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STUDY ON CUTTING CULTIVATION TECHNOLOGY AND ROOTING MECHANISM OF *Cyclocarya paliurus*

Abstract: *Cyclocarya paliurus* is an important rare and multipurpose tree species in China. In view of the difficulty of asexual propagation of *Cyclocarya paliurus*, this paper explores the technical system of *Cyclocarya paliurus* cutting propagation from the aspects of cutting collection position and time, tannin removal pretreatment, hormone treatment, sand storage treatment, cutting matrix, environmental factors and physical factors, and discusses its internal physiological changes in the process of cutting rooting. This paper attempts to clarify the physiological characteristics of *Cyclocarya paliurus* in the process of cutting propagation and rooting. The results of this study can provide technical support and theoretical basis for the cuttings propagation of *Cyclocarya paliurus*. The results show that the rooting rate of cuttings inserted on the mixture of perlite and vermiculite is up to 32.2 %. In summer, when the middle and upper parts of branches were treated with 300 mg/L rooting powder No. 1 and GGR-6 (Green Growth Regulator-6) mixture, the rooting rate was up to 44.4 %; in winter, the rooting rate of the base of branches was 36.7 % under the same treatment. During the rooting process of *Cyclocarya paliurus*, a large number of nutrients such as soluble sugar, starch and soluble protein were consumed. SOD (Superoxide Dismutase), POD (Peroxidase), and PPO (Polyphenol oxidase) are closely related to cutting and rooting. High activity SOD and POD are conducive to the expansion of cuttings, and high activity SOD and PPO are conducive to improving the stress resistance of cuttings. Hormone treatment can improve the enzyme activity and make the enzyme activity change in the direction conducive to rooting. The change of endogenous hormone content in cuttings reflects the rooting ability of *Cyclocarya paliurus*. Substrate heating and hormone treatment can regulate the content of endogenous hormone in cuttings during the rooting process, so as to affect the rooting effect, the stable total nitrogen content in cuttings was conducive to root formation.

Keywords: *Cyclocarya paliurus*, cutting cultivation, rooting rate, physical and chemical properties

Introduction

Cyclocarya paliurus is a unique single genus plant and one of the keys protected endangered plants in China. It belongs to three categories of protected plants, the bark and leaves of *Cyclocarya paliurus* have the functions of clearing away heat, detoxifying and relieving pain, they can be used to treat stubborn ringworm. For a long time, folk use its leaves to make tea, also known as sweet tea, divine tea and so on [1]. Modern medical research has found that *Cyclocarya paliurus* has the effects of reducing blood pressure, blood glucose and blood lipid. At present, antihypertensive tea, Jiangxi Meishan hypoglycemic tea and *Cyclocarya paliurus* compound tea have been developed, which have

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been clinically verified and have remarkable effects [2]. In terms of health care function, *Cyclocarya paliurus* has the effects of enhancing immunity, antioxidation and anti-aging. The timber and ornamental value of *Cyclocarya paliurus* is also very high. Its wood is easy to process, does not split, the wound is smooth, adhesive and good paint performance. It can be used for making furniture, carriage, plywood, interior decoration and general construction materials [3]. *Cyclocarya paliurus* has beautiful tree posture and fruit like copper coin. It can be used as an excellent ornamental greening tree species, in view of the medicinal, health care, timber and ornamental uses of *Cyclocarya paliurus*, it is particularly important to strengthen the breeding of *Cyclocarya paliurus* and provide sufficient seedlings for production [4]. However, because the seeds of *Cyclocarya paliurus* have the characteristics of deep dormancy, they generally germinate every other year or even two years after sowing, the natural germination rate is only 0.1 % - 0.2 %, the development is also relatively poor, the kernel rate is not high, and the seeding emergence rate is low, which restricts its resource cultivation and industrialisation.

