

EVALUATION OF THE GROWTH, YIELD AND QUALITY OF *Rehmannia glutinosa* (DH19) IN THE MIDLAND AND MOUNTAINOUS REGION OF NORTHERN VIETNAM

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The study aimed to determine the growth performance and plant adaptation of *R. glutinosa* (DH19) to the selected plantation locations in Vietnam's Northern Midland and Mountainous regions. The experiments were arranged in a completely randomized block design and performed on three sites in Vinh Phuc, Phu Tho, and Tuyen Quang provinces. Research showed that DH19 was grown and developed well, gaining an average yield of 23.9 to 24.8 tons/ha and the catalpol content from 0.72 - 0.74%. DH19 was adapted to moderate drought conditions but severely damaged and recovered poorly in flooding. Planting DH19 should pay attention to root sores disease (*Rhizoctonia solani*) at the seedling stage and root rot disease (*Fusarium* sp.) at the harvest stage. The above study results show that DH19 can be selected for planting in Vietnam's Northern Midland and Mountainous regions.

Keywords: *Rehmannia glutinosa* (DH19); growth; yield; quality.

1. Introduction

The Midland and Mountainous regions of Northern Vietnam are characterised by their advantages in terms of soil and climate conditions for the cultivation of medicinal plants. Several medicinal plants have been grown and supplied to the domestic market, such as Chinese foxglove, Danshen, Dong quai, Ballon flower, Artichokes, and Cardamom, in which Chinese foxglove (*Rehmannia glutinosa* Libosch.) is considered a high-value kind of medicinal plant. Originated from China, *R. glutinosa* belongs to the family Scrophulariaceae, was imported and extensively cultivated in Vietnam since 1958 and is processed differently for various traditional medicinal uses [1, 2]. Although it is considered a valuable medicinal species, self-propagation and traditional farming methods have made the currently planted *R. glutinosa* variety gradually degenerate and decrease its precious properties, resulting in low yield and quality. Therefore, it is necessary to breed and select *R. glutinosa* varieties that have good growth, high yield and quality of medicinal herbs and are suitable for ecological conditions in the Northern midlands and mountains.

In 2013, the Vietnamese government approved the General Plan for developing medicinal plants in 2020 - 2030, in which *R. glutinosa* was identified as prioritized for development in the Northern midland and mountainous region and the Red River Delta with an area of 200 ha [3]. The Ministry of Health has selected *R. glutinosa* in the list of 54 medicinal plants prioritized for development in 2015 - 2020 [4]. In the past time, with materials collected domestically and from China, Hung Vuong University has conducted research and successfully selected the variety *R. glutinosa*, named DH19 [5]. This cultivar has good growth performance, high yield, and catalpol content four times higher than the commonly grown variety in some northern provinces of Vietnam and compared to the Vietnam Pharmacopoeia V [6]. However, plant traits and characteristics such as yield, quality, and tolerance determined by genotype are expressed phenotypically after interacting with the environment and under specific conditions of each ecological region; as a result, they can change differently. The expansion of DH19 cultivation in some other plantation areas in the Northern part of Vietnam needs to be better designed and managed. It has caused considerable negative impacts on the growth and yield of the crops, especially since *R. glutinosa* is identified as susceptible to abiotic factors such as a high level of rainfall. As in the previous study, we have determined the growth and yield of several varieties of *R. glutinosa* and have selected DH19 as one of the most potential selections to develop in a larger-scale plantation. The present study is a more comprehensive follow-up study to investigate growth performance, yield, and other characteristics, including morphological and quality parameters. This study aimed to compare the growth, yield and quality characteristics of DH19 in the field cultivated in three selected areas, serving as a basis for the continuous use of this variety suitable for ecological conditions in Vietnam's Northern Midlands and Mountains regions.

