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Effects of GA_3 growth regulator on preventing young fruit abscission and improving seed quality of Ngoc Linh Ginseng

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ABSTRACT

Ngoc Linh ginseng (*Panax vietnamensis* Ha et Grushv.) is a valuable endemic medicinal plant of Vietnam. However, premature fruit abscission and low seed quality have limited the production of high-quality seedlings for large-scale cultivation. This study aimed to evaluate the effects of gibberellic acid (GA_3) on young fruit retention, seed quality, seedling establishment and the growth performance of Ngoc Linh ginseng seedlings. The experiment was conducted from March 2022 to March 2024 at the Ngoc Linh Ginseng and Medicinal Plant Development Center, Quang Nam Province, Vietnam. Four treatments were arranged in a randomized complete block design with three replications, including water spray (control), GA_3 at 30 ppm, 60 ppm, and 90 ppm. The results showed that GA_3 application had no effect on flower color but significantly improved several reproductive and seedling characteristics compared with the control. Application of GA_3 at 60 ppm produced the highest number of flowers per inflorescence (61.30 flowers), flower diameter (3.65 mm) and peduncle length (1.48 cm). The same treatment also resulted in the highest germination percentage (82.48%), seedling establishment rate (79.71%) and nursery survival rate (76.88%). Furthermore, seedlings treated with GA_3 at 60 ppm exhibited superior growth, with plant height, canopy diameter, stem diameter and fresh weight of 100 tubers reaching 15.65 cm, 10.62 cm, 1.95 mm and 133.84 g, respectively. These findings indicate that foliar application of GA_3 at 60 ppm is an effective approach to reducing premature fruit drop, improving seed quality and enhancing seedling growth of Ngoc Linh ginseng, thereby contributing to the production of high-quality planting materials for sustainable cultivation.

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Keywords: *Panax vietnamensis*, Ngoc Linh ginseng, gibberellic acid (GA_3), young fruit abscission, seed germination, seedling establishment

1. INTRODUCTION

Ngoc Linh ginseng (*Panax vietnamensis* Ha et Grushv.), belonging to the family Araliaceae, is an endemic medicinal plant species of Vietnam and is regarded as one of the most valuable ginseng species in the world (Arun M *et al.,* 2010). Naturally distributed in the Ngoc Linh Mountain range of Quang Nam and Kon Tum provinces, this species possesses high medicinal and economic value owing to its rich and unique phytochemical composition, particularly the presence of numerous dammarane- and ocotillol-type saponins that are rarely found in other ginseng species (Borror D.J. *et al.* 1989). Previous studies have demonstrated that Ngoc Linh ginseng exhibits various pharmacological activities including immunomodulatory, antioxidant, anti-stress, hepatoprotective and health-promoting effects (Craig A Anderson *et al.* 1983).

The increasing demand for Ngoc Linh ginseng has promoted the expansion of cultivation areas and highlighted the need for a stable supply of high-quality seedlings (Chen J *et al.,* 2018). In commercial production, seed propagation remains the principal method for maintaining genetic purity and preserving desirable characteristics of the species (Christensen LP *et al.,* 2009). However, seed production is often constrained by premature fruit abscission, low seed quality and poor seedling establishment, resulting in limited availability of planting materials and reduced production efficiency (Erbay, Z *et al.,* 2010).

Plant growth regulators play important roles in regulating flowering, fruit development, seed maturation and seed germination. Among them, GA_3 has been widely used to promote reproductive growth, reduce fruit drop, enhance seed viability and stimulate seedling growth in many crop species (Esraa A.M *et al.,* 2024). Nevertheless, information regarding the application of GA_3 in Ngoc Linh ginseng is still limited, particularly with respect to fruit retention and seed quality.

Therefore, the present study was conducted to investigate the effects of different concentrations of GA_3 on preventing young fruit abscission and improving seed quality of Ngoc Linh ginseng (Finch-Savage *et al.,* 2006). In addition, the effects of GA_3 on seed germination, seedling establishment and early seedling growth were evaluated to provide a scientific basis for producing high-quality seedlings and supporting the sustainable development of Ngoc Linh ginseng cultivation (Hedden *et al.,* 2012).

2. MATERIAL AND METHODS

Study Material

Materials: Ngoc Linh ginseng plants and seeds (*Panax vietnamensis* Ha et Grushv.) collected from plants aged five years or older (≥ 5 years) cultivated in the Ngoc Linh mountainous region, Quang Nam Province, Vietnam.

Study location: Ngoc Linh Ginseng and Medicinal Materials Development Center.

Experimental period: March 2022 to March 2024.

Research Contents

Content 1. To evaluate the effects of GA_3 on reducing premature fruit abscission and improving the seed quality of Ngoc Linh ginseng (*Panax vietnamensis* Ha et Grushv.).

