Effects of Amendment on Soil Nutrients in the Root Zone of Replanted Soil in Homestead

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Abstract. In order to improve the soil nutrients of replanted soil in homestead, find the best soil improvement model. The plot experiment was used to study the effects of six amendments addition modes on soil nutrients in the root zone of replanted soil in homestead. The results show: Result 1 organic fertilizer (T2) treatment on organic matter The improvement effect is the best, the average increase is 9.37~15.49 g kg⁻¹, followed by fly ash+organic fertilizer (T5); Result 2 the improvement agent + organic fertilizer (T4) had the best effect on the available phosphorus in the tillage layer, which was 11.95~19.18 mg kg⁻¹ compared with the no fertilization measures; Result 3 fly ash + organic fertilizer (T5) treatment had the best overall effect on the improvement of available potassium and total nitrogen in the tillage layer, compared with the no fertilization measures increase of 31.6~34.8 mg kg⁻¹ and 0.05~0.25 g kg⁻¹. Organic fertilizer and fly ash can be used as the most suitable improvement model for the replanted soil of homestead in residential land in mountainous and hilly areas, it is of great significance to improve the quality of soil for homestead reclamation.

1. Introduction
As a world with a large population and a large agricultural country, China has one of the basic national conditions: insufficient reserves of arable land, low quality of arable land, and a small number of people [1-2]. With the development of the economy, a large number of abandoned homesteads in hollow villages have appeared, occupying a lot of cultivated land, resulting in a waste of land resources, especially in mountainous and hilly areas where the contradiction between people and land is more acute, which seriously hinders the development of rural economy [3-4]. In order to increase the cultivated land area, intensive resources, and revitalize the land stock, governments at all levels across the country actively carry out research on the reclamation and renovation of hollow village homesteads.
In recent years, the remediation of hollow villages in China has achieved remarkable results. Through the reclamation and remediation of abandoned rural homesteads, a certain number of homesteads were vacated for recultivation [5-6]. However, studies have shown that many reclamation methods often completely reverse the soil sequence or directly mix the upper and lower soil layers [7-8], which makes it difficult for the reclaimed soil to re-form a reasonable soil physical structure in a short time. Due to the problem of extremely low content of soil organic matter, moisture, minerals and microorganisms, coupled with the fact that the homestead soil itself has compaction, poor aeration, and a large amount of lime soil, brick impurities and other factors that are not conducive to the growth of crops, the new cultivated land after reclamation The low quality of the soil leads to a series of problems such as low crop yields and poor quality. Low soil nutrients are the limiting factor for the reclamation of abandoned homesteads, which directly determines the availability of homestead land reclamation [9]. According to the soil characteristics of the homestead, carrying out the improvement of reclaimed cultivated land is the fundamental way to solve the contradiction between the demand for crop growth and fertility and the supply of soil nutrients. Homestead land reclamation is one of the ways to increase the amount of cultivated land in mountainous and hilly areas. It is of great significance for achieving the goal of building a new socialist countryside in the region and food security. Therefore, rapid fertilization of new cultivated land after homestead reclamation is an urgent solution. An important issue.

Soil fertility is the basis of land productivity and the basis of agricultural production and its sustainable development. For a long time, people have long recognized that water, fertilizer and gas are important factors that constitute soil fertility [10], and have many scholars have done more effective scientific research. Yang Jin analyzed the soil mineral composition, chemical composition, polluting elements and soil chemical properties of the newly added cultivated land, and found that the newly cultivated land is lack of soil nutrients and organic matter, and must be fertilized. Adding fly ash and phosphogypsum Solid waste has good fertilization effect [11]. Shao Hui et al. Cultivated fertility by planting green manure, applying organic fertilizer, and spraying water-soluble fertilizer on leaves, and found that different fertilization measures all fertilized the soil fertility to different degrees [12]. Cai Jian et al. Found that by cultivating corn and soybean, using different farming methods such as corn intercropping, straw and film mulching, and bare soybean seeding, they found that film mulching, straw mulching and corn intercropping soybean can improve the physical structure and chemical properties of the soil to varying degrees. Provides a method for the rational use of reclaimed homesteads for cultivated land [13]. Ren Shunrong et al. cultivated the reclaimed homestead by adding organic fertilizer, inorganic fertilizer, straw and gypsum, and found that organic fertilizer combined with inorganic fertilizer and straw or gypsum can significantly improve the physical structure of the soil and further benefit crop growth. Tan Xiangping, through different fertilization treatments on the reclaimed homestead, and measured the biological properties of the soil before and after fertilization, found that organic manure or combined with bacterial manure has the most significant effect [14]. Zhang Xumei et al. found that soil improvement is a long-term systematic process through the investigation of soil alkaline nitrogen in the reclamation and consolidation area of Taicang City, which requires biological, chemical, and physical reclamation measures to continuously improve soil fertility [15]. This article mainly studies the improvement of soil nutrients after reclamation of rural homesteads, in order to determine the best soil nutrient improver, and then provide a reference for the improvement of the quality of cultivated land.