2. Research materials and methods

2.1. Research materials

DH19 is a medicinal variety selected from materials collected domestically and imported from China. The variety has an average growth duration of 160 - 170 days. Main crops cultivated in the autumn-winter season with an average root yield of 18 - 20 tons per hectare. The variety has good resistance to pests and diseases and adapts to medium drought conditions but has poor resilience in flooded conditions. The variety is recognized for circulation according to the Ministry of Agriculture and Rural Development [5].

2.2. Research methods

2.2.1. Experimental set-up

The experiments were carried out on sandy soil along the river banks in three Northern Midland and Mountainous provinces of Vietnam representing three ecological zones, namely site 1 - the plain in Anh Dung village, Bach Luu commune, Song Lo district, Vinh Phuc province; site 2 - the midland area in zone 3, Dan Quyen commune, Thanh Thuy district, Phu Tho province; site 3- the mountainous area in Ao Buc village, Trung Yen commune, Son Duong district, Tuyen Quang province. The experimental design was a randomized complete block design with three replications. The experimental plot area was 30 m²/plot x three replicates x three sites. Total experimental area: 270 m².

The experiment period was conducted between 9/2020 - 2/2021. At the site of Bach Luu commune, it was planted on 3/9/2020 and harvested on 22/2/2021. At the site of Dan Quyen commune, it was planted on 4/9/2020 and harvested on 23/2/2021. At the site of Trung Yen commune, it was planted on 5/9/2020 and harvested on 25/2/2021.

The cultivation method of DH19 was applied according to the technical process of Hung Vuong University [7]. The density was 160,000 plants/ha, the number of fertilizers (kg/ha) is 180 N: 120 P₂O₅ : 120 K₂O spread once as a basal application with an additional 10 tons of Que Lam microbial fertilizer/ha and 500 kg of lime/ha [7, 8].

2.2.2. Measurements

Growth parameters (growth duration, number of growing clusters/plots, uniformity between clusters, leaf colour, leaf size, tuber shape, tuber colour), yield (bulb length, tuber diameter, tuber weight, theoretical yield, actual yield, quality (content of catalpol - active ingredient), adaptation to adverse conditions, and resistance to pests and diseases were recorded in the field and analyzed in the laboratory (Table 1). The growth and yield indicators were evaluated according to the regulation for testing the cultivation value and use value of DH19 by Hung Vuong University [8]. The pests and disease infestations were monitored according to the previously published documents of Thanh Loan Pham et al., 2019 [9]. The content of catalpol was evaluated according to the Vietnam Pharmacopoeia V, the monograph of *R. glutinosa* [6], and analyzed at the Center for Drug, Cosmetic and Food Testing of Vinh Phuc Province. The data were processed using IRRISTAT 5.0 software with analysis of variance and separation at a significance level of $p = 0.05$ with ANOVA.

Table 1: Measurements methods

Parameter	Measuring method
Number of growing clusters/plots	Count the number of clusters/plots when the sprouts are visible on the ground after 30 days of planting.
Survival rate (%)	By number of survival plants/number of plants $\times 100$
Plant growth performance	Evaluate after 45 days of growth at three levels: poor (3 points), moderate (5 points), and good (7 points).
The cluster uniformity	Assess after 45 days of growth at the three levels of poor (3 points), moderate (5 points), and good (7 points).
Tuber formation time (day)	Observe and count plants/plots.
Harvesting time (day)	When the tubers are physiologically ripe, about 1/3 of the leaves at the base turn yellow.
Leaf color	Observe the plants at 30 days after planting: purple, green, light green, and other colours.
Tuber colour	Observe tubers when harvested: light yellow, yellow, dark yellow.
Tuber flesh colour	Cut the tubers in half and observe the flesh when harvested: light yellow, yellow, and dark yellow.

