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Effects of Fertilization on Growth and Rhizome Size of Laichau Ginseng (*Panax vietnamensis* var. *fuscidiscus* K. Komatsu, S. Zhu & S.Q. Cai), a Medicinal Plant, in Nursery Conditions

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Abstract: *Laichau ginseng (Panax vietnamensis var. fuscidiscus K. Komatsu, S. Zhu & S.Q. Cai) is a highly valuable medicinal plant endemic to northwestern Vietnam. This study investigated effects of nine fertilization treatments on nursery-grown seedlings in Lai Chau Province. Treatments included control (no fertilization), organic fertilizers (earthworm compost, cattle manure, GROWTH HIHA PT), foliar applications (Nano AKH, Multi T.E, NK KaHuBo + Dolce), and combined treatments (Super Humic + Trichoderma, H2 + Man + IEM). Each treatment had three replicates with 30 seedlings per replicate and experiment was applied in 7-month old seedlings. After experiment 3 months, the results indicated that all treatments achieved 96.67-100% survival rates. The control treatment exhibited superior height (12.75 ± 0.49 cm) and crown diameter (8.77 ± 0.21 cm), while organic fertilizers showed lower growth. Rhizome dimensions showed no significant differences among treatments, ranging from 1.28-1.46 cm in length and 0.52-0.63 cm in diameter. These findings suggest young Laichau ginseng seedlings grow robustly under minimal fertilization, potentially reducing production costs while maintaining quality propagation material for sustainable cultivation.*

Keywords: *Fertilization, Laichau ginseng, Nursery management, Panax vietnamensis var. fuscidiscus, Rhizome development*

1. INTRODUCTION

Panax vietnamensis var. *fuscidiscus*, known as Laichau ginseng, is a perennial herbaceous plant of the Araliaceae family characterized by compound palmate leaves arranged in whorls, small greenish-white flowers, and bright red berries at maturity. The plant develops a fleshy rhizome that accumulates medicinal compounds and exhibits slower growth rates compared to cultivated Asian ginseng species, requiring 2-3 years to reach harvestable maturity (Zhu et al., 2003; Phan et al., 2013).

Laichau ginseng has restricted distribution in northwestern Vietnam, particularly Lai Chau Province, and southern Yunnan Province, China. Such restricted distributions with potential intraspecific genetic variation have been documented in other *Panax* species (Pandey & Ali, 2012), emphasizing the conservation significance of localized populations. This species thrives in evergreen broadleaved forests at 1,400-2,200 m elevation with annual temperatures of 13-20°C, precipitation of 1,700-2,600 mm, and forest canopy cover exceeding 70% (Tuyen et al., 2019b). These shade-tolerant plants grow on organic-rich, well-drained soils with thick litter layers maintaining consistent moisture. The species typically occurs in undisturbed or slightly disturbed primary forests where multi-layered canopy structure provides optimal light conditions.

The medicinal value of Laichau ginseng has been recognized by local ethnic communities for generations. Scientific investigations revealed that wild Laichau ginseng rhizomes contain total saponin content of 23.85%, substantially higher than cultivated specimens (18.48%) and other Vietnamese ginseng species such as *P. vietnamensis* (22.29%) and *P. stipulealatus* (3%) (Tuyen et al., 2019b). These ginsenosides belong primarily to dammarane-type triterpene glycosides, exhibiting diverse pharmacological activities including antioxidant, immunomodulatory, and adaptogenic effects (Qi et al., 2011). Additional bioactive compounds including polyacetylenes (Shim et al., 1987) and malonyl-ginsenosides (Kochkin et al., 2013; Yoshizaki et al., 2012) have been identified in related *Panax* species, contributing to their pharmacological diversity. The economic value has increased dramatically, with market prices for dried rhizomes ranging from 1,000-5,000 USD/kg depending on age and quality, making it one of the most valuable non-timber forest products in Vietnam. This high economic value has generated significant interest among local communities for cultivating the species as poverty reduction and income diversification strategy.

