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The Effects of Different Ratios of Feldspathic Sandstone and Sand Compound Soil on Water-stable Aggregates in 4 Years Crop Planting

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Abstract To study the formation process of feldspathic sandstone and sand compound soil in the Mu Us Desert, 1:1, 1:2 and 1:5 ratios of feldspathic sandstone and sand were mixed to obtain compound soil to plant crops, and analyze the rules of changes in water-stable aggregates of the compound soil among the 4 years crops growing process. The results showed, before crop planting, the order of mass percent of > 0.25 mm and 0.25 – 2.00 mm water-stable aggregates in three kinds of compound soil was 1:1 > 1:2 > 1:5, showing that the overall content was low; the mass percent of > 0.25 mm water-stable aggregates remained at 18.38% – 28.22%; the mass percent of 0.25 – 0.50 mm, 0.50 – 2.00 mm, 2.00 – 5.00 mm, and > 5.00 mm water-stable aggregates was close with each other in each kind of compound soil. After 4 years of planting, the mass percent of > 0.25 mm water-stable aggregates in 1:2 compound soil increased significantly and exceeded other 2 kinds of compound soil, reached 32.34%; the main components of > 0.25 mm water stable aggregates in 1:1, 1:2, and 1:5 compound soil were 0.25 – 0.50 mm (53.54%), 0.25 – 0.50 mm (59.43%), 0.05 – 2.00 mm (52.16%), aggregates; 0.25 – 2.00 mm aggregates increased significantly in all three kinds of compound soil, with the highest increase in 1:2 compound soil; the organic matters of 1:2 compound soil were significantly correlated with 0.25 – 0.50 mm and 0.25 – 2.00 mm water-stable aggregates. The results showed that the ratio of 0.25 – 2.00 mm aggregates in the three kinds of compound soil was increased after 4 years of crop planting and 1:2 compound soil was most favorable for the formation of aggregates.

Key words Feldspathic sandstone and sand compound soil, Water-stable aggregates, Cementation

1 Introduction

Soil aggregates are the basic structural units of soil. In the soil, soil aggregates have the functions of ensuring the soil water, fertilizer, gas and heat, affecting the soil enzymes and activity, and maintaining the soil looseness and curing layer. Different soil particles of aggregates play different roles in the maintenance, supply and conversion of nutrient elements[1]. The soil aggregate structure is the material basis of soil fertility and is an essential condition for high yield of crops. The formation of soil aggregates is a very complex process, including a series of physical, chemical and biological effects, mainly depending on the quantity and nature of cementing matters in the soil[2]. Soil parent material, as the material basis of soil formation, has a great influence on the composition and effect of soil inorganic colloid, while the formation of organic cementing matters is related to the quantity of microorganisms, the activity and its metabolites and plant root exudates and input of organic matters[3]. The stability of aggregates refers to the ability of aggregates to maintain their original form in response to external forces or external environmental changes, including water stability, mechanical stability, chemical stability, acid-base stability and biological stability[4], in which water-stable aggregates are important indicators for assessing land quality. The quantity and stability of soil aggregates are also important indicators of soil erodability[5-6].

The desertification of Mu Us Desert is serious, natural vegetation is sparse, and it is rich in feldspathic sandstone and sand compound soil; the former is loose in cementation when dry, it rapidly expands in water, and the latter has no structure, water retention is poor[7], according to their characteristics, mixed in certain proportion, it is able to plant crops[8-10], thus, it is of great significance for in-depth study of soil formation. Taking the experimental plot of feldspathic sandstone and sand compound soil as the object, we studied the rules of changes in water-stable aggregates with increase in the years of crop planting in different ratios of compound soil, in order to reveal the formation process of water-stable aggregates, to provide a theoretical basis for soil formation mechanism, and the study results have great significance for further utilizing functions of aggregates to cultivate soil fertility, and also provide theoretical and technical guidance for soil formation and field building project of large scale popularization of feldspathic sandstone and sand compound soil for Mu Us Desert.

