J Ginseng Res 39 (2015) 76–80

Contents lists available at ScienceDirect

Journal of Ginseng Research

journal homepage: http://www.ginsengres.org

Research article

Soil properties of cultivation sites for mountain-cultivated ginseng at local level

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ARTICLE INFO

Article history:
Received 3 February 2014
Received in Revised form
25 March 2014
Accepted 11 June 2014
Available online 19 June 2014

Keywords:
Panax ginseng
ginseng
soil property
suitable site for ginseng
wild-simulated ginseng

ABSTRACT

Background: Identifying suitable site for growing mountain-cultivated ginseng is a concern for ginseng producers. This study was conducted to evaluate the soil properties of cultivation sites for mountain-cultivated ginseng in Hamyang-gun, which is one of the most well-known areas for mountain-cultivated ginseng in Korea.

Methods: The sampling plots from 30 sites were randomly selected on or near the center of the ginseng growing sites in July and August 2009. Soil samples for the soil properties analysis were collected from the top 20 cm at five randomly selected points.

Results: Mountain-cultivated ginseng was grown in soils that varied greatly in soil properties on coniferous, mixed, and deciduous broad-leaved stand sites of elevations between > 200 m and < 1,000 m. The soil bulk density was higher in *Pinus densiflora* than in *Larix leptolepis* stand sites and higher in the < 700-m sites than in > 700-m sites. Soil pH was unaffected by the type of stand sites (pH 4.35–4.55), whereas the high-elevation sites of > 700 m were strongly acidified, with pH 4.19. The organic carbon and total nitrogen content were lower in the *P. densiflora* stand sites than in the deciduous broad-leaved stand sites. Available phosphorus was low in all of the stand sites. The exchangeable cation was generally higher in the mixed and low-elevation sites than in the *P. densiflora* and high-elevation sites, respectively.

Conclusion: These results indicate that mountain-cultivated ginseng in Korea is able to grow in very acidic, nutrient-depleted forest soils.

1. Introduction

The ginseng (*Panax ginseng* Meyer) supply in Korea relies mainly on intensive field cultivation under artificial shade structures. However, as an alternative to field cultivation, wild-simulated methods, such as mountain cultivation, currently hold considerable interest because consumers prefer wild-simulated ginseng [1–4]. The first step in growing wild-simulated ginseng is to select a suitable site that allows for ginseng cultivation in a forest environment [4–6]. Thus, identifying suitable site for growing ginseng is an area of concern for many ginseng producers because the environments of the sites have a large impact on ginseng growth and development in wild-simulated environments [1,6,7].

In forest environments, American ginseng grows best in well-drained, porous soils with topsoil that is rich in humus formed from hardwood leaf litter [6]. Soils on ideal ginseng sites are slightly acidic with relatively high calcium content [5]. Duplicating these soil conditions may be the key to the successful cultivation of ginseng in forest environments. In addition, the growth of American ginseng is greatly affected by the soil nutrient status [6].

Although there have been several studies of mountain-cultivated ginseng sites in Korea [1,7], there is a paucity of information about the soil properties of cultivation sites for mountain-cultivated ginseng. The objective of this study was to determine the soil properties of cultivation sites for mountain-cultivated ginseng at a local scale.

2. Materials and methods

The study site was located in Hamyang-gun, Gyeongsang-namdo, which is one of the most well-known areas for mountain-

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http://dx.doi.org/10.1016/j.jgr.2014.06.004

cultivated ginseng in Korea. The mean annual precipitation of the study site was 1,265 mm, which is similar to the nationwide average of 1,274 mm, and the mean annual temperature was 11.4°C. The sampling plots were drawn from 30 sites recommended by the Hamyang-gun office (Table 1). These sites are intensively managed by the ginseng producers in this region. The sampling plots measured 20 m × 20 m and were randomly established on or near the center of the ginseng sites in July and August 2009. Dominant overstory vegetation was catalogued, and elevations were determined using GPS (Garmin GPS V, Olathe, KS, USA).

