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Soil Physical Properties to Grow the Wild Licorice at Semi-arid Area in Mongolia

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Abstract: Wild licorice (*Glycyrrhiza uralensis*) is an important medicinal plant. It is grown in Asia, especially in the semi-arid region of China and Mongolia. Recently, overharvesting of wild licorice has caused land deterioration and/or desertification, and some exporting countries have begun restricting the export of wild licorice. The objective of this study is to prevent desertification by establishing a method for cultivating high quality licorice. First, a field investigation of the habitat of high quality wild licorice was conducted in the semi-arid region of Southern Mongolia in May 2010 and in Northeastern Mongolia in September 2010. Second, to evaluate the soil properties of the areas where wild licorice grows, physical experiments such as soil particle size distribution, soil water retention, saturated hydraulic conductivity, and unsaturated hydraulic conductivity were conducted. Third, to research the relationship between soil water content and the transpiration of licorice from saturation to the wilting point was observed in a pot experiment. As a result, many large areas of wild licorice were found in Southern Mongolia with well-drained sandy soil and little available moisture. These results will contribute to effective water management in semi-arid regions for growing wild licorice because the optimum soil properties for growing high quality licorice have been clarified.

Key Words: Semi-arid region, Soil permeability, Transpiration, Water retention, Wild licorice

1. Introduction

Glycyrrhiza uralensis (L) (hereinafter, called licorice) grows wild in Asia, especially in the semi-arid region of China and Mongolia. Licorice is an important medicinal plant because 70% of traditional Kampo medicines contain Glycyrrhizin (hereinafter, called GL) which is derived from licorice. Recently, the overharvesting of wild licorice has caused land deterioration and/or desertification, and some exporting countries have begun restricting the export of wild licorice. Yamamoto and Tani (2005) reported that in 1984 the Chinese government restricted the collection of licorice by people living in regions other than the 3 northern regions, and in 2000, the Chinese government restricted the collection of wild licorice nationwide (Yamamoto and Tani, 2002). Therefore, the exhaustion of medicinal plant resources is of concern. However, there is a continuing high demand for licorice. Hayashi and Sudo (2009) summarized the economic importance of licorice extracts used for cosmetics, food additives, tobacco flavors, and confectionery foods.

There are two suggested means to increase the supply of licorice. One is to cultivate licorice in the semi-arid regions of China and Mongolia while combating desertification, and the other is to cultivate licorice in Japan. Abe *et al*. (2005) indicated that the cultivation of medicinal plants in arid regions was expected to be an alternative income source. Yamamoto and Tani (2005) reported that licorice harvested in the 4th year after seeding conformed to the JP XV standard (The Japanese Pharmacopoeia XV, 2006) for GL content in China (In order to use licorice as a medicinal plant in Japan, the GL content must exceed 2.5%). In another approach, Zhang and Xiong (2008) reported that N^+ ion beam irradiation made licorice salt-tolerant.

Kusano *et al.* (2003) suggested that selecting a superior strain of the licorice plant produced high quality licorice. Shibano and Ozaki (2011) indicated the possibility of producing high quality licorice in 2 years by selecting superior types. In another approach, nutriculture has been studied. Kakutani *et al.* (1997) reported that nutriculture using Rockwool could increase the GL content of licorice. Sato *et al.* (2004) reported that increasing nutrient concentration increased the GL content of licorice. These efforts have advanced cultivation methods.

The objective of this study is to prevent desertification and to establish cultivation methods for producing high quality licorice in semi-arid regions. First, field investigations of high quality licorice were conducted in semi-arid regions of

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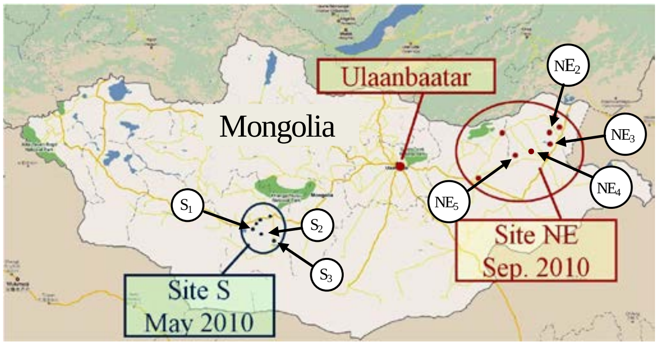

Fig. 1. Map of investigation area in Mongolia.

Southern Mongolia in May 2010 and in Northeastern Mongolia in September 2010. Second, to evaluate soil properties in the area of growing wild licorice, physical soil experiments such as particle size distribution, soil water retention, saturated hydraulic conductivity, and unsaturated hydraulic conductivity were conducted. Third, to research the relationship between soil water content and the transpiration of licorice from saturation to the wilting point was observed in a pot experiment.