Content 2. To investigate the effects of GA_3 on seed germination and seedling growth of Ngoc Linh ginseng.

Methods

- Four treatments were established as follows:

T1, water spray (control); T2, GA_3 at 30 ppm; T3, GA_3 at 60 ppm; and T4, GA_3 at 90 ppm (Iqbal *et al*., 2011). The experiment was arranged in a randomized complete block design with three replications. All non-treatment factors, including cultural practices, fertilization, irrigation and other management conditions, were maintained uniformly among treatments (Irem *et al.,* 2022)

- Cultivation, Management, Protection, and Monitoring of the Seed Production Nursery

Raised beds were constructed with a width of 1.2-1.5 m, a length of 3-5 m or longer and a height of 10-20 cm. The beds were reinforced with wooden borders to prevent erosion and the loss of humus during heavy rainfall and storms. Well-decomposed forest humus was uniformly spread over the bed surface (Kim *et al.,* 2015). Forest humus was replenished annually to maintain soil porosity and provide favorable conditions for the growth and development of Ngoc Linh ginseng (Kim JH *et al.,* 2012).

The planting density was maintained at 20,000 plants ha. An irrigation system was installed to ensure adequate soil moisture throughout the growing period.

Regarding fertilization, the annual application rate was 4 tons/ha/year of forest humus (Laxmi S *et al.,* 2018). The entire amount of forest humus together with biofertilizer was uniformly applied to the planting holes. Topdressing was carried out when the plants began to exhibit leaf yellowing, corresponding to the overwintering stage of Ngoc Linh ginseng (Le, K *et al.,* 2021). Fertilizers were evenly distributed around the plant base and combined with soil loosening and weed control practices (Lee SJ *et al.,* 2015).

The seed production nursery was regularly monitored and protected to ensure the timely detection of any abnormalities, allowing appropriate management measures to be implemented promptly (Lichun Z *et al.,* 2025).

Monitoring indicators

- Germination percentage (%) = (Number of germinated seeds / Number of seeds sown) × 100.
- Seedling establishment percentage (%) = (Number of established seedlings / Number of seeds sown) × 100. (Li-Min Lin *et al.* 2008)
- Nursery survival percentage (%) = (Number of seedlings ready for transplanting / Number of seeds sown) × 100 (Małgorzata N *et al.,* 2023).
- Number of fruits per infructescence (fruits): Fruits were counted on 10 randomly selected plants in each treatment and the average number of fruits per plant was recorded (Park SK *et al.,* 2021).
- Number of flowers per inflorescence (flowers): Flowers were counted on 10 randomly selected plants in each treatment and the average number of flowers per plant was calculated (Qi LW *et*

al., 2011).
- Peduncle length (cm): The distance from the leaf axil to the calyx was measured.
- Flower diameter (mm): Flower diameter was measured along two perpendicular axes and the mean value was calculated (Qianqian Si *et al.,* 2016).
- Flower color: Flower color was visually assessed and recorded.
- Plant height (cm): Plant height was measured from the stem base to the tip of the uppermost leaf using a ruler or measuring tape.
- Canopy diameter (cm): Canopy diameter was determined by measuring two diagonal directions across the canopy and calculating the average value (Ratan ZA *et al.,* 2021).
- Stem diameter (mm): Stem diameter was measured at 1 cm above the stem base using a micrometer.
- Weight of 100 tubers (g): The fresh weight of 100 tubers was determined using an analytical balance (Shanmugaratnam, S. *et al.* 2013).

Statistical Analysis

Experimental data were compiled and subjected to analysis of variance (ANOVA) using IRRISTAT 5.0 and Microsoft Excel software (Siddiqui S.A *et al.,* 2024).

3. RESULT AND DISCUSSION

Study on the effects of GA_3 on germination and seedling establishment rates of Ngoc Linh ginseng in the nursery.

GA_3 is an important plant hormone that plays a crucial role in regulating seed germination and the growth of stems, leaves and roots (Plant Protection Institute, 1997). It also stimulates flowering and fruit set while improving both the quality and yield of agricultural products. The effects of GA_3 on the flowering characteristics of Ngoc Linh ginseng were investigated and the results obtained are presented as follows:

Table 1. Effects of gibberellic acid GA_3 on selected flowering characteristics of Ngoc Linh ginseng.

Treatment	Flower color	Number of flowers per inflorescence (flowers)	Peduncle length (cm)	Flower diameter (mm)
T1 (Control)	Light greenish-yellow	58.97	1.36	3.45
T2	Light greenish-yellow	59.39	1.42	3.53
T3	Light greenish-yellow	61.30	1.48	3.65
T4	Light greenish-yellow	60. 28	1.46	3.61
$LSD_{0.05}$	-	0.57	0.03	0.07
CV%	-	5.5	5.0	6.2

Note: Treatment 1: (Control): Water spray   Treatment 2: GA_3 at 30 ppm
Treatment 3: GA_3 at 60 ppm   Treatment 4: GA_3 at 90 ppm

Figure 1. Ngoc Linh ginseng flowers before GA_3 application.