Soil samples for measuring the bulk density were collected at a depth of 5–10 cm using a 100-cm^3 stainless steel cylinder and dried at 105°C. Soil samples for the chemical analysis were cored through the top 20 cm at five randomly selected points in each plot using an Oakfield soil sampler, Fond du Lac, WI. These samples were air dried, passed through a 2-mm sieve, and used for the soil chemical analyses. Soil pH (1:5 soil:water suspension) was measured using a glass electrode. The carbon (C) and nitrogen (N) content in the soil were determined using an elemental analyzer (CE Instruments EA1110, Thermo Quest Italia S.P.A., Radano, Italy). Available phosphorus (P), calcium (Ca), magnesium (Mg), and potassium (K) were determined by inductively coupled plasma (Perkin Elmer Optima 5300, Waltham, MA, USA) using the standard method recommended by the National Institute of Agricultural Science and Technology [8]. The data were analyzed using the general linear model procedure using SAS version 9.1 (SAS Institute Inc., Cary, NC, USA) to determine the significant difference ($p < 0.05$) of cultivation sites by stand site types and by elevation. The treatment means were compared using Duncan's test [9].

Table 1
Location of the study sites

Stand site type	Latitude (N)	Longitude (E)	Elevation (m)	Parent rock	Soil color
Pinus densiflora	35°35′00″	128°48′48″	280	Granite	10YR 5/6
P. densiflora	35°39′05″	127°48′13″	381	Granite	10YR 4/4
P. densiflora	35°28′16″	127°43′49″	400	Granite	10YR 3/3
P. densiflora	35°31′13″	127°38′39″	427	Granite	10YR 5/3
P. densiflora	35°40′33″	127°46′30″	447	Granite	7.5YR 4/3
P. densiflora	35°30′26″	127°38′14″	450	Granite	7.5YR 5/3
P. densiflora	35°33′01″	127°36′14″	514	Granite	10YR 5/4
P. densiflora	35°26′31″	127°40′49″	714	Granite	10YR 4/3
Larix leptolepis[1)]	35°33′38″	127°40′31″	446	Granite	10YR 3/3
L. leptolepis[1)]	35°36′09″	127°44′23″	448	Granite	10YR 3/2
L. leptolepis[1)]	35°34′39″	127°34′42″	760	Granite	10YR 3/3
L. leptolepis[1)]	35°35′52″	127°39′59″	978	Granite	10YR 3/3
Mixed	35°24′55″	127°42′55″	276	Granite gneiss	10YR 3/2
Mixed	35°27′57″	127°41′22″	490	Granite	10YR 3/3
Mixed	35°34′43″	127°36′39″	777	Granite	10YR 3/2
Broadleaved	35°24′40″	127°43′02″	263	Granite gneiss	10YR 3/3
Broadleaved	35°33′13″	127°39′34″	529	Granite	7.5YR 5/4
Broadleaved	35°42′21″	127°42′14″	603	Granite	10YR 3/2
Broadleaved	35°42′23″	127°45′15″	652	Granite	10YR 4/3
Broadleaved	35°36′23″	127°40′43″	695	Granite	10YR 4/3
Broadleaved	35°36′02″	127°40′19″	753	Granite	10YR 3/2
Broadleaved	35°35′53″	127°39′57″	755	Granite	10YR 3/2
Broadleaved	35°41′08″	127°38′27″	780	Granite	10YR 3/2
Broadleaved	35°42′07″	127°39′27″	842	Granite	10YR 3/1
Broadleaved	35°42′04″	127°39′27″	844	Granite	10YR 3/2
Broadleaved	35°42′03″	127°39′17″	852	Granite	10YR 4/3
Broadleaved	35°42′07″	127°39′32″	879	Granite	10YR 3/2
Broadleaved	35°42′05″	127°39′18″	882	Granite	10YR 3/2
Chamaecyparis obtusa[1)]	35°29′41″	127°43′38″	272	Granite	10YR 4/4
Pinus koraiensis[1)]	35°26′20″	127°42′04″	723	Granite	10YR 3/2

1) Artificial forests

3. Results

3.1. Soil property of cultivation sites by overstory stand types

Mountain-cultivated ginseng was cultivated in three natural and three artificial forests with six different overstory stand types: deciduous broad-leaved forests with *Carpinus laxiflora*, *Quercus* spp., *Acer mono*, *Prunus sargentii; Cornus controversa*: thirteen plots; *P. densiflora*: eight plots; mixed forests of *P. densiflora* and *Quercus* spp.: three plots; *L. leptolepis* plantation: four plots; *Chamaecyparis obtuse* plantation: one plot; and *Pinus koraiensis* plantation: one plot (Table 1).