Understanding effects of different fertilizer types on seedling growth and rhizome development is essential for developing practical cultivation protocols for local farmers. Excessive fertilization may promote rapid vegetative growth at the expense of rhizome quality and medicinal compound accumulation, while inadequate nutrition could limit seedling vigour. Given the high value and conservation importance of Laichau ginseng, identifying cost-effective and environmentally sustainable fertilization strategies becomes particularly important for smallholder farmers in remote mountainous regions. Therefore, this study aims to evaluate effects of various organic and chemical fertilization treatments on growth parameters and rhizome characteristics of nursery-grown Laichau ginseng seedlings, providing scientific evidence to guide practical cultivation recommendations for sustainable production.

2. Material And Method

2.1. Study Site

This study was conducted in Ta Leng commune, Lai Chau Province, northwestern Vietnam, at approximately 1,650 m elevation, where *Panax vietnamensis* var. *fuscidiscus* (Fig. 1) has natural distribution. The climate is humid subtropical montane with annual mean temperature of 15-18°C and annual precipitation of 2,100-2,400 mm. The soil is humic ferralsol with pH 5.0-5.8 and high organic matter content (5-8%). The nursery was established under shade nets providing approximately 70-75% shade to replicate natural forest conditions.

Figure1. *Laichau ginseng, Panax vietnamensis var. fuscidiscus in nature; plants, green fruits*

2.2. Experimental Design

Nine fertilization treatments were evaluated: CT1 (Control - no fertilization), CT2 (earthworm compost 0.5 kg/m²), CT3 (cattle manure 0.5 kg/m²), CT4 (Super Humic 79 + Trichoderma), CT5 (Nano AKH Super Plus), CT6 (NK KaHuBo + Dolce Lingzhi), CT7 (Multi T.E micronutrient), CT8 (H2 + Man + IEM protocol), and CT9 (GROWTH HIHA PT 100 g/m²). Each treatment had three replicates with 30 seedlings per replicate and experiment was applied in 7-month old seedlings. Fertilizers were applied three times at monthly intervals, with second and third applications using half the initial dosage.

2.3. Data Collection

After experiment 3 months, survival rates were calculated. Growth parameters measured included stump diameter D_o (mm), total height H (cm), crown diameter Dc (cm), leaf length and width (cm), and leaf number. Rhizomes were carefully excavated, and rhizome length and diameter (cm) were measured.

2.4. Data Analysis

Means and standard errors were calculated for all parameters. One-way ANOVA tested for significant differences among treatments. Tukey's HSD post-hoc test was applied for pairwise comparisons when ANOVA indicated significance ($p < 0.05$). All analyses used SAS 9.2 software.

3. RESULTS

Survival rates remained exceptionally high across all treatments: eight treatments (CT1-CT8) achieved 100% survival, while CT9 recorded 96.67% (Table 1). Stump diameter showed no significant differences, ranging from 1.01 mm (CT8) to 1.10 mm (CT6).

Seedling height demonstrated significant treatment effects. The control (CT1, 12.75 ± 0.49 cm) performed statistically similarly to CT4 (11.97 ± 0.41 cm), CT6 (12.03 ± 0.41 cm), CT7 (12.77 ± 0.45 cm), and CT8 (13.22 ± 0.50 cm). In contrast, CT2 (11.17 ± 0.41 cm), CT3 (10.75 ± 0.49 cm), and CT5 (11.46 ± 0.35 cm) resulted in significantly shorter plants. CT9 showed intermediate height (11.67 ± 0.49 cm).

Crown diameter patterns paralleled height results. Control (CT1, 8.77 ± 0.21 cm), CT5 (7.98 ± 0.21 cm), CT6 (8.42 ± 0.25 cm), CT7 (8.45 ± 0.25 cm), CT8 (8.35 ± 0.21 cm), and CT9 (8.08 ± 0.30 cm) produced significantly larger crown diameters. CT2 (7.13 ± 0.24 cm), CT3 (7.48 ± 0.24 cm), and CT4 (7.46 ± 0.26 cm) resulted in smaller crowns.

Leaf length varied significantly: CT1 (5.50 ± 0.12 cm), CT5 (5.16 ± 0.18 cm), and CT6 (5.09 ± 0.20 cm) produced longer leaves, while other treatments showed shorter leaves. Leaf width remained relatively uniform except CT7 (2.01 ± 0.04 cm). Leaf number ranged from 4.45-4.90 with no significant differences.

