | 2.73b   | Sand       |

Note: Multiple comparisons were between the treatments in the same line. Letters indicate significant differences among different treatments

2.3 Materials
Winter wheat: Xiaoyan 22, thousand grain weight: 38g, germination percentage: 90.1%, rate of seeding: 150 kg/hm², row spacing: 20 cm. sowing by drilling.

2.4 Fertilizing treatment
Granulated fertilizer was added in the form of phosphorus (P) as \((\text{NH}_4)_2\text{HPO}_4\) (180 kg/hm\(^2\)), potassium (K) as KCl (90 kg/hm\(^2\)), and nitrogen (N) as CO(NH\(_2\))\(_2\) (255 kg/hm\(^2\)) in each plot.

The fertilizers were applied on 18\(^{th}\) September 2008, 20\(^{th}\) September 2009 and 24\(^{th}\) September 2010, when the winter wheat was planted. To make sure thorough blending of the top soil and fertilizers, seeding and tillage were used in this experiment. No fertilizers were used during the growing season. And winter wheat were irrigated once prior to the tillering stage with the same amount of water in 4 treatment plots.

2.5 Sampling and Measurement

2.5.1 Soil aggregates measurement. At harvest (June 6\(^{th}\) 2009, June 10\(^{th}\) 2010 and June 8\(^{th}\) 2011), we collected the surface soil at 0- 30 cm soil depth were collected, and the residuals and large rocks were removed. At last samples were dried by natural air. Quartering method was used to get the soil samples (total weight not less than 400 g). Subsequently, each soil sample was separated into three types by sieves of 5 mm and 2 mm, i.e., larger than 5 mm, 5 – 2 mm and less than 2 mm. Then samples were weighed separately as \(a_1\), \(a_2\), \(a_3\) (g) and the total weight \(a\) (g). Finally, the separated soil was mixed into 4 plastic bags in total, and each weight was 50 g.

The soil aggregates sizes distributions and stabilities were measured using both dry sieving and wet sieving methods. The dry sieving method: soil were sieved through 5, 2, 1, 0.5 and 0.25 mm mesh vertically from top to bottom. The piled sieves were shaken at 200 round/min for 2 min. then the soil was collected from each sieve with different grain sizes such as larger than 5 mm, 5 – 2 mm, 2 – 1 mm, 1 – 0.5 mm, 0.5 – 0.25 mm and less than 0.25 mm. Then samples were weighted as \(W_{di}\). The wet sieving method: four separated samples were put into different plastic cups, and then were added into water to stabilize for 10 min. Then the dispersed samples were sieved through 5 sieves (the hole diameters were 5mm, 2mm, 1mm, 0.5mm and 0.25 mm, respectively), and shaken up and down within 3 cm vertically, and finally were washed into aluminum boxes and then dried at 105°C for 12 hours. At last, samples were weighed as \(W_{wi}\).

2.5.2 Soil organic carbon measurement. The top soil samples were collected at 0- 30 cm soil depth at harvest and the crop residuals and small rocks were removed. Then samples were dried by natural air. Quartering method was used to get the soil samples through the 0.149 mm sieves for measuring the carbon. using Potassium dichromate volume method were used (by using \(K_2\text{Cr}_2\text{O}_7-\text{H}_2\text{SO}_4\) solution to oxidize the carbon in soil organic matter under oil-bath heating condition, \(\text{Cr}_2\text{O}_7^{2-}\)turned to \(\text{Cr}^{3+}\), and the remained \(K_2\text{Cr}_2\text{O}_7\) was titrated by standard \(\text{FeSO}_4\) solution, finally, the content of organic carbon could be calculated based on the consumed \(K_2\text{Cr}_2\text{O}_7\)).

2.6 Statistical analyses

To calculate the content of water stable aggregates, with wet sieving method,

\[
W_i = \frac{W_{ori}W_{wi}}{50} \times 100\%.
\]

Where \(W_i\) is the mass proportion of i size soil aggregates, e.g. To calculate the mass proportion of the aggregates with size over 0.25 mm (\(R_{0.25}\)), mean weight diameter (MWD) and geometric mean diameter(GMD) [20].


\[ R_{0.25} = \sum_{i=1}^{n} (W_i) \]  
\[ MWD = \sum_{i=1}^{n} (\bar{X}_i \times W_i) \]  
\[ GWD = \sum_{i=1}^{n} (\bar{X}_i \times W_i) \]

To calculate the water stable aggregates rate:

\[ \text{WSAR} = \frac{\text{WSA}}{\text{MSA}} \times 100\% \]  

Where WSA is the mass of water stable aggregates in size over 0.25 mm, MSA is the mass of stable aggregates in size over 0.25 mm.