2 Materials and methods

2.1 Materials Samples of feldspathic sandstone and sand were taken from Xiaojihan Village, Yuyang District, Yulin City in

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Shaanxi Province. The percentage of clay particles, powder and sand grains of feldspathic sandstone and sand was 7.06%, 58.09%, 34.85% and 0.24%, 4.45% and 95.31% respectively. The collected feldspathic sandstone and sand were naturally air-dried, and ground and screened with 2 mm sieve. The experiment was carried out in Fuping Experimental Base of ShaanxiLand Engineering Construction Group. The county is 375.8 – 1420.7 m above sea level. The climate belongs to mild temperate semi-arid continental monsoon climate with annual total radiation volume of 5 187.4 MJ/m^2, annual average sunshine of 2 389.6 h, the average annual temperature of 13.1 ℃, and the average annual rainfall of 527.2 mm (in 1960 – 1995).

2.2 Experiment design The experimental area was 9 artificial plots arranged from the north to south, each plot had an area of 2 m × 2 m and 1 m depth, 30 – 70 cm section in all plots are sandy soil, 0 – 30 cm arable layer was compound soil evenly mixed with different ratios of feldspathic sandstone and sand. The volume ratio of feldspathic sandstone and sand was 1:1, 1:2, and 1:5, and each ratio was arranged with 3 repeated plots. From 2010, 3 plots of each ratio of compound soil were planted with winter wheat-maize, winter wheat-soybean, winter wheat-potato every year and local traditional methods were used to irrigate and apply fertilizer. The maize variety was Hudan 4, the wheat variety was Xiaoyan 22, the soybean variety was Qindou 11, and the potato variety was Xiabodi. Before planting of maize, soybean and potato, base fertilizer (300 kg/ha diammonium phosphate and 150 kg/ha urea) was applied, one time of irrigation and topdressing 150 kg/ha urea was implemented in spring, wheat irrigation was divided into spring irrigation, grain filling irrigation, and winter irrigation, and 150 kg/ha urea topdressing was applied in spring irrigation and winter irrigation.

2.3 Measurement items and methods Samples of each kind of compound soil were collected before the crop planting in 2010, after crop harvesting in 2010, 2011, and 2014 (marked as 0 year, 0.5 year, 1 year, and 4 years of crop planting), to measure the water stable aggregates and organic matters of soil. The content of water-stable aggregates was measured by traditional wet sieve method[11], while organic matters were measured using the potassium dichromate heating method[12].

2.4 Data processing Data were analyzed by Excel 2003, ANOVA in SPSS 17.0 was used to do single factor variance analysis, and least significant difference (LSD) was used to conduct the difference test.

3 Results and analyses

3.1 Changes in the content of water-stable aggregates of three kinds of compound soil with crop planting years

3.1.1 Changes in >0.25 mm water-stable aggregates of three kinds of compound soil. As shown in Fig. 1, the mass percent of >0.25 mm water-stable aggregates was 1:1 > 1:2 > 1:5 for 3 ratios of feldspathic sandstone and sand compound soil, and the value was 28.22%, 21.55%, and 18.38% respectively. After 1 year of planting, there was no significant change in the three kinds of compound soil and the difference in changes of each kind of compound soil was not significant ($P > 0.05$). After 4 years of planting, the mass percent of 1:2 compound soil increased significantly, reaching 32.34%, which was 50.07% higher than that before planting and the difference was significant ($P < 0.01$), while there was no significant change in 1:1 and 1:5 compound soil, with the former dropping by 3.15% and the latter dropping by 2.29%, and the difference was not significant ($P > 0.05$). After 4 years of planting, the order of mass percent of >0.25 mm water-stable aggregates in three kinds of compound soil was 1:2 > 1:1 > 1:5.

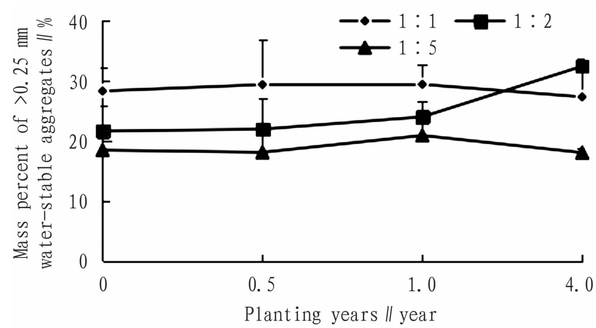

Fig. 1 Changes in the content of >0.25 mm water-stable aggregates of three kinds of compound soil with crop planting years