Rhizome dimensions showed remarkable consistency. Length ranged from 1.28 cm (CT9) to 1.46 cm (CT1), and diameter from 0.52 cm (CT4) to 0.63 cm (CT8), with no significant differences among treatments.

Table1. *Effects of fertilization on growth and rhizome size of nursery-grown Laichau ginseng*

Experiment	Parameter (±SE)								
	Survival rate (%)	D_o (mm)	H (cm)	D_c (cm)	Leaf length (cm)	Leaf width (cm)	Leaf number	Rhizome length (cm)	Rhizome diameter (cm)
CT1	100,00	1,03 ±0,02	12,75 ±0,49^a	8,77 ±0,21^a	5,50 ±0,12^a	2,41 ±0,10^a	4,80 ±0,10	1,46 ±0,07	0,62 ±0,03
CT2	100,00	1,07 ±0,03	11,17 ±0,41^b	7,13 ±0,24^b	4,81 ±0,17^b	2,27 ±0,08^a	4,50 ±0,18	1,29 ±0,05	0,60 ±0,03
CT3	100,00	1,02 ±0,02	10,75 ±0,49^b	7,48 ±0,24^b	4,53 ±0,15^b	2,19 ±0,08^a	4,70 ±0,14	1,36 ±0,07	0,54 ±0,03
CT4	100,00	1,02 ±0,03	11,97 ±0,41^a	7,46 ±0,26^b	4,57 ±0,17^b	2,11 ±0,09^a	4,90 ±0,10	1,31 ±0,07	0,52 ±0,02
CT5	100,00	1,04 ±0,03	11,46 ±0,35^b	7,98 ±0,21^a	5,16 ±0,18^a	2,32 ±0,09^a	4,70 ±0,13	1,34 ±0,07	0,59 ±0,03
CT6	100,00	1,10 ±0,04	12,03 ±0,41^a	8,42 ±0,25^a	5,09 ±0,20^a	2,14 ±0,09^a	4,73 ±0,13	1,29 ±0,07	0,58 ±0,02

CT7	100,00	1,05 ±0,01	12,77 ±0,45^{a}	8,45 ±0,25$_{a}$	4,45 ±0,12$_{b}$	2,01 ±0,04^{b}	4,90 ±0,07	1,42 ±0,07	0,59 ±0,02
CT8	100,00	1,01 ±0,02	13,22 ±0,50^{a}	8,35 ±0,21$_{a}$	4,90 ±0,17$_{b}$	2,33 ±0,08^{a}	4,53 ±0,15	1,40 ±0,08	0,63 ±0,02
CT9	96,67	1,06 ±0,03	11,67 ±0,49$^{a}_{b}$	8,08 ±0,30 a	5,01 ±0,20$_{b}$	2,24 ±0,10^{a}	4,69 ±0,14	1,28 ±0,07	0,57 ±0,04

Note: ^{a,b} different letters in a column indicates statistically significant difference of means between treatments. SE is standard error. D_o is stump diameter. H is total height. D_c is crown diameter.

4. DISCUSSION

The high survival rates (96.67-100%) across all treatments demonstrate that Laichau ginseng exhibits strong adaptability to nursery conditions and tolerance to various fertility management strategies. These rates are considerably higher than those reported for *P. quinquefolium* (60-85%) under various cultivation systems (Anderson et al., 1993). The superior survival may be attributed to optimal environmental conditions mimicking natural habitat, and inherent species vigour. This resilience is particularly valuable for smallholder farmers with limited access to commercial fertilizers, suggesting successful nursery production can be achieved with minimal external inputs.

