 DOI: 10.19601/j.cnki.issn1943 - 9903.2020.08.013

Effects of Different Propagation Materials and Cultivation Years on the Yield of *Polygonatum odoratum* under the Forest

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Abstract This paper mainly studies the effects of different propagation materials and cultivation years on the yield of *Polygonatum odoratum* under the forest. In this study, the cultivation experiment of *P. odoratum* was carried out by using the stem tip, stem body and seeds of *P. odoratum* as propagation materials. The yield of *P. odoratum* in different cultivation years with propagation by rhizome was also investigated. That is, the continuous growth of *P. odoratum* and the yield of *P. odoratum* each year after cultivation was statistically analyzed. The results showed that the germination rate under stem tip cultivation was fast, and the emergence time was also fast, which was more than 2 weeks earlier than that under stem body cultivation, and the seedling emergence rate reached 100%. The stem body was a new plant formed by sprouting from the buds of internodes, and the emergence rate was more than 95%. *P. odoratum* propagated by rhizome was harvested in the third or fourth year after cultivation, and the third year was the best harvest time.

Key words Propagation materials, Cultivation years, *Polygonatum odoratum*; Yield, Effects

1 Introduction

Polygonatum odoratum is a species of flowering plant in the family Asparagaceae. It is a perennial herb which can be used as medicine with its rhizome. It can treat current frequently-occurring diseases—diabetes and heart disease, and it is edible and can be used as a variety of health foods, so it is a promising plant for both medicine and food. In this study, the effects of different propagation materials and cultivation years on the yield of *P. odoratum* under the forest were investigated in order to obtain the best propagation material and the best harvest time, with the characteristics of independent intellectual property rights.

2 General situation of the experimental site

The experimental site (47°43′ N, 128°54′ E) is located in Xiaoxinganling Botanical Garden, Yichun District, Yichun City, Heilongjiang Province, with an altitude of 231.3 m. The annual frost-free period is about 110 days, the annual average temperature is about 0 ℃, the maximum temperature is 35.1 ℃, the absolute minimum temperature is −41.1 ℃, and the annual precipitation is about 600 mm. The experimental site is located in the sparse woodland of the botanical garden, and the distribution of trees in the sparse woodland is uneven. There are white birch, poplar and elm in the upper layer, with an average height of 8 m and a canopy density of about 0.2. Shrubs include *Corylus heterophylla*, *Rosa davurica pall. etc.*. After manual removal of shrubs, cutting of some upper unwanted tree species, it was manually reclaimed, and tree roots, stones and other sundries were picked up. The soil is typical dark brown soil, the thickness of the whole soil layer is greater than 60 cm and the thickness of A layer is greater than 30 cm. The terrain is flat, with an average slope of 6°. High ridge was built along the contours. The width of the ridge is 1.1 - 1.2 m, the height is 25 cm, and the distance between the ridges is 60 cm.

3 Experimental materials and methods

3.1 Experimental materials The seeds and rhizomes of *P. odoratum* were used as propagation materials, and the seeds were collected when they turned purple-black and matured in the middle of September. The rhizomes with a diameter of more than 1 cm and a length of 7 - 10 cm were selected and collected from mid to late September after wilting (before winter). The seeds and rhizomes of *P. odoratum* were collected from the natural wild resources in Yichun forest region. The propagation of *P. odoratum* was divided into seed propagation and rhizome propagation, and rhizome propagation is divided into stem tip propagation and stem body propagation. In this study, different materials (stem tip, stem body, seeds) were used for propagation.

3.2 Experimental methods The method of yield investigation and comparison test was mainly adopted. The yield investigation was carried out by setting up small sample plots at random temporarily. After pulling out the rhizome of *P. odoratum*, the soil was shaken and the aboveground part was removed, then it was washed with clean water and aired until the water evaporated completely before its fresh weight, stem (root) length and diameter class were measured. When it was naturally dried to a constant weight, the drying rate and dry matter content were measured. All the experiments of *P. odoratum* were repeated more than 3 times.

