

Article

Correlation Analysis Between the Growth of Wild-Simulated Ginseng and the Soil Bacterial Community in the Central Region of South Korea

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Abstract: Wild-simulated ginseng (WSG, *Panax ginseng* C.A. Meyer) is the most important medicinal plant naturally cultivated in the forestry environment. The growth and active component content of WSG can be influenced by various environmental factors, such as climate conditions, physiognomy, soil properties, and soil bacterial structure. The aim of this study was to investigate the relationship between the growth characteristics of WSG and the soil bacterial community living in a rhizosphere environment. Experimental subjects were 7- and 13-year-old WSG cultivated in the central region (Yeongju) of Korea. The growth characteristics of WSG, divided into aerial parts, root parts, and weight parts, were measured. Rhizome length was significantly higher for 13-year-old WSG, while the number of rootlets was higher for 7-year-old WSG. As a result of analyzing the soil bacterial communities of WSG cultivation sites using next-generation sequencing (NGS), *Proteobacteria* and *Holophagae* were found to be the dominant species in the phylum level and class level, respectively. Rhizome length was positively correlated with *Bacteroidetes* at the phylum level, but it was negatively correlated with *Thermoleophilia* and *Gemmatimonadetes* at the class level. *Pedospharae* showed a negative correlation with the number of leaflets and petiole length, while *Clostridia* showed a positive correlation with the number of rootlets. The growth of WSG might vary depending on the environment in which it is cultivated. It is especially affected by soil properties and soil bacterial communities. Therefore, in future studies, it will be necessary to isolate and identify soil microorganisms living in WSG cultivation sites and then confirm their growth-promoting effects on WSG.

Keywords: bacterial composition; growth characteristics; next-generation sequencing; correlation analysis; wild-simulated ginseng



Academic Editor: Ramona Iseppi

Received: 11 February 2025

Revised: 12 March 2025

Accepted: 18 March 2025

Published: 21 March 2025

Citation: Kim, K.; Yun, Y.-B.; Park, M.; Um, Y. Correlation Analysis Between the Growth of Wild-Simulated Ginseng and the Soil Bacterial Community in the Central Region of South Korea. *Appl. Sci.* **2025**, *15*, 3465. <https://doi.org/10.3390/app15073465>

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1. Introduction

Medicinal plants play a crucial role in human health and have been utilized since ancient times to treat a diverse array of diseases [1]. Ginseng, one of the most ancient medicinal plants, belongs to the ginseng genus (*Panax*), which is part of the Araliaceae family. The genus *Panax*, which includes *Panax ginseng*, *P. notoginseng*, *P. pseudoginseng*, *P. trifolius*, *P. stipuleanatus*, *P. quinquefolius*, *P. japonicus*, *P. japonicus* (var. *angustifolius*, var. *bipinnatifidus*, var. *major*), and *P. zingiberensis*, is predominantly found in East Asia and North America [2,3].

In Korea, *Panax ginseng* is classified into three types according to the cultivation environment and method. Wild ginseng (WG) naturally grows without any artificial

intervention. Wild-simulated ginseng (WSG) is produced in natural conditions without the application of artificial facilities, pesticides, or chemical fertilizers. In contrast, cultivated ginseng (CG) is grown in controlled environments with artificial facilities.

WSG is designated as a specially managed forest product under the Korean Forest Service's Act on the Promotion of Forestry and Mountain Villages, which characterizes it as 'WSG produced without the installation of artificial facilities such as shading screens in the production area. It also prohibits the use of chemically synthesized pesticides or fertilizers during the cultivation process'. Therefore, since it is cultivated without the use of agricultural chemicals, it is reported to possess medicinal properties akin to those of WG [4].

The growth and bioactive compounds of *P. ginseng* are influenced by the environmental characteristics of the cultivation site, including climate change, soil properties, and microbial communities [5]. Numerous environmental factors impact plant growth and the biosynthesis of bioactive compounds in their habitat; however, microorganisms living in the rhizosphere soil exert the most significant influence [6–9]. The rhizosphere soil represents the interface where plant roots interact with soil-dwelling microorganisms [5,10,11]. Microorganisms in rhizosphere soil play crucial roles in pollutant degradation, organic matter decomposition, nutrient cycling, and supplying nutrients to plants [12,13], and they enhance the secretion of plant hormones, increasing environmental stress resistance [14]. The diversity and composition of microbial communities in rhizosphere soils are closely associated with plant species and soil functionality [15–17]. Although microbial communities can be very similar in geographically diverse environments [18,19], they vary in their abilities to support plant nutrient uptake or suppress pathogens through rhizosphere soil microbes. Recently, high-throughput sequencing—a next-generation, culture-independent marker gene sequencing method—has been utilized to examine soil microbial communities. In the metagenomic analysis of CG, variability in the microbial community has been discovered, depending on the site, in CG aged 2–6 years [19,20]. In the roots, the order of *Proteobacteria-Actinobacteria-Firmicutes-Bacteroidetes* was observed [21], while in the stems, the order of *Firmicutes-Proteobacteria-Actinobacteria* was noted [22]. Thus, various microbial communities are distributed in accordance with the growth of each part of the ginseng, playing roles in promoting plant growth and protecting the plant from external stressors [23].

