Spatial Differences in Soil Improvement Effect and *Panax ginseng* Yield: A Case Study of Yanbian Chaoxianzu (Korean) Autonomous Prefecture

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Abstract [**Objectives**] Farmland ginseng cultivation, as a sustainable alternative to traditional forest-clearing ginseng planting, requires systematic evaluation of soil optimization strategies. This study aimed to quantify the linkage between soil improvement outcomes and ginseng (*Panax ginseng*) yield across five regions in Yanbian Korean Autonomous Prefecture. [**Methods**] Soil improvement trials were conducted using farmland soils, with forest soils as the baseline. Soil nutrient contents were measured via soil agrochemical analysis method using a continuous flow analyzer. Statistical approaches, including significance tests, correlation analysis, and regression analysis, were applied to identify key factors influencing yield. [**Results**] Ginseng yield exhibited a significant positive correlation with organic matter content and available phosphorus, but a negative correlation with electrical conductivity, ammonium nitrogen, and available potassium. Wangqing and Liucai regions achieved post-improvement yields equivalent to 94% and 88% of forest soil yields, respectively, demonstrating the highest soil similarity to forest ecosystems. [**Conclusions**] Region-specific soil improvement protocols in Wangqing and Liucai show high replicability and efficacy. These strategies can serve as benchmarks for sustainable farmland ginseng cultivation, minimizing ecological disruption while maintaining productivity.

Key words Farmland ginseng cultivation; Soil improvement; Soil nutrients; Yield; Correlation analysis
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Ginseng (*Panax ginseng* C. A. *Mey*), a perennial herbaceous plant belonging to the genus *Panax* in the family Araliaceae, is a Tertiary relict species native to the temperate regions of the Northern Hemisphere, with an evolutionary history spanning over 60 million years[1]. According to *Shennong's Classic of Materia Medica*, ginseng has been traditionally used to "tonify the five viscera, tranquilize the mind, relieve palpitations, expel pathogenic factors, improve vision, and enhance cognitive function"[2-3]. Modern pharmacological and clinical studies have further validated its therapeutic effects on the central nervous, cardiovascular, endocrine, and digestive systems[4-6], as well as its roles in enhancing physical performance, mitigating shock, and delaying aging. As a perennial plant, the growth, yield, and quality of ginseng are profoundly influenced by soil physicochemical properties and microbial activity[7].

The traditional cultivation method in China, known as cultivating ginseng by cutting down forests, has caused severe ecological consequences, including deforestation, soil erosion, and ecosystem degradation. To address these issues, the Chinese State Council implemented "the Grain for Green Policy" in 1998, prohibiting indiscriminate forest-clearing cultivation. In 2008, Jilin Province further enacted "the Opinions on Revitalizing the Ginseng Industry" and "the Jilin Ginseng Management Regulations", strictly controlling land approvals for forest-based cultivation. Due to overharvesting and habitat destruction, wild ginseng resources are now critically endangered and listed in China's *National Key Protected Wild Medicinal Species Catalog*[8]. Consequently, transitioning to non-forest cultivation is imperative[9].

Cultivating ginseng in farmland offers a sustainable solution to replace forest-clearing practices and ensure the long-term viability of the ginseng industry[10]. However, farmland soils generally exhibit lower organic matter content, reduced total and capillary porosity, diminished nutrient availability[11], and higher bulk density compared to forest humus soils, all of which hinder ginseng growth[12-13]. Therefore, optimizing soil improvement strategies and refining farmland cultivation techniques are critical for enhancing yield and promoting widespread adoption of this model.

This study investigated soil amendment strategies for ginseng cultivation in Yanbian Korean Autonomous Prefecture, a region with nearly four decades of experience in cultivating ginseng in farmland[13]. Different soil improvement methods were applied to improve farmland soils, and compositional assessments were conducted on modified soils across five representative areas, hoping to identify soil amendment protocols that most closely replicate forest soil conditions. The findings will provide actionable insights for refining soil optimization technologies, ultimately advancing farmland ginseng productivity and scalable implementation of effective cultivation practices.

Materials and Methods

Materials

Samples Soil samples were collected from five regions in Yanbian Korean Autonomous Prefecture, including Yanji, Hunchun,

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Chaoyangchuan, Wangqing, and Liucai. Forest soil samples from Wangqing were used as the baseline.

