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Original Research Article

An Investigation of Characteristics of Chinese Bellflower (*Platycodon grandiflorum* A.) Cultivated Soil

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Abstract - In order to understand the characteristics of soil according to the cultivation environment of Chinese bellflower (*Platycodon grandiflorum* A.), soil chemical properties of 12 collected soil samples from 6 cultivated fields in Okcheon, Chungbuk province in August. 2017 were analyzed. The soil pH was distributed within the range of 4.61 to 5.25 at all cultivation years and E.C (Electric Conductivity) and T-N (Total Nitrogen) of the cultivation year were not significant. Available P_2O_5 was higher than the average for medicinal crops and *P. grandiflorum* in Korea and C.E.C (Cation Exchange Capacity) was inconsistent for each cultivation year. In particularly, it was validated that the content of exchangeable cations K, Ca, Ma, and Na in this experiment was similar to that of C.E.C according to the cultivation years, because C.E.C had a high correlation with the exchangeable cations. For the available P_2O_5, as affected by trans-planting, 5Y-NT-H (cultivated 5 years and non-transplanted) had 58 mg/kg, while 5Y-T-H (cultivated 5 years and transplanted) had 246 ㎎/㎏. The soil pH was found to be lower (acidic) in diseased soils than healthy soils. E.C was confirmed to be was higher in diseased soils than healthy soils except for the one cultivated for 2 years. The contents of T-N and available P_2O_5 were higher in diseased soil except for the one cultivated for 5 years and 11 years. The exchangeable cation K and Na tended to be higher in diseased soils rather than that in healthy soils, and the exchangeable cation Ca and Mg contents were higher in healthy soils than in diseased soils. The C.E.C of the soil was lower than that of healthy soils in all of the years except for the one which was cultivated for 5 years (transplanted).

Key words – Available P_2O_5, C.E.C, Chinese bellflower, E.C, Exchangeable cations, *Platycodon grandiflorum*

Introduction

Platycodon grandiflorum, a perennial plant belonging to *Campanulaceae,* is native to all parts of Korea and is a wild vegetable which represents the only genus and species in the world (Park and Chae, 1996; Lee *et al*; 1999; Jeon *et al*., 2013). Moreover *P. grandiflorum* contains proteins, lipids, sugars, ash, iron, saponin, inulin and phytosterin. It is a very useful crop for medicinal purposes because it is known to exhibit various pharmacological actions such as expectorant, antitussive, antibacterial, hypotensive and hypoglycemic (Cho, 1984; Lee *et al*., 2010; Lee *et al*., 2014).

In recent years, the production of *P. grandiflorum* has increased from 6,112 tons in 2012 to 6,665 tons in 2016 (Forest Service, 2016). In order to produce *P. grandiflorum* with excellent pharmacological properties, long term cultivation is used for medicinal purposes but generally, it is known that transplanting and managing the crops for 3 years is being done to prevent root rot disease which occurs in long term cultivation (Lee *et al*., 1999; Kim and Cho, 2011).

For farmers who cultivate *P. grandiflorum* for medicinal purposes, long term cultivation through transplanting is continuously being carried out but it is difficult to select the land with the same conditions with land as used before transplanting. When fertilization and management of the cultivated land is carried out through farmer's practice, the yield and quality tend to be uneven and the important active ingredient content in the *P. grandiflorum* is affected (Jung *et al*., 1996; Lee *et al*., 2010). In addition, while the damage of root rot disease is great at a certain time when cultivation for 3 years, research on specific occurrence causes of the disease is still incomplete.

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The purpose of this study is utilize the basic data for the reduction of the root rot disease and determine the soil environmental conditions for the long term cultivation of *P. grandiflorum* which is highly utilize as a medicinal resource through the investigation of chemical properties of the cultivated field compare and analyze the changes in various years.

Materials and Methods

Soil sampling and processing

In order to analyze the soil chemical properties where *P. grandiflorum* is cultivated by long term, one farm which does this practice for medicinal purposes, was selected and a total of 12 soil samples were collected from 3 fields, located in Okcheon gun, Chungbuk province in August 2017. Soil samples were collected from the soil of about 3 ㎝ from the root surface except for the topsoil layer (20 ㎝) (Fig. 2A). The collected soil samples were mixed with air-dried in the shade for two weeks and used as a soil chemical analysis sample using test sieve (No.10, 2 ㎜).