Compared to cultivated ginseng, WSG, which is cultivated in natural forests without the use of chemical fertilizers and pesticides and without the installation of artificial facilities, the environmental conditions of the cultivation site, including climate, soil properties, and microbial communities, are crucial. Accordingly, establishing scientific and systematic data is imperative for selecting WSG cultivation sites. Previous studies have analyzed soil properties and microbial communities across various environments [24–26]. However, research focused on these aspects at WSG cultivation sites by region remains insufficient. Thus, this study aims to explore the growth characteristics of WSG in the central region of Korea and to examine the soil properties and microbial communities at WSG cultivation sites to assess their interaction and impact on the growth of WSG.

2. Materials and Methods

2.1. Collecting Wild-Simulated Ginseng and Soil Samples

The WSG cultivation site was selected in Yeongju, Gyeongsangbuk-do, and 5 samples of 7-year-old (36°54'49.1" N, 128°32'11.4" E) and 13-year-old (36°54'42.8" N, 128°32'04.5" E) WSG were collected for the experiment. Soil samples were collected from the rhizosphere where the WSG was planted after the collection of the WSG samples. Surface soil was removed, and soil samples were collected at a depth within 20 cm. The soil samples for

analysis were filtered using a 2 mm sieve and air-dried at room temperature, and those for microbial community analysis were transported in an ice box and frozen at $-20\text{ }^{\circ}\text{C}$.

2.2. Investigating Soil Chemistry in Wild-Simulated Ginseng Plantations

Soil chemical properties at the WSG cultivation site were analyzed in accordance with the Comprehensive Laboratory Analysis Manual published by the Rural Development Administration [27]. Soil pH and electrical conductivity (EC) were determined using a pH meter and an EC meter, respectively, after mixing the soil with distilled water in a 1:5 ratio and agitating for 30 min. The organic matter (OM) content was assessed via the Walkley–Black method, while the total nitrogen (TN) content was measured using the Kjeldahl distillation method after treating 1 g of soil with 5 mL of concentrated sulfuric acid and processing it in a block digester. The available phosphate (Avail. P) content was quantified by absorbance using 1-amino-2-naphthol-sulfonic acid via the Lancaster leaching method. The exchangeable cations content was determined through Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) after leaching the soil with 1 N-ammonium acetate (NH_4OAc), and cation exchange capacity (CEC) was measured by the Kjeldahl distillation of substituted NH_4^+ in the soil after leaching with 1 N- NH_4OAc .

2.3. Collecting Wild-Simulated Ginseng Samples and Investigating Growth Characteristics

The investigation of growth characteristics for the collected 7- and 13-year-old WSG was conducted in accordance with the guidelines for crop-specific characteristic investigations (ginseng TG). The aerial parts examined included stem length, stem diameter, flower stalk length, number of leaflets per stem, petiole length, leaflet length, and leaflet width. Root parts assessed were rhizome length, root diameter, root length, and number of rootlets. Weights were measured as total weight, aerial weight, root weight, and dry weight [28].

2.4. Soil Microbiome Analysis

Total DNA was extracted from soil samples collected to analyze the soil microbial community of WSG plantations using the DNeasy PowerSoil kit (QUIAGEN, Hilden, Germany). Gene amplification and sequencing were performed in accordance with the Illumina MiSeqTM sequencing system (Illumina Inc., San Diego, CA, USA) at Macrogen (Macrogen Inc., Seoul, Republic of Korea). The soil microbial community sequence data were processed using the Mothur pipeline (version 1.43.0, The University of Michigan, Ann Arbor, MI, USA). The sequences database was then clustered into operational taxonomic units (OTUs) at a 97% similarity threshold, utilizing the Greengene reference database to establish the phylogenetic tree and determine the relative abundance [29–31].

2.5. Statistical and Correlation Analysis

The obtained quantitative experimental data were presented as means $\pm$ standard error (S.E.), and the significance of these data was tested using a t-test through the Statistical Analysis System (SAS, version 7.1, SAS Institute, Cary, NC, USA) software, with the Least Significant Difference (LSD) statistically analyzed at the $p < 0.05$ level. Spearman's rho (r) and significance were determined through correlation analysis between soil chemical properties, growth characteristics of WSG, and the soil microbial community at WSG cultivation sites using the IBM SPSS statistics (version 25, IBM Corp., Armonk, NY, USA) software ($p < 0.05$).