2. Materials and methods

2.1. Overview of the study area

The research site was selected in Chuyuan Village, Fuping County, Shaanxi Province. This area is located in the Weibei Dry Highland, a typical mountainous hilly area, with an elevation of 800-1300 m and annual precipitation of 650 mm, mainly concentrated in July-September. The annual average temperature is 10.5 °C, frost-free period of 225 days. The area belongs to a continental temperate semi-arid and humid climate zone, with distinct dry, wet, cold and warm seasons. The climate in winter is
cold, dry, and there is little rain and snow; in spring, the temperature rises quickly, and the climate difference is large. It is easy to appear cold winds such as strong winds and floating dust, and spring droughts often occur. In summer, the temperature is high and the rainfall is concentrated. Droughts often occur; autumn is cooler and humid, with more and more rain, and a large temperature difference between morning and evening. Grain production is dominated by a winter wheat / summer corn wheel with two crops a year. The soil in this study area is developed from the parent material of loess, the soil layer is deep, the soil is loose and porous, and the texture is middle soil.

2.2. Experimental design
Design of experiment the three modifiers such as organic fertilizer, curing agent and fly ash were used in different ratio experiments. A total of 6 improved treatments and a control treatment without cultivation fertilizer were designed, a total of 7 treatments (2 m × 2 m), each process is repeated three times, a total of 21 cells. The test treatment is shown in Table 1.

| Number | Treatment                        | Amount of fertilizer application |
|--------|----------------------------------|---------------------------------|
| 1      | Curing agent                     | T1                              | 0.6 t hm-2 |
| 2      | Organic fertilizer               | T2                              | 30 t hm-2 |
| 3      | Fly ash                          | T3                              | 45 t hm-2 |
| 4      | Curing agent + organic fertilizer| T4                              | (30+0.6) t hm-2 |
| 5      | Fly ash + organic fertilizer     | T5                              | (22.5+15) t hm-2 |
| 6      | Curing agent + fly ash           | T6                              | (45+0.6) t hm-2 |
| 7      | Control                          | T0                              | 0 |

2.3. Field management
The planting method is based on local planting habits, and adopts summer maize-wheat rotation to develop three-season crops. Summer corn planted on June 15, 2015, harvested on October 5, 2015; Winter wheat planted on October 12, 2015, harvested on June 2, 2016; Summer corn planted on June 5, 2016, October 10, 2016 Harvest on the 6th. Summer maize is a variety of Xianyu No. 335, which is sown in a hole, with a total seeding volume of 60,000 plants / hm². All treatment base fertilizers are uniformly configured as a compound fertilizer of 150 kg / mu. The wheat variety is Changwu 134, the seeding amount is 225 kg · hm-2, and the compound fertilizer is 150 kg / mu before sowing.

2.4. Data analysis
The data analysis involved in this study was performed using the corresponding programs in SPSS and Excel software.

3. Results and analysis

3.1. Effect of different modifiers on soil organic matter content in summer corn root zone
After two years of crop planting, the content of soil organic matter in the 0-15 cm and 45-60 cm soil layers of the summer maize root area was significantly affected by different amelioration treatments (P<0.05) (Table 2), and the other soil layers were not significantly affected.