The soil bulk density was significantly higher for the *P. densiflora* stand sites (0.96 g/cm^3) than for the *L. leptolepis* stand sites (0.69 g/cm^3). Among the three phases of the soil, there was a significantly higher proportion of the liquid phase for the deciduous broad-leaved (34.0%) and mixed stand sites (34.6%) than for the *P. densiflora* stand sites (18.8%), but the air phase was reversely related to the liquid phase (Fig. 1). The soil pH was not significantly different among stand sites, although the soil pH in the mixed stand sites was 0.1–0.2 units higher compared with that of the other stand sites. The soil pH was highest on average in the mixed stand sites (pH 4.55), followed by a pH 4.46 for the *P. densiflora* stand sites, pH 4.36 for the deciduous broad-leaved stand sites, and pH 4.35 for the *L. leptolepis* stand sites (Fig. 2). All of the stands were strongly acidified, with a soil pH below 4.55.

The organic C and total N content were significantly higher for the deciduous broad-leaved stand sites (C: 6.16%; N: 0.44%) than for the *P. densiflora* (C: 2.64%; N: 0.19%) stand sites. The C/N ratio ranged from 12.8 to 16.5, with the highest value of 16.5 in *P. densiflora* stand sites. The available P was low in all of the stand sites. The exchangeable K^+ was not significantly different among the stand site types, but the exchangeable Ca^{2+} and Mg^{2+} were significantly higher in the mixed stand sites (Ca^{2+}: 2.52 cmolc/kg; Mg^{2+}: 0.64 cmolc/kg) than in the *P. densiflora* stand (Ca^{2+}: 0.64 cmolc/kg; Mg^{2+}: 0.25 cmolc/kg) sites (Fig. 2).

3.2. Soil properties of cultivation sites by elevation

The soil bulk density of cultivation sites generally decreased with increased elevation (Fig. 3) and was significantly lower in the >700-m sites (0.73 g/cm^3) than in the < 700-m sites (0.85–0.96 g/cm^3). Except for the solid phase, the other soil phases were not significantly different among elevation sites. The soil pH was significantly lower in the > 700-m sites (pH 4.19) than in the < 700-m sites (pH 4.52–4.55). The organic C content was significantly higher in the >700-m sites (6.12%) than in the 300–700-m sites (3.20%). The C/N ratio ranged from 13.7 to 16.1. Other nutrients (N, P, K, and Ca), except for Mg, were not significantly different among elevation sites (Fig. 4).

4. Discussion

Stand site types in mountain-cultivated ginseng may influence the growth of ginseng because soil nutrients can be changed after stand establishment by different nutrient requirements and nutrient cycling mechanisms of different tree species. Mountain-cultivated ginseng has adapted to various overstory vegetation types, such as coniferous, mixed, and deciduous broad-leaved stands. Past studies have shown that mountain-cultivated ginseng in Korea grows better in deciduous broad-leaved forests than in mixed forest and pine forest types [7,10,11].

This study revealed notable differences in the soil properties of cultivation sites for mountain-cultivated ginseng. The high bulk density of the *P. densiflora* stand sites and low-elevation sites may