Sampling was conducted between June 10 and June 20, 2024, from farmland cultivated with transplanted three-year-old ginseng. Soil layers were categorized as follows: upper layer (<10 cm depth), middle layer (10 – 20 cm), and lower layer (20 – 30 cm). Each layer was sampled using a foil sampler to ensure uniform soil porosity measurement. After air-drying and homogenization, six replicate samples per region were prepared for analysis.

Equipment and Reagents Continuous Flow Analyzer (AA3 model, Tianjin Zhongtong Technology Development Co., Ltd.); Electronic scale (ACS-30-JC31/JE31).

Sodium chloride (NaCl); sodium carbonate (Na_2CO_3); potassium sulfate (K_2SO_4); sodium hydroxide (NaOH); phenol; ascorbic acid; potassium hydroxide (KOH); disodium phenyl phosphate; sodium hypochlorite (NaClO); hydrogen peroxide (H_2O_2); analytical-grade potassium chloride (KCl); ammonium acetate (CH_3COONH_4), boric acid (H_3BO_3); hydrochloric acid (HCl); sulfuric acid (H_2SO_4); anhydrous ethanol; toluene; potassium permanganate ($KMnO_4$); 3,5-dinitrosalicylic acid; sodium hydroxide; sodium potassium tartrate; disodium hydrogen phosphate (Na_2HPO_4); glucose; sodium dihydrogen phosphate (NaH_2PO_4).

Methods

Soil treatment Soil improvement protocols were initiated in March 2022 across all regions, tailored to local conditions. Ginseng seedlings was transplanted in August 2022.

Transplanting protocol Two-year-old Damaya ginseng seedlings (individual weight: 6 – 7 g; sourced from Changbai County) were bought on August 25 and then transplanted on August 29, 2022. Prior to transplanting, roots were disinfected by dipping in an 800-fold diluted carbendazim solution. Seedlings were planted at a spacing of 8 cm × 25 cm, followed by surface mulching with rice straw.

Soil Parameter Measurement Soil nutrient parameters including total nitrogen (TN), available nitrogen (AN), total phosphorus (TP), available phosphorus (AP), total potassium (TK), available potassium (AK), pH, organic matter (OM), and electrical conductivity (EC), were analyzed using the continuous flow analyzer (AA3). Comparative analyses were performed against forest soil benchmarks. pH and EC were measured with a pH meter and conductivity meter, respectively, at a 5:1 water-to-soil ratio. Organic matter was determined via the potassium dichromate volumetric method and heat dilution method. Ammonium nitrogen (NH_4^+-N) and nitrate nitrogen (NO_3^--N) were extracted with calcium chloride ($CaCl_2$) and analyzed by continuous flow analysis. Available phosphorus was extracted with sodium bicarbonate ($NaHCO_3$) and quantified via continuous flow analysis. Available potassium was extracted with ammonium acetate (CH_3COONH_4) and measured by flame photometry. Total nitrogen was analyzed by the continuous flow analyzer after digestion according to the Kjeldahl method. Total phosphorus and total potassium were quantified via continuous flow analyzer after digestion with perchloric-sulfuric acid. All procedures followed the protocols described in *Soil Agrochemical Analysis* by Bao Shidan[14].

Fresh ginseng root weights were measured in August 2022, and yield values were averaged across replicates.

Soil Improvement Methods and Post-Improvement Soil Composition Analysis

Forest soils are the most suitable for ginseng cultivation, whereas unimproved farmland soils exhibit extremely low seedling survival rates. The goal of farmland soil improvement is to align post-improvement soil properties with forest soil conditions to enhance ginseng yield. In this study, soil improvement protocols for cultivating ginseng in farmland were evaluated across Yanbian Korean Autonomous Prefecture, so as to identify optimal strategies through composition analysis and propose scalable solutions.

Region-specific soil improvement methods

Liucai method: Adapted from South Korean practices, this method involves prolonged soil conditioning. Key steps include pre-winter plowing (2021), followed by organic fertilizer application (March 2022), barley (*Hordeum vulgare*) sowing in May 2022, rotary tillage for burying biomass-maximized barley into the soil, repeated tilling with microbial inoculants (0.013 kg/m^2) and fungicides (0.003 kg/m^2), final pre-winter plowing and seedbed preparation.

Chaoyangchuan method: The utilized land was previously cultivated with *Schisandra chinensis* (Chinese magnolia vine) without additional soil improvement. Organic fertilizers were applied during Schisandra cultivation. Post-harvest field clearing and tilling were conducted in August 2022, followed by direct ginseng transplanting.