Received: June 17, 2020 Accepted: July 24, 2020

Supported by Special Project for Central Guidance in Local Science and Technology Development (ZY19C11); Special Project for the Investigation of Basic Resources of Science and Technology (2017FY101302-5).

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4 Results and analysis

4.1 Effects of different propagation materials on the yield of *P. odoratum*

The experimental results of different propagation materials such as stem tip, stem body and seeds showed that the germination rate under stem tip cultivation was fast and the emergence time was early, which was more than 2 weeks earlier than that under stem body cultivation, and the seedling emergence rate reached 100%. The stem body was a new plant formed by sprouting from the buds of internodes, and the emergence rate was more than 95%. The growth rate was slower than that of the stem tip, and the diameter class was also low, but the growth rate was similar after the second year. It took a long time to harvest with seeds for propagation, but it saved materials by using seeds, and the emergence rate was more than 70%. In the course of the experiment, a comparative experiment was carried out with stem tip, stem body and seeds. The yield per unit area and stem growth of *P. odoratum* with 2 years of rhizome propagation and 5 years of seed propagation are listed in Table 1 and Fig. 1. As can be seen from Table 1 and Fig. 1, the yield per unit area of *P. odoratum* propagated with stem tip was 39% higher than that under stem propagation in 2 years; the unit area yield of *P. odoratum* propagated with seeds was only 639 g/m^2 after 5 years from sowing to harvest (actually growing for 4 years). In addition, from the point of view of individual growth in Table 1, the growth index under stem tip propagation in the past two years far exceeded the individual growth under stem body and seed propagation.

Table 1 The yield per unit area of Polygonatum odoratum using different propagation materials

Propagation materials	Fresh weight//g/m^2	Growth of the current year			Growth of the previous year		
		Stem weight//g	Stem length//cm	Diameter class//mm	Stem weight//g	Stem length//cm	Diameter class//mm
Stem tip(2 years)	372	9.87	7.07	11.51	5.52	6.96	9.6
	430	9.59	6.17	12.51	7.30	6.61	11.84
	480	7.32	5.08	11.17	3.87	4.2	9.71
	395	5.49	6.37	9.22	6.84	7.67	10.13
	408	9.13	7.44	10.68	6.24	6.96	9.35
Average	417	8.28	6.43	11.02	5.95	6.48	10.13
Stem body(2 years)	290	6.32	5.23	10.83	4.75	4.56	8.6
	140	3.26	4.71	7.81	3.43	4.57	8.38
	533	4.32	5.71	8.50	4.40	5.56	8.90
	235	4.07	4.86	8.88	4.23	5.5	8.11
Average	300	4.49	5.13	9.00	4.20	5.05	8.50
Seeds(5 years)	458	2.71	5.77	6.48	2.47	6.38	5.70
	610	4.61	7.19	7.82	2.11	5.46	5.68
	850	2.57	5.67	6.47	3.05	6.60	6.43
Average	639	3.30	6.21	6.92	2.54	6.15	5.94

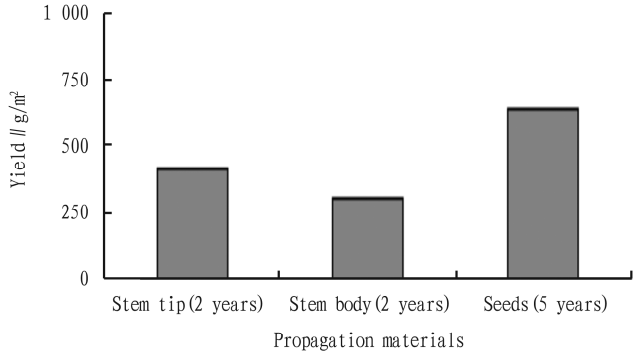

Fig. 1 Relationship between different propagation materials and yield of *Polygonatum odoratum*

The fresh weight of the main stem under stem tip propagation was 184.4% of that under stem body propagation and 250.9% of that under seed propagation, indicating that in the fifth year of propagation with seeds, the growth was still relatively slow. The reason for the small individual size of *P. odoratum* rhizome used in this experiment under seed propagation was that after direct seeding, the original seedlings were not transplanted, and some were too dense, resulting in small space between individuals. The results of analysis of variance showed that there were significant differences in the growth of *P. odoratum* except the stem length of the same year caused by different propagation materials. The analysis of variance is shown in Table 2.