On the basis of provenance collection and screening, asexual propagation has become an important means to make the scarce excellent provenances reproduce rapidly. Transplanting is the most widely used one in asexual propagation. Compared with tissue culture and grafting, it has the advantages of low cost, fast propagation speed, required facilities and simple operation [5]. With the continuous maturity of cutting propagation technology and the breakthrough of tissue culture technology, the combination of cutting and tissue culture will become a modern framework in the field of seed and seedling raising of *Cyclocarya paliurus* [6]. Huang et al. [7] experiment of cutting and breeding of *Cyclocarya paliurus*, but the survival rate of cutting was close to zero. However, Li et al. [8] treated it with their own rooting powder, and the survival rate of cutting reached 41 %. They believed that the difficulty of root primordium differentiation and tissue activation was the main reason for the difficulty of taking root of *Cyclocarya paliurus*, the high content of gibberellin and nutrient consumption are the direct reasons for the difficulty of root primordium activation and the low seedling rate after activation [8]. Since then, relevant scholars have studied the cottage propagation of *Cyclocarya paliurus* from different aspects [9]. The results showed that exogenous hormone treatment could significantly promote the rooting of *Cyclocarya paliurus*, and the rooting rate of tender branch was better than that of hard branch. Temperature is closely related to the formation rate of adventitious root of cuttings [10]. Maintaining a constant temperature difference between substrate and soil air and substrate can significantly improve the rooting rate of *Cyclocarya paliurus* [11]. In terms of rooting mechanism, Kitahara et al. [12] believed that the absolute content and relative ratio of endogenous hormones were related to the induction and occurrence of adventitious roots, and IAA (Indole-acetic acid) played a key role in the rooting process. Although the cutting and propagation technology of *Cyclocarya paliurus* has been successful, and the rooting rate is as high as 98.01 %, but the cutting and rooting *Cyclocarya paliurus* is fleshy root, and its transplanting survival rate is quite low [13]. Therefore, so far, it has not been widely used in forestry production.

In order to expand the available resources of *Cyclocarya paliurus*, this paper explores the technical system of *Cyclocarya paliurus* cutting propagation from the aspects of cutting collection position and time, cutting tannin removal process, hormone treatment, sand storage treatment, cutting matrix, environmental factors and physical factors, and discusses its internal physiological changes in the process of cutting rooting. This paper attempts to clarify the physiological characteristics of *Cyclocarya paliurus* in the process of cutting

propagation and rooting. Through the changes of soluble sugar, starch, soluble protein and other nutrients in cuttings during the rooting process of *Cyclocarya paliurus*, the rooting mechanism was demonstrated, so as to provide a strong reference basis for the research of *Cyclocarya paliurus* cuttings propagation, so as to establish a perfect clonal propagation system as soon as possible. In order to build an efficient rapid propagation system of *Cyclocarya paliurus* and truly meet the needs of industrialised large-scale production.

Methods and materials

The test materials are from the ear picking nursery of *Cyclocarya paliurus* in a test base. The *Cyclocarya paliurus* seedlings are 2 to 4 years old. According to the test period, the healthy, full and disease-free branches of 1 year old or that year old are collected to cut cuttings. The branches are mainly the lateral branches of seedlings, and the sprouting branches are cut off. In principle, the cuttings should be 0.3 cm to 1.5 cm thick and 9 cm to 13 cm long. The cuttings should have at least two buds. The upper end of the cuttings should be close to the plump bud. The plump bud should be 1 cm to 2 cm away from the upper cut of the cuttings. The upper end of the cuttings should be cut flat. The lower end of the cuttings should be cut at an angle of 45. The lower bud should be about 1.5 cm away from the lowest part of the lower cut. The upper and lower cuts of the cuttings should be smooth and cannot be broken. In summer and autumn, the twigs are inserted and the upper 1 to 2 leaflets of the cuttings are retained.