Hunchun method: Green manure preparation: Silage corn was sown around April 20 (Grain Rain season) and rotary-tilled more than 10 times in early July. Soil enrichment: Micronutrient fertilizers (0.8 kg/m^2) and microbial fertilizers (0.3 kg/m^2) were applied. Post-absorption conditioning: Additional microbial fertilizers (0.15 kg/m^2) and inoculants (0.01 kg/m^2) were added, followed by one-time tilling and seedbed preparation before transplanting.

Wangqing method: Silage corn was planted as the previous crop. Before the corn tasseled, the soil was plowed, with soil amendments added, including pig manure (3 kg/m^2), microbial inoculants (0.001 5 kg/m^2), and soybean meal (0.3 kg/m^2). The soil underwent 10 rounds of tilling. Then, during seedbed preparation, fungicides (0.003 kg/m^2) were applied before transplanting.

Yanji method: Soil plowing was performed in April 2022, with rice straw (4 kg/m^2) and organic fertilizers (2 kg/m^2) added, followed by 8 – 10 tilling cycles. Seedbeds were prepared for autumn transplanting.

Post-improvement soil composition

Summary of soil composition Forest soils, which is the the most suitable for ginseng cultivation and requires no soil improvement, served as the benchmark. All regions except Liucai (pre-winter plowed in 2021) initiated soil improvement in spring 2022. Two-year-old ginseng seedlings were transplanted in autumn 2022, and soil samples were collected in June 2024 from four-year-old ginseng plots. Key parameters are summarized in Table 1.

Table 1 Post-improvement soil composition and yield across regions

Post-improvement	pH	EC	OM	TN	NH_4^+-N	TP	AP	TK	AK	Yield
		us/cm	g/kg	g/kg	mg/kg	g/kg	mg/kg	g/kg	mg/kg	kg/m^2
Forest	6.50	96.9	23.0	2.07	9.4	0.19	22.7	10.10	190	2.5
Liucai	5.55	192.4	45.4	2.11	25.2	0.73	15.8	3.89	231	2.2
Chaoyangchuan	6.24	50.2	13.3	0.79	30.5	0.40	9.4	4.20	236	1.4
Hunchun	4.93	511.0	19.3	2.72	95.0	0.51	18.4	4.75	328	1.5
Wangqing	6.04	130.7	43.7	2.30	41.9	1.02	33.3	4.06	230	2.35
Yanji	7.24	168.1	41.8	1.50	12.3	0.25	30.3	12.07	391	2.0

According to Table 1, the ginseng yields of Liucai and Wangqing were closest to that of forest soil ginseng, while Chaoyangchuan and Hunchun had lower ginseng yields. The following text analyzes in detail the impact of different levels of each component on ginseng yield.

Comparative analysis of soil composition against forest soil

To compare the differences in soil components between the improved soil and the forest soil, taking the Forest soil as the benchmark, independent samples *T*-tests were conducted on the 9 component indicators of the improved soil in each region and the corresponding indicators of the forest soil. That is to say, an independent *T*-test was performed between the 6 groups of pH values of the Liucai soil and the 6 groups of pH values of the forest soil, and the same treatment was carried out for other 8 indicators such as EC, organic matter, and total nitrogen (TN). The data processing methods for other regions were the same as above. The results are summarized in Table 2 below. Among them, the data in the first 9 columns are significance test values. The subtotal counts the number of data that pass the hypothesis test (that is, Sig. >0.05).

Table 2 Summary of the differences in soil components between the improved soil in each region and the forest soil

Region	pH	EC	OM	TN	NH_4^+-N	TP	AP	TK	AK	Subtotal
Liucai	0.021	0.000	0.000	0.847	0.001	0.000	0.038*	0.000	0.141	3
Chaoyangchuan	0.221	0.000	0.000	0.001*	0.000	0.001	0.013*	0.000*	0.045	1
Hunchun	0.000	0.001*	0.009	0.020	0.001	0.000	0.405	0.001*	0.000	1
Wangqing	0.068	0.066	0.001*	0.453	0.006*	0.000	0.389*	0.000	0.114	5
Yanji	0.032*	0.002	0.000	0.020	0.107*	0.207	0.110	0.255	0.000	4

If there is no significant difference in the homogeneity of variance test (*F*-test) of the data (Sig. >0.05), that is, the variances of the two groups are homogeneous, the Sig value of the T-test under the condition of homogeneous variances is shown in the table, and the value has no mark. Conversely, if the variances are heterogeneous (Sig. <0.05 in the *F*-test), the Sig value of the *t*-test is shown in the table, and the value is marked with an asterisk (*).