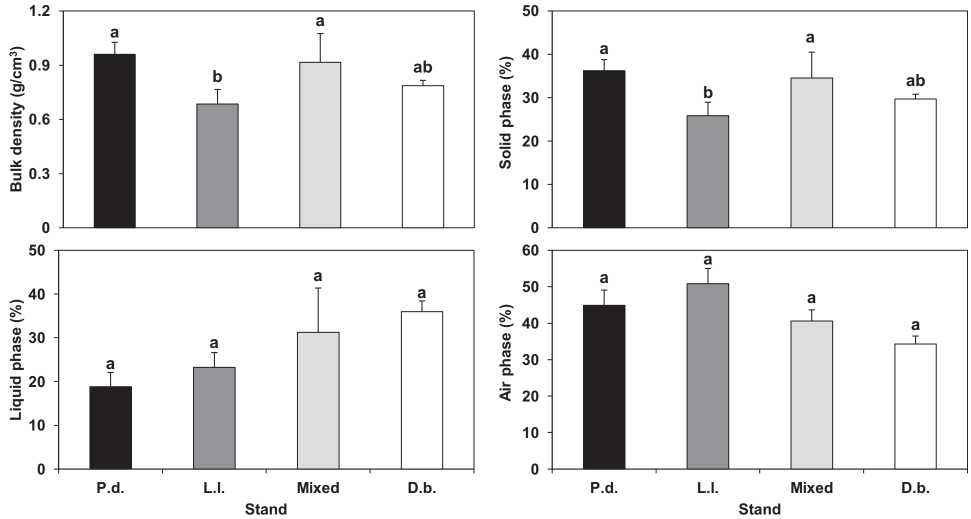

Fig. 1. Soil bulk density and three phase of cultivation site by stand sites (D.b. = deciduous broadleaved; L.l. = *Larix leptolepis*, Mixed = mixed of *P. densiflora* and oak spp., P.d. = *Pinus densiflora*) for mountain-cultivated ginseng. Bars are means±standard error. Different letters above the bars denote significant treatment effects at $p < 0.05$.

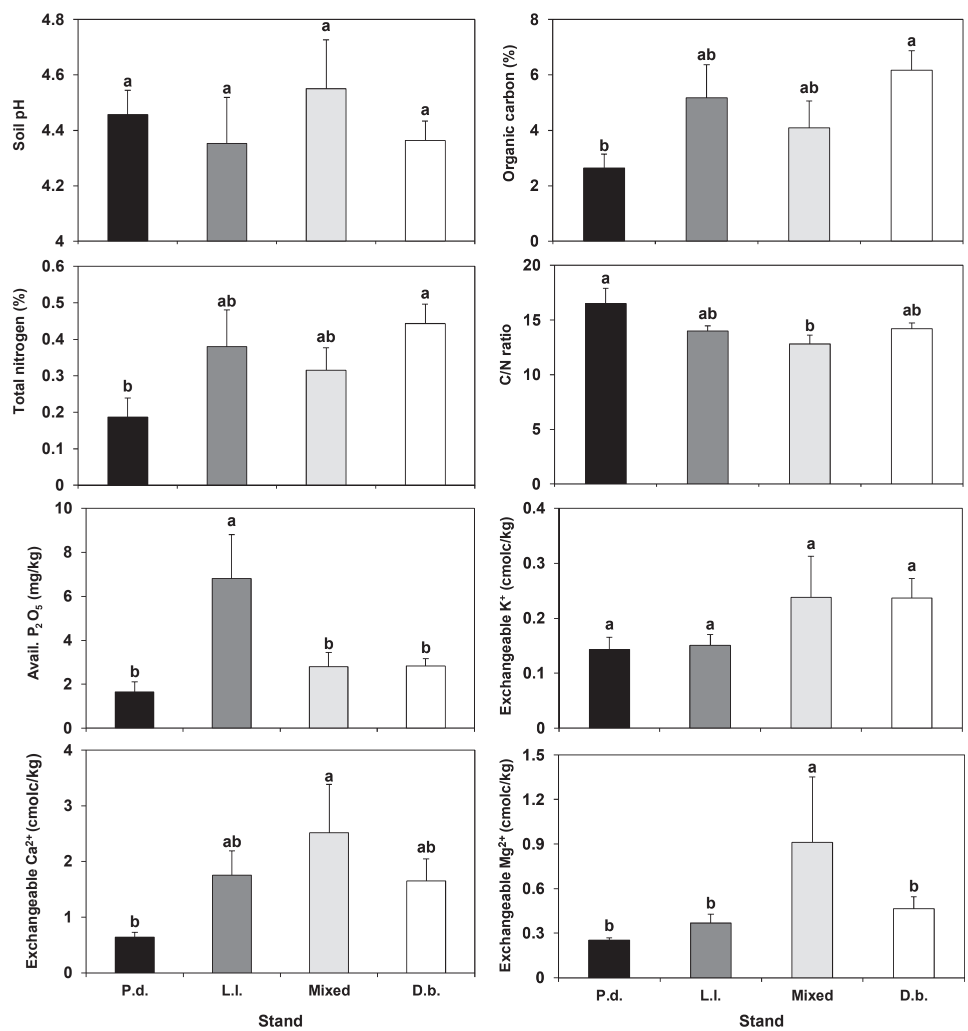

Fig. 2. Soil pH and nutrient of cultivation site by stand sites (D.b. = deciduous broadleaved; L.l. = *Larix leptolepis*, Mixed = mixed of *P. densiflora* and oak spp., P.d. = *Pinus densiflora*) for mountain-cultivated ginseng. Bars are means±standard error. Different letters above the bars denote significant treatment effects at $p < 0.05$.