3.1.2 Changes in 0.25 – 2.00 mm water-stable aggregates of three kinds of compound soil. As shown in Fig. 2, before crop planting, the mass percent of 0.25 – 2.00 mm water-stable aggregates in 1:1 compound soil of feldspathic sandstone and sand was 13.24%, significantly higher than 9.13% and 8.44% in 1:2 and 1:5 compound soil, showing significant difference ($P < 0.05$). After 1 year of planting, the mass percent of 0.25 – 2.00 mm water stable aggregates in three kinds of compound soil had no significant change. After 4 years of planting, the mass percent of 0.25 – 2.00 mm water-stable aggregates in three kinds of compound soil increased significantly, the mass percent of 1:2 compound soil increased to 26.63%, which was 191.68% higher than that before planting, showing the largest increase; the mass percent of 1:1 compound soil increased to 21.16%, increasing by 59.82%; the mass percent of 1:5 compound soil increased to 13.87%, increasing by 64.34%; compared with before the crop planting, there were significant changes in all three kinds of compound soil ($P < 0.01$). The order of mass percent of 0.25 – 2.00 mm water-stable aggregates was 1:2 > 1:1 > 1:5, and the mass percent of water-stable aggregates in 1:2 compound soil was 1.26 times of that in 1:1 compound soil, and 1.92 times of that in 1:5 compound soil. Combining Fig. 1, it can be known that in the 1:1, 1:2 and 1:5 compound soil, the mass percent of 0.25 – 2.00 mm water-stable aggregates to >0.25 mm aggregates changed from 46.92%, 42.37% and 45.92% before crop planting to 77.71%, 82.34% and 77.23% after 4 years of crop planting. At this time, 0.25 – 2.00 mm aggregates became major components of >0.25 mm water-stable aggregates.

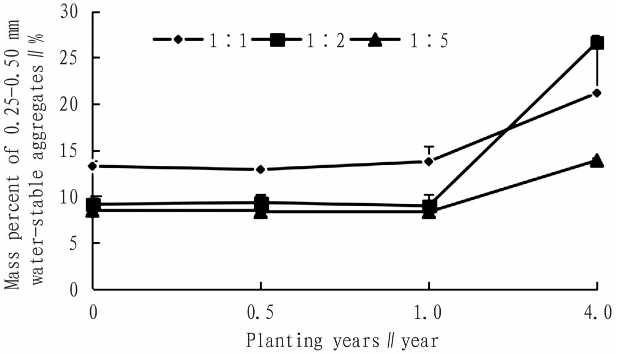

Fig. 2 Changes in the content of 0.25 – 2.00 mm water-stable aggregates of three kinds of compound soil with crop planting years

3.2 Changes in 4 different grain size of water-stable aggregates of each kind of compound soil with crop planting years

3.2.1 Changes in water-stable aggregates in 1:1 compound soil. As shown in Fig. 3, before crop planting, the mass percent of 0.25 – 0.50 mm, 0.50 – 2.00 mm, 2.00 – 5.00 mm, and > 5.00 mm water-stable aggregates in 1:1 feldspathic sandstone and sand compound soil was 6.01%, 7.23%, 6.86%, and 8.11% respectively; after the half year and one year planting, there was little change in the mass percent of each grain size, the fluctuation range was 5.80% – 9.63%, showing no significant difference ($P > 0.05$). After 4 years of planting, there were significant changes in each grain size of water-stable aggregates in compound soil. Compared with that before planting, the mass percent of 0.25 – 0.50 mm water-stable aggregates increased to 14.58%, increasing by 142.60%; the mass percent of 0.50 – 2.00 mm water-stable aggregates had little change; the mass percent of 2.00 – 5.00 mm water-stable aggregates dropped to 3.12%, reducing by 54.52%; the mass percent of > 5.00 mm water-stable aggregates dropped to 2.95%, reducing by 6.63%; except 0.50 – 0.02 mm water-stable aggregates, the mass percent of other three grain size of water-stable aggregates had significant difference between that before and after the crop planting ($P < 0.05$).