It can be seen from the above table that Wangqing had the smallest difference in soil components from the forest soil, with a total of 5 indicators showing no significant difference from those of the forest soil. Yanji exhibited the second smallest difference, with Liucai following closely behind. The soil components in Chaoyangchuan and Hunchun had relatively large differences from those of the forest soil. This result had a good corresponding relationship with the ginseng yield in each region.

Correlation of soil component indicators after improvement

A simple correlation analysis was conducted on the component indicators of a total of 36 soil samples from 6 regions, including forest and Liucai. The results are shown in Table 3.

Table 3 Correlation analysis of soil component indicators

Item	pH	EC	OM	TN	NH_4^+-N	TP	AP	TK	AK
pH	1								
EC	-0.505**	1							
OM	0.174	-0.114	1						
(TN)	-0.462	0.614**	0.188	1					
NH_4^+-N	-0.625**	0.606**	-0.291	0.387*	1				
TP	-0.368*	0.057	0.475**	0.3	0.231	1			
AP	0.180	0.088	0.328	0.202	-0.059	0.1	1		
TK	0.590**	-0.162	0.109	-0.159	-0.429**	-0.580**	0.249	1	
AK	0.199	0.405*	0.104	-0.037	0.268	-0.195	0.288	0.323	1

* and ** indicate that the correlation reaches levels of 0.05 and 0.01 respectively.

Correlation between ginseng yield and soil component indicators A simple correlation analysis was carried out between the nutrient components of a total of 36 soil samples from 6 regions, such as forest and Liucai, and the ginseng yield in their respective plots. The results are shown in the following table.

Table 4 Correlation analysis between ginseng yield and each soil component indicator

Item	pH	EC	OM	TN	NH_4^+-N
Yield	0.266	−0.357*	0.585**	0.301	−0.473**
	TP	AP	TK	AK	
	0.168	0.338*	0.296	−0.353*	

* and ** indicate that the correlation reaches levels of 0.05 and 0.01 respectively.

The above table demonstrated significant positive relationships between ginseng yield and organic matter and available phosphorus, and significant negative correlations with electrical conductivity, ammonium nitrogen, and available potassium. OM exhibited the strongest correlation with yield.

Correlation analysis between soil components and ginseng yield after improvement

Given the absence of standardized criteria for improving farmland soil for ginseng cultivation in China, forest soil parameters were used as the benchmark to evaluate regional soil composition.

pH value Soil pH critically influences fertility, organic matter dynamics, and conversion and availability of nutrient. The optimal pH range for ginseng growth is 5.5 − 7.0, with high-yield soils typically exhibiting slightly lower pH values (5.4 − 5.7)[15]. Although Yanji's soil parameters closely resembled forest soil, its elevated pH (> 7) likely contributed to lower yields compared to Liucai (Table 1 and Table 2).

According to Table 1, except for Yanji (pH 7.24) and Hunchun (pH 4.93), all improved soils fell within the suitable pH range. Soil pH variations were correlated significantly to EC, ammonium nitrogen (NH_4^+-N), total phosphorus (TP), and total potassium (TK) (Table 3). However, due to the narrow optimal pH range, no linear relationship between pH and yield was observed (Table 4).

EC Elevated EC reflects high soluble salt concentrations, which can cause plant damage or root death. In ginseng cultivation soils with excessively high EC values, symptoms such as wilting, chlorosis (yellowing), stunted growth, and increased susceptibility to diseases may occur. Hunchun's notably low yield (Table 1) aligned with its extreme EC value, consistent with the significant negative correlation between EC and yield (Table 4). EC exhibited positive correlations with total nitrogen (TN), NH_4^+-N, and available potassium (AK) (Table 3), suggesting that reducing these nutrient inputs could mitigate EC value.

Notably, as can be seen from Table 1, Chaoyangchuan's EC (50.2 μS/cm), 48.2% lower than forest soil, highlighted the role of *S. chinensis* as a previous crop in salt reduction, offering potential for yield enhancement when combined with targeted soil amendments.