Further multiple comparison showed that the yield per unit area of *P. odoratum* propagated with stem tip and stem body had no significant difference, but the difference between stem body and seeds was significant, but it was 5-year yield for seeds. There were significant differences in other unit indexes. See Table 3 for multiple comparisons. The above experimental results showed that when cultivating *P. odoratum*, the stem tip should be used for propagation as far as possible, so that it not only had a high seedling emergence rate, but also had a high yield per unit area, and the harvest time could be 1 – 2 years ahead of schedule compared with the seed propagation. Secondly, when the stem tip cannot meet the needs for cultivation and supply of seeds, the stem can be used for propagation. In addition, seed propagation can also be used, and it can be transplanted and cultivated under seed propagation in the third year, which can not only rapidly expand the cultivation area, but also realize effective propagation.

Table 2 Variance analysis of the effect of different propagation materials on yield of *Polygonatum odoratum*

Item		Sum of squares of deviations	Degree of freedom	Mean square	*F* value	0.05 significance level
Yield per square meter	Inter-group	20 0287.250	2	100 143.625	5.331	0.030
	Intra-group	169 063.667	9	18 784.852		
	Sum	369 350.917	11			
Stem weight of the current year	Inter-group	56.381	2	28.190	11.891	0.003
	Intra-group	21.337	9	2.371		
	Sum	77.717	11			
Stem length of the current year	Inter-group	4.040	2	2.020	3.389	0.080
	Intra-group	5.365	9	0.596		
	Sum	9.405	11			
Diameter class of the current year	Inter-group	32.045	2	16.022	11.944	0.003
	Intra-group	12.074	9	1.342		
	Sum	44.118	11			

Table 3 Multiple comparisons of the effects of different propagation materials on yield of *Polygonatum odoratum*

Different variables	Propagation materials	Propagation materials	Mean difference value	Standard error	Significance level	95% confidence interval	
						Lower limit value	Upper limit value
Yield per square meter	Stem tip	Stem body	117.500 00	91.941 00	0.233	-90.490 0	325.490 0
	Seeds	Stem tip	222.333 00	100.093 00	0.053	-4.090 0	448.760 0
		Stem body	339.833 00(*)	104.680 00	0.010	103.030 0	576.640 0
Stem weight of the current year	Stem tip	Stem body	3.787 50(*)	1.032 87	0.005	1.451 0	6.124 0
		Seeds	4.983 33(*)	1.124 45	0.002	2.439 7	7.527 0
	Stem body	Seeds	1.195 83	1.175 98	0.336	-1.464 4	3.856 1
Stem length of the current year	Stem tip	Stem body	1.298 50(*)	0.517 91	0.033	0.126 9	2.470 1
		Seeds	0.216 00	0.563 83	0.711	-1.059 5	1.491 5
	Seeds	Stem body	1.082 50	0.589 67	0.100	-0.251 4	2.416 4
Diameter class of the current year	Stem tip	Stem body	2.013 00(*)	0.776 97	0.029	0.255 4	3.770 6
		Seeds	4.094 67(*)	0.845 86	0.001	2.181 2	6.008 1
	Stem body	Seeds	2.081 67(*)	0.884 62	0.043	0.080 5	4.082 8

Note: * represents a significant difference, the same as below.

