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Effects of the plant growth regulator NAA on young fruit drop prevention and seed quality of Ngoc Linh ginseng (*Panax vietnamensis* Ha et Grushv.)

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ABSTRACT

Ngoc Linh ginseng (*Panax vietnamensis* Ha et Grushv.) is a rare and highly valuable medicinal plant endemic to Vietnam, whose large-scale cultivation is constrained by low fruit set, early fruit drop and limited seedling quality. This study evaluated the effects of different concentrations of the plant growth regulator Naphthalene Acetic Acid (NAA) on flower and fruit development, seed quality, seed germination and seedling growth of Ngoc Linh ginseng under nursery conditions. The experiment was conducted from March 2022 to March 2024 at Ngoc Linh Mountain, Quang Nam Province, using four treatments: water spray (control) and foliar application of NAA at 20, 30 and 40 ppm, arranged in a randomized complete block design. The results showed that NAA application significantly influenced reproductive and seedling-related parameters compared with the untreated control. NAA at 30 ppm produced the most favorable outcomes, increasing the number of flowers per inflorescence (61.63 flowers), flower stalk length (1.43 cm), flower diameter (3.59 mm), and the number of fruits per cluster (44.08 fruits). Fruit quality was also improved, with the highest proportion of red fruits (>46%) and the lowest proportion of green fruits. In addition, seed treatment with NAA at 30 ppm resulted in the highest germination rate (78.89%), seedling formation rate (75.56%) and proportion of marketable seedlings (74.11%). Seedlings from this treatment exhibited superior growth performance, including greater plant height, canopy diameter, and the highest weight of 100 tubers (132.65 g). Overall, foliar application of NAA at a concentration of 30 ppm is recommended to enhance flower and fruit set, improve seed quality and promote seedling growth of Ngoc Linh ginseng, thereby contributing to the development of a standardized and sustainable seedling production system.

Keywords: Ngoc Linh ginseng, *Panax vietnamensis*, Naphthalene acetic acid, flower and fruit set, seed germination and seedling quality, plant growth regulator

1. INTRODUCTION

Ngoc Linh ginseng is a medicinal plant traditionally kept as a “*secret remedy*” by the Xe Dang ethnic people living in the high mountainous region of Ngoc Linh Mountain (Bao, T. *et al.*, 2017) [1], located in the former Kon Tum and Quang Nam provinces. To date, the exact time of its emergence and the beginning of its medicinal use remain unknown. Local communities have long used this “*hidden*” medicinal plant to treat seriously ill family members in need of health restoration, to enhance endurance during prolonged forest expeditions for hunting, to treat snake bites, and even to alleviate common ailments such as stomachache, with remarkable effectiveness (Ali, T. *et al.*, 2010) [2].

In 1985, based on standard voucher specimens and botanical data provided by the Vietnam Ginseng Center, Ha Thi Dung and I. V. Grushvitsky identified this plant as a new species and officially published its scientific name as *Panax vietnamensis* Ha et Grushv (Bao, T. *et al.*, 2017) [1].

This species represents a newly recognized ginseng of the world, belonging to the genus *Panax* and the family *Araliaceae*, distinguished by its unique characteristics in flowers, fruits, and seeds (Bradford, M.M. 1976) [3].

From various local names such as *cây thuốc giầu*, *ngải dọm con*, and *sâm cung*, Ngoc Linh ginseng has now been officially recognized as a rare and valuable medicinal plant of the Ngoc Linh region and of Vietnam as a whole (Chakrabarti, N. *et al.*, 2003) [4].

According to the orientation of the National Product Development Program toward 2020, approved by Decision No. 2441/QĐ-TTg dated December 31, 2010 of the Prime Minister, Priority is given to new products with competitive advantages that serve the restructuring and sustainable development of agricultural and rural economies, particularly those developed by science and technology enterprises. Vietnamese ginseng was officially added to the list of national products under this program in 2017, pursuant to Decision No. 787/QĐ-TTg dated June 5, 2017.

The Ngoc Linh Ginseng Center has been allocated more than 50 hectares of forest land at an elevation ranging from 1,800 to 1,900 m above sea level in Village 2, in Tra Linh Commune by the Da Nang City People’s Committee to carry out its assigned functions and tasks.

The Center has identified and focused on implementing key strategic objectives aimed at developing Ngoc Linh ginseng not only in terms of cultivation scale but also through strict management of origin and quality, thereby contributing to the establishment and promotion of the Ngoc Linh ginseng brand in both domestic and international markets and gradually enhancing the economic value of this precious ginseng species.

Research on the effects of the plant growth regulator NAA on reducing early fruit drop and improving the quality of Ngoc Linh ginseng seeds is considered one of the essential research activities to support the large-scale development of standardized seedling production, thereby ensuring the supply of qualified planting materials to local communities and enterprises engaged in ginseng cultivation and production (Chauhan, J.S. *et al.*, 2009) [5].