3. Results and Discussion

3.1. Soil Chemistry of Wild-Simulated Ginseng Cultivation Sites

Soil chemical properties of 7- and 13-year-old WSG plantations were analyzed (Figure 1). Soil pH ranged from 3.96 to 4.02, electrical conductivity (EC) from 0.56 to 0.76 dS/m, organic matter content (OM) from 5.04 to 6.42%, total nitrogen content (TN) from 0.21 to 0.29%, available phosphorus content (Avail. P) from 92.69 to 143.51 mg/kg, exchangeable potassium (Ex. K) from 0.2 to 0.23 cmol⁺/kg, exchangeable calcium (Ex. Ca) from 0.50 to 2.13 cmol⁺/kg, exchangeable magnesium (Ex. Mg) from 0.39 to 0.56 cmol⁺/kg, exchangeable sodium (Ex. Na) from 0.02 to 0.03 cmol⁺/kg, and cation exchange capacity (CEC) from 16.91 to 18.88 cmol⁺/kg. Ex. K and Mg contents were significantly higher in the soil of the 7-year-old WSG plantations compared to that of the 13-year-old WSG plantations. Conversely, EC and levels of OM, TN, Avail. P, Ex. Ca, and Ex. Na were significantly higher in the 13-year-old WSG plantations than in the 7-year-old WSG plantations. The soil pH of Korean WSG plantations is typically acidic or slightly acidic, ranging from 4.0 to 6.0 [32], and the 7- and 13-year-old WSG plantations in this study also presented acidic soils around pH 4. Soil acidity directly and indirectly affects the solubility, mobility, and bioavailability of nutrients and toxic components in plants [33,34]. Unlike cultivated ginseng, which is grown in controlled environments and regularly receives pesticide treatments, WSG is grown in forests, where its growth rate is slower than that of cultivated ginseng, likely due to nutrient scarcity compared to soil in controlled environments, thus limiting growth [35,36]. *P. ginseng* requires substantial soil nutrients during its long growth season, with soil organic matter and total nitrogen playing critical roles during the flowering stage, as well as being essential components of the plant body [37]. As the cultivation period increases, the soil in WSG plantations becomes more acidic, thereby enhancing the adsorption of nitrogen and phosphorus onto soil particles and further reducing the concentration of soluble phosphorus available to plants [38,39]. In this context, the higher content of total nitrogen and available phosphorus in 13-year-old WSG plantations compared to 7-year-old plantations is notable, potentially due to the presence of phosphate-solubilizing bacteria in the older plantations, which convert phosphorus made insoluble by soil acidification into soluble phosphorus available for plant uptake [40,41]. Therefore, the 13-year-old WSG plantations are likely to exhibit better growth than their 7-year-old counterparts due to higher levels of total nitrogen and available phosphoric acid in the soil.

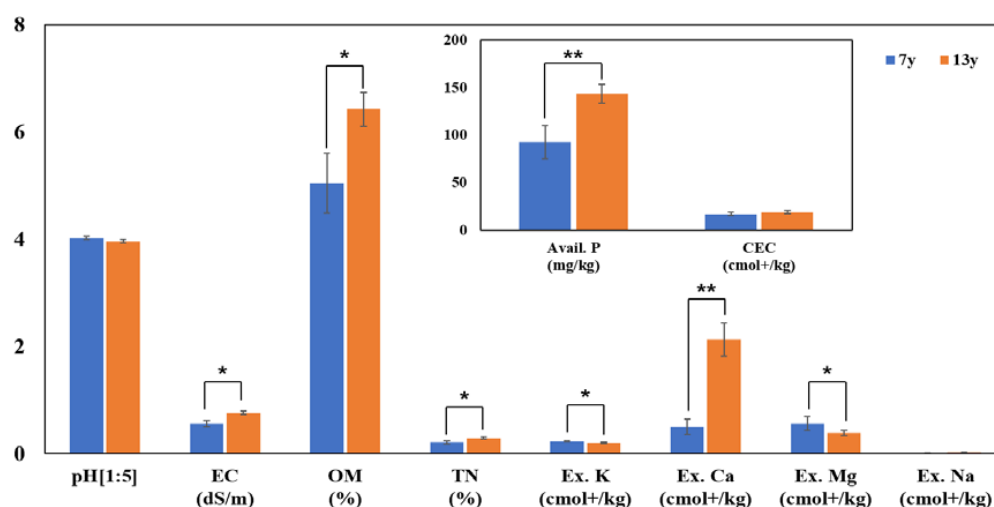


Figure 1. Soil chemical properties of 7- and 13-year-old wild-simulated ginseng plantations. EC, electrical conductivity; OM, organic matter; TN, total nitrogen; Avail. P, available phosphate; Ex. K, exchangeable potassium; Ex. Ca, exchangeable calcium; Ex. Mg, exchangeable magnesium; Ex. Na, exchangeable sodium; CEC, cation exchange capacity. * $p < 0.05$, ** $p < 0.01$.