2. Materials and Methods

2.1. Investigation for soil properties growing wild licorice in Mongolia

Field investigations of soil properties for growing wild licorice were conducted in the Bayankhongor prefecture, Southern Mongolia, in May 2010 and in the Dornod prefecture, Northeastern Mongolia, in September 2010. **Figure 1** shows the location of the fields under investigation designated as sites S_1-S_3 at Bayankhongor and sites NE_2-NE_5 at Dornad. There was some licorice as well as other native plants at site S_1, which had an area of 25 × 5 km. Only licorice was growing in high density at site S_3, which had an area of 15 × 5 km. There were no plants growing at site S_2. The ground water level was –3.0 m near site S_1 and –1.9 m near site S_3. The total precipitation near the investigation site S was 129.6 mm/year, making it an arid region. However, there was some licorice along with more than 50 species of weeds around site NE, an area classified as meadow and steppe. Site NE had a low density of licorice. The ground water level was –3.0 m near site NE_3, and the total precipitation near site NE was 207.6 mm.

Soil samples near wild licorice roots were collected at sites S_1 and S_3, and at sites NE_2-NE_5. For comparison, Japanese soil, silica sand (size 7), and decomposed granite soil were analyzed. These samples were analyzed for saturated hydraulic conductivity, unsaturated hydraulic conductivity, soil texture, and soil moisture characteristic curve. Saturated hydraulic conductivity was measured using a falling head permeability test. The soil moisture characteristic curve was measured using a suction plate method and a centrifuging method. The unsaturated hydraulic conductivity was measured using the one-step method (Doering 1955). The unsaturated hydraulic conductivity of the low moisture area could not be measured by the one-step method, so the capillary tube model (Jury and Horton, 2004) was used for estimation Eq. (1).

$$K(\theta_s - \Delta\theta) = \frac{\tau\sigma^2\Delta\theta}{2\eta\rho_w g}\sum_{J=i+1}^{M}\frac{1}{h_J^2} \qquad (1)$$

where τ is tortuosity, σ is surface tension, ρ_w is the density of water, g is the acceleration due to gravity, η is viscosity, θ is the volumetric water content, and h is the potential head.

2.2. Pot experiment of licorice transpiration

Plastic tube cultivation experiments to evaluate the transpiration rate of licorice from a saturated condition to dry were conducted over 50 days at the Phytotron at Biotron Institute, Kyushu University. Silica sand (size 7) was placed in a plastic tube made of polyvinyl chloride (φ = 10.74 cm, h = 50 cm) at a bulk density of 1.4 (g/cm^3). Licorice was cultivated for 1 year in a greenhouse and then transplanted to the tube where it was grown for a month before the experiment. The air in the greenhouse was maintained at an even temperature of 25ºC, and the relative humidity was 70%. The soil water content was measured by TDR at depths of 10 cm, 20 cm, 30 cm, and 40 cm. The soil surface was covered with vinyl to prevent evaporation so the cultivation pot could be weighed with an electronic balance to determine transpiration.

3. Results and Discussions

3.1. Soil properties

The soil textures of all samples from the southern site S_3 contained high percentages of sand according to the standard of International Society of Soil Science (**Table 1**). In the northeast site, almost all of the soil textures were "loam" or "silt loam." As a result, the soil best suited for growing wild licorice was sandy soil with good drainage and little water retention, though licorice can be grown with lower yields in other conditions.

Figure 2 shows the soil moisture characteristic curves of each site. The volumetric water content of the southern site was 1-3.6 % at sampling time. The graphs of sites S_1 and S_3 were similar, and the soil at site S_3 was similar to silica sand above 130 cm of H_2O. The readily available moisture at site S_1 (60 cm), site S_1 (80 cm), and site S_3 was 8.4%, 7.9%, and 13.0% respectively. These values were low compared with general farmland. The metric potential at the sampling time was 1300-10,000 cm of H_2O, which is more than the wilting point (1000 cm of H_2O). This indicated the possibility that

Table 1. Soil separation and soil texture classification
Cf.: ISSS (International Society of Soil Science)