2. MATERIALS AND METHODS

2. 1. Research materials

Research subjects: Ngoc Linh ginseng plants and seeds (*Panax vietnamensis* Ha et Grushv.) with a plant age of ≥ 5 years, currently cultivated on Ngoc Linh Mountain, Quang Nam Province.



Figure 1. Ngoc Linh ginseng plants.
Research location: Ngoc Linh Ginseng Center.
Research period: From March 2022 to March 2024.

2. 2. Research contents

- Investigation of the effects of NAA on the prevention of early fruit drop and the improvement of seed quality in Ngoc Linh ginseng.
- Investigation of the effects of NAA on the germination rate and growth performance of Ngoc Linh ginseng seedlings.

2. 3. Experimental

- *Experimental Treatments were arranged as follows:*

Treatment 1: Water spray (control)

Treatment 2: NAA at 20 ppm

Treatment 3: NAA at 30 ppm

Treatment 4: NAA at 40 ppm

The experiment consisted of four treatments with three replications, arranged in a randomized complete block design (Demirsoy, L. *et al.*, 2010) [6]. Non-experimental factors, including cultivation practices, fertilization, irrigation and crop management, were kept identical across all treatments.

- *Cultivation, maintenance, protection, and monitoring of the seed-producing garden*

Seed production beds were 1.2–1.5 m in width, 3–5 m or more in length and 10–20 cm in height and were reinforced with wooden borders to prevent erosion during heavy rainfall (Dewir, Y.H. *et al.*, 2011) [7].

Well-decomposed forest humus was evenly applied to the bed surface and replenished annually to maintain soil looseness. The planting density was 20,000 plants per hectare. Irrigation was provided to ensure adequate soil moisture (Dhoran, V.S. *et al.*, 2012) [8]. Fertilization involved the uniform application of 4 tons of forest humus per hectare per year to the planting holes.

Fertilization was carried out when leaves began to yellow, corresponding to winter fertilization and was combined with weeding and soil loosening. Regular monitoring was conducted to detect abnormalities and to implement timely management measures (Domingues Neto, F. J. *et al.*, 2024) [9].

2. 4. Observed parameters

- Germination rate (%): $(\text{Number of germinated seeds} / \text{Number of seeds sown}) \times 100$.
- Seedling formation rate (%): $(\text{Number of seedlings formed} / \text{Number of seeds sown}) \times 100$.
- Rate of marketable seedlings (%): $(\text{Number of seedlings ready for nursery release} / \text{Number of seeds sown}) \times 100$.
- Number of fruits per fruit cluster (fruits): Total number of fruits per plant; for each treatment, fruits were counted on 10 plants and the mean value was calculated.
- Number of flowers per inflorescence (flowers): Total number of flowers per plant; for each treatment, flowers were counted on 10 plants and the mean value was calculated.
- Flower stalk length (cm): Measured from the leaf axil to the calyx.
- Flower diameter (mm): Measured at two diagonal points across the flower canopy and averaged.
- Flower color: Recorded visually.
- Plant height (cm): Measured from the stem base to the tip of the apical leaf using a measuring ruler (straight ruler or measuring tape).
- - Canopy diameter (cm): Measured along two diagonal directions across the canopy and averaged.
- Stem diameter (mm): Measured at 1 cm above the stem base using a micrometer.
- Weight of 100 tubers (g): Determined by weighing 100 tubers.

2. 5. Data analysis

Experimental data were statistically analyzed using analysis of variance (ANOVA) with IRRISTAT 5.0 and Excel software.

3. RESULTS AND DISCUSSION

3. 1. The effects of the plant growth regulator NAA on the germination rate and seedling formation rate of Ngoc Linh ginseng in the nursery

Naphthalene Acetic Acid (NAA) is a synthetic plant growth regulator belonging to the auxin group (El-Mahdy, A. *et al.*, 1982) [10]. NAA is widely used in crop cultivation and exerts multiple effects on plant physiological processes including root and apical shoot formation, leaf senescence, leaf and fruit abscission, flowering, fruit set, cell elongation and tissue development (Esechie, H. *et al.*, 1994) [11]. The effects of NAA on flower-related parameters of Ngoc Linh ginseng described in the Table 1.

Table 1. Effects of the plant growth regulator NAA on selected flower developmental parameters of Ngoc Linh ginseng.