The experiment was carried out in the greenhouse of a biotechnology building. Invert the matrix in the seedbed one week before transplanting, pour it through with 3000 mg/L Carbendazim or 300 times Bordeaux solution, and cover the film until it is opened the day before transplanting. Before transplanting, punch holes in the substrate to reduce the damage of the substrate to the incision under the cuttings. After the cuttings are soaked in the treatment solution, take them out and dry in the shade for 15 minutes, and then insert them. The insertion depth is about 2/3 of the length of cuttings [14]. Air conditioning, sunshade net and automatic spray are properly adjusted according to weather conditions. In winter and spring, the indoor temperature of hard branch transplanting is controlled at 20 ℃ to 25 ℃ during the day and 15 ℃ to 20 ℃ at night. For the substrate heating test of hard branch transplanting in winter and spring, the electric hot wire is evenly arranged at the bottom of the transplanting bed by the zigzag wiring method [15]. The electric hot wire is connected with the digital display temperature controller to form an automatic constant temperature heating seedbed, and the substrate temperature is controlled at 25 ℃ to 28 ℃. The indoor temperature of twig transplanting in summer and autumn shall be controlled at 25 ℃ to 30 ℃. The air humidity shall be controlled above 80 %, and the humidity shall be properly reduced in the later stage of interpolation. During the insertion period, 1000 mg/L Carbendazim and 300 times Bordeaux solution were sprayed alternately every 10 days for sterilisation.

In this experiment, four factors were set, including three hormones GGR-6, No. 1 rooting powder and IBA (Indole Butyric Acid) and soaking time. Each factor was set at 3 levels. A total of 9 treatments were adopted by orthogonal design. Each treatment was repeated for 3 times, and the number of samples per repetition was 30 cuttings. After 50 days of cutting, the rooting of single plant was counted. The specific scheme is shown in Tables 1 and 2.

Table 1

Factor level of orthogonal test

Level	[mg/L]	Rooting powder -1 [mg/L]	GGR-6 [mg/L]	Time [h]
1	100	100	100	1
2	200	200	200	2
3	300	300	300	3

Table 2

Design scheme of orthogonal test

Test number	Column number			
	A **[-]**	***B*** **[-]**	***C*** **[-]**	***D*** **[-]**
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Three factors were set up in this experiment, including hormone type, treatment time and hormone concentration. Each factor was set at 3 levels. The orthogonal design scheme was adopted, with a total of 9 treatments. Each treatment was repeated for 3 times, and the number of samples in each repetition was 30 cuttings. After 50 days of cutting, the rooting of single plant was counted. See Tables 3 and 4 for the specific scheme.

Table 3

Three factor orthogonal test factor level

Level	Types of hormones [-]	Processing time [h]	Hormone concentration [mg/L]
1	Mixed solution of No. 1 rooting powder and GGR-6	1	100
2	No. 1 rooting powder	3	200
3	GGR-6	6	300

Table 4

Orthogonal experimental design of hormone treatment

Test number	Column number		
	A **[-]**	***B*** **[-]**	***C*** **[-]**
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Humidity gradient of atmosphere and intercalated substrate: substrate humidity and air humidity are respectively set in the test. On the basis of adjusting substrate humidity to 20 %, the air humidity is controlled to 50 %, 60 %, 70 %, 80 % and 90 %. In addition, on the basis of controlling the air humidity to 70 %, the substrate humidity is controlled to 20 %, 30 % and 40 %. The air humidity and substrate humidity are monitored and adjusted by hand-held agricultural environment monitor. The hormone is mixed with No. 1 rooting powder and GGR-6 in equal proportion and No. 1 rooting powder. The concentration is set as 300 mg/L and the cuttings are soaked for 6 h. Each treatment was repeated 3 times, and the number of samples per repeat was 60 cuttings. After 50 days of cutting, the rooting of single plant was counted [16-18].

The intercalation matrix adopts four types: pure perlite, perlite and peat soil mixed in equal proportion, perlite and carbonised rice husk mixed in equal proportion, and perlite and vermiculite mixed in equal proportion. The hormones are No. 1 rooting powder and No. 1 rooting powder and GGR-6 rooting powder. The concentration is set as 300 mg/L and the soaking cutting time is 6 h. Each treatment was repeated 3 times, and the number of samples per repeat was 60 cuttings. After 50 days of cutting, the rooting of single plant was counted.