Organic matter (OM) Organic matter is an important component for soil to maintain its fertility and agricultural productivity. It consists of a series of organic compounds that exist in the soil, have non-uniform compositions and structures, and mainly contain carbon and nitrogen as their components[16]. It supports essential microbial communities required for ginseng growth, while its superior water retention and nutrient retention capacities play a pivotal role in enhancing soil quality[17]. Soil organic matter content serves as a key indicator for assessing fertility, directly influencing ginseng quality and yield, and is a pivotal reference metric for evaluating farmland improvement efficacy[18].

As shown in Table 1, the soil improvement methods applied in Liucai, Wangqing, and Yanji resulted in higher organic matter content compared to forest soil, demonstrating enhanced soil fertility and nutrient availability for ginseng growth. These findings align with the conclusion by Zhao *et al.*[19] that optimal ginseng cultivation soils should maintain organic matter levels between 3% − 5%. Table 4 further confirms a significant positive correlation between organic matter content and ginseng yield, underscoring the importance of organic matter enrichment as a priority for soil improvement. In contrast, soils with *S. chinensis* as the previous crop exhibited the lowest organic matter content, likely linked to substantial organic matter decomposition and depletion during *Schisandra* cultivation[20].

Nitrogen content Soil nitrogen content is an important indicator for evaluating soil fertility. Nitrogen usually exists in the soil in the form of organic matter, providing nutrients for the normal growth of ginseng, influencing its metabolism and regulating the nutrient absorption level. Research shows that in the growth process of ginseng, phenomena such as delayed germination, short stems and leaves, a significant reduction in ginseng roots, and a delayed withering period are related to high nitrogen content in the soil[21]. Among them, ammonium nitrogen (NH_4^+-N) is more harmful than nitrate nitrogen. On the other hand, insufficient nitrogen content can lead to small and underdeveloped stems and leaves[22−23]. Therefore, when cultivating ginseng in farmland, an appropriate amount of nitrogen fertilizer should be applied to ensure the normal growth of ginseng.

As shown in Table 1, total nitrogen (TN) levels in Liucai closely resembled forest soil, while Wangqing and Hunchun slightly exceeded it, meeting ginseng's nitrogen requirements. However, Chaoyangchuan (0.79 g/kg) and Yanji (1.50 g/kg) exhibited deficient TN levels. Notably, Hunchun's soil contained exceptionally high NH_4^+-N, approximately tenfold higher than forest soil. The significant negative correlation between NH_4^+-N and yield (Table 4) suggests that excessive ammonium nitrogen likely contributed to Hunchun's low productivity.

Phosphorus content Phosphorus (P) is a key component of numerous compounds in ginseng and plays vital roles in physiological and biochemical processes during growth[24]. Available phosphorus (AP) reflects soil phosphorus supply, and its deficiency directly reduces yield. Meng and Niu's research demonstrated that combined nitrogen, phosphorus, and potassium fertilization enhanced both ginseng growth and saponin content[25]. Although ginseng requires less phosphorus (1/4 − 1/6 of nitrogen demand), phosphorus promotes root development, drought resistance, and disease resilience. Phosphorus deficiency inhibits growth, impairs root systems, disrupts carbohydrate accumulation, and reduces seed quantity and quality[22].

Post-improvement soils across all regions showed elevated total phosphorus levels compared to forest soil, fulfilling ginseng's phosphorus needs (Table 1). Table 4 confirms a significant positive correlation between AP and yield. Chaoyangchuan's low yield might partly stem from its low AP, highlighting the importance of optimizing phosphorus availability.

Potassium content Potassium (K) is an essential element for ginseng growth. As a potassium-loving plant, ginseng benefits from basal or topdressing potassium fertilizers at optimal levels, which enhance nutrient uptake, promote plant growth, improve yield and quality, and strengthen stress resistance[26]. Studies indicate that the combined application of potassium and micronutrients significantly increases individual weight compared to phosphorus-potassium fertilization alone[27]. Ginseng's demand for potassium is the highest among macronutrients, escalating with plant development and growth duration, with absorption rates proportionally increasing over cultivation year[28].

As shown in Table 1, total potassium (TK) levels in most regions post-improvement remained below forest soil values, except in Yanji. Available potassium (AK) in Liucai, Chaoyangchuan, and Wangqing exceeded forest soil by ≤25%, meeting cultivation requirements, while Hunchun and Yanji exhibited higher AK.