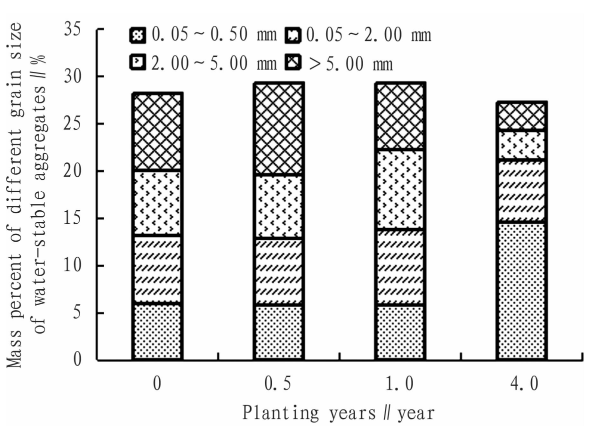

Fig. 3 Changes in the content of 4 grain size of water-stable aggregates of 1:1 compound soil with crop planting years

3.2.2 Changes in water-stable aggregates in 1:2 compound soil. As shown in Fig. 4, before crop planting, the mass percent of 0.25 – 0.50 mm, 0.50 – 2.00 mm, 2.00 – 5.00 mm, and > 5.00 mm water-stable aggregates in 1:2 feldspathic sandstone and sand compound soil was 4.06%, 5.07%, 3.94%, and 8.47% respectively; after the half year and one year planting, there was little change in the mass percent of each grain size; after one year of planting, the mass percent of > 0.25 mm water-stable aggregates increased by 11.00% compared with that before planting, but the difference was not significant ($P > 0.05$). After 4 years of planting, there were significant changes in each grain size of water-stable aggregates in compound soil. Compared with that before planting, the mass percent of 0.25 – 0.50 mm water-stable aggregates increased to 19.22%, increasing by 373.40%; the mass percent of 0.50 – 2.00 mm water-stable aggregates increased to 7.42%, increasing by 46.35%; the mass percent of 2.00 – 5.00 mm water-stable aggregates had little change; the mass percent of > 5.00 mm water-stable aggregates dropped to 2.30%, reducing by 72.85%; except 2.00 – 0.02 mm water-stable aggregates, the mass percent of other three grain size of water-stable aggregates had significant difference between that before and after the crop planting ($P < 0.05$). The mass percent of > 0.25 mm water-stable aggregates increased by 33.36%, showing significant difference ($P < 0.01$).

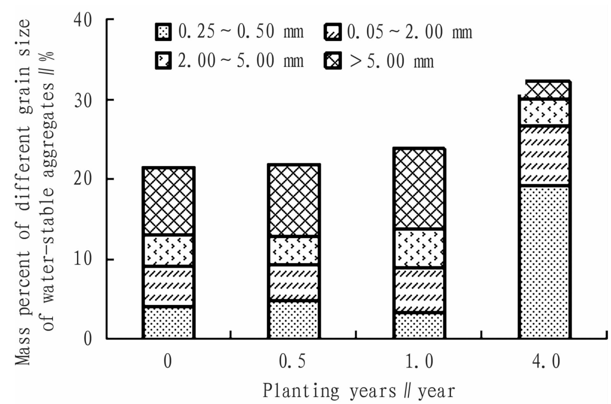

Fig. 4 Changes in the content of 4 grain size of water-stable aggregates of 1:2 compound soil with crop planting years

3.2.3 Changes in water-stable aggregates in 1:5 compound soil. As shown in Fig. 4, before crop planting, the mass percent of 0.25 – 0.50 mm, 0.50 – 2.00 mm, 2.00 – 5.00 mm, and > 5.00 mm water-stable aggregates in 1:5 feldspathic sandstone and sand compound soil was 4.67%, 3.77%, 4.34%, and 5.60% respectively; after a half year of planting, there was little change in mass percent of each grain size and the fluctuation range was 3.50% – 5.60%. After one year of planting, the mass percent of 0.50 – 2.00 mm and > 5.0 mm water-stable aggregates increased by 23.87% and 38.93% compared with that before planting, but the difference was not significant ($P > 0.05$). After 4 years of planting, there were significant changes in 0.50 – 2.00 mm and > 5.00 mm water-stable aggregates in compound soil. Compared with that before planting, the mass percent of 0.50 – 2.00 mm water-stable aggregates increased to 9.36%, increasing by 148.28%; the mass percent of > 5.00 mm water-stable aggregates dropped to 0.40%, reducing by 92.86%, showing significant change before and after crop planting ($P < 0.05$).