Parameter	Measuring method
Tuber shape	Observe the tuber's skin when harvested: round, long oval, and long.
Tuber length (cm), tuber diameter (cm)	Measure at harvest.
Tuber grade (%)	Big tubers ($\phi > 2$ cm), medium tubers (ϕ 1-2 cm), and small tubers (ϕ 0.5-1 cm).
Number of tuber/plant	Count the number of tuber/plant.
Tuber weight (g/plant)	Weigh the total weight of tubers/plant.
Tuber weight (kg/plot)	Weigh the total weight of tubers/plot.
Adaptability to adverse conditions (point)	Observe the extent of damage and the ability of plants to recover after adverse conditions, evaluate and score: No harm (1), slight damage, quick recovery (2), moderate damage, slow recovery (3), severe damage, poor recovery (4), complete death (5).
Pests and diseases (point)	Survey all clusters with symptoms of disease/plot: 0 - No disease, 1 - very slight damage (1-10%), 2 - slight damage (11-25%), 3 - moderate damage (26-50%), 4 - severe damage (51-75%), 5 - very serious damage (>75%).

3. Results and Discussion

3.1. Growth performance of the DH19

Growth and development duration of DH19 were recorded at different time points: from planting to sprouting, tuber formation, and harvesting. The result was presented in Table 2.

Table 2: Growth duration of DH19

Location	Days from planting to... (days)		
	Sprouting	Tuber formation	Harvesting
Phu Tho	12.5	44.6	172.0
Vinh Phuc	11.2	43.2	172.0
Tuyen Quang	12.5	44.6	173.0
<i>LSD_{0.5}</i>	1.25	4.05	11.30
<i>CV%</i>	4.6	4.1	2.9

The time that DH19 plants started sprouting, forming tuber, and harvesting in three study sites was similar at the 95% confidence level. At these sites, the time from planting to sprouting ranged from 11.2 - 12.5 days; the starting time of forming tubers was 43.2 - 44.6 days, and the harvesting time was 172 - 173 days after planting.

Table 3: Growth performance of the DH19

Locations (Province)	Number of clusters		Plant growth performance (points)	The cluster uniformity (points)
	Cluster/plot	Survival rate (%)		
Phu Tho	417.6	87	7	7
Vinh Phuc	408.0	85	7	7
Tuyen Quang	413.1	86	7	7
<i>LSD</i> _{0,5}	13.62	-	-	-
<i>CV</i> %	4.4	-	-	-

The results from Table 3 show that planting with the same density according to the technical process, the number of clusters growing per plot at 30 days after planting has no difference between the three sites at the significance level of 0.05. The number of clusters growing/plot at the sites ranged from 408.0 - 417.6 clusters/plot, corresponding to a survival rate of 85% - 87%. Plant growth performance and uniformity among clusters at all locations was 7 points.

3.2. Evaluation of some morphological characteristics, tuber yield, and quality of the DH19

The results presented in Table 4 and Table 5 showed that the morphological characteristics of DH19 were relatively stable. It was not different between experimental sites. The leaves retained as dark green, with a leaf length of 22.4 - 22.7 cm and a leaf width of 11.5 - 12.6 cm. Tubers were cylindrical, with yellow skin and dark yellow flesh. The size of the DH19 tuber at three sites did not differ at the 95% confidence level, corresponding to the average tuber length from 22.1 - 22.6 cm and the mean tuber diameter from 2.2 - 2.4cm (Table 4). The average weight of tubers was from 54.2 - 55.8g/tuber, and there was no significant difference at the significance level of 0.05. The content of active ingredient catalpol in DH19 ranges from 0.72 - 0.74% and is higher than that of Vietnam Pharmacopoeia V (required to reach $\geq 0.20\%$) [6].

According to Li et al. (2001) and Wang et al. (2013), the larger the leaf size, the higher the yield [10, 11]. The leaf size of DH19 is equivalent to the leaf size of 6 varieties of *R. glutinosa* in the study by Li et al. (2007) (length 23.64 - 33.76 cm, width 9.08 - 12.36 cm) [12]. Nguyen Thi Huong et al. (2021), when evaluating ten varieties of *R. glutinosa*, selected a promising variety RS-02 (collected from China), with large tuber size for high medicinal quality, with a yield of 22.75 tons/ha [13]. Therefore, the elliptic tuber morphology and the enlarged part in the middle of the tuber of the DH19 were consistent with the requirements for selecting the variety *R. glutinosa* [12, 13], so the DH19 had good characteristics.