No.	Experimental treatment	Flower color	Number of flowers per inflorescence (flowers)	Flower stalk length (cm)	Flower diameter (mm)
1	Treatment 1 (Control)	Pale yellowish green	59.03	1.37	3.47
2	Treatment 2	Pale yellowish green	60.57	1.41	3.50
3	Treatment 3	Pale yellowish green	61.63	1.43	3.59
4	Treatment 4	Pale yellowish green	60.77	1.43	3.57
LSD _{0.05}		—	0.82	0.04	0.05
CV (%)		—	6.3	5.7	6.0

Notes: Treatment 1: Water spray (control)
 Treatment 2: NAA at a concentration of 20 ppm
 Treatment 3: NAA at a concentration of 30 ppm
 Treatment 4: NAA at a concentration of 40 ppm

Table 1 shows that the application of the plant growth regulator NAA did not affect the flower color of Ngoc Linh ginseng. All treatments produced flowers of a pale yellowish-green color. In contrast, the parameters related to floral development, including number of flowers per inflorescence, flower stalk length and flower diameter, were influenced by different NAA concentrations (Fang, S. *et al.*, 2006) [12].

As the NAA concentration increased from 0 to 30 ppm, all floral parameters increased accordingly (Farhoudi, R. *et al.*, 2007) [13]. Specifically, the number of flowers per inflorescence increased from 59.03 to 61.63 flowers, the flower stalk length increased from 1.37 cm to 1.43 cm and the flower diameter increased from 3.47 mm to 3.59 mm. Treatment 3, in which NAA was applied at a concentration of 30 ppm, produced the highest values, with

61.63 flowers per inflorescence, a flower stalk length of 1.43 cm and a flower diameter of 3.59 mm. These differences were statistically significant at the 95% confidence level (Gerardo, C.C. *et al.*, 2020) [14].

However, when the NAA concentration was increased to 40 ppm, the floral parameters tended to decline (Jeong, Y.-S. *et al.*, 2003) [15]; specifically, the number of flowers per inflorescence decreased to 60.77 flowers and the flower diameter decreased to 3.57 mm. Thus, foliar application of NAA at a concentration of 30 ppm is considered appropriate for enhancing flower production in Ngoc Linh ginseng (Kumaran, K. *et al.*, 1994) [16].



Figure 2. Immature Ngoc Linh ginseng fruits.



Figure 3. Mature Ngoc Linh ginseng fruits.



Figure 4. Ripe Ngoc Linh ginseng fruits.

Further monitoring of the effects of NAA on fruit-related parameters of Ngoc Linh ginseng yielded the following results:

Table 2. Effects of the plant growth regulator NAA on selected fruit-related parameters of Ngoc Linh ginseng.

No	Experimental treatment	Number of fruits per fruit cluster (fruits)	Fruit color distribution				Characteristics of ripe fruit
			Red	Reddish brown	Yellowish green	Green	
1	Treatment 1 (Control)	39.86	15.47	8.13	7.89	8.37	Red color with a black spot at the apex
2	Treatment 2	41.04	18.74	8.30	6.87	7.13	Red color with a black spot at the apex
3	Treatment 3	44.08	20.64	10.56	8.61	4.27	Red color with a black spot at the apex
4	Treatment 4	42.92	19.43	9.12	8.08	6.29	Red color with a black spot at the apex
LSD _{0.05}		1.57	—	—	—	—	
CV%		6.5	—	—	—	—	

Notes: Treatment 1: Water spray (control)
 Treatment 2: NAA at a concentration of 20 ppm
 Treatment 3: NAA at a concentration of 30 ppm
 Treatment 4: NAA at a concentration of 40 ppm

Monitoring the effects of NAA on fruit-related parameters of Ngoc Linh ginseng indicated that NAA concentration significantly influenced both fruit number and fruit quality (Nguyen, Q. T.*et al.*, 2025) [18].



Figure 5. Ngoc Linh ginseng fruits are red in color.



Figure 6. Ngoc Linh ginseng fruits are reddish brown in color.



Figure 7. Ngoc Linh ginseng fruits are yellowish green in color



Figure 8. Ngoc Linh ginseng fruits are green in color

Application of NAA at 30 ppm resulted in the highest number of fruits per cluster (44.08 fruits) and the best fruit quality, as reflected by the highest proportion of red fruits, accounting for more than 46% of the total (20.64 red fruits out of 44.08 fruits), while the proportion of green fruits was the lowest among all treatments (Pandey, A.*et al.*, 2024) [19]. The differences in fruit number among treatments were statistically significant at the 95% confidence level.

3. 2. Effects of NAA on Seed Germination and Seedling Growth

For seedlings propagated from seeds, the germination rate, seedling formation rate, as well as the proportion of seedlings meeting nursery standards for transplanting, are important indicators for evaluating the germination capacity of seeds (Pankaj Kumar.*et al.*, 2022) [20]. A study on the effects of NAA on the germination rate and seedling formation rate of Ngoc Linh ginseng produced the following results:

Table 3. Effects of the plant growth regulator NAA on the germination rate and seedling formation rate of Ngoc Linh ginseng.