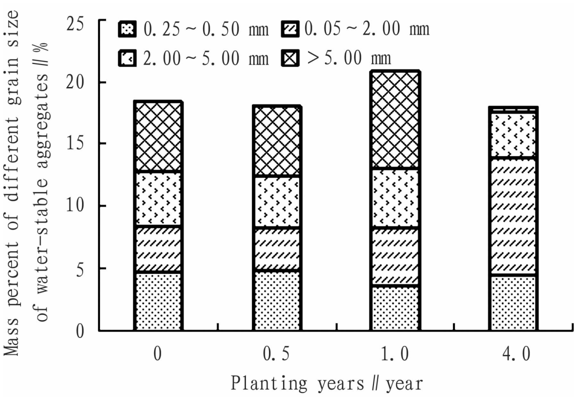

Fig. 5 Changes in the content of 4 grain size of water-stable aggregates of 1∶5 compound soil with crop planting years

3.3 Changes in physical and chemical properties of three kinds of compound soil with crop planting years

3.3.1 Changes in soil organic matters of three kinds of compound soil with crop planting years. It can be seen from Table 1 that the organic matters of three kinds of compound soil increased significantly with the increase of crop planting years, from 0.46 g/kg – 0.56 g/kg before planting to 2.67 g/kg – 4.41 g/kg after 4 years of planting; there was significant difference in the organic matters of 1∶2 and 1∶5 compound soil between before and after 4 years of planting ($P < 0.05$), and the organic matter was the highest in 1∶2 compound soil.

3.3.2 The correlation between organic matters in three kinds of compound soil and the content of different grain size of water-stable aggregates. As shown in Table 2, there was no correlation between organic matters of 1∶1 compound soil and 6 different grain sizes of water-stable aggregates; there was significant correlation between organic matters of 1∶2 compound soil and >0.25 mm water-stable aggregates; there was extremely significant correlation between organic matters of 1∶2 compound soil and 0.25 – 0.50 mm and 0.25 – 2.00 mm water-stable aggregates; there was significant correlation between organic matters of 1∶5 compound soil and 0.25 – 2.00 mm water-stable aggregates; there was extremely significant correlation between organic matters of 1∶5 compound soil and 0.50 – 2.00 mm water-stable aggregates.

Table 1 Changes in organic matters of three kinds of compound soil with crop planting years

Crop planting years // year	Organic matters // g/kg		
	1∶1 compound soil	1∶2 compound soil	1∶5 compound soil
0	0.56 ± 0.06 a	0.50 ± 0.06 a	0.46 ± 0.03 a
0.5	0.64 ± 0.28 a	0.54 ± 0.13 a	0.78 ± 0.06 ac
1	2.35 ± 0.15 bc	1.55 ± 0.15 a	2.00 ± 0.23 bc
4	3.60 ± 0.20 ac	4.41 ± 2.72 b	2.67 ± 0.53 bc

Note: different small letters denote significant difference ($P<0.05$).

Table 2 Correlation between soil organic matters in three kinds of compound soil after 4 years of planting and 6 different grain sizes of water-stable aggregates

Compound soil	Different grain size of water-stable aggregates // mm					
	0.25 – 0.50	0.50 – 2.00	2.00 – 5.00	>5.00	0.25 – 2.00	>0.25
1∶1	–0.130	0.156	0.393	–0.024	–0.74	0.091
1∶2	0.796**	0.547	–0.512	–0.463	0.792**	0.689*
1∶5	–0.227	0.795**	–0.122	–0.451	0.698*	0.132

Note: * and ** denote significant and extremely significant level of correlation.