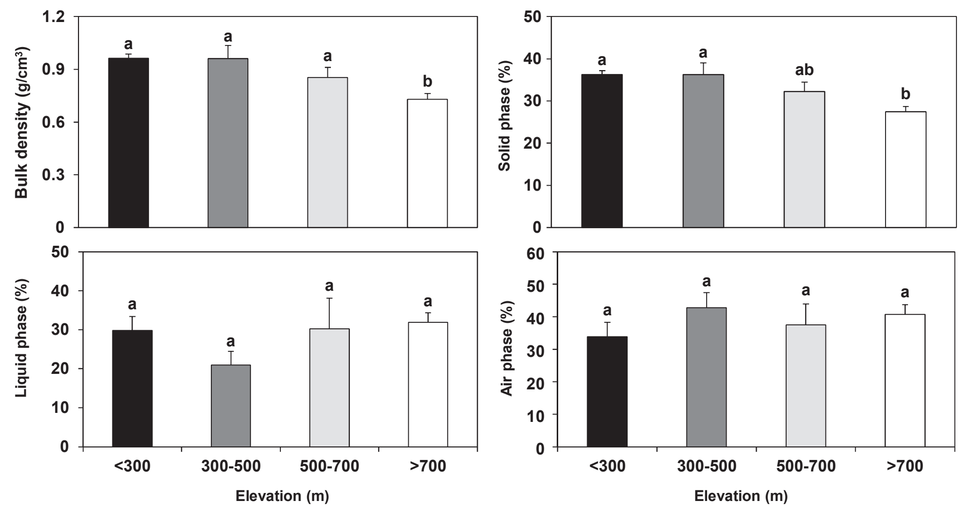

Fig. 3. Soil bulk density and three phase of cultivation site by elevation for mountain-cultivated ginseng. Bars are means±standard error. Different letters above the bars denote significant treatment effects at $p < 0.05$.

be due to a low organic C content compared with the other cultivation sites because the soil bulk density was affected by soil organic C content [12]. Also the high proportion of the liquid phase in deciduous broad-leaved and mixed stand sites compared with the *P. densiflora* stand sites was due to the high organic C content that directly and indirectly influenced the soil water content. The high bulk density in the *P. densiflora* stand sites and low-elevation sites may affect the establishment and growth of ginseng seedlings because a high bulk density may induce a reduction of seedling growth [13].