Soil pH and E.C (Electronic Conductivity)

Soil analysis was carried out three times on the basis of the Rural Development Administration soil chemical analysis (NIAST, 2000). Soil pH (soil acidity) and E.C were measured in 1:5 soil to water suspensions by electrode method (Orion 3 star, Thermo) (Fig. 2C).

Available P_2O_5 and O.M (Organic Matter)

Available P_2O_5 analysis was performed using the Lancaster method (UV2550PC, Pekinelmer) and Tyurin method were used for the analysis of available P_2O_5 and O.M (organic matter).

Determination of T-N (Total Nitrogen)

The Kjeldahl method (Bremner, 1965) was performed for total nitrogen (T-N) analysis by nitrogen auto analyser (K-350, Buchi distillation unit) (Fig. 2B). Soil was digested and distilled, NH_4^+ collected in the 2% boric acid solution was quantitatively titrated with acid.

Exchangeable cations (K, Ca, Mg, Na)

Exchangeable cations (K, Ca, Mg, Na) were analyzed using ICP (ICPE-9000, Shimadzu) after extraction using 1N-NH_4OAc solution.

Statistical analysis

Statistical analysis was performed using Duncan's Multiple Range Test (DMRT) at 5% significance level for each comparison item using SAS (9.1 ver., SAS Institute Inc.) program.

Results

Soil chemistry by cultivation years

The soil chemistry was investigated in order to analyze the characteristics of the soil environment according to the long term cultivation of *P. grandiflorum* in the area of Samnam myeon, Okcheon gun, Chungbuk province in August 2017 (Fig. 1). The first site where the soil samples were collected, was cultivated it for 5 years (Samnam ri, Okcheon gun, Chungbuk province, 36° 17'51.2 "N, 127° 44'54.1" E), the second site was cultivated for 2 and 5 years (Gungchon ri, Okcheon gun, Chungbuk province, 36° 18'22.5 "N, 127° 45'23.9 "E) and third site was cultivated for 6, 11 and 15 years (Soseo ri, Okcheon gun, Chungbuk province, 36° 18'49.6" N 127° 46'10.2 "E) (Table 1).

The results of soil environment survey according to year number of cultivations years were shown in Table 2. Generally, the pH was 4 to 6, indicating an acid to slightly acidic distribution. 2Y-NT-H was the lowest at 4.61 and 5Y-T-H was the highest at 6.35. In the case of E.C and T-N, the pH was similar but there was no significant difference according to the number of cultivation years. O.M content was the highest at 25.04 g/㎏ in the 5Y-T-H and it was similar to 25 g/㎏ on average O.M content at cultivated area of *P. grandiflorum* in Korea. But other soil samples were lower than average O.M content (Jung *et al*., 1996). The average available P_2O_5 content in the *P. grandiflorum* field was 577 ㎎/㎏ and the content of available P_2O_5 was slightly lower than the average value.

As a result of C.E.C survey, 11Y-T-H was the highest at 11.38 cmol/㎏ and the 5Y-T-H was the lowest at 5.65 cmol/㎏.

Fig. 1. Soil sampling cites for soil properties analysis at *P. grandiflorum* from 3 fields of Okcheon-gun, Chungbuk province. (A) Soil samples of cultivated for 5 years (non transplanted) collected from Samnam, Okcheon-gun. (B) Soil samples of cultivated for 2 years (non transplanted) and 5 years (transplanted) collected from Gwongchon, Okcheon-gun. (C) Soil samples of cultivated for 6 years (transplanted), 11 years (transplanted) and 15 years (transplanted) collected from Soseo, Okcheon-gun.