From the perspective of the spatial effect of soil, the application of different types of modifiers can significantly increase the content of soil organic matter in a short period of time. Among them, fly ash+ organic fertilizer (T5) treatment, organic fertilizer (T2) treatment, The treatment of curing agent + organic fertilizer (T4) is due to the application of organic fertilizer, so the organic matter in the soil of the plough layer has been significantly improved, which is much higher than other treatments. The three treatments with organic fertilizer added are organic fertilizer (T2)> powder Ash + organic fertilizer (T5)> curing agent + organic fertilizer (T4), the average content of organic matter is up to 16.8 g · kg⁻¹, an
increase of 157% compared with the control, but fly ash + organic fertilizer (T5) and organic fertilizer (T2) There is no significant difference, and the organic matter content is close to the same.

From the perspective of time effect, the organic matter content of the soil tillage layer is significantly affected by the year. Compared with the pre-planting period in 2015, the increase range was 0.07 ~ 9.59 g · kg⁻¹. In 2016, the increase range was 0.75 ~ 15.69 g · kg⁻¹.

The content of organic matter below the surface of the soil is not significantly affected by the combined effects of year and treatment.

Table 2. Soil organic matter content in the root zone treated with different modifiers

| Year   | Treatment | 0~15cm | 15~30cm | 30~45cm | 45-60cm |
|--------|-----------|--------|---------|---------|---------|
|        |           | g·kg⁻¹ |         |         |         |
| Before planting | T0 | 4.11 | 4.43 | 6.20 | 5.82 |
|       | T0 | 3.66 c | 5.17 b | 6.17 ab | 5.32 bc |
|       | T3 | 6.51 b | 5.37 b | 6.82 ab | 6.38 b |
|       | T1 | 4.54 bc | 5.53 b | 6.74 ab | 8.29 a |
| 2015   | T2 | 13.7 a | 10.6 a | 6.27 ab | 6.56 b |
|       | T6 | 6.62 b | 5.31 b | 6.89 ab | 7.43 ab |
|       | T4 | 12.2 a | 9.75 a | 6.32 ab | 6.37 b |
|       | T5 | 13.1 a | 10.2 a | 7.23 a  | 6.86 b |
|       | T0 | 4.31 d | 5.23 b | 6.50 ab | 6.08 b |
|       | T3 | 7.42 c | 5.68 b | 7.23 ab | 6.23 b |
|       | T1 | 4.83 d | 5.65 b | 8.00 a  | 9.51 a |
| 2016   | T2 | 19.8 a | 14.6 a | 6.95 ab | 6.53 b |
|       | T6 | 7.26 c | 5.97 b | 7.46 ab | 8.00 ab |
|       | T4 | 17.2 b | 13.9 a | 7.49 ab | 6.96 b |
|       | T5 | 19.4 a | 14.5 a | 7.95 a  | 6.67 b |
| Treatment | 0.0000 | 0.0510 | 0.0520 | 0.0020 |
| Year    | 0.0000 | 0.0000 | 0.0030 | 0.3150 |
| Treatment×Year | 0.0000 | 0.2000 | 0.1030 | 0.0730 |

Different lower case letters in the same column indicate significant differences between treatments in the same year (P = 0.05).

3.2. Effect of different modifiers on soil total nitrogen content in summer corn root zone

After two years of crop planting, in addition to the 45–60 cm soil layer, the total nitrogen content of 0–45 cm soil in the summer corn root zone was significantly affected by each improvement treatment (P <0.05) (Table 3).

From the perspective of soil spatial effect, the soil total nitrogen content increased first and then decreased in the corn root zone. At the surface layer of the soil, there were significant differences between the various treatments. After two consecutive years of summer corn fly ash + organic fertilizer (T5) treatments were significantly higher than other treatments, respectively 0.39 and 0.51 g · kg⁻¹, compared with the control (T0 ). The increase is 94.74% and 96.15%, but there is no significant difference between the treatment of fly ash (T3) and the curing agent (T1) compared with the control (T0). In the range from the surface layer to the cultivated layer, in addition to the treatment with organic fertilizers in 2015, the other soil modifier treatments were not significantly different from the control; in 2016, the total nitrogen content of the different improvement treatments was significantly higher than the control treatment. Below the tillage layer, the fly ash + organic fertilizer (T5) treatment was significantly higher than the control (T0), and the difference between other treatments was not obvious.

