Conditions of developed Greening Soil Materials (GSM) for survival of licorice and combating desertification

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ABSTRACT

Desertification is a kind of land degradation phenomena which can be caused by natural or artificial geo-environmental problems. Especially, Asia is considered to be highly vulnerable to desertification than other area. Authors have been trying to develop the measures of anti-desertification which is sustainable and with highly added value. In order to accomplish this purpose, licorice (Glycyrrhiza uralensis Fisch.), a kind of medical herb grows natively in Chinese and Mongolian arid region, was experimentally planted in Mongolian arid area. It is one of the most demanded medicinal herbs in Japanese pharmaceutical industry, but numbers of native licorice in these regions are decreasing due to several causes. Authors developed Greening Soil Material (GSM) as one of the effective methods to plant licorice where once was habitat of licorice. It is pipe-shaped with more than 10 times higher water and nutrient holding capacity compared to the deserted ground. The experimental research using GSM has been conducted in Southern Mongolia. From the results of past experimental study, important factors for survive and healthy growth of licorice in arid area were revealed: volume, water content, and calcium content in GSs. In order to suggest the suitable conditions for survive of licorice in non-habitat area, this paper presents the relationship between survival ratio of licorice and volume of GSs, water content of GSs, and calcium content of GSs and quantifies these relationships.

**Keywords:** water content, saline content, Greening Soil Material, licorice

1 INTRODUCTION

Desertification is a kind of serious geo-environmental problems. It is progressed by natural environmental problems such as irregular precipitation and lowering of groundwater level as well as by artificial environmental problems such as overtakeing and overharvesting the native plants. Also desertification is closely related to the decrease of biological resource (UNEP, 1992). Asia is more vulnerable to desertification than the rest of the world.

Licorice (Glycyrrhiza uralensis Fisch., Fig. 1) growing in Mongolian and Chinese arid region is especially apprehended about decrease of native species and supply shortage, because it is the highest-demanded medicinal herb which is contained in the 70% of medicinal herbs in Japan (Japanese Ministry of Finance). Recently, the amount of wild licorice in Mongolia is decreased to half compared to 30 years ago by irregular rainfalls and excessive ingathering (Tuvsintogotokh et al., 2013). COP10 (Conference of the Parties, Convention on Biological Diversity, 2010) designated the licorice as one of the “precious genetic resources”. Therefore, a study on developing anti-desertification method by utilizing licorice can contribute to growing plants with highly added-value and a sustainable effort in desert area.
Although many researchers try to reveal the suitable way of growing licorice (ex. Ozaki et al., 2013), the mechanisms of surviving and growing licorice have not been cleared.

Our research group developed Greening Soil Material (GSM) to break through these circumstances. It is pipe-shaped, and mixed sand of Mongolian arid ground and compost gotten from Mongolia. It has several or several score times higher water and nutrition retentive capacity than arid ground which is estimated to compensate adequate water and nutrition to licorice in blighained ground. Therefore, it can be placed as one of the geo-environmental improvement which is able to be done at ease, with low cost, and in environmental-friendly. This paper presents the results of cultural experiments of growing licorice using GSM with various volume and mixing ratio in Mongolian arid ground and indicates suitable physical and chemical environment of GSM for growing licorice.

2 EXPERIMENTAL METHOD AND CONDITIONS

The experiments were conducted nearby Bogd soum (administrative subdivision in Mongolia), Bayanhongor aimag (province in Mongolia), located in the southern part of Mongolia (45° 08' 49.9"N, 100° 48' 53.3"E, 1200 m of altitude). The area was non-habitat of licorice.

2.1 Setting conditions of GSM

As mentioned in the INTRODUCTION, GSM is consisted of sand and compost. Figure 2 shows the schematic design of various types of GSM. They were made of sand from habitat of licorice (SiSand), compost sold in Ulaanbaatar, capital in Mongolia (UB), and animal compost taken from a manure disposal site in Bogd soum (LC). Each fertilizer had high water and nutrient holding capacity. The mixed material (SiSand + UB, 0 – 100 % or SiSand + LC 0 – 20 % by wet weight) was put in cylindrical plastic bag. The plastic bags were three types of “Small (6 cm of diameter, 25 cm of length), “Medium (20 cm of diameter, 25 cm of length)” and “Big (20 cm of diameter, 40 cm of length)”. The mixed material of “Medium” and “Big” conditions were covered with biodegradable plastic or buried directly.