Figure 2. Immature fruits of Ngoc Linh ginseng.

Figure 3. Mature fruits of Ngoc Linh ginseng.

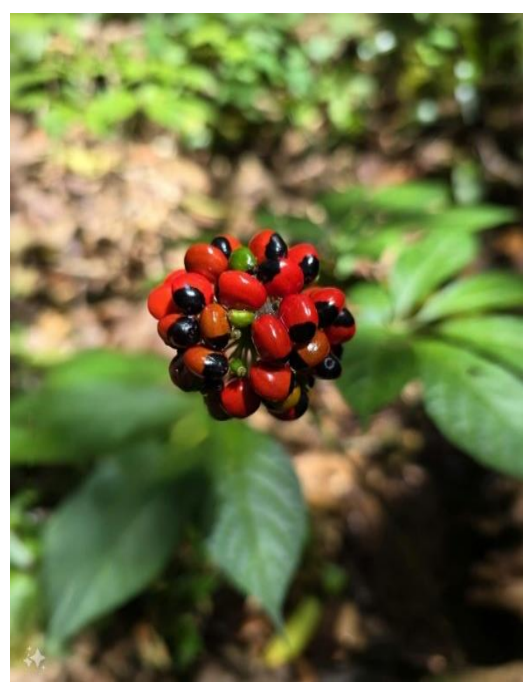

Figure 4. Ripe fruits of Ngoc Linh ginseng.

As shown in Table 1, the application of GA_3 had no effect on the flower color of Ngoc Linh ginseng. All treatments produced flowers with a light greenish-yellow color. However, the number of flowers per inflorescence, peduncle length and flower diameter were significantly influenced by different GA_3 concentrations (Sparks, T., *et al.* 2008).

As the GA_3 concentration increased from 0 to 60 ppm, all flowering parameters increased accordingly. Specifically, the number of flowers per inflorescence increased from 58.97 to 61.30 flowers, peduncle length increased from 1.36 cm to 1.48 cm, and flower diameter increased from 3.45 mm to 3.65 mm. Treatment 3, in which GA_3 was applied at a concentration of 60 ppm, produced the highest values, with 61.30 flowers per inflorescence, a peduncle length of 1.48 cm and a flower diameter of 3.65 mm. These differences were statistically significant at the 95% confidence level (Singh, A *et al.,* 2020).

However, when the GA_3 concentration was increased to 90 ppm, all flowering parameters showed a decreasing trend compared with Treatment 3; however, these differences were not statistically significant. Therefore, application of GA_3 at 60 ppm was considered the most suitable concentration for enhancing flower production in Ngoc Linh ginseng (Van L, T. *et al.,* 2010).

The effects of GA_3 on fruit characteristics of Ngoc Linh ginseng were further evaluated and the results obtained are presented below:

Table 2. Effects of GA_3 on selected fruit characteristics of Ngoc Linh ginseng.

Treatment	**Number of fruits per infructescence (fruits)**	**Fruit color**				**Characteristics of ripe fruits**
		Red	**Reddish-brown**	**Greenish-yellow**	**Green**	
T1 (Control)	39.55	15.23	8.16	7.81	8.35	Red fruits with a black spot at the apex
T2	40.51	18.25	8.47	6.71	7.08	Red fruits with a black spot at the apex
T3	43.35	21.12	10.39	7.55	4.29	Red fruits with a black spot at the apex
T4	42.48	18.99	9.01	8.16	6.32	Red fruits with a black spot at the apex
$LSD_{0.05}$	0.9	-	-	-	-	
CV%	5.4	-	-	-	-	

Note: Treatment 1: (Control): Water spray Treatment 2: GA_3 at 30 ppm
Treatment 3: GA_3 at 60 ppm Treatment 4: GA_3 at 90 ppm

Evaluation of the effects of GA_3 on fruit characteristics of Ngoc Linh ginseng showed that GA_3 concentration influenced both fruit number and fruit quality. The application of GA_3 at 60 ppm resulted in the highest number of fruits per infructescence, reaching 43.35 fruits and also produced the best fruit quality (Vega G.A *et al.,* 2008).

This was evidenced by the highest proportion of red fruits, accounting for more than 48% of the total fruits (21.12 red fruits out of 43.35 fruits), while the proportion of green fruits was the lowest among all treatments (Yamaguchi, 2008).

The differences in fruit number among treatments were statistically significant at the 95% confidence level.