Regression analysis of ginseng yield and soil parameters

A stepwise regression analysis was performed with ginseng yield as the dependent variable and soil parameters as independent variables. The standardized regression equation yielded:

$$\text{Yield} = -0.472X_{EC} + 0.419X_{OM} + 0.558X_{TN} + 0.359X_{TK} - 0.301X_{AK}$$

$R^2 = 0.794^{**}$, F-value = 23.09, Sig. = 0.000

The high R^2 value (close to 0.8) indicates robust model fit, while the significant F-test ($P < 0.01$) validates the equation's predictive capability. This equation can be used to predict the ginseng yield of soil improvement strategies, and further optimize the soil improvement strategies.

Summary of Experimental Analysis

(1) Comparative analysis of forest soil and regionally improved soils revealed that Wangqing, Yanji, and Liucai exhibited soil compositions closest to forest soil. However, Yanji's overly elevated pH suppressed ginseng growth, resulting in lower yields compared to Liucai. Wangqing and Liucai achieved yields of 2.35 and 2.2 kg/m^2, respectively, approaching the forest soil's yield. This confirms the efficacy of their improvement protocols, providing a technical reference for soil optimization across Yanbian's diverse soil types.

(2) Correlation analysis demonstrated significant positive relationships between ginseng yield and organic matter and available phosphorus, and significant negative correlations with electrical conductivity, ammonium nitrogen, and available potassium. OM exhibited the strongest correlation with yield.

(3) Unimproved farmland typically yields negligible ginseng. However, Chaoyangchuan's use of *S. chinensis* as a previous crop resulted in a yield of 1.4 kg/m^2, significantly higher than unmodified soils (about 0.2 kg/m^2), though significantly lower than that of forest soil. This highlights the potential of *S. chinensis* in preconditioning soils for ginseng cultivation.

Discussion and Future Perspectives

(1) This study systematically evaluated soil improvement methods for cultivating ginseng in farmland across five regions and analyzed post-improvement nutrient profiles against forest soil benchmarks. However, soil sampling was conducted only two months before harvest, limiting insights into dynamic nutrient variations during ginseng's growth stages. Future research should incorporate multi-seasonal soil monitoring to elucidate temporal nutrient dynamics.

(2) Discrepancies between the correlation analysis of soil components (Table 3) and findings from previous studies[7] were observed. These inconsistencies may arise from the limited amount of sample or methodological differences in sampling protocols.

(3) *S. chinensis*, as a previous crop, demonstrated potential to reduce soluble salt accumulation. Building on this, subsequent trials should integrate organic fertilizers and green manure into Chaoyangchuan's protocol to elevate organic matter and available phosphorus levels, thereby testing synergistic effects on yield.

References

[1] SHEN L, XU J, DONG LL, *et al.* Cropping system and research strategies in *Panax ginseng*[J]. China Journal of Chinese Materia Medica, 2015, 40(17): 3367–3373.

[2] SUN XY, SUN FY. Shennong's classic of materia medica[M]. Beijing: People's Medical Publishing House, 1963.

[3] Pharmacopoeia of the People's Republic of China. Part I[S]. 2010.

[4] ZHANG G, LIU A, ZHOU Y, *et al.* *Panax ginseng* sinsenoside-Rg2 protects memory impairment via anti-apoptosis in a rat model with vascular dementia[J]. J Ethnopharmacol, 2008, 115(3): 441.

[5] YU XT, WANG SP. Clinical observation on treatment for postoperative gastric cancer by ginsenoside Rg3 combined with chemotherapy[J]. Chinese Journal of Cancer Prevention and Treatment, 2010, 17(10): 779.

[6] PENG H, LYU LS. Research on the medicinal and cultivation history of ginseng in China and related planting techniques[J]. Journal of Anhui Agricultural Sciences, 2012, 40(20): 10400.

[7] CHENG HT, ZHANG YY, ZHANG LX, *et al.* Changes of soil nutrients in ginseng under forest at different growth stages[J]. Chinese Agricultural Science Bulletin, 2011, 27(8): 47–52.

[8] SHEN L, WU J, LI XW, *et al.* A study of global ecological adaptability and field selection practices of *Panax ginseng*[J]. China Journal of Chinese Materia Medica, 2016, 41(18): 3314–3322.