Fractal dimension values were calculated using the equation below by Yang Peiling et al [17].

\[ \frac{M(r \leq \bar{X}_i)}{M_i} = \left( \frac{\bar{X}_i}{X_{\text{max}}} \right)^{3-D} \]  

Take logarithm for both sides,

\[ \lg \left[ \frac{M(r \leq \bar{X}_i)}{M_i} \right] = (3-D) \lg \left( \frac{\bar{X}_i}{X_{\text{max}}} \right) \]  

Where \( \bar{X}_i \) the mean diameter of the aggregates is in a specific size, \( M(r \leq \bar{X}_i) \) is the mass of aggregates in size less than \( \bar{X}_i \), \( M_i \) is the total mass of aggregates (50 g), \( X_{\text{max}} \) is the maximum diameter of aggregates. D value can be obtained by linear regression using equation (6) and (7) through least square fitting method.

Using Origin 8 to process the data and figures, and then SPSS (PASW Statistics 18) was used to do the data statistical analysis and the multiple comparisons were done using duncan's new multiple range method (SSR).

3. Results and analysis

3.1 Water-stable aggregates distribution characteristics among three planting seasons under Different mixed ratio of feldspathic sandstone and sand

Dry sieving and wet sieving were commonly used to study the distribution of soil aggregates. Stable aggregates that are able to resist mechanical force, could be obtained by dry sieving which includes both aggregates of resisting water and unresisting water. Water resisting and stable soil aggregates could be acquired by wet sieving. For the composited artificial soils, quantities and distributions of aggregates could be obtain by wet sieving that demonstrate more characteristics of stability, water retention, permeability and ability of resisting erosion of soil structure[21]. Hence wet sieving method was used in this study to determine the proportions of soil aggregates by their grain sizes at >5 mm, 5 - 2 mm, 2 - 1 mm, 0.5 – 1 mm, 0.25 - 0.5 mm and >0.25 mm (table 1). The aggregates that were larger...
than 0.25 mm were called $R_{0.25}$ in this study and were very important for the soil structure, and their proportions have positive correlation with soil fertility [22,23]. This study found that the amount of $R_{0.25}$ increased with the years of planting but decreased with the increase of the proportion of the sand in the treatments. Treatment C4 had the highest amount of $R_{0.25}$ with an average of 18.93%; the treatments C1, C2, C3 and C4 all had the least amount of aggregates, with their average sizes during 1 - 0.25 mm in the three years; In 2009 and 2010, treatments C1, C2 and C3 had the most amount of aggregates, and their sizes were larger than 5 mm, with percentage of 24.84% - 37.36% of $R_{0.25}$. In 2011, the aggregates’ sizes between 1 and 0.5 mm were 32.91% - 37.19% of $R_{0.25}$, indicating soil aggregates with their size larger than 0.25 mm were enriched during 1 - 0.5 mm, and soil aggregates in treatment C1 were significantly higher than that in others by 0.44~2.85 percentages ($p<0.05$). Treatments C1, C2, and C3 all had significantly more the amount of $R_{0.25}$ in 2011 were significantly higher than that in 2009 by 28.99%, 48.67%, 41.45% and 48.32 % ($p<0.05$) respectively. With the increasing of planting years, treatments C1, C2 and C3 all had higher the amount of average $R_{0.25}$ in treatments C1, C2 and C3 were significantly higher than C4.