Table 4: Morphological characteristics of DH19 leaves and tubers

Location	Leaf colour	Mature leaf size (L x W cm)	Tuber shape	Tuber skin color	Tuber flesh color
Phu Tho	Dark green	22.7 x 12.5	Round cylinder	Yellow	Dark yellow

Location	Leaf colour	Mature leaf size (L x W cm)	Tuber shape	Tuber skin color	Tuber flesh color
Vinh Phuc	Dark green	22.4 x 12.6	Round cylinder	Yellow	Dark yellow
Tuyen Quang	Dark green	22.4 x 11.5	Round cylinder	Yellow	Dark yellow

Table 5: *Quality and catalpol content of DH19*

Location	Av. tuber length (cm)	Av. tuber diameter (cm)	Tube size percentage			Av. tuber weight (g/tuber)	Catalpol content (%)
			Big ($\phi > 2.5$ cm) (%)	Medium ($\phi 1-2$ cm) (%)	Small ($\phi 0.5-1$ cm) (%)		
Phu Tho	22.6	2.2	32.6	46.2	21.2	55.8	0.72
Vinh Phuc	22.1	2.3	32.4	45.2	22.4	54.2	0.74
Tuyen Quang	22.2	2.4	32.2	44.3	23.5	55.2	0.72
<i>LSD</i> _{0.5}	1.77	0.20	3.45	4.74	2.06	4.90	-
CV%	3.5	3.9	4.7	4.6	4.0	3.9	-

3.3. The influence of planting sites on the yield of DH19

The yield of DH19 grown in Phu Tho, Vinh Phuc and Tuyen Quang provinces was characterized by tuber and cluster-related parameters and shown in Table 6. No significant differences between these three regions regarding these yield component parameters were confirmed at the 95% confidence level. The results showed that the number of harvested clusters/plots ranged from 106.4 - 112.4 clusters. The number of tubers/plants fluctuated from 4.1 - 4.3 tubers/plant, with the corresponding tuber weight per plant from 222.22 - 235.21 grams. The actual yield ranged from 23.9 - 24.8 tons/ha, reaching 64.6% - 67.7% of theoretical yield. The yield was relatively stable in all selected ecological regions. The actual yield of DH1 was higher than that of the *R. glutinosa* (R.S-02) collected from China from the DA17 project (reaching 22.75 tons/ha). It had an actual yield of 31.6% of the yield theoretically (71.87 tons/ha) in the study by Nguyen Thi Huong et al. (2021) [13]. It was lower than the variety of *R. glutinosa* (Hoai Khanh No. 85-2), reaching 27.36 tons/ha in the study by Li et al. (2001) [10]. That proves the stability of the variety and the potential to expand production in this area is considerable.

Table 6: *Yield parameters of DH19*

Location	Cluster (Cluster/plot)	Tuber number (tuber/plant)	Tuber weight (g/plant)	Tuber weight (kg/plot)	Theoretic al yield (ton/ha)	Actual yield (ton/ha)
Phu Tho	112.4	4.3	235.21	26.01	38.39	24.80
Vinh Phuc	106.4	4.1	222.22	23.64	35.56	23.90
Tuyen Quang	108.4	4.1	228.78	23.90	36.21	24.55
<i>LSD</i> _{0.5}	5.39	0.59	2.84	-	3.76	3.17
CV%	2.2	6.2	5.1	-	4.5	5.7

3.4. The adaptability of the DH19 to adverse weather conditions and pests, disease infestations

The results of assessing the ability to adapt to adverse conditions tolerating pests and diseases were presented in Table 7. Regarding the ability to adapt to adverse conditions, in all three sites, DH19 was moderately tolerant and slowly recovered from drought. Meanwhile, DH19 were severely damaged and poorly recovered to waterlogged conditions. Some pests, such as red spider (*Tetranychus* sp.), green worm (*Helicoverpa armigera*) and grey worm (*Agrotis ipsilon*), cause slight damage to DH19 plants. When exposed to heavy rain and high soil moisture, root sores disease (*Rhizoctonia solani*) caused slight damage to seedlings. The root rot disease (*Fusarium* sp.) caused slight damage when it was about to be harvested with heavy rain. Therefore, when planting DH19, it was necessary to pay attention to root sores disease at the seedling stage and root rot disease when about to harvest.