From the perspective of time effect, the comparative analysis of the total nitrogen content (0.12 ~ 0.17 g kg⁻¹) of the soil for the two consecutive years of improvement and the test before planting, it was found that the total nitrogen content of 0 ~ 60 cm soil under different treatments was With different degrees of improvement, the total nitrogen content of the cultivated soil layer was significantly affected
by the improvement period. Compared with before planting in 2015, the increase range was 0.05 ~ 0.27 g·kg\(^{-1}\); in 2016, the increase range was 0.14~0.42 mg·kg\(^{-1}\).

The total nitrogen content in the root zone of summer maize is not significantly affected by the combined effects of year and treatment.

**Table 3. Total nitrogen content of root zone soil treated with different modifiers**

| Year   | Treatment   | 0~15cm | 15~30cm | 30~45cm | 45~60cm |
|--------|-------------|--------|---------|---------|---------|
| Before planting | T0          | 0.17   | 0.17    | 0.16    | 0.12    |
|        | T0          | 0.20 ab| 0.20 ab | 0.26 b  | 0.17 b  |
|        | T3          | 0.22 ab| 0.22 ab | 0.31 ab  | 0.25 ab  |
|        | T1          | 0.24 ab| 0.24 ab | 0.32 ab  | 0.21 b  |
|        | T2          | 0.26 a | 0.26 a | 0.34 ab  | 0.24 ab  |
|        | T4          | 0.27 a | 0.27 a | 0.3 b    | 0.24 ab  |
|        | T5          | 0.3 a  | 0.3 a  | 0.38 a   | 0.29 a  |
|        | T0          | 0.28 ab| 0.28 ab | 0.3 c    | 0.24ab   |
|        | T3          | 0.35 a | 0.35 a | 0.44 b   | 0.29 ab  |
|        | T1          | 0.35 a | 0.35 a | 0.38 bc  | 0.26 ab  |
|        | T2          | 0.33 a | 0.33 a | 0.41 b   | 0.26 ab  |
|        | T6          | 0.34 a | 0.34 a | 0.55 a   | 0.29 ab  |
|        | T4          | 0.33 a | 0.33 a | 0.38 bc  | 0.27 a   |
|        | T5          | 0.33 a | 0.33 a | 0.58 a   | 0.31 a   |

### Treatment × Year

| Treatment × Year | 0.0000 | 0.0000 | 0.0030 | 0.3421 | 0.0000 | 0.5820 | 0.0790 | 0.3890 |
|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|

Different lower case letters in the same column indicate significant differences between treatments in the same year (P = 0.05).

3.3. Effect of different modifiers on soil available phosphorus content in summer corn root zone

In this paper, the available phosphorus content of the rural homestead before planting is cultivated land is very low (≤3.06 mg·kg\(^{-1}\)). However, after the crops were planted in 2015 and 2016, the available phosphorus content of the soil changed significantly under different soil amendments. Overall, the available phosphorus content in the root zone of summer maize was significantly affected by various improvements (P<0.05) (Table 4). Compared with before planting, the available phosphorus content in the soil layer of 0~60 cm was significantly increased Promotion.

From the perspective of the spatial effect of the soil, at the surface of the soil, the treatment of curing agent + organic fertilizer (T4) was higher than other treatments for two consecutive years, and the available phosphorus content in the soil was 14.98 and 25.33 mg·kg\(^{-1}\), respectively, compared with the control (T0). The increases were 212% and 311%, respectively. There was no significant difference between the curing agent + organic fertilizer (T4) treatment, fly ash + organic fertilizer (T5) treatment, organic fertilizer (T2) treatment and curing agent (T1) treatment in 2015; 2016 fly ash + organic fertilizer (T5) treatment, organic fertilizer (T2) treatment and curing agent (T1) treatment are not significantly different, but they are significantly lower than curing agent + organic fertilizer (T4) treatment, fly ash (T3) treatment and curing agent + Fly ash (T6) treatment is lower, but significantly higher than control (T0) treatment. Below the surface layer and above the tillage layer, the available phosphorus content of each treatment decreased as a whole, but the curing agent + organic fertilizer (T4) treatment was significantly higher than the other treatments, which were 10.15 and 18.06 mg·kg\(^{-1}\), respectively. In the 30~45 cm soil layer, each of the modified treatments was significantly higher than the control (T0) treatment for two consecutive years. The highest content of available phosphorus was curing agent (T1) treatment and curing agent + organic fertilizer (T4) treatment, the highest content was 9.72 and 19.09.
mg · kg⁻¹ increased by 150% and 236% compared with the control (T0). In the 45~60 cm soil layer, the available phosphorus content of each modified treatment continued to decrease, but it was significantly higher than the control treatment, and there was no significant difference between the modified treatments.