4 Discussions

4.1 Effects of crop planting years on >0.25 mm and 0.25 – 2.00 mm water-stable aggregates in three kinds of compound soil The micro-structure of soil aggregates is composed of colloidal cementation and bonding of soil primary particles[13]. Generally, the > 0.25 mm water-stable aggregates are called soil aggregate configuration, which are formed by micro-aggregates with relatively stable structure and morphology[14]. Aggregates have important influence on the soil organic carbon content, fertility and quality, and erosion degree[15]. In this study, the mass percent of > 0.25 mm water-stable aggregates was maintained in the range of 18.38% and 28.22% before planting in three kinds of compound soil. The low mass percent was because the components of compound soil only contain feldspathic sandstone and sand and belong to the soil parent material. It is generally believed that organic matter has a dominant role in aggregate cementation in soil with higher soil organic matter content and lower clay content and iron oxide content. In soil with low organic matter content but high content of clay and iron oxide, the formation of aggregates mainly depends on the cohesion of clay and the cementation of iron-aluminum oxide[16–17]. Before crop planting, the 1∶1 compound soil contained the highest mass percent of feldspathic sandstone because feldspathic sandstone contains rich carbonate minerals and can promote inorganic cementation of feldspathic sandstone and sand to form aggregates[9], proving that >0.25 mm water-stable aggregates were formed mainly through inorganic cementation of feldspathic sandstone; the 1∶5 compound soil contained the lowest mass percent of feldspathic sandstone. Studies have shown that in the condition of 1∶1, 1∶2, 1∶5 and whole sand of feldspathic sandstone and sand, the yield of wheat, maize and soybean planted in 1∶2 compound soil was the highest, indicating that 1∶2 compound soil was most favorable for the crop growth[9]. According to studies of Sun Yuting *et al.*, the application of organic fertilizer and with the increase in crop planting years, the > 0.25 mm water-stable aggregates in soil significantly increased[18]. Because the cementation ability of clay and calcium carbonate is weaker than that of humus[19], the increase in soil organic matters will promote the organic cementation to become the dominant action for formation of aggregates[20]. The excellent soil structure suitable for plant growth mainly depends on 1 – 10 mm water-stable aggregates, and Oades stated that organic cementation plays an important role in the formation of water-stable aggregates[21]. In this study, the aggregates in 1∶2 compound soil after 4 years of planting increased significantly and exceeded that in 1∶1 compound soil before planting, possibly because the gradually increasing organic cementation promoted > 0.25 mm water stable aggregates, and organic cementation can provide excellent moisture and void structure for root growth, which is conducive to crop growth. The mass percent of water-stable aggregates was maintained at 17.96% – 32.34% after 4 years of crop planting, indicating that the total amount of effective aggregates remained low and the formation of more aggregates required more years of planting.

Since the 1∶1 compound soil contained the highest feldspathic sandstone, compared with the other two kinds of soil, it is more favorable for the formation of aggregates under the inorganic cementation. The trend of changes in 0.25 – 2.00 mm and > 0.25 mm water-stable aggregates in the three kinds of compound soils was consistent between each other before and after one year of crop planting, indicating that the inorganic cementation also well promoted the formation of 0.25 – 2.00 mm water-stable aggregates. With the increase in crop planting years, the root exudates and microbial metabolites in soil increased, and the increase of organic matters in soil promoted the formation of organic aggregates in soil particles and became the main reason for the formation of such aggregates[22]. The study of Zhang *et al.* indicated that water-stable aggregates of red soil mainly relied on the formation of organic matter cementation[23]. After 4 years of crop planting, 0.25 – 2.00 mm water-stable aggregates increased significantly in the three kinds of compound soil, increasing by 59.82% – 191.68%, which was probably because of organic cementation, and 1∶2 compound soil had the highest growth rate and became the highest one in the mass percent of 0.25 – 2.00 mm water-stable aggregates in three kinds of compound soil, showing that the physical and chemical conditions of such combined soil was most favorable for the formation of 0.25 – 2.00 mm water-stable aggregates.

4.2 Effects of crop planting years on 4 different grain sizes of water-stable aggregates in three kinds of compound soil The formation of soil aggregates is a very complex process, including a series of physical, chemical, biological processes, small micro-aggregates further build up to form different grain sizes of aggregates through various ways[24]. In the early stage of the formation of compound soil, the formation of aggregates was mainly the result of the interaction between inorganic feldspathic sandstone and sand, so that the mass percent of 0.25 – 0.50 mm, 0.50 – 2.00 mm, 2.00 – 5.00 mm, and > 5.00 mm water-stable aggregates was similar, indicating that the function of inorganic cementation was equivalent to the function of formation of aggregates. With the increase in the planting years, plant root system extended, plant root exudates and microbial metabolites increased, and organic matters promoted the formation of 0.25 – 2.00 mm water stable aggregates[25]. Li Jie *et al.* have found that long-term fertilization will reduce the mass percent of > 1.00 mm and increase the mass percent of 0.25 – 1.00 mm water-stable aggregates[20]. In this study, the proportion of 2.00 – 5.00 mm and > 5.00 mm aggregates in three kinds of compound soil after 4 years of planting rapidly declined, while the proportion of 0.25 – 0.50 mm and 0.50 – 2.00 mm water-stable aggregates increased significantly, and the mass percent was maintained between 77.23% and 82.34%, possibly because the extension of the root system causes the dispersion of the original inorganic cemented aggregates with large grain size, and the organic colloid promoted the feldspathic sandstone and sand particles to form 0.25 – 0.50 mm and 0.50 – 2.00 mm water-stable aggregates.