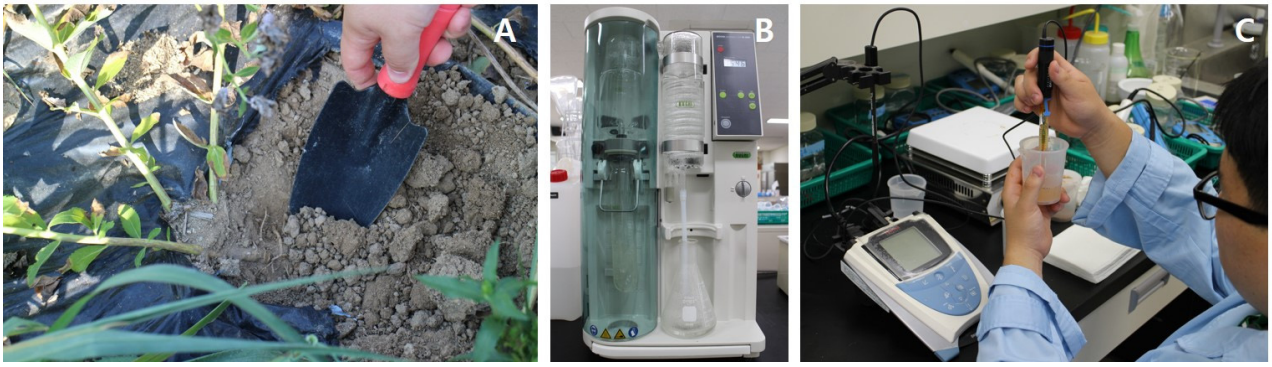

Fig. 2. (A) 12 soil samples were collected from the root surface except for the topsoil layer (20 ㎝). Soil analysis was carried out on the basis of the Rural Development Administration soil chemical analysis. (B) Determination of T-N (Total Nitrogen) was performed by nitrogen auto analyzer (K-350, Buchi distillation unit). (C) Soil pH and E.C (Electronic Conductivity) were performed by electrode method (Orion 3 star, Thermo).

Table 1. List of soil samples collected from Okcheon-gun, Chungbuk province

Region	No.	Sample	Number of cultivated year	Trans-planting	Variety
Samnam, Okcheon	1	5Y-NT-H[Z] 5Y-NT-D[Y]	2	×	Etteum
Gwongchon, Okcheon	2	2Y-NT-H 2Y-NT-D	5	×	
	3	5Y-T-H[X] 5Y-T-D	5	○	
Soseo, Okcheon	4	6Y-T-H 6Y-T-D	6	○	
	5	11Y-T-H 11Y-T-D	11	○	
	6	15Y-T-H 15Y-T-D	15	○	

[Z]-Y: Cultivation year, NT: Non transplanted field, H: Healthy plant.
[Y]D: Diseased plant.
[X]T: Transplanted field.

Table 2. Soil properties as cultivated year of *P. grandiflorum*

Sample	pH (1:5)	E.C (dS/m)	O.M (g/kg)	T-N (mg/kg)	Avail. P_2O_5 (mg/kg)	Exch. Cations (cmolc/kg)				
						K	Ca	Mg	Na	C.E.C
2Y-NT-H	4.61e[z]	0.18a	20.59b	688a	229c	0.34a	6.56a	1.17ab	0.45a	10.86a
5Y-T-H	6.35a	0.24a	25.04a	866a	246c	0.20ab	5.91a	1.10ab	0.29b	5.65b
6Y-T-H	5.77a	0.20a	22.65ab	927a	503a	0.30ab	6.62a	1.20a	0.34ab	9.04ab
11Y-T-H	4.79d	0.13a	21.53b	907a	491a	0.28ab	6.11a	1.01b	0.29b	11.38a
15Y-T-H	5.25b	0.18a	20.10b	781a	438b	0.27b	6.41a	1.09ab	0.28b	9.02ab

[z]Means followed by same letter in column are not significantly different at the 5% level according to DMRT (Duncan's multiple range test).

Table 3. Soil properties of trans planting for 5 years of cultivation of *P. grandiflorum*

Sample	pH (1:5)	E.C (dS/m)	O.M (g/kg)	T-N (mg/kg)	Avail. P_2O_5 (mg/kg)	Exch. Cations (cmolc/kg)				
						K	Ca	Mg	Na	C.E.C
5Y-NT-H	5.01b[z]	0.14b	26.02a	794a	58b	0.23b	5.91a	0.91a	0.20b	8.47a
5Y-T-H	6.35a	0.24a	25.04a	866a	246a	0.20a	5.91a	1.10a	0.29a	5.65b

[z]Means followed by same letter in column not are significantly different at the 5% level according to DMRT (Duncan's multiple range test).

The increase of C.E.C in the soil can be used to understand the degree of exchangeable cation capacity, so that the content of the exchangeable cation K, Ca, Mg and Na are also affected. In this study, the content exchangeable cations K, Ca, Mg and Na decreased with the decrease of C.E.C from 2 years cultivated field to 5 years cultivated field, and it was confirmed that content of exchangeable cations also increased with the increase of C.E.C in 6 years cultivated field.

Jung *et al*. (1996) reported that average contents of exchangeable cation K, Ca and Mg were 0.43, 4.5, and 0.8 cmol/kg in survey about soil chemistry of the cultivated area of the medicinal plants in Korea. When the results of the contents of exchangeable cation of the cultivated soil of field examined in this study were compared, the exchangeable cation K content was in the range of 0.27~0.34 cmol/kg, which was lower than the reference value in the previously cited-study, while the exchangeable Ca and Mg contents were 5.91~6.62 cmolc/kg and 1.01~1.20 cmolc/kg, respectively, the content of which were higher than the reference result.