Figure 5. Red fruits of Ngoc Linh ginseng

Figure 6. Reddish-brown fruits of Ngoc Linh ginseng

Figure 7. Greenish-yellow fruits of Ngoc Linh ginseng

Figure 8. Green fruits of Ngoc Linh ginseng

Study on the effects of GA_3 on selected growth parameters of Ngoc Linh ginseng in the nursery.

Table 3. Effects of GA_3 on germination and seedling establishment rates of Ngoc Linh ginseng.

Treatment	Germination rate (%)	Seedling establishment rate (%)	Marketable seedling rate (%)
T1 (Control)	64.94	62.05	58.47
T2	78.43	76.87	73.91
T3	82.48	79.71	76.88
T4	77.98	77.40	75.07
$LSD_{0.05}$	2.49	3.11	2.35
CV%	4.5	5.9	4.3

Note: Treatment 1: (Control): Water spray; Treatment 2: GA_3 at 30 ppm; Treatment 3: GA_3 at 60 ppm; Treatment 4: GA_3 at 90 ppm

As shown in Table 3, the application of GA_3 significantly affected seedling performance in the nursery compared with the untreated control. Specifically, the control treatment (without GA_3 application) resulted in a germination rate of 64.94%, a seedling establishment rate of 62.05%, and a nursery-ready seedling rate of 58.47%. These values were significantly lower than those of the GA_3 treatments, with the differences being statistically significant at the 95% confidence level.

Figure 9. Monitoring the seedling establishment rate.

Figure 10. Monitoring the nursery-ready seedling rate.

The application of different GA_3 concentrations resulted in different responses. The treatment with GA_3 at 60 ppm gave the highest results, with germination rate, seedling establishment rate, and nursery-ready seedling rate reaching 82.48%, 79.71% and 76.88%, respectively. Thus, foliar application of GA_3 at a concentration of 60 ppm was considered most suitable for enhancing the production of Ngoc Linh ginseng seedlings.

The effects of GA_3 on the growth parameters of Ngoc Linh ginseng seedlings in the nursery were further investigated and the results are presented as follows:

Table 4. Effects of GA_3 on selected growth parameters of Ngoc Linh ginseng seedlings.

Treatment	Plant height (cm)	Canopy diameter (cm)	Stem diameter (mm)	Weight of 100 tubers (g)
CT 1 (đ/c)	14.47	10.05	1.86	120.00
CT 2	15.59	10.55	1.94	129.46
CT 3	15.65	10.62	1.95	133.84
CT 4	15.66	10.55	1.94	130.24
$LSD_{0.05}$	0.25	0.46	0.08	3.75
$CV_{\%}$	5.8	4.8	5.2	5.1

Note: Treatment 1 (Control): Water spray Treatment 2: GA_3 at 30 ppm
Treatment 3: GA_3 at 60 ppm Treatment 4: GA_3 at 90 ppm

The results in Table 4 show that GA_3 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 other GA_3 treatments. Under the experimental conditions, plant height ranged from 14.47 to 15.65 cm.

Figure 11. Monitoring plant height.

Figure 12. Monitoring canopy diameter.

Similarly to plant height, canopy diameter ranged from 10.05 to 10.62 cm and the control treatment showed lower values than the GA_3 treatments at a significant level ($\alpha = 0.05$). Stem diameter ranged from 1.86 to 1.95 mm.

For the parameter of weight of 100 tubers, the results varied from 120 g to 133.84 g. The lowest value was recorded in the untreated control (120 g), while all GA_3 treatments showed higher values. The highest value was obtained in the treatment with GA_3 at 60 ppm, reaching 133.84 g. Thus, GA_3 application had a positive effect on the quality parameters of Ngoc Linh ginseng seedlings, with the 60 ppm treatment showing the most optimal results overall.

4. CONCLUSIONS

Seed treatment with GA_3 at a concentration of 60 ppm was found to be suitable for enhancing flowering and fruit set in Ngoc Linh ginseng. At this concentration, the number of flowers per inflorescence reached 61.30 flowers, peduncle length was 1.48 cm, and flower diameter was 3.65 mm. The number of fruits per infructescence was the highest at 43.35 fruits and fruit quality was also superior, with red fruits accounting for more than 48% (21.12 red fruits out of 43.35 fruits), while the proportion of green fruits was the lowest among all treatments. Different GA_3 concentrations produced different results. The treatment with GA_3 at 60 ppm gave the highest values for germination rate, seedling establishment rate and nursery-ready seedling rate, reaching 82.48%, 79.71% and 76.88%, respectively and also resulted in the highest weight of 100 tubers (133.84 g). GA_3 application did not affect the incidence of pests and diseases in Ngoc Linh ginseng seedlings in the nursery.

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