Cutting collection site: the experimental materials were 1 year old lignified hardwood and 1 year old semi lignified twig of *Cyclocarya paliurus*. According to the actual position on the branch, the cuttings can be divided into two types: base branch and middle and upper branch. The hormone was mixed with No. 1 rooting powder with a concentration of 300 mg/L and GGR-6 with a concentration of 300 mg/L, and the cuttings were soaked for 6 h. Each treatment was repeated 3 times, and the number of samples per repeat was 60 cuttings. After 50 days of cutting, the callus formation and rooting of single cuttings were counted.

The physiological test materials of hardwood cuttings were taken from the cuttings treated with 500 mg/L No. 1 rooting powder for 6 h and then inserted on the substrate heated seedling bed. Samples were taken every 10 days. The cuttings treated with water were used as the control for the three indexes of soluble sugar, starch and soluble protein, and the cuttings treated with the same hormone were used as the control for the activity indexes of endogenous hormones, the sampling part of cuttings is the base and skin of cuttings [19]. After sampling, place it in –70 ℃ ultra-low temperature refrigerator for storage. The cuttings of twig cuttings treated with 300 mg/L No. 1 rooting powder for 6 hours were sampled every 10 days, and the cuttings treated with water for 3 hours were used as the control. The sampling part of cuttings is the base and skin of cuttings. After sampling, place it in –70 ℃ ultra-low temperature refrigerator for storage. The soluble sugar content, starch content, soluble protein content and total atmosphere content were detected.

Results and analysis

In the process of plant transplanting, water plays an important role in its life activities. It can be seen that hormone types have a certain impact on the rooting of young branches of *Cyclocarya paliurus*. Under various air humidity conditions, the rooting rate of the mixed solution of No. 1 rooting powder and GGR-6 was higher than that of No. 1 rooting powder of 300 mg/L, and the difference was significant under 90 % air humidity (P = 0.013). Under other air humidity conditions, it did not reach a statistically significant level. Air

humidity had a significant effect on rooting. When the cuttings were treated with No. 1 rooting powder and GGR-6 mixture, the rooting rate was significantly different among different air humidity, and the rooting rate was the highest when the air humidity was controlled at 70 %. Overall, in this experiment, the rooting rate of No. 1 rooting powder and GGR-6 was as high as 32.2 % when they were treated with the mixture of No. 1 rooting powder and GGR-6 for 6 hours and inserted under the conditions of air humidity of 70 % and substrate humidity of 20 %. The rooting rate of the mixed solution treatment of No. 1 rooting powder and GGR-6 under different substrate humidity is still higher than that of No. 1 rooting powder treatment of 300 mg/L. The medium humidity also had a significant effect on rooting. When the medium humidity was controlled at 30 %, the average rooting rate was 35.6 %, which was significantly higher than that of 40 % and 50 %. Overall, in this experiment, the rooting rate of No. 1 rooting powder and GGR-6 was as high as 35.6 % when treated with the mixture of No. 1 rooting powder and GGR-6 for 6 hours and inserted under the conditions of 70 % air humidity and 30 % substrate humidity.

It can be seen that different hormone types and concentrations have certain effects on the rooting of young branches of *Cyclocarya paliurus*, the rooting rate of cuttings treated with perlite, peat soil and perlite, vermiculite and perlite was the highest; using the mixture of carbonised rice husk and perlite as the cutting matrix, the rooting rate of No. 1 rooting powder with 300 mg/L was the highest, but there was no statistically significant difference compared with other kinds or different concentrations. The rooting rate of cuttings was significantly affected by different rooting media. Under the treatment of No. 1 rooting powder and GGR-6, the rooting rate of cuttings inserted in four substrates was significantly different (P = 0.0413), and the rooting rate of cuttings inserted in vermiculite and perlite was the highest, multiple comparisons showed that there was a significant difference in rooting rate between it and the cuttings planted on other test substrates; under the treatment of 600 mg/L No. 1 rooting powder and GGR-6, there was also a significant difference in rooting rate among the cuttings inserted in four substrates (P = 0.0326), and the rooting rate of cuttings inserted in vermiculite and perlite was the highest. In general, the rooting rate of cuttings on vermiculite and perlite was as high as 32.2 % after being treated with 300 mg/L rooting powder No. 1 and GGR-6 for 6 hours.