Table 2. Soil aggregate size fraction content by wet sieving at 0-30 cm depth under different percentage of mixed sand on soil texture from 2009 to 2011.

| Year | Size fraction (mm) | Treatments / WSA (%) |
|------|-------------------|----------------------|
| 2009 | >5                | C1       | C2       | C3       | C4       |
|      | 6.63a             | 6.88a    | 5.61ab   | 1.62b    |
|      | 2-5mm             | 6.78a    | 4.79ab   | 4.12bc   | 2.44c    |
|      | 1-2mm             | 2.43a    | 1.65a    | 1.02b    | 1.58b    |
|      | 0.5-1mm           | 4.65a    | 2.44b    | 2.48b    | 2.51c    |
|      | 0.25-0.5mm        | 5.80ab   | 5.33ab   | 4.79b    | 7.35a    |
|      | >0.25mm           | 26.69b   | 21.08ab  | 18.02a   | 15.50a   |
| 2010 | >5                | 7.15a    | 7.77a    | 7.78a    | 3.39b    |
|      | 2-5mm             | 6.44a    | 6.54b    | 4.75b    | 8.61a    |
|      | 1-2mm             | 3.20a    | 2.23ab   | 1.99b    | 1.69b    |
|      | 0.5-1mm           | 4.64a    | 4.80b    | 2.68bc   | 1.78c    |
|      | 0.25-0.5mm        | 5.89a    | 4.48a    | 3.62b    | 3.45b    |
|      | >0.25mm           | 27.32b   | 25.82a   | 20.82a   | 18.92a   |
| 2011 | >5                | 8.11a    | 6.42a    | 5.61a    | 3.28a    |
|      | 2-5mm             | 6.86a    | 6.01ab   | 4.34bc   | 6.39c    |
|      | 1-2mm             | 2.89a    | 2.06a    | 1.41b    | 1.25b    |
|      | 0.5-1mm           | 11.33a   | 10.89b   | 9.48bc   | 8.48c    |
|      | 0.25-0.5mm        | 6.01a    | 5.96a    | 4.66ab   | 3.59b    |
|      | >0.25mm           | 34.43b   | 31.34ab  | 25.49a   | 22.99a   |

Multiple comparisons were between the treatments in the same line. Letters indicate significant differences among different treatments at 5% level of probability (SSR).
3.2 Water-stable aggregates rate among three planting seasons

Equation (5) calculated the water aggregate stability rate (WASR) of each treatment in 2009, 2010 and 2011. In 2009 and 2010, at 0-30 cm soil depth, the WASRs of different treatments decreased with the increase of sand proportions in the composite soils, but increased the planting years. The WASRs in each treatment ranked as C1 > C2 > C3 > C4. There were significant differences between the C4 and C1 or C2, but there were no significant differences compared with C3 (p<0.05). In 2011, for C2 the highest WASR was 22.76%, which was higher than that in other treatments (p<0.05). According to Figure 1, the average WASR in C1 treatment was higher than that in C2, C3 and C4 by 2.97%, 21.88% and 31.90%, respectively, but no significant difference with C2 (p<0.05).

![Figure 1](image_url)

**Figure 1.** WASR of wet sieving at 0-30 cm depth under different percentage of mixed sand on soil texture form 2009 to 2011. Letters indicate significant differences among different treatments at the 0.05 levels (p < 0.05).

3.3 Mean weight diameter (MWD) and Geometric mean diameter (GMD)

The mean weight diameter (MWD) and geometric mean diameter (GMD) of soil aggregates indicated their size distributions. And the higher MWD and GMD demonstrated the higher degree of concentration of aggregates and stabilities. Different sizes of soil aggregates have different abilities to coordinate, maintain, supply soil nutrients, and to improve soil porous networks, hydraulic and biological properties. So that is reason that the sizes of distributions are very important to soil qualities. This study used the soil aggregates with sizes over 0.25 mm were used in this study and their MWD and GMD were calculated to evaluate the soil aggregates stabilities (Table 3).

During the same year, negative correlation was found between the proportions of sand and MWD or GMD of each treatment. Both the MWD and GMD decreased with the increasing proportion of sand. The MWD and GMD were positively correlated with the planting year in the same treatment, i.e., they both increased in the year after. In 2009, there were no significant differences between the MWD from each treatment, but the reverse was true for the GMD (p<0.05). MWD and GMD in treatments C1, C2 and C3 were significantly higher than that in C4 (p<0.05) in 2010 and 2011. The three-year
average MWD and GMD of C1 were significantly higher than that of C2, C3 and C4 by 9.88%, 29.61% and 39.06% for MWD, and 18.84%, 26.15% and 43.85% for GMD, respectively (p<0.05).