[9] HUANG RX, HUANG SM, HUANG J, *et al.* The inevitable path for sustainable development of ginseng cultivation in farmland[J]. Ginseng Research, 2002, 14(3): 2–4.

[10] WANG R, DONG LL, XU J, *et al.* Identification and prevention of root rot pathogen in model of ginseng cultivated in farmlands[J]. China Journal of Chinese Materia Medica, 2016, 41(10): 1787–1791.

[11] GAO JC, GUAN S, XU YH. Effects of different livestock manure fertilizers on soil nutrients and humus composition in farmland-cultivated ginseng[J]. Jiangsu Agricultural Sciences, 2017, 45(6): 255–259.

[12] IM W, KIM S, LIU Q, *et al.* Nocardioides ginsengisegetis sp. nov, isolated from soil of a ginseng field[J]. Journal of Microbiology, 2010, 48(5): 623–628.

[13] VENDAN RT, YU YJ, LEE SH, *et al*. Diversity of endophytic bacteria in ginseng and their potential for plant growth promotion[J]. Journal of Microbiology, 2010, 48(5): 559 – 565.
[14] TENG XM. Site selection, soil improvement, and pesticide residue degradation in farmland-cultivated ginseng[J]. Ginseng Research, 2005 (3): 32 – 33.
[15] BAO SD. Soil and agricultural chemistry analysis[M]. Beijing: China Agriculture Press, 1999.
[16] PAN JL, DAI WA, SHANG ZH, *et al*. Review of research progress on the influence and mechanism of field straw residue incorporation on soil organic matter and nitrogen availability[J]. Chinese Journal of Eco-Agriculture, 2013, 21(5): 526 – 535.
[17] WU AX, WANG X, LYU Y, *et al*. Progress of soil nutrients in cultivation of *Panax ginseng* in farmland[J]. Northern Horticulture, 2018 (22): 177 – 186.
[18] SONG CY, ZHANG XY, LIU XB, *et al*. Effect of soil organic matter on soil fertility and crop productivity[J]. Journal of Agricultural System Science and Comprehensive Research, 2008(3): 357 – 362.
[19] ZHAO SJ, YU DR, CAO XY, *et al*. Study on suitable soil conditions for ginseng cultivation[J]. Specialty Research, 1992(1): 16 – 19.
[20] JIN Y. Effect of different fertilization on the yield and quality of *Schisandra chinensis*[D]. Northeast Agricultural University, 2011.
[21] GONG JZ, ZHANG SJ, WANG YR, *et al*. Effects of nitrogen forms on the physiological characteristics of *Panax ginseng*[J]. Northern Horticulture, 2024(16): 96 – 101.
[22] ZHONGYL, FAN JB. Genotypic differences in grain Yield and physiological nitrogen use efficiency among riecultivars[J]. Pedos Phere, 2009, 19(6): 681 – 691.
[23] YANG JX, TIAN YX. Cultivation of medicinal plants[M]. Beijing: China Agriculture Press, 2004: 158 – 162.
[24] LYU L, ZHANG YY, SUN H, *et al*. Effects of phosphorus stress on nutrient elements and saponins in ginseng plants[J]. Journal of Jilin Agricultural University, 2023, 45(3): 307 – 315.
[25] MENG XY, LIU YY. Study on the effects of combined application of nitrogen, phosphorus, and potassium on ginseng quality[J]. Standardization Reports, 1996, 17(6): 36 – 37.
[26] ZHANG CG. Study on the effect of potassium fertilizer on ginseng growth [D]. Chinese Academy of Agricultural Sciences, 2018.
[27] ZHAO Y, WANG XQ, ZHENG YN, *et al*. Effect of inorganic fertilizers on yield properties of ginseng[J]. Journal of Jilin Agricultural University, 2001, 23(4): 56 – 59.
[28] XU YH, CAO ZQ, SONG XD. Discussion on scientific fertilization in ginseng production[J]. Ginseng Research, 2004(1): 22 – 25.