After mixed soil was put in the plastic bags, roots of licorice were put in each GSMs. The roots were collected in habitat area of licorice, which had no more than one adventitious bud. The GSMs with roots are buried in the holes in the ground shown in Figure 1. GSMs were buried in two directions: vertically and horizontally to the ground. As the final settings of GSMs, water was added to each GSM, and covered with mulching sheet to avoid evaporation. The amount of poured water is shown in Figure 2.

2.2 Geo-environmental conditions of GSM

Although setting conditions of GSMs is important, geo-environmental conditions were more important. As the results of our previous in-situ investigation and cultural experiment, licorice lives natively in sandy ground (Furukawa et al., 2013). The ground water level was 160 cm - 240 cm and sand had high calcium carbonate (CaCO₃) content with at most 10 % of dry mass. In addition, it is assumed that the effective medicinal ingredient found in the root (glycyrrhizin) of licorice was higher in case that CaCO₃ was added in the sandy ground in Japan. (Furukawa, et al., 2014).

Fig. 2. Setting and mixing conditions of GSMs.

Table 1. Initial geo-environmental conditions of GSMs.

| pH  | EC - mS / cm | CaCO₃-Ca | Ca²⁺ | Mg²⁺ | K⁺ | Na⁺ |
|-----|--------------|----------|------|------|----|-----|
| SiSand 7.51 - 9.73 | 0.033 | 44614.98 | 133.69 - 161.24 | 32.49 - 44.78 | 3.30 - 140.11 | 47.51 - 175.10 |
| UB 5 % | 9.65 | 0.323 | 3719.30 - 13997.97 | 127.01 | 75.07 | 194.80 | 628.90 |
| UB 10 % | 9.32 | 0.225 | 7572.75 | 120.32 | 1188.99 | 166.00 | 341.00 |
| UB 20 % | 8.19, 8.59 | 0.184 - 0.388 | 5173.29 - 11633.14 | 106.95 | 90.17 | 243.00 | 413.00 |
| UB 40 % | 8.33 | 0.278 | 5988.08 | 73.21 | 112.86 | 164.82 | 254.17 |
| UB 60 % | 8.10 | 0.309 | 5759.67 | 102.56 | 135.56 | 207.18 | 357.50 |
| UB 80 % | 8.13 | 0.380 | 5657.00 | 131.9 | 158.25 | 229.53 | 460.82 |
| UB 9.70 | 0.370 | 3791.30 | 161.243 - 212.99 | 75.07 - 158.25 | 251.89 | 460.03 - 564.15 |
| LC 5 % | 8.72 | 0.033 | 3719.30 - 4445.25 | 152.71 | 44.78 | 1625.00 | 1810.97 |
| LC 10 % | 8.13 | 0.514 | 1992.90 - 7950.36 | 171.73 | 105.81 | 140.11 | 3574.42 |
| LC 20 % | 8.78 | 9.14 | 3878.91 | 209.78 | 166.84 | 437.09 | 5337.87 |
| LC 8.40 | 1.472 | 4024.40 | 514.11 - 896.45 | 1188.98 - 1265.37 | 1625.00 - 1960.94 | 6103.49 - 8864.77 |
Therefore, saline content in GSM may be strongly related with growth of licorice as well as the water content.

Table 1 indicates the initial conditions of GSM. It indicates the water and saline conditions of each GSM. “Water content” in the table is the value after adding water. The amount of water is written in Figure 1. As for pH and electric conductivity (EC) value measured after the fashion of JGS 021, 022 (JGS 2010), pH of materials were all alkaline, similar to in-situ condition. Almost all the materials of EC were in the range where the general plants grow healthily (0.1 - 1.5 mS / cm) (Fujiwara, et al., 1996).

Contents of CaCO₃ was measured by ignition loss test (Shinjo, et al., 2003). The values of CaCO₃-Ca written in the table are the value of Ca calculated from measured CaCO₃ values. In addition, four kinds of water soluble cations (Ca²⁺, Mg²⁺, K⁺, Na⁺) are indicated in the next to the item of CaCO₃-Ca in the table. Solute of samples were made for measuring water soluble cations by atomic absorption method using atomic absorption spectrophotometer (ANA-121, made by Tokyo Koden, Co, Ltd.). Solute of samples mixed soil and distilled water at the rate of 1:5, filtered by 0.2 μm cellulose filter (Hakubunkan Shinsha, 2003).

Compared with the value of Ca as CaCO₃ and total values of water soluble cations in GSMs, content of Ca as CaCO₃ were greater than that of water soluble cations. These values might be fit for suitable condition for growing licorice.