No.	Experimental treatment	Germination rate (%)	Seedling formation rate (%)	Proportion of marketable seedlings (%)
1	Treatment 1 (control)	64.44	61.00	58.65
2	Treatment 2	75.78	73.33	71.67
3	Treatment 3	78.89	75.56	74.11
4	Treatment 4	76.11	74.44	72.67

LSD _{0.05}	3.62	4.05	3.76
CV%	5.0	4.7	4.8

Notes: Treatment 1: Water spray (control)
 Treatment 2: NAA at a concentration of 20 ppm
 Treatment 3: NAA at a concentration of 30 ppm
 Treatment 4: NAA at a concentration of 40 ppm

Table 3 shows that treatment with the plant growth regulator NAA significantly affected seedling-related parameters in the nursery compared with the untreated control (Suman, M.*et al.*, 2017) [21]. Specifically, the control treatment without NAA application resulted in a germination rate of 64.44%, a seedling formation rate of 61.00%, and a proportion of marketable seedlings of 58.65%, which were significantly lower than those of the NAA-treated treatments, with differences being statistically significant at the 95% confidence level.



Figure 9(A,B). Monitoring of the proportion of marketable seedlings across treatments

Application of NAA at different concentrations resulted in different responses (Wu, Q.*et al.*, 2023) [22]. Treatment with NAA at 30 ppm produced the highest values, with a germination rate of 78.89%, a seedling formation rate of 75.56%, and a proportion of marketable seedlings of 74.11%. However, differences among the treatments were not statistically significant (Zhang, T.*et al.*, 2021) [23]. Further monitoring of the effects of NAA on growth parameters of Ngoc Linh ginseng seedlings in the nursery yielded the following results:

The results presented in Table 4 indicate that NAA application affected the quality of Ngoc Linh ginseng seedlings in the nursery compared with the untreated control. The control treatment exhibited significantly lower plant height than the NAA-treated treatments. Under the experimental conditions, plant height ranged from 14.34 to 15.52 cm.

Similar to plant height, the canopy diameter ranged from 9.96 to 10.53 cm, with the control treatment exhibiting a significantly lower value at $\alpha = 0.05$. The stem diameter varied from 1.84 to 1.93 mm.

Table 4. Effects of the plant growth regulator NAA on selected growth parameters of Ngoc Linh ginseng seedlings.

No.	Experimental treatment	Plant height (cm)	Canopy diameter (cm)	Stem diameter (mm)	Weight of 100 tubers (g)
1	Treatment 1 (Control)	14.34	9.96	1.84	118.93
2	Treatment 2	15.45	10.46	1.93	128.31
3	Treatment 3	15.51	10.53	1.92	132.65
4	Treatment 4	15.52	10.46	1.92	129.08
LSD _{0.05}		0.23	0.41	0.06	3.03
CV%		2.8	3.8	3.8	4.1

Notes: Treatment 1: Water spray (control)

Treatment 2: NAA at a concentration of 20 ppm

Treatment 3: NAA at a concentration of 30 ppm

Treatment 4: NAA at a concentration of 40 ppm



Figure 10. Monitoring of plant height.



Figure 11. Monitoring of canopy diameter.

Regarding the weight of 100 tubers, the values ranged from 118.93 g to 132.65 g. The untreated control showed the lowest value (118.93 g), whereas all NAA-treated treatments resulted in higher values. Among them, treatment with NAA at 30 ppm produced the highest weight of 100 tubers (132.65 g). This result is consistent with previous studies on the plant growth regulator NAA, which have demonstrated its role in stimulating root development, thereby promoting tuber growth in Ngoc Linh ginseng (Zare, A.R. *et al.*, 2011) [24].

In conclusion, NAA application significantly influenced the quality-related parameters of Ngoc Linh ginseng seedlings, with the treatment at a concentration of 30 ppm yielding the most optimal results.

4. CONCLUSIONS

The preliminary results indicate that seed treatment with NAA at a concentration of 30 ppm is appropriate for enhancing flower and fruit set. At this concentration, the number of flowers per inflorescence reached 61.63 flowers, the flower stalk length was 1.43 cm, the flower diameter was 3.59 mm, and the number of fruits per fruit cluster was the highest, at 44.08 fruits. Fruit quality was also superior, as evidenced by the high proportion of red fruits, accounting for more than 46% of the total (20.64 red fruits out of 44.08 fruits), while the proportion of green fruits was the lowest among all treatments.

Different NAA concentrations produced different effects; however, treatment with NAA at 30 ppm yielded the most optimal results, achieving a germination rate of 78.89%, a seedling formation rate of 75.56%, a proportion of marketable seedlings of 74.11%, and a weight of 100 tubers of 132.65 g.

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