From the perspective of time effect, the available phosphorus content in the root zone of summer maize is significantly affected by the improvement period. In the range of 0~60 cm soil layer, the available phosphorus content of each improvement treatment showed an increasing law with time. Compared with before planting in 2015, the increase range was 1.84~13.84 mg · kg⁻¹; compared with before planting in 2016, the increase range was 4.28~24.19 mg · kg⁻¹; in 2016, compared with 2015, the increase range at 0.44~10.43 mg · kg⁻¹.

On the whole, the available phosphorus content of the soil in the cultivated layer is significantly affected by the combined effects of year and improvement treatment, but not in the deep layer. The curing agent + organic fertilizer (T6) treatment can effectively increase the available phosphorus content in the cultivated layer compared with other improved treatments.

Table 4. Available phosphorus content in root zone soil treated with different modifiers

| Year     | Treatment | 0~15cm | 15~30cm | 30~45cm | 45-60cm |
|----------|-----------|--------|---------|---------|---------|
| Before planting | T0        | 1.14   | 3.06    | 2.51    | 1.03    |
|           | T0        | 4.79 c | 3.44 cd | 3.88 c  | 2.03 b  |
|           | T3        | 9.68 b | 4.9 c   | 7.26 ab | 6.19 a  |
|           | T1        | 13.67 a| 8.75 b  | 9.72 a  | 5.95 a  |
| 2015     | T2        | 12.53 a| 9.26 ab | 8.87 ab | 6.92 a  |
|           | T6        | 8.80 b | 5.84 c  | 8.35 ab | 7.35 a  |
|           | T4        | 14.98 a| 10.15 a | 8.66 ab | 6.77 a  |
|           | T5        | 14.37 a| 8.02 b  | 5.48 b  | 5.35 a  |
|           | T0        | 6.15 d | 6.09 cd | 5.68 d  | 3.67 b  |
|           | T3        | 10.38 c| 15.15 b | 8.18 cd | 7.65 a  |
| 2016     | T1        | 20.01 b| 12.42 b | 10.22 c | 7.03 a  |
|           | T2        | 21.21 b| 13.26 b | 14.85 b | 8.26 a  |
|           | T6        | 9.61 c | 7.34 c  | 8.79 cd | 8.33 a  |
|           | T4        | 25.33 a| 18.06 a | 19.09 a | 8.48 a  |
|           | T5        | 18.38 b| 12.16 b | 8.85 cd | 8.75 a  |

| Treatment | Year | Treatment×Year |
|-----------|------|----------------|
|           |      | 0.0000         |
|           | 2015 | 0.0000         |
|           | 2016 | 0.0000         |

Different lower case letters in the same column indicate significant differences between treatments in the same year (P = 0.05).

3.4. The effect of different modifiers on the soil available potassium content in the root zone of summer maize

After two years of crop planting, the soil available potassium content in the maize root zone cultivation area was significantly affected by various improvements (P <0.05) (Table 5).

From the perspective of soil spatial effects, the soil available potassium content under different amelioration treatments showed a decreasing trend as a whole in the 0-60 cm soil layer. In a single season, on the surface of the soil, the two-year improvement treatments were significantly higher than the control, but there was no significant difference between the improvement treatments. The highest available potassium content in 2015 was the highest curing agent + organic fertilizer (T4) was 117.2 mg · kg⁻¹, an increase of 48.35% compared with the control. In 2016, the highest available potassium content of fly ash + organic fertilizer (T5) treatment was 126.2 mg · kg⁻¹, an increase of 34.80% compared with the control. From the surface layer of the soil to the cultivated layer, the treatment with
fly ash + organic fertilizer (T5) was significantly higher than other treatments for two consecutive years, at 107.1 and 118.1 mg · kg⁻¹, respectively, and the increase was 36.22 compared to the control (T0). % and 36.53%, the difference between the remaining treatments was not significant. In the 30-45 cm soil layer, the same treatment with fly ash + organic fertilizer (T5) was significantly higher than other treatments, but in 2016, except for the treatment with fly ash + organic fertilizer (T5), the other treatments and control (T0) had no significant differences. In the 45 ~ 60 cm soil layer, the content of available potassium decreased as a whole compared with the upper layer. There was no significant difference between the treatment of fly ash (T3) and the curing agent (T1) in 2015, but it was significantly higher than that of other treatments, fly ash (T3) The treatment content was 89.2 mg·kg⁻¹, an increase of 15.84% compared with the control (T0). In 2016, the treatment of fly ash + organic fertilizer (T5) was significantly higher than that of other treatments.

