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Influence of Soil Fertility on Angelica Quality and Yield

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Abstract We studied the relationship between soil fertility indicator and angelica yield and quality by the methods of correlation analysis and path analysis. The results showed that, in Yunnan Province, the content of ferulic acid (major indicator of angelica quality) is 1.5 –2.5 mg/g and single plant fresh weight (major indicator of yield) is 60 –250 g. The content of angelica ferulic acid and angelica single plant fresh weight are positively correlated with the content of total N, quick-acting K, organic matter, whereas negatively correlated with the content of quick-acting P. It is shown that the most direct factor that influence the content of the angelica ferulic acid is the quick-acting K, and the least direct factor is organic matter; the most direct factor that influences the single plant fresh weight of angelica is the total N, while the least direct factor is the quick-acting P. In conclusion, the soil fertility indicators that have great influence on quality and yield of angelica are the quick-acting K, total N, quick-acting P and organic matter.

Key words Angelica, Soil fertility, Ferulic acid, Single plant fresh weight

In China, the angelica is mainly produced in northwest Yunnan Province. As a type of major commonly used traditional Chinese medicine, the angelica consumption is high. The ferulic acid, which is an effective constituent of angelica, has the function of anti-oxidation and free radical, and can effectively inhibit aggregation of blood platelet and formation of thrombus (Kang Jun, 2005). In Kunming, Qujing, Dali and Lijiang of Yunnan Province, the angelica has gradually realized large-scale planting, and become an important approach for farmers in high and cold mountain areas to shake off poverty and set out on the road to prosperity (Yang Zhixin *et al.*, 2004). Thus, carrying out scientific research on artificial planting of angelica in Yunnan Province is of great realistic significance. The research on artificial planting of angelica has been extensively carried out in Gansu Province, but mainly concentrated on substrate resource, cultivation technology, plant diseases and insect pests, and efficacy of constituents (Qiu Daiyu, *et al.*, 2005). At present, the research of artificial planting of angelica in Yunnan Province only touches on cultivation (Yang Zhixin, *et al.*, 2004). There is no overall and systematic research, let alone the relationship between soil fertility and quality and yield of angelica. In this situation, we discussed the influence of soil fertility on quality and yield of angelica, in the hope of enriching and improving basic theory of the relationship between liquid manure and quality and yield of angelica. Under the conditions of the same climate, region and variety, we compared the quality and yield of angelica in different soil fertility. By methods of correlation analysis and path analysis, we analyzed the influence of soil fertility indicator on quality and yield of angelica, to provide reference for liquid manure control of normalized planting of angelica in accordance with provisions of *Good Agricultural Practice for Chinese Crude Drugs* (*GAP*).

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1 Materials and methods

1.1 General information of experiment place The experiment was carried out in Key Laboratory of Water Resources and Water-saving Irrigation of Yunnan Agricultural University in north of Kunming City. The geographical coordinate is 25°8′N and 102°45′E. It is 197 4 m above sea level. The annual hours of sunshine reach 244 5.6, with rate of sunshine 56%. The rainfall is mainly in May to October. The average annual rainfall is 103 1 mm; relative humidity is 74%; annual average temperature is 14.5℃; average frost-free period is longer than 240 days. The soil type is red clay with volumetric weight of 1.25 g/cm^3 and water mass fraction of 22.5%. We designed 12 parcels of field, each of which is 2 m wide and 3 m long with row spacing 40 cm and spacing in the roles 30 cm. In 2010, the entire growth period of angelica is 195 d, while the effective rainfall in the entire growth period is 520.4 mm. Experiment of Key Laboratory of Water Resources and Water-saving Irrigation of Yunnan Agricultural University is listed in Table 1.

1.2 Collection of samples In December 2012 when the angelica is harvested, we collected 16 angelica samples in the Key Laboratory of Water Resources and Water-saving Irrigation of Yunnan Agricultural University and also in Qujing where the angelica is planted on a large scale. Specifically, the distribution of these 16 samples is as follows: 12 samples from the Key Laboratory of Water Resources and Water-saving Irrigation of Yunnan Agricultural University; 1 sample from Baishui Town,

Yanfang Township, Panjiang Township of Zhanyi county, and Wuxing Township of Huize County respectively. At the same time, we collected 16 soil samples at the depth of 0 to 20 cm from the above angelica sample collecting points. The soil samples were then air dried, grounded, screened and bottled for future test.