sample		sand (%)	silt (%)	clay (%)	soil texture	sample		sand (%)	silt (%)	clay (%)	soil texture
Site S_3	0cm	100	0	0	S	Site NE_3	10cm	62	33	5	L
	30cm	94	5	1	S		20cm	48	43	9	L
	60cm	94	5	1	S		30cm	36	52	12	SiL
	100cm	80	16	4	S		40cm	36	46	18	SiCL
decomposed soil		96	3	1	S	Site NE_4	5cm	59	32	9	L
silica sand (7size)		100	0	0	S		10cm	59	32	9	L
Site NE_{2-1}	5cm	66	28	6	SL		20cm	51	38	11	L
	10cm	46	43	11	L		30cm	46	44	10	SiL
	20cm	44	45	11	L		40cm	36	43	21	SiCL
	30cm	36	52	12	SiL		60cm	12	61	27	SiL
	40cm	29	57	14	SiL	Site NE_{5-1}	5cm	57	36	7	L
	80cm	38	49	13	SiL		10cm	47	42	11	L
Site NE_{2-2}	10cm	60	32	8	L		20cm	45	44	11	L
	20cm	34	54	12	SiL		30cm	42	47	11	L
	30cm	32	56	12	SiL		40cm	50	41	9	L
Site NE_2 (N-H)	5cm	64	28	8	L	Site NE_{5-2}	10cm	57	35	8	L
	10cm	64	31	5	L		30cm	43	46	11	L
	20cm	4	70	26	SiC		40cm	38	50	12	SiL

Table 2. Saturated hydraulic conductivities (Ks) of soil at each site.

sample		Ks (cm/s)
Site S_1	60cm	9.5×10^{-3}
	80cm	7.6×10^{-3}
Site S_3	50cm	9.5×10^{-3}
decomposed granite soil		8.7×10^{-3}
silica sand (size 7)		1.8×10^{-3}
Site NE_{2-1}	10cm	5.4×10^{-3}
	20cm	9.3×10^{-3}
	30cm	3.0×10^{-3}
	40cm	1.8×10^{-3}
	80cm	2.5×10^{-4}
Site NE_{2-2}	10cm	1.5×10^{-3}
	20cm	2.0×10^{-3}
	30cm	2.2×10^{-3}
Site NE_2 (N-H)	10cm	1.2×10^{-6}
	20cm	3.0×10^{-4}

sample		Ks (cm/s)
Site NE_3	10cm	2.4×10^{-3}
	20cm	6.0×10^{-3}
	30cm	1.4×10^{-3}
	40cm	7.1×10^{-4}
Site NE_4	10cm	5.5×10^{-3}
	20cm	6.1×10^{-3}
	30cm	6.5×10^{-3}
	40cm	1.5×10^{-3}
	60cm	6.6×10^{-4}
Site NE_{5-1}	10cm	2.4×10^{-3}
	20cm	2.6×10^{-3}
	30cm	3.5×10^{-3}
	40cm	2.9×10^{-4}
Site NE_{5-2}	10cm	1.0×10^{-3}
	30cm	2.0×10^{-4}
	40cm	2.7×10^{-4}

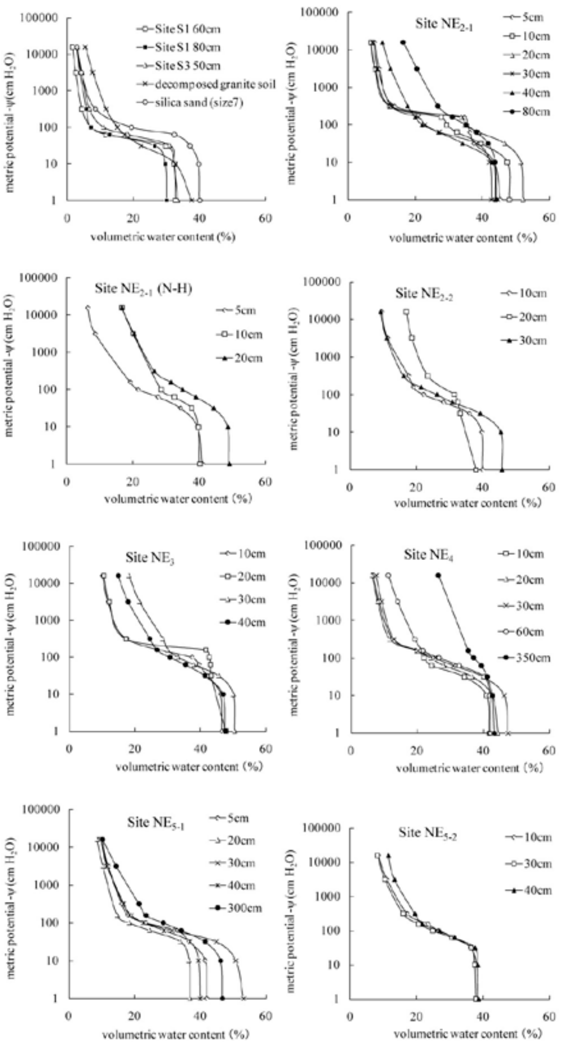

Fig.2. Soil water characteristic curves of each site.