The callus rate of cuttings cut from different parts of branches in different seasons was significantly different. The callus rate of lignified hard branches in winter was significantly higher than that of semi lignified tender branches in summer, especially at the base of branches, the callus rate of cuttings was 78.9 %. The rooting rate of the middle and upper parts of branches in summer is up to 44.4 %, which is significantly higher than that of other treatments; in winter, the rooting rate at the base of branches was 36.7%. Therefore, in terms of rooting rate, it is better to select the middle and upper part of branches in summer and the base of branches in winter.

In the process of cutting, substrate heating and hormone treatment can regulate the changes of internal storage material content in the rooting process of *Cyclocarya paliurus* cuttings, so as to affect the rooting effect. Soluble sugar, starch and soluble protein provide energy and nutrients for cutting rooting. During the cutting rooting process of *Cyclocarya paliurus*, the content of soluble sugar and starch decreased first and then increased, while the content of soluble protein decreased gradually. In the early stage of cutting, a large amount of soluble sugar and starch need to be consumed to provide energy. Soluble protein plays an important role in the whole rooting process. This continuous process needs to consume a certain amount of soluble protein. The stable total nitrogen content in cuttings is

conducive to root formation, and the stable change of total nitrogen content in leaves is not conducive to rooting.

The activities of SOD, POD and PPO were closely related to the cutting rooting of *Cyclocarya paliurus*. In the whole cutting rooting process, the activities of SOD and POD increased first and then decreased. The high activity of SOD and POD was conducive to the expansion of cuttings. POD activity had a valley value during adventitious root formation, POD activity decreased, IAA content increased and root extension was promoted. From the initial stage of cutting to the formation of SOD in adventitious roots, PPO activity gradually increased, and SOD activity reached the peak in the formation of adventitious roots, indicating that the increase of SOD and PPO activity is conducive to increasing the stress resistance of cuttings. Hormone treatment can improve the enzyme activity and make the enzyme activity to changes in the direction conducive to rooting.

Soluble sugar is the basic material of plant metabolism and energy storage. It is the main source of energy required to start the formation of adventitious roots, and provides a large number of nutrients for the formation of adventitious roots. It can be seen that in the process of hard branch rooting of *Cyclocarya paliurus*, the change of soluble sugar content in phloem of cuttings treated with 500 mg/L No. 1 rooting powder and the change of soluble sugar content in the control showed a similar trend. The soluble sugar content in the skin decreased slightly at the beginning of insertion. After 10 days, the soluble sugar content increased, and the soluble sugar content of the treatment increased faster than that of the control. At this stage, the basal metabolism of cuttings was active and a large amount of nutrients were needed. At this stage, amylase at the basal part of cuttings was activated, starch was hydrolysed into soluble sugar, and the soluble sugar in the upper cortex of cuttings was also transported to the rooting part of the basal part, the total amount of soluble sugar at the base of cuttings increased. Compared with the control, the soluble sugar content in the base of cuttings treated with 500 mg/L No. 1 rooting powder increased significantly, which shows that the treatment of No. 1 rooting powder at this concentration can enhance the differentiation and regeneration ability of cuttings incision cells, activate the activity of amylase, accelerate the hydrolysis of starch, and promote the downward transportation of phloem nutrients, so as to increase the content of soluble sugar. After 20 days of transplanting, callus formation needs to consume a lot of energy, and soluble sugar is the main material source of energy. In spring, the hardwood was inserted in the greenhouse, and the leaf buds also began to sprout at the callus formation stage, which needed to consume soluble sugar, so the content of soluble sugar decreased significantly. The callus formation time of cuttings treated with No. 1 rooting powder was earlier than that of the control. After 30 days of transplanting, the soluble sugar content of the treated cuttings further decreased, while the soluble sugar content of the control cuttings changed little. This period of time was the period of adventitious root formation of the treatment, the soluble sugar of the treatment group was further consumed and supplied to root formation. Compared with the control, the root formation time of the treatment group was earlier than that of the control, and the generation amount of the same transplanting time was also more than that of the control. The consumption of soluble sugar was also more than that of the control. It can be seen that exogenous hormone treatment can increase the utilisation of soluble sugar. After 40 days of transplanting, the soluble sugar content of the treatment group increased. Although the elongation and growth of adventitious roots needed to consume soluble reducing sugar, the upper leaves of the cuttings had expanded at this time, which could carry out photosynthesis and produce photosynthetic products, which were