4.2 Effects of different cultivation years on the yield of *P. odoratum* After the cultivation of *P. odoratum*, the number of harvest years is also a key problem to be solved in this study, so the appropriate harvest years were obtained by comparing the yields of different years. In order to determine the reasonable harvest years of *P. odoratum*, experiments on cultivation in different years and yield investigation were carried out. The annual growth of *P. odoratum*, that is, the yield of *P. odoratum* each year after cultivation was statistically analyzed. The yield per unit area and annual growth each year are shown in Table 4, Table 5 and Fig. 2. As can be seen from Table 4, Table 5 and Fig. 2, with the increase of cultivation years, the yield per unit area of *P. odoratum* also increased, but the rate of increase slowed down since the fourth year, and increased by 39.7% in the third year compared with the second year, and 24% in the fourth year compared with the third year. From Table 5 and Fig. 2, the annual growth of underground stem showed that the stem length and stem weight decreased greatly, and the diameter class, that is, the thickness, did not change much. The stem weight in the fourth year was 23.9% lower than that in the third year, and the stem length decreased by 25.2%. In addition, from the analysis of variance of yield per unit area and growth per plant each year, there were significant differences, as shown in Table 6 and Table 7.

Table 4 The yield per unit area of *Polygonatum odoratum* in different cultivation years

Number of years	Yield//g/m^2									Average
	Group 1			Group 2			Group 3			
2	968	871	871	777	774	809	967	853	694	806
3	1 035	945	675	765	2 380	935	1 200	600	1 600	1 126
4	1 546	1 187	1 535	1 727	1 440	1 209	1 240	1 404	1 307	1 399

Note: The three data in each group represent three repeated trials of yield per unit area.

Table 5 Continuous growth of *Polygonatum odoratum* under rhizome propagation

Item	First year	Second year	Third year	Fourth year
Stem weight // g	6.28	7.43	10.16	7.73
Stem length // cm	7.87	7.86	9.36	7
Diameter class // mm	8.79	9.23	10.49	10.41

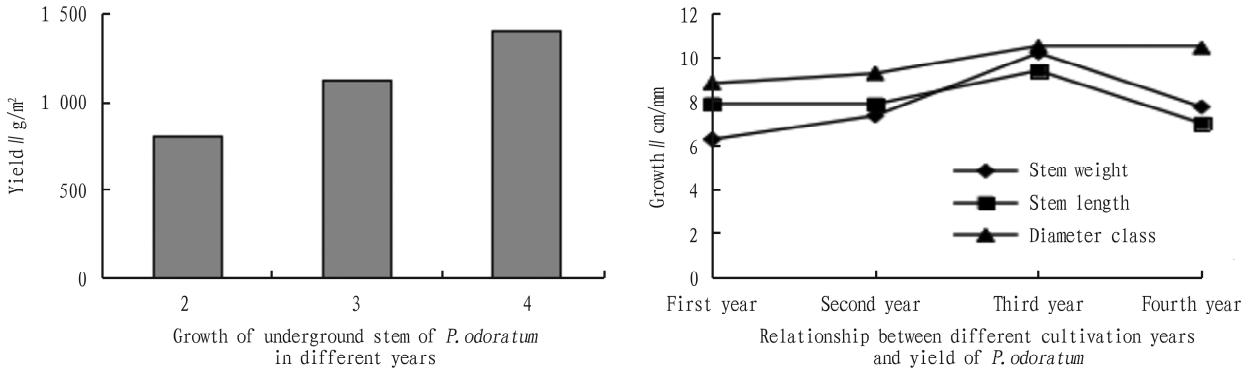

Fig. 2 The yield per unit area and annual growth of *Polygonatum odoratum* in different cultivation years

Table 6 Variance analysis of yield per unit area of *Polygonatum odoratum* in different cultivation years

Item	Sum of squares of deviations	Degree of freedom	Mean square	*F* value	0.05 significance level
Inter-group	1 588 075.630	2	794 037.815	6.321	0.006
Intra-group	3 014 833.111	24	125 618.046		
Sum	4 602 908.741	26			

Table 7 Variance analysis of growth of *Polygonatum odoratum* in different cultivation years

Item		Sum of squares of deviations	Degree of freedom	Mean square	*F* value	0.05 significance level
Stem weight	Inter-group	218.255	3	72.752	12.438	0.000
	Intra-group	631.703	108	5.849		
	Sum	849.958	111			
Stem length	Inter-group	75.214	3	25.071	16.648	0.000
	Intra-group	162.642	108	1.506		
	Sum	237.857	111			
Diameter class	Inter-group	60.462	3	20.154	21.588	0.000
	Intra-group	100.825	108	0.934		
	Sum	161.288	111			

It showed that there were significant differences in yield per unit area caused by different years. However, further multiple comparison showed that there was no significant difference in yield per unit area between the third year and the fourth year (Table 8). From Table 8, there was only a significant difference in yield between the second year and the fourth year. The difference of yield between the third year and the fourth year was small. With the increase of the number of years, the increase of yield was not obvious.