3.2. Growth Characteristics of 7- and 13-Year-Old Wild-Simulated Ginseng

When analyzing the growth characteristics of 7- and 13-year-old WSG collected from the Yeongju area, significant differences were observed ($p < 0.0032$, Figure 2). The measured growth characteristics included the following: stem length 17.6~22.1 cm, stem diameter 2.1~3.0 mm, flower stalk length 10.2~18.1 cm, number of leaflets per stem 14.8~18.4, petiole length 4.5~5.8 cm, leaflet length 8.8~9.9 cm, leaflet width 3.4~3.8 cm, rhizome length 13.1~29.2 mm, root diameter 9.2~10.7 mm, root length 16.2~16.9 cm, number of rootlets 18.4~26, total weight 5.0~7.9 g, root weight 3.32~3.34 g, and dry weight 0.9~1.04 g (Figure 2). Parameters such as stem length ($p < 0.0358$), stem thickness ($p < 0.0422$), flower head length ($p < 0.0032$), root thickness ($p < 0.0489$), and total weight ($p < 0.0318$) were significantly better in 13-year-old WSG than in 7-year-old WSG. Conversely, flower stalk length ($p < 0.0074$) and the number of rootlets ($p < 0.0375$) showed superior results in 7-year-old WSG compared to 13-year-old WSG. Jeong et al. [42] also reported that an increase in the age of WSG corresponded to greater rhizome lengths, but root length and main root diameter decreased. Similarly, Kim et al. [43] noted that rhizome length increased with the age of WSG, but no significant differences in root length, main root diameter, and weight were observed. Additionally, the growth and ginsenoside content in 13-year-old WSG was higher than in 7-year-old WSG [44]. WSG is grown in the mountains without the use of pesticides and fertilizer. The 13-year-old WSG grows better than the 7-year-old WSG because it is affected by soil nutrients and environmental factors for a long period.

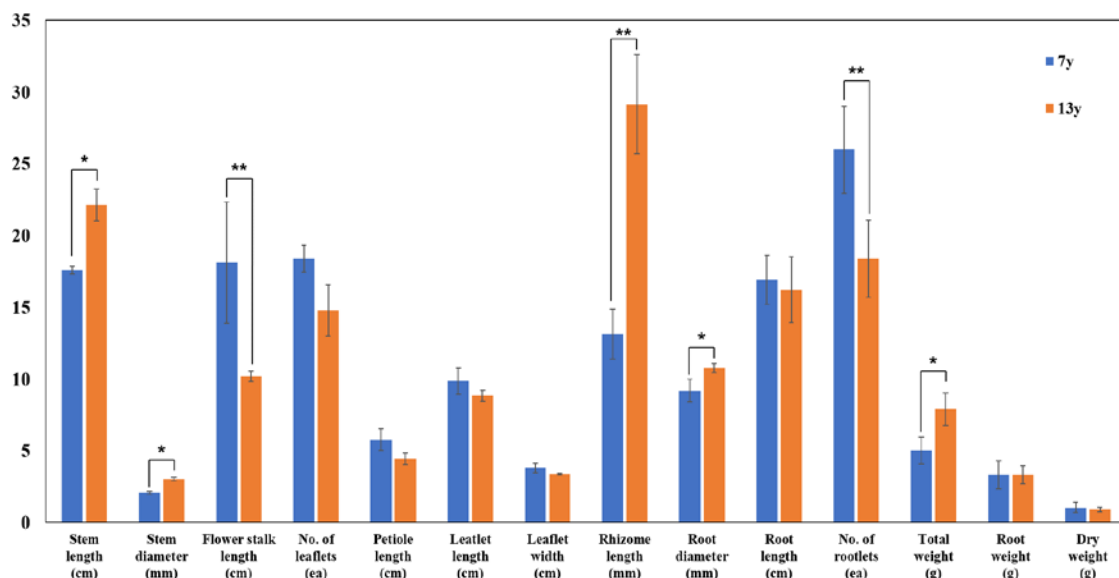


Figure 2. Growth characteristics of 7- and 13-year-old wild-simulated ginseng. Aerial parts: stem length, stem diameter, flower stalk length, number of leaflets, petiole length, leaflet length, leaflet width. Root parts: rhizome length, root diameter, root length, number of rootlets. Weight parts: total weight, root weight, dry weight. * $p < 0.05$, ** $p < 0.01$.

The growth characteristics of WSG can vary depending on the soil component content, and previous studies have indicated that increased levels of exchangeable calcium in the soil correlate with improved WSG growth [45,46]. However, in this study, despite the significantly higher exchangeable calcium content in the soil of the 13-year-old WSG planting site, most growth characteristics, except for the rhizome length, were greater in the 7-year-old site than in the 13-year-old site, suggesting that another factor may have influenced growth. Soil microorganisms enhance plant growth by mineralizing organic matter into ionic forms, which plants can utilize as nutrients [47–51], and beneficial bacteria strengthen plant immunity against the external environment, thus boosting plant

productivity [52,53]. This facilitation enables plants to grow more rapidly and to develop greater resistance and tolerance to external stressors such as soil salinity [54,55], drought [56,57], heavy metals present in the soil [58], and pathogens [59].