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References

[1] MANKERTZ A, CALISKAN R, HATTERMANN K, *et al*. Molecular biology of porcine circovirus: Analyses of gene expression and viral replication[J]. Vet Microbiol., 2004, 98(2): 81 – 88.
[2] SUN W, DU Q, HAN Z, *et al*. Detection and genetic characterization of porcine circovirus 4 (PCV4) in Guangxi, China[J]. Gene, 2021, 773: 145384.
[3] SEGALES J. Porcine circovirus type 2 (PCV2) infections: Clinical sings,pathology and laboratory diagnosis[J]. Virus Res., 2012, 167 (1 – 2): 10 – 19.
[4] LIU CM, ZHANG CF, WEI YW, *et al*. Cultivation and identification of porcine circovirus type 2 (PCV2) cell culture-adapted strain[J]. Chinese Journal of Preventive Veterinary Medicine, 2006, 28(3): 248 – 251. (in Chinese).
[5] YI J, LIU C. Molecular characterization of porcine circovirus 2 isolated from diseased pigs coinfected with porcine reproductive and respiratory syndrome virus[J]. Virol J., 2010, 7: 286.
[6] PEREZ LJ, DIAZ DE ARCE H, PERCEDO MI, *et al*. First report of porcine circovirus type 2 infections in Cuba[J]. Res Vet Sci, 2010, 88 (3): 528 – 530.
[7] TANG Q,GE L,TAN S, *et al*. Epidemiological survey of four reproductive disorder associated viruses of sows in Human Province during 2019 – 2021[J]. Vet Sci., 2022, 9(8): 425.
[8] GUO Z, RUAN H, QIAO S, *et al*. Co-infection status of porcine circoviruses (PCV2 and PCV3) and porcine epidemic diarrrhea virus (PEDV) in pigs with watery diarrhea in Henan province, central China [J]. Microb Pathog., 2020, 142: 104047.
[9] ALLAN GM, MCNEILLY F, ELLIS J, *et al*. PMWS: Experimental model and co-infections[J]. Vet Microbiol, 2004, 98(2): 165 – 168.
[10] HE ZQ, XU C, WANG AF, *et al*. Quantitative method of porcine circovirus II vaccine antigen and its application[J]. China Animal Industry, 2024, 4: 43 – 44. (in Chinese).
[11] SANCHEZ RE JR, MEERTS P, NAUWYNCK HJ, *et al*. Characteristics of porcine circovirus-2 replication in lymphoid organs of pigs inoculated in late gestation or postnatally and possible relation to clinical and pathological outcome of infection[J]. J Vet Diagn Invest., 2004, 16 (3): 175 – 185.
[12] CUI SJ, JIN YP, LI X, *et al*. The development of an indirect immunofluorescent technique of porcine circovirus[J]. Chinese Journal of Preventive Veterinary Medicine, 2007, 29(1): 63 – 66. (in Chinese).
[13] YANG X. Study on the culture characteristics of PCV2 in vitro and the effect of HMGCR on the replication of OCV2[D]. Jilin: Jilin University, 2015. (in Chinese).
[14] LIN YX, SUN YW, LIU ZM, *et al*. Development of an indirect ELISA diagnostic method with the main antigentic region of PCV2 capsid protein expressed in *E. coli*[J]. Chinese Journal of Preventive Veterinary Medicine, 2007(3): 217 – 221. (in Chinese).
[15] XU ZJ, WEI RR, LI YA, *et al*. Development of a double antibody sandwich ELISA for quantitative detection of porcine circovirus type 2 Cap protein[J]. Animal Husbandry and Veterinary Medicine, 2018, 50 (10): 73 – 77. (in Chinese).
[16] WALKER IW, KONOBY CA, JEWHURST VA, *et al*. Development and application of a competitive enzyme-linked immunosorbent assay for the detection of serum antibodies to porcine circovirus type 2[J]. J Vet Diagn Invest., 2000, 12(5): 400 – 405.
[17] TANG N, LYU YL, GUO X, *et al*. Detection of distribution of porcine circovirus II in experimentally infected piglets with immunohistochemical method[J]. Acta Veterinaria et Zootechnica Sinica, 2008(3): 372 – 375. (in Chinese).
[18] WEI XM, REN RP. Handbook of laboratory testing of animal diseases [M]. Beijing: China Agriculture Press, 2006. (in Chinese).
[19] GAO J, HU JH, SUN FP, *et al*. Establishment and application of PCR method for detection of porcine circovirus II[J]. Acta Agriculturae Shanghai, 2007, 23(4): 102 – 104. (in Chinese).
[20] GUO QH, LIU XL. Establishment of immunoperoxidase monolayer cell assay for detection of porcine circovirus type 2[J]. Heilongjiang Animal Science and Veterinary Medicine, 2012, 6: 122 – 123. (in Chinese).

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