From the perspective of time effect, the soil available potassium content in the root zone of summer maize is significantly affected by the number of years. Under each improvement treatment in the corn root zone, the soil available potassium content increased first and then decreased with time. Compared with before planting in 2015, the increase range was 4.60 ~ 55.80 mg · kg⁻¹; in 2016, compared with before planting, the content of the cultivated layer increased, and the increase range was 14.70 ~ 64.80mg · kg⁻¹, but in the deep soil content cut back.

The content of available potassium in the cultivated layer of summer maize root area is significantly affected by the combined effects of year and treatment, but not significantly below the cultivated layer.

### Table 5. The available potassium content in the root zone soil treated with different modifiers

| Year       | Treatment | 0~15cm | 15~30cm | 30~45cm | 45~60cm |
|------------|-----------|--------|---------|---------|---------|
|            |           | mg·kg⁻¹|         |         |         |
| Before planting | T0       | 61.4   | 59.4    | 69.5    | 74.3    |
|             | T0       | 79.0   | b       | 81.0 b  | 77.0 b  | 74.3 b  |
|             | T3       | 107.4 a| 99.4 ab | 85.0 a  | 77.0 ab |
|             | T1       | 97.1 ab| 93.1 ab | 88.0 a  | 89.2 a  |
| 2015       | T2       | 105.1 a| 97.1 ab | 93.0 a  | 84.9 a  |
|             | T6       | 103.0 a| 97.1 ab | 90.0 a  | 81.0 ab |
|             | T4       | 117.2 a| 101 ab  | 89.0 a  | 78.9 ab |
|             | T5       | 109.2 a| 107.1 a| 93.0 a  | 83.0 a  |
|             | T0       | 91.4 b | 86.5 b  | 82.5 b  | 83.0 ab |
|             | T3       | 118.4 a| 115.2 ab| 88.9 b  | 63.7 ab |
|             | T1       | 120.0 a| 112.4 ab| 87.1 b  | 67.7 ab |
| 2016       | T2       | 121.2 a| 113.3 ab| 84.2 b  | 77.0 a  |
|             | T6       | 118.6 a| 105.8 ab| 88.9 b  | 68.3 ab |
|             | T4       | 125.3 a| 112.2 ab| 85.7 b  | 68.3 ab |
|             | T5       | 126.2 a| 118.1 a| 99.1 a  | 65.8 ab |
| Treatment  | 0.0000   | 0.0000 | 0.8970  | 0.0280  |
| Year       | 0.0000   | 0.0000 | 0.0000  | 0.0000  |
| Treatment×Year | 0.0000 | 0.0000 | 0.0000 | 0.1330 |

Different lower case letters in the same column indicate significant differences between treatments in the same year (P = 0.05).

### 4. Conclusion

1) Different modifiers have a significant effect on the surface soil organic matter content in the summer corn root zone, and the effect of continuous application for two years is more significant. Organic fertilizer (T2) treatment has the best effect on improving organic matter, with an average increase of 9.37-15.49 g · kg⁻¹ compared with the control, followed by fly ash + organic fertilizer (T5) treatment, with an average increase of 0.59 ~ 15.09 g · kg⁻¹.
2) The improvement results for two consecutive years show that different modifiers have a significant effect on the soil total nitrogen content in the summer corn root zone. Fly ash + organic fertilizer (T5) treatment had the best overall effect on total nitrogen in the cultivated layer, with an average increase of 0.05 ~ 0.25 g · kg⁻¹ compared with the control.