3.3. Microbial Communities in the Soil of 7- and 13-Year-Old Wild-Simulated Ginseng Plantations

As it is posited that microorganisms residing in the soil impact plant growth differently, we examined the soil microbial community in 7- and 13-year-old WSG plantations (Figure 3). Distinct clustering was observed within the soil microbial communities of 7- and 13-year-old WSG plantations. Upon analyzing the relative abundance at the phylum level (Figure 3A), *Proteobacteria* recorded the highest relative frequency, accounting for 65.1% of the total soil microbial community in the 7-year-old WSG plantation, followed by *Actinobacteria* (15.2%), *Bacteroidetes* (10.6%), and *Acidobacteria* (2.9%). Conversely, in the 13-year-old WSG plantation, *Proteobacteria* also dominated, with a relative frequency of 80.0%, followed by *Actinobacteria* (8.5%). However, unlike in the 7-year-old WSG plantation, *Acidobacteria* (3.3%) was not substantially different from *Bacteroidetes* (2.8%).

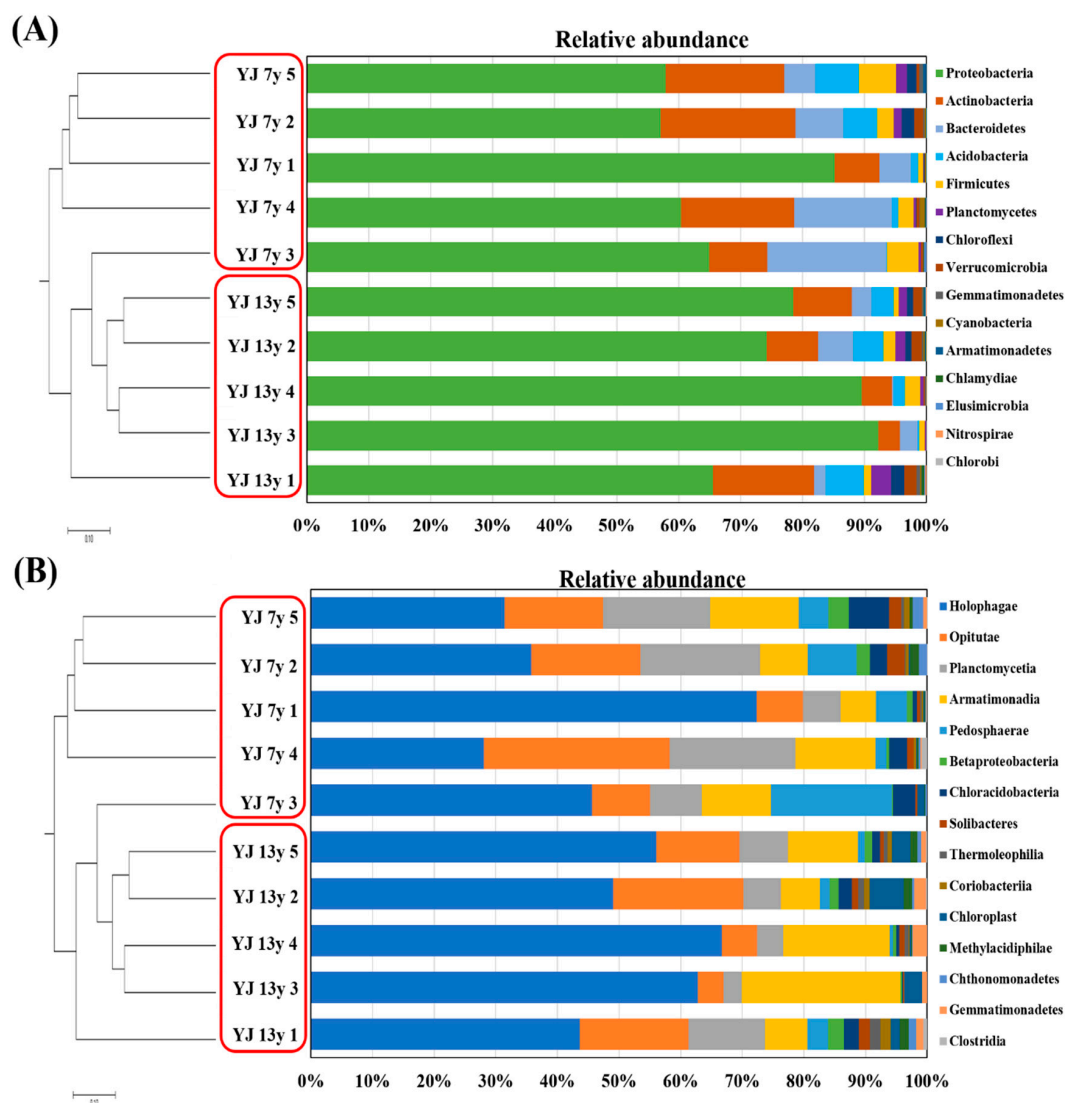


Figure 3. Clustering and relative abundance of bacterial community of wild-simulated ginseng experimental sites. Relative abundance of the phylum and top 15 classes in 7- and 13-year-old wild-simulated experimental sites using phylotype-based analysis of taxonomy. (A) phylum; (B) class. Red box means the clusters of microbial community in each experimental site.