**Table 3.** The mean weight diameter (MWD) and geometric mean diameter (GMD) at 0-30 cm depth under different percentage of mixed sand on soil texture from 2009 to 2011.

| Years | Parameters | C1  | C2  | C3  | C4  |
|-------|------------|-----|-----|-----|-----|
| 2009  | MWD        | 0.83a| 0.72a| 0.64a| 0.63a|
|       | GWD        | 0.26a| 0.22ab| 0.20b| 0.15c|
| 2010  | MWD        | 0.85a| 0.74b| 0.69b| 0.64c|
|       | GWD        | 0.27a| 0.23b| 0.22bc| 0.21c|
| 2011  | MWD        | 0.99a| 0.97a| 0.79a| 0.65ab|
|       | GWD        | 0.29a| 0.24a| 0.23a| 0.21ab|

MWD : mean weight diameter, GWD : mean geometric diameter.

3.4 Fractal dimension characteristics

The fractal dimension of soil aggregates under each treatments was fitted using equation (7) (the values of $R^2$ were all higher than 0.92). Then the values of fractal dimension (D value) for each treatment at 0 – 30 cm depth could be calculated (Figure 2) as 2.89 – 2.96. The figure showed that the D values for each treatment had similar trend of curves, and all went downward with the passing of the planting years. The D values in 2011 were lower than that in 2010 by 1.21% - 3.20%. The average D values of C1 and C2 were lower than that of C3 and C4 by 13.75% and 16.76%, respectively, and 0.79% and 10.99%, respectively. The D values were mainly related to the proportions of water stable aggregates for each treatment, i.e., with the increasing of the planting years, more interactions of crop roots and soil particles were involved, which may increase the contents of larger soil aggregates, thus resulting in the decreasing trend of D values.

![Figure 2](image-url)  
**Figure 2.** Fractal dimension of soil aggregates at 0 - 30 cm depth under different percentage of mixed sand on soil texture from 2009 to 2011.
3.5 Soil organic carbon

This study found that soil organic carbon mainly contributed to the formation of soil water stable aggregates, which was an important element between soil aggregates and B. The decrease of soil organic carbon would result in the loss of larger soil aggregates and deteriorated soil quality[24]. Crops could significantly increase the amount of soil organic carbon, showing positive effect of carbon sequestration. On the other hand, with the increasing of the proportions of sand in the artificial soils, soil stability decreased, which could result in decomposition of soil organic carbon and emission of CO₂.

The study showed that soil organic carbon (SOC) contents significantly differed from each other treatment (p<0.05) (table 4). Significant trends that with the year increase the SOC also increased at 0 – 30 cm soil depth, were found. There were no significant differences among the contents of the SOC of C1 in the three years. There were significant differences between the SOC from C2, C3 and C4 in 2009 and 2010, and that from 2011 (p<0.05). In 2011, the SOC contents of C1(1.18g/kg), C2(1.22g/kg), C3(1.11g/kg) and C4(0.41g/kg) in 2011 were higher than that in 2009 by 52.54% - 77.29%.

Table 4. Effects of different percentage of mixed sand on soil texture on soil organic carbon in 0-30 cm from 2009 to 2011. /g/kg.

| Treatments | C1      | C2      | C3      | C4      |
|------------|---------|---------|---------|---------|
| 2009       | 0.42±0.03aAB | 0.57±0.13bA | 0.45±0.03bB | 0.28±0.04bC |
| 2010       | 0.98±0.84aB | 1.24±0.11bA | 1.06±0.28bA | 0.38±0.11bC |
| 2011       | 1.85±0.48aAB | 1.98±0.35aA | 1.83±0.87aB | 0.59±0.09aC |

Note: values followed by the different letters are significantly different at P<0.01 and P<0.05, the data: mean ± standard deviation.