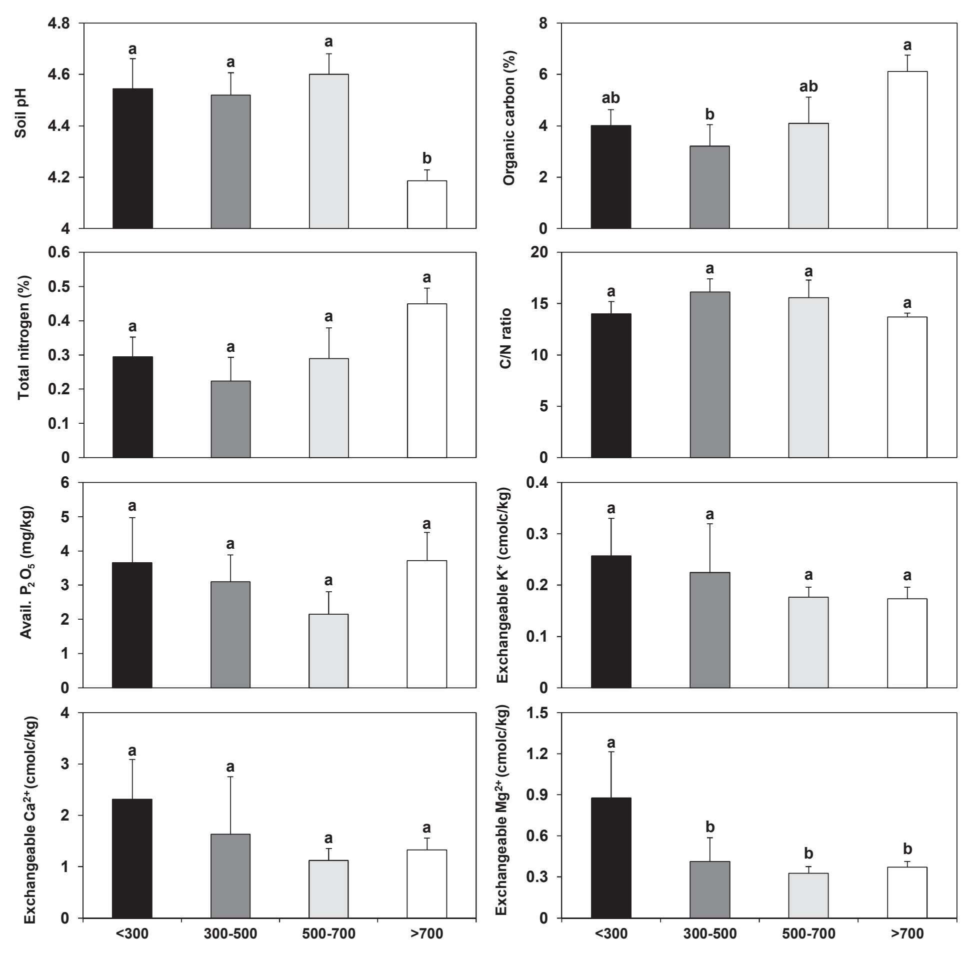

Fig. 4. Soil pH and nutrient of cultivation site by elevation for mountain-cultivated ginseng. Bars are means±standard error. Different letters above the bars denote significant treatment effects at $p < 0.05$.

The soil pH was unaffected by stand site types (pH 4.35–4.55), but the high-elevation sites (>700 m) were strongly acidified, with pH 4.19. The soil pH in forest stands depends on the uptake of cations and anions by vegetation, the nitrification potential, and the soil buffering capacity, among others [13]. However, the low soil pH in the >700-m sites may be due to humic acid with a high organic C content. The pH values in all of the study sites were lower than the optimum soil pH (pH 5.5–6.0) for American ginseng growth [1,6].

The organic C and total N contents were lower in the *P. densiflora* than in the deciduous broad-leaved stand sites, while the C/N ratio was highest in the *P. densiflora* stand sites. The high organic C content of the deciduous broad-leaved stand sites and high-elevation sites may be due to the increased sources of organic C from the litter fluxes [13] compared with the slowly decomposing litter in the *P. densiflora* stand sites.

Available P was low in all of the stand sites. This low value may be due to decreased P availability in acidified soils [13]. Also, this result suggests that P fertilizer in these stand sites was not applied during cultivation because the concentration of P in all of stand sites was similar or lower than that of the natural forest stands (28 mg/kg) in Korea [14]. Generally, the addition of P fertilizers increases the concentration of P in the soil because P fertilizers typically exhibit little leaching characteristics [13].

Soil fertility levels, such as exchangeable K^+, Ca^{2+}, and Mg^{2+}, were generally higher in the mixed stand sites and low-elevation sites than in the *P. densiflora* stand sites and high-elevation sites. This difference in exchangeable cation may arise from differences in the mineralogical character, tree root distribution, and nutrient cycling mechanisms inherent in these sites [13]. American ginseng grew well on acidic soils with a relatively high Ca content and a preferred Ca/Mg ratio of 5:1 [6]. However, the levels of exchangeable cation in all of the cultivation sites for mountain-cultivated ginseng showed lower values compared to the levels of exchangeable cation originating from granite parent materials of Korean forest soils [14].

Mountain-cultivated ginseng at the local level was mostly grown in highly acidified soils that varied greatly in their levels of soil nutrients. In addition, a significant proportion of the cultivation sites for mountain-cultivated ginseng occurred in forest environments that did not correspond to the ideal type of soil environment for ginseng cultivation, as reported in other studies. It is difficult to determine the ideal sites for mountain-cultivated ginseng that tolerates a wide variety of soil physical and chemical attributes. However, ginseng cultivation in *P. densiflora* stand sites may not be suited for growing ginseng because many of these soils are acidic and nutrient depleted. Also, the survival and productivity of ginseng in high elevation sites may be affected by an increased susceptibility to fungal diseases because of low soil pH and poorly drained characteristics with high organic C content. The results of this study suggest that soil nutrient management may be essential to produce mountain-cultivated ginseng in Korea to alleviate nutrient deficiencies or aluminum toxicities in strongly acidified soils. However, mountain cultivation techniques for ginseng should not include fungicide spray or soil amendment application.

Conflicts of interest

All authors have no conflicts of interest to declare.

Acknowledgments

This work was partially supported by Gyeongnam National University of Science and Technology (2013) and a Forest Science & Technology Project (Project No. S211212L030320) provided by Korea Forest Service.

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