The unexpected finding that control seedlings exhibited superior or equivalent growth compared to most fertilized treatments challenges conventional assumptions about nutrient requirements during ginseng nursery phase. This result aligns with ecological observations that wild Laichau ginseng thrives in forest understory environments with moderate nutrient availability (Tuyen et al., 2019b). Ginsengs are slow-growing, shade-adapted species that evolved strategies for efficient nutrient acquisition under nutrient-limited conditions. Excessive nutrient availability, particularly nitrogen, may disrupt metabolic balance, potentially diverting resources toward vegetative growth at the expense of root development and stress tolerance. Additionally, some organic fertilizers may temporarily immobilize available nutrients during decomposition, limiting uptake despite high total nutrient content. The relatively short experimental duration (three months) may not have provided sufficient time for slower-release organic fertilizers to fully mineralize and demonstrate benefits.

The lack of significant fertilization effects on rhizome development represents a particularly important finding for practical cultivation. Rhizome size and quality determine economic value, as these organs accumulate medicinally active ginsenosides commanding premium market prices (Tuyen et al., 2019b). Previous research on other *Panax* species demonstrated that excessive nitrogen fertilization is often associated with reduced secondary metabolite accumulation and increased disease susceptibility (Qi et al., 2011). At this early seedling stage (8-10 months old), rhizome development is primarily governed by endogenous developmental programs rather than immediate nutrient availability. This developmental stage may represent a critical transition when seedlings establish basic architecture and allocate resources primarily to root system development rather than storage organ enlargement. Longer-term studies following seedlings through multiple growing seasons would determine whether fertilization effects on rhizome development become more pronounced as plants mature.

The practical implications for Laichau ginseng cultivation are substantial. The superior performance of unfertilized seedlings suggests growers can reduce or eliminate fertilizer applications during nursery phase without compromising seedling quality or survival, resulting in significant cost savings. However, several important caveats exist. This study examined only initial three months under controlled nursery conditions. Longer-term studies tracking plants through transplanting and multiple growing seasons in field conditions are essential to determine whether early-stage fertilization influences subsequent performance, medicinal compound accumulation, and ultimate economic yield. Integration of these findings with existing knowledge about wild Laichau ginseng containing substantially higher saponin content (23.85%) compared to cultivated plants (18.48%) suggests minimal fertilization approach may help maintain closer physiological similarity to wild plants by avoiding rapid growth and altered metabolic profiles associated with intensive fertility management (Tuyen et al., 2019b).

Future research should investigate long-term effects of nursery fertilization on post-transplant performance, ginsenoside profiles, and rhizome quality at harvest maturity. Studies examining interactions between fertilization regime and other management factors such as shade level, planting density, and harvesting age would provide more complete cultivation recommendations. Investigation of soil microbial communities and mycorrhizal associations under different fertility regimes could reveal important mechanisms underlying observed growth responses, as ginsengs form beneficial associations with arbuscular mycorrhizal fungi enhancing nutrient acquisition and stress tolerance (Anderson et al., 1993). From broader perspective, this research supports sustainable, low-input cultivation approaches for high-value medicinal plants, aligning with principles of agroecological intensification while reducing environmental impacts and supporting both local livelihoods and conservation of remaining natural populations.

5. Conclusion

This study demonstrates that nursery-grown Laichau ginseng seedlings exhibit exceptional survival rates (96.67-100%) across all nine fertilization treatments after a 3-month experiment. Contrary to conventional expectations, unfertilized control seedlings achieved superior growth with stem height of 12.75 ± 0.49 cm and crown diameter of 8.77 ± 0.21 cm, outperforming most fertilized treatments. Organic fertilizers (CT2, CT3) resulted in significantly lower height (10.75-11.17 cm) and crown diameter (7.13-7.48 cm). Importantly, rhizome dimensions showed no significant differences among treatments, with length ranging from 1.28-1.46 cm and diameter from 0.52-0.63 cm, suggesting early-stage rhizome development is governed by endogenous patterns rather than immediate nutrient availability. These findings indicate farmers can successfully propagate high-quality seedlings with minimal or no fertilizer inputs, substantially reducing production costs while maintaining excellent seedling vigor. This low-input approach aligns with the species' ecological characteristics and may help maintain physiological profiles similar to wild plants that contain higher saponin content (23.85% vs 18.48% in cultivated plants). However, longer-term field trials are needed to evaluate effects on post-transplant performance, ginsenoside profiles, and ultimate rhizome quality at harvest maturity.

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