4. Discussion

Soil aggregates, as a very important component in soils, are the key factors to maintain and coordinate water and nutrition in soil, and to affect the types and activities of enzymes, and to stabilize the loose slaking soil layers that directly influence the productivity of crops[25]. The size of aggregates over 0.25 mm (R₀.₂₅) are called soil structural aggregates, which are the best structural units in soil, whose percentages are very important to indicate structure related to soil qualities, eg., the R₀.₂₅ contents had positive correlation with soil fertility. The size of soil aggregates less than 0.25 mm are called miro-soil aggregates[14]. Many researchers had confirmed that different tillage regimes would affect the transition and redistribution between the soil structural aggregates and miro-soil aggregates[26,27] 0, resulting in changing the structural stabilities and anti-erosion abilities. The wet sieving method is used to determine the characteristics of water stable aggregates, since water stable aggregates also has great contribution to maintaining soil structural stability[28]. In this study, the 3-year experiment with different ratios of feldspathic sandstoneto sand in different composited soil treatments showed that the soil aggregates over 0.25 mm from each treatment increased with the increase of the planting years. Result may indicate that the mixture of artificial soils could enhance the capability to maintain
water and nutrition. And the SOC increasing could lead to forming more water stable aggregates and improving the incompact structure of sand, also could alleviate the hardening phenomena of feldspathic sandstones. In the same planting year, the soil aggregates over 0.25 mm decreased with the increase of the proportions of sand, and the average size of soil aggregates over 0.25 mm in treatments C1 and C2 were 29.48% and 26.08% over the three years, respectively. which were higher than that in C3 and C4, meaning proper mixture of the composited soils could improve the structural quality of soil.

The mean weight diameter of soil aggregates (MWD) and geometrical mean diameter (GMD) at some degree could reflect the distribution characteristics of soil aggregates[29]. This study found that there were negative correlations between the values of MWD and GMD and the percentages of the sand in the same year, and there were positive correlations between the values of MWD and GMD and the planting years. The MWD and GWD values in 2011 were higher than that in 2009 by 3.17% - 23.43% and 7.41% - 40.1%, respectively.

The values of fractal dimension (D values) also could be used to indicate the change of soil structure[30]. The higher proportions of clay particles, finer texture and weaker permeability of soil indicated higher D values[3,18]. It was reported that the D values of soil had significant negative correlations with the contents of large soil aggregates[31,32]. Liu Yunpeng et al studied the D values of 4 types of soils in Shaanxi, China, indicating that D values were ranged from 2.63 to 2.87, and the ideal value should be around 2.75[33]. This study discovered that the D values of each treatment all decreased with the passing planting year, but increased with the increase of the sand proportions in soil. And the 3-year average D values were between 2.89 and 2.94, which were higher than the ideal value. Result may need related practices, eg., increasing the planting years and reducing tillage activities to reduce D values.

The soil organic carbon contents would significantly affect the proportions and distributions of soil aggregates[34]. Higher amount of SOC contents could improve soil structure and enhance its stability[35]. The sequestration of SOC could reduce the scattering of large aggregates, which in turn reduces the decomposition rate of SOC[36]. This study showed that the SOC contents at 0 – 30 cm soil depth increased with the increase of planting years. Puget et al. found that SOC in soil miro-aggregates was more stable than that in large soil aggregates, but the amount of SOC was more in the larger sizes of soil aggregates[37], which was consistent to this study. The increase of SOC of treatment C1 in 2011 were higher than that in 2010 by 77.92%. The amount of average SOC was the highest in the 3 years. Total organic carbon content was lower than normal organic carbon content, but through the reasonable fertilizer and farming methods, the soil organic carbon content could increase, and thus the reasonable fertilizer and farming methods could contribute to improve the large aggregate content.

This study only tested the effects of the composite soils under a 3-year experiment with limited treatments, because longer term of experiment are need to further study the effects of other mixture ratios of feldspathic sandstone to sand on soil structure. Only by synthesizing the economic benefits, technique difficulties and soil structure, water movement and crop growth status affected by specific combination of feldspathic sandstone and sand, could we evaluate its application more accurately[38,39].
5. Conclusion
The 3-year experiment showed that the soil structure was improved with the increase of the planting years, and the amount of the soil aggregates over 0.25 mm were significantly increased, and the stability of soil structure also improves. After 3-year experiment, there were significant differences among the contents of soil aggregates in composite artificial soil. With the increase of the planting years, the soil aggregates stabilities, mean weight diameter, geometric mean diameter and fractal dimension were all affected. Treatment C1 and C2 all had better comprehensive indices than C3 and C4. There were high correlations between the ratios of sand in treatments C1, C2 and C3 and the values of fractal dimension ($R^2=0.9701$). Significant improvements were found in treatments C1 and C2, and their composite ratios are recommended.

After 3-year experiment, there were increasing trends of soil organic carbon at 0 – 30 soil depth, and the highest content of SOC was 1.22g/kg, observed in treatment C2 at 0- 30cm soil depth.

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