Upon evaluating the relative frequencies at the class level (Figure 3B), it was found that *Holophagae* exhibited the highest relative frequency of 42.6% in the 7-year-old WSG plantation, followed by *Opitutae* (16.2%), *Planctomycetia* (14.3%), *Armatimonadia* (10.4%), and *Pedospaerae* (7.9%). Conversely, in the 13-year-old WSG plantations, *Holophagae* remained the most prevalent at 55.6%, similar to its presence in the 7-year-old plantation, followed by *Armatimonadia* (13.5%), *Opitutae* (12.4%), *Planctomycetia* (6.7%), and *Chloroplast* (2.7%).

Forest soils, including alpine regions, are recognized as acidic soils characterized by low soil pH, with *proteobacteria* and *Acidobacteria* predominating in the microbial communities of these soils, as indicated by phylum-level analyses [43,60–62]. *Proteobacteria*, *Actinobacteria*, *Acidobacteria*, *Bacteroidetes*, and *Firmicutes* have also been reported as dominant in both domestic and international cultivation sites for ginseng and WSG [63–66]. These bacterial groups colonize the rhizosphere soil of cultivated WSG and ginseng, contributing to growth, the biosynthesis of active compounds, and plant defense against pathogens through their interactions with soil and plant systems [67,68]. In the current study, the effective phosphoric acid content was observed to be significantly higher in 13-year-old WSG plants than in 7-year-old plants (Figure 1). With increasing cultivation duration in WSG, the effective phosphoric acid content in the soil decreases due to soil acidification; however, this trend is influenced by phosphate-solubilizing bacteria, which convert insoluble phosphorus into soluble form [69]. When comparing the soil microbial communities between 7- and 13-year-old WSG cultivars, *Proteobacteria* were more prevalent in the latter, constituting 65.1% and 80% in the respective age groups (Figure 3A). Plant compartments will host distinct community structures and exhibit different responses to plant age [70]. Also, in the analysis of MiSeq sequencing of ginseng transplantation soils, the abundances of some bacterial classes decreased, and some fungal genera increased with the increasing age of ginseng plants [71]. Among the microorganisms within the *Proteobacteria* group, phosphate-solubilizing bacteria are remarkably diverse [72–74], and it is likely that *proteobacteria* contributed to increased free phosphate content in soil in 13-year-old WSG plantations [75]. Jiang et al. [76] demonstrated that treatment with the *Providencia rettgeri* strain in saline soils enhanced soil biochemical properties and promoted plant growth by solubilizing insoluble phosphorus, while Saadoul et al. [77] reported a 69% increase in soil free phosphorus content following treatment with the strain. Moreover, a variety of *Proteobacteria*, such as *P. rettgeri* and *P. agglomerans*, contribute to plant growth by solubilizing insoluble phosphorus in the soil. It is believed that the strains of microorganisms from the *Proteobacteria*, which exhibited a higher relative frequency in the soil of the 13-year-old WSG cultivation site in this study, may have enhanced the growth of WSG by solubilizing insoluble phosphorus and increasing the availability of free phosphoric acid to plants.

Holophagae, which exhibited the highest relative frequency in 7- and 13-year-old WSG plantations at the class level, belong to the phylum *Acidobacteria*, subdivision 8 [78–81]. They are predominantly found in forest soils under natural conditions and in rhizosphere soils colonized by plants [82–85]. Microorganisms from the *Holophagae* class have been identified to play an essential role in regulating carbon and nitrogen cycling in soils, specifically by influencing the C/N ratio through the mineralization of soil components [86–88]. In a related investigation [89], the microbial communities in soil from ginseng cultivation sites in Korea were examined using pyrosequencing. This analysis revealed that *Proteobacteria* constituted the highest proportion (30.2%), followed by *Acidobacteria* (29.2%) and *Chloroflexi* (18.2%), indicative of trends similar to those observed in the aforementioned study. Likewise, when analyzing the soil microbial community at a ginseng cultivation site, the dominant species were *Proteobacteria* at 40.9%, followed by *Acidobacteria* (15.6%) and *Actinobacteria* (11.6%) in terms of relative frequency [90]. Kim et al. [91] also reported that *Acidobacteria* and

Proteobacteria were dominant phyla in WSG cultivation sites. *Acidobacteria* are acidophilic bacteria that mainly inhabit acidic soil, and bacteria belonging to *Acidobacteria* have a mechanism of enzymatic activity that allows them to survive under acidic conditions.

3.4. Correlation Between Soil Chemical Properties and Wild-Simulated Ginseng Growth Characteristics at the Growing Site

When analyzing the correlation between soil chemical properties and the growth characteristics of WSG cultivation sites, the exchangeable calcium content and electrical conductivity were found to be significantly and negatively correlated with stem length ($r = -0.829$, $p = 0.042$) and flower stalk length ($r = -0.949$, $p = 0.014$), respectively (Table 1). Moreover, the content of free phosphoric acid and exchangeable potassium content exhibited significant negative correlations with rhizome length ($r = -0.636$, $p = 0.048$) and number of rootlets ($r = -0.670$, $p = 0.034$), respectively. Conversely, soil pH demonstrated a significantly positive correlation with total weight ($r = 0.857$, $p = 0.014$). Generally, significant positive correlations between WSG growth characteristics and soil organic matter, total nitrogen, and cation exchange capacity have been documented [24]; however, in this study, only soil pH and total weight showed significant positive correlations. These findings suggest that the growth of WSG, a perennial plant, may be influenced not only by soil chemical properties but also by diverse site conditions, including climatic conditions, topography, and forest physiognomies, in contrast to annual plants [92,93]. Mansinhos et al. [94] noted that the abiotic factors influencing the growth and active ingredient content of medicinal plants encompass temperature, light intensity, soil moisture content, and salinity. Additionally, Yuan et al. [95] identified soil pH, total nitrogen content, and free phosphoric acid content as primary ecological factors influencing plant growth.