2.3 Meteorological conditions on growing period

Besides, Meteorological data such as air temperature, relative humidity, and precipitation is very important for growth of plants from the perspective of natural supply of water. Table 2 shows climatic data of growing period and annual data in 2013. These data were collected by compound climate sensor (WXT520, made by VAISALA) around Bogd soum. The sensor was set 1.5 m from the ground.

As indicated in the table, “Small” GSMs had been used for about four month, “Medium” GSMs had been used for about 9 month including wintertime. Therefore average and minimum air temperature were negative values. “Big” GSMs had been used for about three month in summertime. Rainy season comes summertime, especially from end of June to beginning of September in this region, and snow falls in wintertime. However, used sensor could not measure the amount of snowfall in

![Fig. 3. Relationships between survival rate of licorice and setting directions of GSMs (Numbers in middle of bars are numbers of individuals in each conditions).](image)
licorice was investigated. Survival of licorice is defined as 1) licorice have leaves over the ground, or 2) the root is alive under the ground. GSM was dug up to confirm if the roots were alive or not as shown in Figure 1.

3 THE RELATIONSHIPS BETWEEN WATER IN GSMS AND SURVIVAL RATE OF LICORICE

GSMs were partially collected together with checking survival rate of licorice when the experimental period finished to analyze the changes of geo-environmental factors. Upper part and bottom part of each GSMs were gathered for measuring water content, calcium carbonate, and water soluble cations. It was measured with the same method written in 2.2. From the next chapter, the relationships between survival rate of licorice and conditions of GSMs are considered.

3.1 Setting directions of GSM

Figure 3 describes the maximum, average and minimum survival ratio of each setting conditions. The number in the figure means number of individuals of each condition. As shown in Figure 3, compared with average survival ratio of setting conditions, VR conditions could heighten the survival rate about 10% than that of HR conditions. Therefore, it could be assumed that licorice has a preference for lengthening its root vertically than horizontally to suggest that vertical setting of root might be better than horizontal setting.

3.2 Volume of GSM

Survival rate in volume of each GSM is shown in Figure 4. The survival rate “Small” GSM was lower than the rest. Amazingly, “Medium” GSM could make the root survive same as “Big” conditions, in spite of being exposed to cold temperature in wintertime. It can be assumed that roots were protected from extremely low temperature by burying 10 cm depth in the ground.

Above all, these results explained that the suitable volume of GSM is more than 7800 cm³ (Φ 20 cm, h 20 cm).

3.3 Residual water content in GSM

The residual amount of water per root in each GSMs and survival rate appeared in Figure 5. This figure indicates that there is a positive correlation between residual water content and survival ratio. In this experimental range, when there was more residual water, the survival rate was higher. In addition, when there was more than 50 g of water in GSM, it could keep more than 50% of survival rate.

3.4 Residual saline content in GSM

Figure 6 shows relationships between survival rate and amount of calcium as CaCO₃ in GSMs. As shown in this figure, there is positive correlation between calcium content and survival rate in the range of 0.00 – 5.46 g/root, but there might be negative correlation between calcium content and survival rate in case when GSMs kept more than about 5 g/root of CaCO₃-Ca. This result indicated that there might be optimum Ca content as CaCO₃ around 5 g/root in GSMs for keeping roots survive.

Figure 7 illustrates relationships between total amount of water soluble cations (Ca²⁺, Mg²⁺, K⁺, Na⁺) in
each GSM and survival rate. This figure represents that there is a weak positive correlation between water soluble cations and survival rate in this experimental range. This result shows that root needed much water soluble cations in the range. However, there is variance as indicated in the figure, and more data will be needed to clarify these relationships.

4 CONCLUSIONS

This paper presents the effect and function of developed Greening Soil Material (GSM) by conducting several conditions of cultural experiments using licorice (Glycyrrhiza uralensis Fisch.) in Mongolian arid land for combating desertification. The results of this experiment are as follows;
1) VR conditions, which buried GSMs and roots vertically could heighten the survival rate about 10 % higher than HR conditions which set GSMs horizontally to the ground.
2) The suitable volume of GSM was more than 7800 cm$^3$ ($\phi$ 20 cm, h 20 cm).
3) There is a positive correlation between residual water content and survival ratio. In addition, more than 50 g of water in GSM could keep more than 50 % of survival rate.
4) There might be optimum Ca content as CaCO$_3$ around 5 g /root in GSMs for keeping roots survive.
5) Weakly positive correlation between water soluble cations and survival rate exists in 0 – 4 g /root of water soluble cations.

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