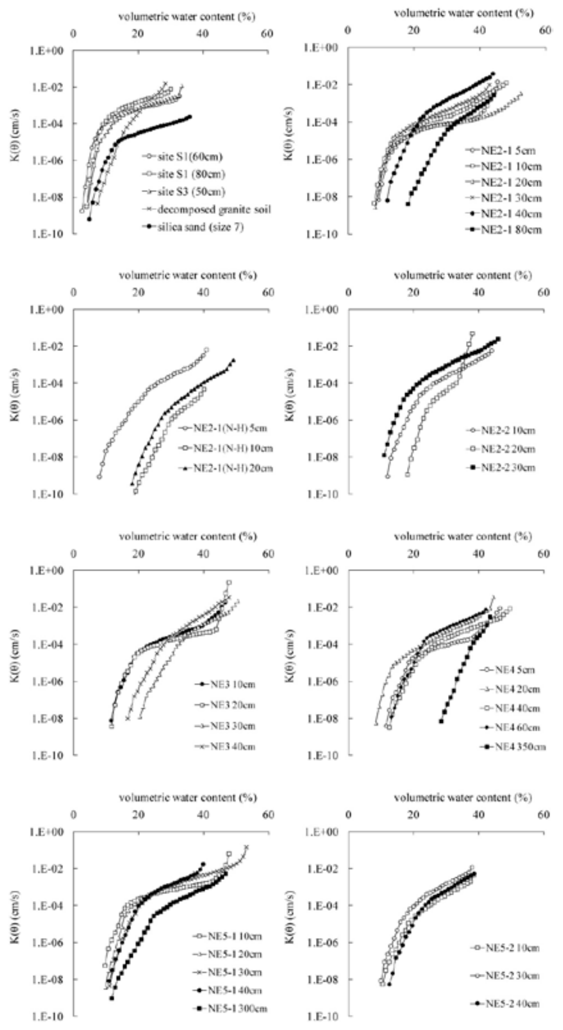

Fig.3. Unsaturated hydraulic conductivities (K (θ)) using capillary tube model for soil at each site.

licorice can grow in severe dry conditions or that its roots can extend deep into the earth, sufficient to reach groundwater. However, the soil at sites NE_2-NE_5 had saturated water content and water holding capacity that were better than the soil at the southern site. The volumetric water content of the northeast site was 6.8-19.5% at sampling time. Almost all of the metric potential at that time was 1000-10,000 cm of H_2O indicating severe dry conditions, especially at the southern site.

Table 2 shows saturated hydraulic conductivity (Ks). The results of Ks measurements showed good drainage for all

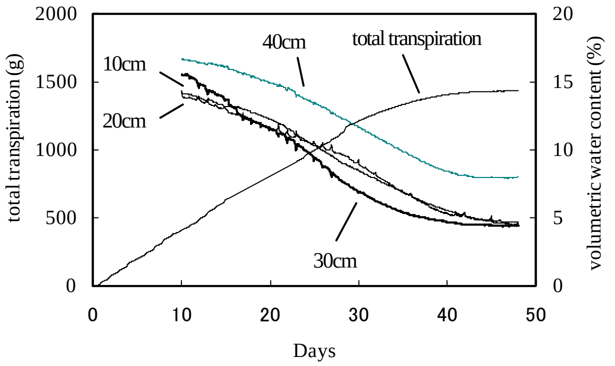

Fig. 4. Total transpiration of licorice and soil water content at each depth.

samples except for the deeper layer at the northeast site and all of $NE_{2\text{-}1}$(N-H) (N-H indicates a non-habitat of licorice). **Figure 3** shows the unsaturated hydraulic conductivity (K (θ)) of each sample. Sites S_1 and S_3 showed the same variation and good drainage, which were different from the decomposed granite soil. The deeper the soil layer was, the lower K (θ) became at the northeast site.

3.2. Transpiration of licorice in dry conditions

Figure 4 shows the transpiration rate of licorice and soil water content at each depth during the drying process. Water consumption was large at 30 cm because of root density. Dead leaves were observed by the 30th day when the volumetric water content at 30 cm was 6%. The metric potential at that time was about –1000 cm of H_2O, which is same as the generally used wilting point. Transpiration stopped by about the 40th day when volumetric water content at 30 cm was 4% and the metric potential was –4000 cm of H_2O. After the experiment, the metric potential of the root zone was more than –15,000 cm of H_2O. All the leaves appeared to have died, but exhibited signs of life after irrigation. This indicated that the licorice could survive in severe drought conditions.

4. Conclusions

In this study, the soil properties for growing wild licorice in Mongolia were investigated, and transpiration experiments on licorice were conducted. We found that there were many large licorice-growing areas in Southern Mongolia, and that these regions had sandy soil, good drainage, and little available moisture. However, the northeast site, where the soil comprises loam and silt loam, had low density of licorice. Transpiration of licorice in the drying process caused the leaves of the licorice plants to appear to die at the generally accepted wilting point. We hope that these results will contribute to effective water management for growing wild licorice in semi-arid regions, because the optimum soil properties for growing high quality licorice have been clarified.

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