Table 1. Relationship between growth characteristics of wild-simulated ginseng and soil properties of experimental sites using Spearman's rank correlation analysis.

Soil Properties	Growth Characteristics				
	Stem Length	Flower Stalk Length	Rhizome Length	No. of Rootlets	Total Weight
pH	0.429 (0.397)	0.200 (0.747)	0.418 (0.229)	0.079 (0.828)	0.857 (0.014) *
EC	0.370 (0.470)	−0.949 (0.014) *	−0.219 (0.544)	−0.157 (0.665)	−0.337 (0.460)
OM	0.493 (0.321)	−0.718 (0.172)	0.237 (0.510)	−0.585 (0.155)	−0.180 (0.699)
TN	0.371 (0.468)	−0.500 (0.391)	0.006 (0.987)	−0.492 (0.148)	0.029 (0.961)
Avail. P	−0.086 (0.872)	−0.600 (0.285)	−0.636 (0.048) *	0.243 (0.498)	−0.464 (0.294)
Ex. K	−0.086 (0.872)	−0.400 (0.505)	0.335 (0.343)	−0.670 (0.034) *	0.114 (0.758)
Ex. Ca	−0.829 (0.042) *	−0.100 (0.873)	−0.381 (0.352)	0.024 (0.955)	−0.500 (0.253)
Ex. Mg	−0.116 (0.827)	−0.359 (0.553)	−0.170 (0.638)	−0.210 (0.560)	0.030 (0.954)
Ex. Na	−0.145 (0.784)	−0.308 (0.614)	−0.351 (0.320)	0.049 (0.892)	−0.704 (0.077)
CEC	0.200 (0.704)	−0.500 (0.391)	0.164 (0.651)	−0.377 (0.283)	0.214 (0.645)

Spearman's rho values (r) are significantly correlated between the variables compared. Negative values denote negative correlation, and positive values denote positive correlation. Values in parentheses mean p value (* $p \leq 0.05$).

3.5. Correlation Between Wild-Simulated Ginseng Growth Characteristics and Soil Microbial Communities

The correlation analysis between the growth characteristics of WSG and soil microbial communities revealed that rhizome length was significantly positively correlated with *Bacteroidetes* at the phylum level ($r = 0.673$, $p = 0.033$), as well as *Thermoleophilia* ($r = -0.855$, $p = 0.002$) and *Gemmatimonadetes* ($r = -0.891$, $p = 0.001$). *Pedospaerae* demonstrated a significant negative correlation with both the number of leaflets per stem ($r = -0.739$, $p = 0.015$) and petiole length ($r = -0.730$, $p = 0.017$), while the number of rootlets exhibited a significant positive correlation with *Clostridia* ($r = 0.634$, $p = 0.049$) (Table 2). *Bacteroidetes*

are prevalent in forest soils and enhance plant growth by neutralizing soil salts [96] and facilitating nutrient absorption [97,98]. *Pedospaerae* are prevalent in peat layers formed from the fossilization of plant material and exist in substantial quantities independent of the soil core, showing a significant definite correlation with both soil moisture and the C/N ratio, which are vital for plant growth [99,100]. *Thermoleophilia* and *Gemmatimonadetes* are microbial communities typically found in soils with shrub layers and deep, saline soils, respectively [101,102]. Although WSG growth in shrub layers tends to surpass that in non-shrub layers [103], this study reveals a significant inverse correlation with rhizome length, indicating that factors such as the microbial community, meteorological conditions (solar radiation, air temperature, soil moisture), and forest characteristics (dominant tree species, height, trunk diameter) influence WSG growth. *Clostridia* predominantly reside in forest soils, inhibit soil pathogen activity [104–106], and facilitate plant growth through nitrogen and CO₂ fixation [107–109]. This bacterial community indirectly affects plant root growth by competing with pathogens for both space and nutrients in rhizosphere soils [110]. In this study, the relative frequency of *Clostridia* demonstrated a significant positive correlation with the number of WSG rootlets, potentially augmenting WSG growth.

Table 2. Relationship between the relative abundance of the bacterial communities and growth characteristics of wild-simulated ginseng using Spearman’s rank correlation analysis.