Table 7: The adaptability of the DH19 to adverse weather conditions and pests, disease infestations

Evaluation criteria	Location		
	Phu Tho	Vinh Phuc	Tuyen Quang
Drought resistance (points)	3	3	3
Flooded resistance (points)	4	4	4
Red spider (<i>Tetranychus</i> sp.) (points)	2	2	2
Green worm (<i>Helicoverpa armigera</i>) (points)	2	2	2
Grey worm (<i>Agrotis ipsilon</i>) (points)	2	2	2
Root sores (<i>Rhizoctonia solani</i>) (points)	2	2	2
Withered white mould root (<i>Sclerotium rolfsii</i>) (points)	1	1	1
Leaf blight (<i>Phomopsis</i> sp.) (points)	1	1	1
Root rot (<i>Fusarium</i> sp.) (points)	2	2	2

4. Conclusion

The DH19 could grow and develop well in the chosen Northern Midland and Mountainous provinces. The DH19 had good growth performance and high yield, with the average number of tubers per plant from 4.1 to 4.3 tubers/plant; The average weight of tubers is from 54.2 to 55.6 grams/tuber. The actual yield ranged from 23.9 to 24.8 tons/ha in three cultivated sites. Catalpol content showed a relatively high level, from 0.72 to 0.74%. The variety could adapt to medium drought conditions but suffered severe damage and had poor resilience to flooded conditions. The red spider, green worm, grey worm, and withered white mould root disease slightly damage plants. Attention should be paid to root sores at the seedling stage and root rot at harvest time.

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TÓM TẮT

ĐÁNH GIÁ KHẢ NĂNG SINH TRƯỞNG, NĂNG SUẤT VÀ CHẤT LƯỢNG CỦA GIỐNG ĐỊA HOÀNG 19 (DH19) TẠI VÙNG TRUNG DU MIỀN NÚI PHÍA BẮC VIỆT NAM

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Ngày nhận bài 14/8/2023, ngày nhận đăng 08/9/2023

Nghiên cứu nhằm xác định khả năng sinh trưởng của giống Địa hoàng 19 (DH19) (*Rehmannia glutinosa*) trồng tại vùng trung du miền núi phía Bắc Việt Nam. Thí nghiệm giống được bố trí theo kiểu khối ngẫu nhiên hoàn chỉnh, thực hiện trên 3 địa điểm thuộc tỉnh Vĩnh Phúc, Phú Thọ, Tuyên Quang. Kết quả nghiên cứu chỉ ra rằng, giống Địa hoàng 19 có khả năng sinh trưởng, phát triển tốt, năng suất củ thực tế đạt trung bình từ 23,9 - 24,8 tấn/ha, hàm lượng catalpol đạt từ 0,72 - 0,74%. Giống có khả năng thích ứng với điều kiện khô hạn trung bình, có thể bị hại nặng và khả năng phục hồi kém ở điều kiện ngập úng. Trồng DH19 cần chú ý đến bệnh lở cổ rễ (*Rhizoctonia solani*) ở giai đoạn cây con và bệnh thối củ (*Fusarium sp.*) giai đoạn sắp thu hoạch. Kết quả nghiên cứu trên cho thấy có thể lựa chọn giống DH19 để gây trồng trong vụ thu đông ở khu vực trung du miền núi phía Bắc Việt Nam.

Từ khóa: Giống Địa hoàng 19; sinh trưởng; năng suất; chất lượng.