transported to the base of the cuttings, slowed down the consumption of soluble sugar, and the soluble sugar began to accumulate gradually at the base of the cuttings. In this period, the content of the control was significantly lower than that of the treatment, because in this period, there were still many cuttings in the control in false life and no root formation.

However, at the beginning of transplanting, the soluble sugar content in the treatment group decreased faster than that in the control group. It is speculated that the protective tissue may be formed in the early stage of twig cutting, the mechanical damage caused by cutting incision of cuttings and the prevention of cuttings infection need to consume energy.

The change of starch content in the base phloem of cuttings during the rooting process of hard branch of *Cyclocarya paliurus*. It can be seen that during the whole rooting process, the change of starch content in the cuttings treated with 500 mg/L rooting powder No. 1 showed a decreasing trend compared with the control group. Before rooting, the formation of callus and adventitious root needs to consume a lot of nutrients. Therefore, within 0 to 30 days, the leaves have not expanded and cannot carry out photosynthesis. The energy required can only be provided by the nutrients stored by themselves. Starch is hydrolysed into soluble sugar, and the starch decreases rapidly; the starch content of the treatment group was lower than that of the control group, indicating that the exogenous hormone treatment increased the activity of amylase in cuttings, accelerated the hydrolysis of starch and provided energy for soluble sugar. From 30 days to 50 days, the leaves partially expanded and could carry out photosynthesis, which slowed down the decline of starch in phloem of cuttings. Hormone treatment activated amylase promoted the decomposition of starch into soluble sugar and provided energy for cuttings to form callus. Therefore, the reduction rate of starch content in the treatment group was faster than that in the control group at 0 to 20 days. The time of callus formation and leaf development of the treatment was earlier than that of the control, and the start time of photosynthesis was also earlier. Therefore, at 30 days, some leaves of the treatment expanded more than that of the control, and the starch content of the treatment was higher than that of the control. 30 days to 40 days was the key period for the treatment group to induce root formation. A large amount of starch was hydrolysed into soluble sugar for rooting, and the starch content decreased.

It can be seen that the change trend of starch content in the basal skin of the tender branch of *Cyclocarya paliurus* is roughly the same as that of the hard branch. The experiment showed that exogenous hormone treatment strengthened the utilisation of internal starch, improved the nutritional conditions at the base of cuttings, and promoted the rooting of cuttings.

It can be seen that during the whole rooting process of cuttings, the change trend of soluble protein content of hormone treatment and control is the same, which shows that it continues to decline during rooting and reaches the lowest at 50 days. It shows that during the continuous period of callus induction and adventitious root formation and the elongation period of adventitious root, soluble protein is continuously consumed to provide necessary nutrients for vigorous life activities. At the same time, soluble sugar and starch were also consumed in large quantities during this period, and the production of protein dependent on carbohydrates to provide energy and raw materials was reduced. In the process of reduction, the soluble protein content of cuttings treated with 500 mg/L rooting powder No. 1 was always lower than that of the control group. It may be that hormones activate some proteases in the cuttings, improve the enzyme activity and promote the decomposition and utilisation of proteins. In the middle and late stage of cuttings rooting,

the leaves gradually spread out for photosynthesis to produce organic matter and promote the accumulation of soluble protein. Therefore, the decline rate of soluble protein content decreased in 30 to 50 days. It can be seen that the change trend of soluble content in the basal skin of the tender branch of *Cyclocarya paliurus* is roughly the same as that of the hard branch, and the treatment is lower than that of the control.