3) Different modifiers have obvious effects on available phosphorus and available potassium in the soil tillage layer of summer corn root zone, and the effect is more significant in the second year of application. The curing agent + organic fertilizer (T4) had the best effect of increasing available phosphorus in the cultivated layer, and the increase amount was 11.95 ~ 19.18 mg kg⁻¹ compared with the control. Fly ash + organic fertilizer (T5) treatment had the best overall effect on improving available potassium in the cultivated layer, with an increase of 31.6 ~ 34.8 mg kg⁻¹ compared with the control, followed by curing agent + organic fertilizer (T4) treatment, compared with the control The increase is 25.7 ~ 33.9 mg kg⁻¹.

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References
[1] Y. G. Tian, National arable land quality evaluation method and application based on GIS[D]. Wuhan: Huazhong Agricultural University, 2004.
[2] S. R. Ren, Y. C. Shao, J. Yang, Study on the effect of homestead reclamation soil fertilization[J]. Journal of Soil and Water Conservation. 26 (2012) 78-86.
[3] Y. Y. Liu, Performance Evaluation of Chengdu Rural Homestead Property Right System Reform Based on Satisfaction[D]. Ya'an: Sichuan Agricultural University, 2014.
[4] A. R. Zhang, "Hollow village" problem analysis and countermeasures—— Thoughts caused by the investigation of rural abandoned homesteads in Chengcheng County, Shaanxi [J]. Theoretical Guide, 2008, pp. 73-74.
[5] Z. C. Hu, J. Peng, Y. Y. Du, et al. Research on comprehensive improvement of hollow villages based on supply-side structural reforms [J]. Journal of Geography, 2012, pp. 46-53.
[6] Z. Q. Hu, Basic principles and methods of reconstructing soil profile of coal mine reclamation [J]. Coal Journal, 1997, pp. 59-64.
[7] G. M. Ying, Y. Z. Feng, X. L. Liu, Comparison of physical and chemical properties of soil after reclamation of abandoned alley dwellings in Hutong-style and cliff-style [J]. Gansu Agricultural Science and Technology, 2014, pp. 16-17.
[8] L. A. Qiao, comparative study on the evaluation methods of cultivated land fertility of rural homesteads in Chongqing [D]. Chongqing: Southwest University, 2015.
[9] B. S. Luo, J. H. Zhong, J. J. Chen, Research on numerical comprehensive evaluation of soil fertility [J]. Soil, 2004, pp. 106-108 + 113.
[10] J. Yang, L. Liu, C. M. Sun, et al. Research on the characteristics of soil material composition of newly added cultivated land and its fertilization [J]. Journal of Agricultural Engineering, 24 (2008) 102-105.
[11] H. Shao, Z. L. Qian, Soil restoration and fertility cultivation of reclaimed land [J]. Shanghai Agricultural Science and Technology, 2005. pp. 120-121.
[12] J. Cai, W. Lan, Study on Reclamation and Cultivation Methods of Idle Rural Homesteads in Rural Areas [J]. Chinese Agricultural Science Bulletin, 23 (2007) 170-173.
[13] X. P. Tan, Y. Hu, L. Luo, et al. Study on the characteristics of soil enzymes and microorganisms in the fertile land for reclaiming homesteads [J]. Journal of Northwest A & F University (Natural Science Edition), 2012, pp. 115-122.
suggestions in the reclamation area of Taicang City [J]. Anhui Agricultural Science Bulletin, 2013, pp. 78 + 120.

[16] H. H. Ji, M. L. Huang, J. He, et al. Research progress of the effect of fly ash on soil properties improvement and fertility improvement [J]. Soil, 2017, pp. 26-30.

[17] H. Feng, Effect of gravel mulching degree on farmland moisture and water consumption features of crops. Transactions of the Chinese Society for Agricultural Machinery [J]. 47 (2016) 155-163.

[18] C. G. Liu, L. M. Zhou. Soil organic carbon sequestration and fertility response to newly-built terraces with organic manure and mineral fertilizer in a semi-arid environment. Soil and Tillage Research [J]. 172 (2017) 39-47.

[19] Z. T. Yao, X. S. Ji, Sarker P, et al. A comprehensive review on the applications of coal fly ash. Earth-Science Reviews [J]. 141 (2015) 105-121.