Further study found that the 0.25 – 0.50 mm water-stable aggregates in 1∶2 compound soil accounted for the highest proportion in > 0.25 mm water-stable aggregates, thus, in the formation process of > 0.25 mm water-stable aggregates, it firstly formed the 0.25 – 0.50 mm small aggregates, and then with the extension of time, it gradually formed large grain size aggregates from fine roots and hyphae[26]. According to the study of Feng Gu *et al.*, hyphae could directly promote the 2.00 – 5.00 mm water-stable aggregates[27], and the stability of large aggregates depended to a large extent on plant roots and hyphae[28]. In this study, crops were planted only 4 years, and the microbial content was very low, it may lack the growth of mycorrhizal fungi. Therefore, the mass percent of 2.00 – 5.00 mm water-stable aggregates was very low, which indicated that the soil ripening degree was not enough, and it is necessary to further study the trend of changes in water-stable aggregates in compound soil, so as to provide a theoretical reference for the soil formation mechanism.

4.3 The correlation between organic matters in three kinds of compound soil and the content of different grain size of water-stable aggregates Extensive studies have shown that the application of organic fertilizers can promote the content of organic carbon in soil aggregates, and there is a mutual promotion effect between aggregates and organic carbon[29 – 30], and 0.25 – 0.50 m water stable aggregates have the highest content of organic carbon[31]. 1∶2 compound soil is most favorable for the formation of soil aggregates, 0.25 – 0.50 mm and 0.25 – 2.00 mm water-stable aggregates and organic matters were significantly correlated with organic matters. At the same time, organic matters in 1∶1 and 1∶2 compound soil had similar changes in 4 years of planting process, while the correlation between 1∶1 compound soil and different grain sizes of aggregates was not significant, indicating that apart from organic matters, physical structure of soil is another essential factor influencing the formation of soil aggregates. Jiang Xuebing *et al.* studied the non-tillage field experimental station of Yucheng Experimental Station and found that organic carbon of 0.25 – 2.00 mm water-stable aggregate was positively correlated with total organic carbon, while there was weak correlation between organic carbon and total organic carbon of < 0.25 mm water-stable aggregates, indicating that the organic matters were mainly present in the 0.25 – 2.00 mm water stable aggregates[32], which is consistent with the results of this study. The study of Xie Xianjian showed that the organic matter was mainly present in 0.25 – 0.50 mm and <0.25 mm water-stable aggregates in 4 kinds of soil planting patterns[33].

5 Conclusions

(i) Before the crop planting, the order mass percent of > 0.25 and 0.25 – 2 mm water-stable aggregates in the three kinds of compound soil was 1∶1 > 1∶2 > 1∶5, which were related to the proportion of the respective components; after 4 years of crop planting, the changes of > 0.25 mm water-stable aggregates in 1∶1 and 1∶5 compound soil were not obvious, and the increase in 1∶2 compound soil was 50.07%, exceeding the 1∶1 compound soil; the mass percent of 0.25 – 2 mm water-stable aggregates was significantly increased in all three kinds of compound soil, with the highest increase in 1∶2 compound soil. 1∶2 compound soil promote the formation of >0.25 mm and 0.25 – 2 mm water-stable aggregates.