Soil chemistry by transplanting of *P. grandiflorum*

Soil chemical properties as affected by transplanting *P. grandiflorum* were analyzed on 5Y-NT-H (cultivated for 5 years, non transplanted) and 5Y-T-H (cultivated for 5 years, transplanted) (Table 3).

O.M content, T-N, and exchangeable Ca content were not significantly different depending on transplanting in cultivated *P. grandiflorum* for 5 years. However, in the case of C.E.C, it was confirmed that 5Y-NT-H was 5.65 cmolc/kg and 5Y-T-H was 8.47 cmolc/kg. In the case of available P_2O_5 content, 5Y-NT-H was 82 mg/kg, which was significantly different from 246 mg/kg of 5Y-T-H. This has shown that it is possible to overcome the available P_2O_5 decrease in soil condition for the growth of the *P. grandiflorum* through transplanting like the results of soil properties by cultural years of *P. grandiflorum.* However, it is considered necessary to prepare for the reduction or loss of available P_2O_5 which may occur during long term cultivation. Since cultivation of *P. grandiflorum* is continuously performed at the same place, it will have a great influence on the maintenance of available P_2O_5 in the soil.

Soil chemistry by occurrence of root rot disease of *P. grandiflorum*

In order to compare the soil chemical properties by as affected by the occurrence of root rot disease in cultivated years, soil chemical characteristics were analyzed on healthy plant and diseased plant in all cultivated years in study (Table 4).

Table 4. Soil properties affected by root rot disease of *P. grandiflorum*

Sample	pH (1:5)	E.C (dS/m)	O.M (g/kg)	T-N (mg/kg)	Avail. P_2O_5 (mg/kg)	Exch. Cations (cmolc/kg)				
						K	Ca	Mg	Na	C.E.C
2Y-NT-H	4.61a[z]	0.18a	20.59a	688b	229a	0.34a	6.56a	1.17a	0.45a	10.86a
2Y-NT-D	4.63a	0.11b	22.20a	977a	244a	0.32a	6.06a	1.10a	0.36a	9.90a
5Y-NT-H	5.01b	0.14b	26.02b	794b	58b	0.23b	5.91a	0.91b	0.20a	8.47a
5Y-NT-D	6.04a	0.35a	32.87a	1048a	112a	0.27a	6.07a	1.04a	0.25a	7.37b
5Y-T-H	6.35a	0.24a	25.04a	866a	246a	0.28b	5.94a	1.10b	0.29a	5.65b
5Y-T-D	6.49a	0.26a	18.80b	688b	172b	0.33a	6.61a	1.23a	0.31a	7.29a
6Y-T-H	5.77b	0.20a	22.65a	927b	503a	0.30b	6.62a	1.20a	0.34a	9.03a
6Y-T-D	5.92a	0.23a	22.80a	1105a	519a	0.35a	6.19a	1.19a	0.45a	6.98b
11Y-T-H	4.79b	0.13b	21.53a	907a	491a	0.28a	6.11a	1.01a	0.28a	11.38a
11Y-T-D	5.31a	0.16a	21.52a	757b	387b	0.26a	5.76b	0.93a	0.21a	8.16a
15Y-T-H	5.25b	0.18b	20.10b	781b	438a	0.27a	6.41a	1.09a	0.28a	9.02a
15Y-T-D	5.55a	0.21a	22.38a	904a	450a	0.30a	5.91a	1.15a	0.30a	8.07a

[z]Means followed by same letter in column not are significantly different at the 5% level according to DMRT (Duncan's multiple range test).

In the case of E.C, the result of 2Y-NT-H (cultivated for 2 years, healthy plant) was 0.18 dS/m while for 2-NT-D (cultivated for 2 years, diseased plant) it was 0.11 dS/m. The T-N contents of 2Y-NT-H was 688 mg/kg and 2Y-NT-D was 977 mg/kg, significant difference was confirmed between the two soils, but there was no significant difference in the other analysis items. It is thought that this is due to the fact that the cultural period of *P. grandiflorum* is short and the consumption of the chemical composition of the soil is not large. In the case of pH, in all cultural years, soils of healthy plant and diseased plant were distributed in the acidic range with 2Y-T-H as the most acidic at pH 4.61. It was also found that the soil pH of a cultivated land with diseased plants was lower than the soil pH of where healthy plants were grown in all cultivated years in study.