Table 8 Multiple comparison of yield per unit area of *Polygonatum odoratum* in different cultivation years

Number of cultivation years	Number of cultivation years	Mean difference value	Standard error	Significance level	95% confidence interval	
					Lower limit value	Upper limit value
3	2	320.111	167.078	0.067	-24.72	664.94
4	2	593.444(*)	167.078	0.002	248.61	938.28
	3	273.333	167.078	0.115	-71.50	618.17

In addition, from the multiple comparative analysis of the annual growth of a single plant, except for the diameter class in the third year and the fourth year, there were significant differences in other indexes (Table 9). Therefore, the *P. odoratum* propagated with rhizome was harvested in the third or fourth year after cultivation, and the third year was the best harvest time, when the average yield per unit area could reach 1 126 g.

Table 9 Multiple comparisons of growth of *Polygonatum odoratum* in different cultivation years

Different variables	Cultivation time	Cultivation time	Mean difference value	Standard error	Significance level	95% confidence interval	
						Lower limit value	Upper limit value
Stem weight	Second year	First year	1.144 67	0.624 45	0.070	−0.093 1	2.382 4
	Third year	First year	3.878 64(*)	0.648 02	0.000	2.594 1	5.163 1
		Second year	2.733 97(*)	0.648 02	0.000	1.449 5	4.018 5
		Fourth year	2.430 38(*)	0.670 77	0.000	1.100 8	3.760 0
	Fourth year	First year	1.448 26(*)	0.648 02	0.027	0.163 8	2.732 8
		Second year	0.303 59	0.648 02	0.640	−0.980 9	1.588 1
Stem length	First year	Second year	0.017 00	0.316 85	0.957	−0.611 1	0.645 1
		Fourth year	0.875 77(*)	0.328 81	0.009	0.224 0	1.527 5
	Second year	Fourth year	0.858 77(*)	0.328 81	0.010	0.207 0	1.510 5
	Third year	First year	1.485 38(*)	0.328 81	0.000	0.833 6	2.137 2
		Second year	1.502 38(*)	0.328 81	0.000	0.850 6	2.154 2
		Fourth year	2.361 15(*)	0.340 36	0.000	1.686 5	3.035 8
Diameter class	Second year	First year	0.443 00	0.249 47	0.079	−0.051 5	0.937 5
	Third year	First year	1.692 82(*)	0.258 89	0.000	1.179 7	2.206 0
		Second year	1.249 82(*)	0.258 89	0.000	0.736 7	1.763 0
		Fourth year	0.070 38	0.267 98	0.793	−0.460 8	0.601 6
	Fourth year	First year	1.622 44(*)	0.258 89	0.000	1.109 3	2.135 6
		Second year	1.179 44(*)	0.258 89	0.000	0.666 3	1.692 6

5 Conclusion and discussion

(i) The experimental results on the effect of stem tip, stem body and seed as propagation materials on the yield of *P. odoratum* showed that when *P. odoratum* was cultivated, the stem tip should be used for propagation as much as possible, so that it not only had a high seedling emergence rate, but also had a high yield per unit area, and the harvest time could be 1 – 2 years earlier than that under seed propagation. Secondly, when the stem tip cannot meet the needs for cultivation and supply of seeds, the stem body can be used for propagation. In addition, seed propagation can also be used, and it can be transplanted and cultivated under seed propagation in the third year, which can not only rapidly expand the cultivation area, but also realize effective propagation.

(ii) Through the cultivation experiment and yield investigation in different years, the results showed that the *P. odoratum* propagated with rhizome was harvested in the third or fourth year after cultivation, and the third year was the best harvest time.

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