(ii) After 4 years of planting, the mass percent of 2 – 5 mm and >5 mm water-stable aggregates in 1∶1 compound soil was significantly reduced, while the mass percent of 0.25 – 0.5 mm significantly increased; the mass percent of 2 – 5 mm and >5 mm water-stable aggregates in 1∶2 compound soil was significantly increased; the mass percent of >5 mm water-stable aggregates in 1∶5 compound soil was significantly reduced, while that of 0.5 – 2 mm was significantly increased. After 4 years of planting, the major component of >0.25mm water-stable aggregates was different in three compound soil, the 0.25 – 0.5mm water-stable aggregates accounted for 53.54% in 1∶1 compound soil, the 0.25 – 0.5 mm accounted for 59.43% in 1∶2 compound soil, and 0.5 – 2 mm accounted for 52.16% in 1∶5 compound soil respectively, showing 0.25 – 2 mm aggregates were the major components in three kinds of compound soil after crop planting.

(iii) The organic matters of the three kinds of compound soil were maintained at 0.46 g/kg – 0.56 g/kg and 2.67 g/kg – 4.41 g/kg respectively before planting and after 4 years of planting. The increase rate of organic matter was 480.43% – 782.00% after 4 years of planting, the highest was 1∶2 compound soil, and soil organic matters in 1∶2 compound soil were significantly correlated with 0.25 – 0.5 mm and 0.25 – 2 mm water-stable aggregates.

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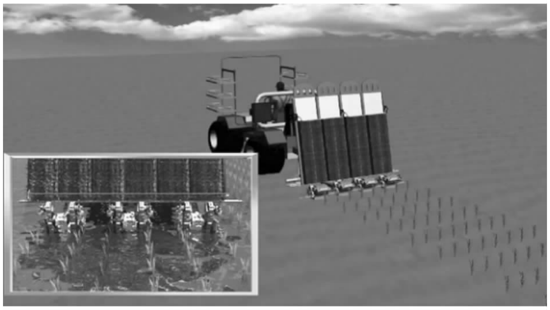

Fig. 6 Transplanting effect

matically opened, and the water is discharged into reservoir through the drains; when the water level is lower than the required consumption of water, the inlet valve is automatically opened, and the water is injected through the inlet channel. Drainage and water inflow animation is achieved by Super Spray, and we only need to change the water inflow and outflow direction. The intelligent irrigation is shown in Fig. 7.

3.5 Mechanization of harvesting Harvesting process includes reaping, returning straw to fields, threshing, ploughing after autumn harvest[4]. The harvester model is established in 3ds Max, the plane is created, and the material is set as soil after the harvest. A rectangular box is created below harvester model, the ripe rice material is added, and the size of the box is adjusted to be in line with the width of the harvester. The harvester is selected, the key frames are added, and the uniform motion of harvester is done. The Slice attributes are selected to make the rice gradually disappear with the rotation of reel. The distant lenses are used in this paper, so the internal working principle of harvester does not have to be realized.

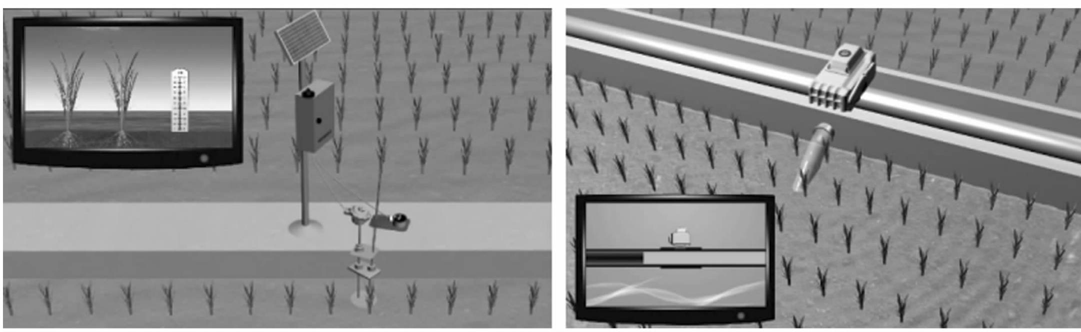

Fig. 7 Intelligent irrigation

4 Conclusions

By 3dmax and Flash, this paper vividly describes the whole process of mechanized rice production, and increases people's knowledge about the rice production process. The use of mechanized rice production increases the scientific and technological content of rice cultivation, promotes large-scale rice cultivation, increases yield, reduces cost, enhances market competitiveness, and increases income and economic benefits. The design of virtual display about whole process mechanization of rice production in cold region fully demonstrates the application of modern agriculture in Heilongjiang Reclamation Area.

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