Growth Characteristics	Bacterial Communities				
	Phylum	Class			
	<i>Bacterioidetes</i>	<i>Pedospaerae</i>	<i>Thermoleophilia</i>	<i>Gemmatimonadetes</i>	<i>Clostridia</i>
Stem length	−0.164 (0.651)	−0.491 (0.150)	−0.091 (0.803)	0.127 (0.726)	0.288 (0.419)
Stem diameter	0.236 (0.511)	−0.176 (0.627)	−0.358 (0.310)	−0.285 (0.425)	0.276 (0.440)
Flower stalk length	−0.029 (0.957)	−0.543 (0.266)	−0.600 (0.208)	−0.429 (0.397)	−0.429 (0.397)
Number of leaflets	−0.449 (0.193)	−0.739 (0.015) *	0.209 (0.562)	0.548 (0.101)	0.118 (0.745)
Petiole length	−0.448 (0.194)	−0.730 (0.017) *	0.129 (0.723)	0.448 (0.194)	0.267 (0.456)
Leaflet length	0.018 (0.960)	−0.322 (0.364)	−0.097 (0.789)	0.036 (0.920)	0.135 (0.709)
Leaflet width	−0.098 (0.789)	−0.366 (0.298)	0.104 (0.776)	0.171 (0.637)	0.228 (0.526)
Rhizome length	0.673 (0.033) *	0.624 (0.054)	−0.855 (0.002) **	−0.891 (0.001) **	−0.239 (0.506)
Root diameter	−0.152 (0.676)	−0.382 (0.276)	0.224 (0.533)	0.200 (0.580)	0.301 (0.399)
Root length	0.109 (0.763)	−0.231 (0.521)	0.164 (0.650)	0.097 (0.789)	0.517 (0.126)
Number of rootlets	−0.280 (0.434)	−0.584 (0.077) *	0.626 (0.053)	0.608 (0.062)	0.634 (0.049) *
Total weight	0.067 (0.855)	−0.285 (0.425)	−0.248 (0.489)	−0.103 (0.777)	−0.018 (0.960)
Root weight	0.115 (0.751)	−0.079 (0.829)	−0.152 (0.676)	−0.200 (0.580)	−0.006 (0.987)
Dry weight	0.085 (0.815)	−0.146 (0.688)	−0.164 (0.650)	−0.158 (0.663)	0.080 (0.826)

Spearman’s rho values (r) are significantly correlated between the variables compared. Negative values denote negative correlation, and positive values denote positive correlation. Values in parentheses mean p value (** $p \leq 0.01$, * $p \leq 0.05$).

Various beneficial microorganisms, including plant growth-promoting rhizobacteria (PGPR), showed plant growth stimulation by secreting plant hormones such as auxins, cytokinins, and gibberellins. These plant hormones can stimulate root development, thereby promoting the growth of the whole plant [111]. Also, the production of 1-aminocyclopropane-1-carboxylate (ACC) deaminase is able to enhance plant growth [112]. These beneficial bacteria can be biological control agents of pathogens as a mechanism of competition for nutrients [113], antibiosis [114,115], lytic enzymes [116], and the induction of systematic resistance [117,118]. In addition to bacteria, research is being actively conducted for ginseng growth through various microorganisms, such as arbuscular mycorrhizal fungi (AMF) [119,120]. The selection of an optimal site for the cultivation of WSG is important because WSG is grown without the use of pesticides and fertilizer in the mountains for a long period [91]. Based on this study, in the future, studying the

microorganisms involved in the growth of ginseng and various environmental conditions can help enable us to provide optimum cultivation sites for WSG.

4. Conclusions

In this research, we explored the association between the growth characteristics of WSG aged 7 and 13 years cultivated in the central region of Korea and the soil microbial communities within these WSG plantations. The growth data indicated that the rhizome length of the 13-year-old WSG was significantly greater than that of the 7-year-old WSG. Furthermore, the rhizome length and number of rootlets displayed significant correlations with the relative abundances of *Bacteroidetes* at the phylum level and *Clostridia* at the class level, respectively, suggesting their potential influence on WSG growth. Moreover, although the soil microbial community and the growth characteristics of WSG exhibited a significant correlation, multiple factors can influence WSG growth, including location, environment, climate, and soil chemical properties. Thus, future studies should analyze the soil microbial community in an environment where all other conditions are constant to clarify its correlation with WSG growth, elucidate changes in growth characteristics due to shifts in the soil microbial community, and forecast the extent of growth.

Author Contributions: K.K., Y.-B.Y. and Y.U. conceptualized the study; K.K. and Y.U. designed experiments, performed experiments, and analyzed sequencing data; Y.-B.Y. and M.P. assisted in soil sampling and experiments; Y.-B.Y. and M.P. assisted in data analysis and discussion; K.K. wrote the manuscript; K.K. and Y.U. performed critical reviewing and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the National Institute of Forest Science (Grant Number: FP0802-2022-03-2025).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data and analyses from the current study are available from the corresponding author (Y.U.) upon reasonable request.

Acknowledgments: This research was supported by the National Institute of Forest Science (Grant Number: FP0802-2022-03-2025).

Conflicts of Interest: The authors declare no conflicts of interest.

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