Generally, E.C was found to be higher in diseased plant soil except the one cultivated for 2 years. However, significance was recognized only in healthy plant and diseased plant soil of cultivated for 5 years, 11 years and 15 years areas. In particular, the excess of the exchangeable cation Na affects the E.C increase but in this study, it was confirmed that the exchangeable cation Na content was higher in the exchangeable cation Na content of diseased plant soil than healthy plant soil in all cultural years, but the significance was not recognized.

O.M contents were highest in 5Y-NT-D at 32.87 mg/kg and O.M of healthy plant and diseased soil of all cultural years was similar to the average O.M content of 25 g/kg and correlation with O.M by occurrence root rot in *P. grandiflorum* was not found (Jung *et al*., 1996).

In the case of T-N and available P_2O_5 content, diseased plant soil was higher than healthy plant soil in most cultural years except for those cultivated for 5 years and 11 years, transplanted but T-N was significant. Available P_2O_5 was not significant.

The contents of exchangeable cation K and Na of diseased plant soil were slightly higher than healthy plant soil but exchangeable cation K was significant only in soils of cultivated for 5 years in both non transplanted and transplanted and soils of cultivated for 6 years, transplanted. In the case of the exchangeable cation Na, no significant difference was found depending on occurrence root rot disease in all cultural years. The exchangeable cation Ca and Mg contents were higher in healthy plant soils than diseased plant soils but exchangeable cation Ca was found to be significant only in soils of cultivated for 11 years, and the exchangeable cation Mg was found to be significant only in transplanted and non transplanted soils of cultivated for 5 years.

C.E.C of diseased plant soils was found to be lower in

cultivated years except for those cultivated for 5 years, transplanted soils than healthy plant soils but significance was shown only in cultivated for 5 years transplants and non transplanted soils and in cultivated for 6 transplants and non transplanted soils.

Discussion

Soil chemical properties of 12 soil samples from Okcheon, Chungbuk province were analyzed in August, 2017 in order to determine the soil environmental conditions for stable the long term cultivation and reduction root rot disease of *P. grandiflorum* which is known as a medicinal resource. The soil pH was distributed within the range of 4.61 to 5.25 at all of cultivated years. E.C (Electric Conductivity) and T-N (Total Nitrogen) at all cultivation years were not significant. Available P_2O_5 was higher than the 405 ㎎/㎏, average for medicinal crops and 320 ㎎/㎏, the average for *P. grandiflorum* in Korea as cultivation years. C.E.C (Cation Exchange Capacity) was inconsistent for each cultivation year. In particularly, it was validated that the content of exchangeable cations K, Ca, Ma, and Na in this experiment was similar to that of C.E.C according to the cultivation years, because C.E.C had a high correlation with the exchangeable cations. Soil chemistry by transplanting of *P. grandiflorum* in this study, showed the distinct difference at available P_2O_5. 5-NT-H (cultivated 5 years and non-transplanted) had 58 ㎎/㎏, while 5Y-T-H (cultivated 5 years and transplanted) had 246 mg/kg. Thus, measures were required to prevent the loss of available P_2O_5 when cultivation of *P. grandiflorum*. In soil chemistry by occurrence root rot disease of *P. grandiflorum*, the soil pH was found to be lower (acidic) in diseased soils than healthy soils at all cultivation years. E.C was confirmed to be was higher in diseased soils than healthy soils except for the one cultivated for 2 years with a relatively stable soil environment. O.M (Organic Matter) content was distributed within the range of 18.80 g/㎏ to 25.04 g/㎏ found to be within the average (25 g/㎏) of *P. grandiflorum* in Korea, but correlation between O.M and disease occurrence could not be determined. The contents of T-N and available P_2O_5 were higher in diseased soil except for the one cultivated for 5 years and 11 years but T-N was significant only. The exchangeable cation K and Na tended to be higher in diseased soils rather than that in healthy soils, but soils of cultivated for 5 years (transplanted and non transplanted) and 6 years (transplanted) were significant only. The exchangeable cation Ca and Mg contents were higher in healthy soils than in diseased soils and the contents were also higher than average (25 g/㎏) of *P. grandiflorum* in Korea. The C.E.C of the soil was lower than that of healthy soils in all of the years except for the one which was cultivated for 5 years (transplanted). As a result, it is also expected to be necessary to prepare for the reduction of nutrient holding capacity as continuous cropping and transplant of *P. grandiflorum* for stable long term cultivation of the one.

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