Within 0 to 20 days, the control group increased faster than the treatment group, and the control group peaked at 20 days; within 20 days to 30 days, the total nitrogen content in the control group decreased faster than that in the treatment group, and reached the valley value at 30 days. From 30 days to 50 days, the content of total ammonia in the skin of the control group changed little, and the content was lower than that of the treatment group. Within 50 days to 60 days, the total atmosphere content of the skin gradually increased, and the recovery speed of the control group was faster than that of the treatment group. In the whole rooting process, the total nitrogen content in the treatment group changed little, which was lower than that in the control group from 0 to 30 days and slightly higher than that in the control group from 30 to 60 days. It can be seen that the stable change of total nitrogen content in the skin is conducive to rooting.

The change of total nitrogen content in leaves is slightly more complex than that in skin. Both the treatment group and the control group show a curve trend. The treatment group reaches the peak on the 10^{th} day and the valley on the 30^{th} day; the control group reaches the peak on the 20^{th} day and the valley on the 50^{th} day. Compared with the treatment group, the change of total nitrogen content in leaves is smaller, which shows that the stable change of total nitrogen content in leaves is not conducive to rooting.

Conclusion

(1) The effect of substrate and air humidity on the rooting rate of *Cyclocarya paliurus* cuttings was significant. The air humidity of *Cyclocarya paliurus* cuttings in summer was better to be controlled at 70 % and the substrate humidity was about 30 %. Different substrates had different responses to different hormone treatments. In the experiment, the rooting rate of cuttings inserted on vermiculite and perlite was the highest, up to 32.2 %. When twigs were inserted, there were less external callus, mainly skin swelling, cracking and rooting. When the hard branch is inserted, the incision under the cuttings is easy to form developed external callus, mainly callus rooting, but the rooting rate is slightly lower than that of the tender branch. In the experiment, the rooting rate of the middle and upper parts of branches treated with 300 mg/L rooting powder No. 1 and GGR-6 for 6 h was the highest, up to 44.4 %; in winter, the rooting rate of the base of branches was 36.7 % under the same treatment. In terms of rooting rate, it is better to select the middle and upper part of branches in summer and the base of branches in winter.

(2) Substrate heating and hormone treatment can regulate the changes of internal storage material content in the rooting process of *Cyclocarya paliurus* cuttings, so as to affect the rooting effect. Soluble sugar, starch and soluble protein provide energy and nutrients for rooting. During the rooting process of *Cyclocarya paliurus*, the content of soluble sugar and starch decreased first and then increased, while the content of soluble protein decreased gradually. In the early stage of transplanting, a large amount of soluble sugar and starch need to be consumed to provide energy. Soluble protein plays an important role in the whole rooting process. This continuous process needs to

continuously consume a certain amount of soluble protein. The stable total ammonia content in cuttings is conducive to root formation, and the stable change of total nitrogen content in leaves is not conducive to rooting.

(3) This experiment has made some progress in the research of cottage propagation of *Cyclocarya paliurus*, but further exploration and research are still needed to reach the level of industrialised production. The results of this study can provide a strong reference basis for the future research on cuttings propagation of *Cyclocarya paliurus*, so as to establish a perfect asexual propagation system as soon as possible. In the future research work, first, increase the control of the insertion environment, improve the insertion environmental conditions, effectively control the temperature and humidity of the atmosphere and matrix in the insertion environment, and explore better matrix disinfection and sterilisation methods. Secondly, different optimal treatments were explored for different cuttings to break through the limitations of cuttings. The rapid propagation system is an interconnected whole, not a single existence. Tissue culture or cutthroat propagation cannot be treated separately. We can learn from and optimise the results obtained in the tissue culture and propagation of *Cyclocarya paliurus*. It is believed that in the near future, the cutting propagation technology of *Cyclocarya paliurus* will be able to break through the difficulties, build an efficient rapid propagation system of *Cyclocarya paliurus*, and truly meet the industrialised large-scale production.

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