Table 1 List of experiment field

Item	No fertilizer	Low fertilizer	Moderate fertilizer	High fertilizer
High water	Experiment field 9	Experiment field 10	Experiment field 11	Experiment field 12
Moderate water	Experiment field 5	Experiment field 6	Experiment field 7	Experiment field 8
Low water	Experiment field 1	Experiment field 2	Experiment field 3	Experiment field 4

1.3 Analysis and measurement of samples Main indicator of angelica quality is the content of ferulic acid, and main indicator of its yield is the single plant fresh weight. These were measured by the Basic Experiment Center of Agricultural Science Discipline in Yunnan Agricultural University; major factors of soil fertility include total N, quick-acting P, quick-acting K and organic matter. These factors were measured by Soil Analytical Laboratory of Yunnan Agricultural University.

The laboratory apparatus includes Agilent Technologies 1200 series high performance liquid chromatograph, electronic scale (Sartorius Sartorius Scientific Instruments (Beijing) Co., Ltd), DGG-9240 electric thermostatic air blowing drying box (Shanghai Sumsung Experimental Instrument Co., Ltd), numerical show constant temperature water-bathing boiler, and agent (including methanol, phosphoric acid, and ferulic acid control article).

Measurement of ferulic acid content: high-performance liquid chromatography (HPLC) method.

Main indicators of soil fertility adopt conventional method: Semi-micro Kjeldahl Method for total N; $NaHCO_3$ method for quick-acting P; NH_4OAc extraction and flame photometry for quick-acting K; potassium dichromate volumetric method combined with thermal measurement for organic matters.

1.4 Data processing Experimental data cleansing adopts Excel 2003 software and data processing adopts SPSS 17.0 software.

2 Results and analyses

2.1 Major factors of soil fertility and major indicators of angelica quality and yield From the measurement of major indicators of angelica quality (ferulic acid content and single plant fresh weight) and major factors of soil fertility (total N, quick-acting P, quick-acting K, and organic matter) listed in Table 2, it is shown that the content of quick-acting P in soil from the experimental field of Key Laboratory of Water Resources and Water-saving Irrigation of Yunnan Agricultural University is higher than that from large-scale angelica production region in Qujing (hereafter referred to as Qujing region); while the content of total N, quick-acting K and organic matter is lower than that in Quqing region. As to the angelica yield, the content of ferulic acid (major indicator of angelica quality) is 1.5-2.5 mg/g and single plant fresh weight (major indicator of yield) is 60-250 g. Single plant fresh weight of angelica from the experimental field is slightly lower than that in Qujing region.

Table 2 Major indicators of soil fertility and angelica quality and yield

Sample No	Major factor of soil fertility				Angelica yield and quality indicator	
	Total N g/kg	Quick-acting P mg/kg	Quick-acting K mg/kg)	Organic matter g/kg	Ferulic mg/kg	Average single plant fresh weight//g
Field 1	1.23	40.54	77.12	29.65	1.91	86.53
Field 2	1.01	54.68	72.85	36.20	2.42	58.92
Field 3	1.57	70.40	92.47	33.79	2.01	137.75
Field 4	1.40	72.76	59.26	29.65	1.91	38.95
Field 5	1.34	53.90	74.11	31.38	1.56	135.58
Field 6	0.73	31.11	55.99	34.48	2.19	86.40
Field 7	1.96	57.83	73.60	36.55	1.98	145.19
Field 8	1.62	27.19	58.26	28.27	2.17	66.59
Field 9	1.74	71.18	72.60	36.20	2.36	141.01
Field 10	1.68	36.61	62.03	28.27	2.13	84.82
Field 11	1.57	49.18	45.18	27.24	1.78	193.48
Field 12	1.46	42.90	54.48	27.24	2.34	207.25
Baishui Town	2.78	7.06	652.09	50.39	2.32	257.26
Yanfang Township	2.90	29.58	773.40	59.51	2.00	243.76
Panjiang Township	2.11	10.03	757.64	32.09	2.32	178.05
Wuxing Township	1.50	46.76	620.52	22.92	2.42	201.22

2.2 Analysis on correlation of soil fertility factors with major indicators of angelica quality and yield To further understand the relationship between angelica quality and yield and soil fertility, we carried out gradual regression analysis on two indicators of angelic quality and yield in Table 2 and major factors of soil fertility in Table 2.

The analysis results listed in Table 3 show that the ferulic acid content is positively correlated with total N, quick-acting K

and organic matter content, while negatively correlated with the content of quick-acting P. The extremely significant correlation between ferulic acid content and quick-acting K content in soil indicates that their relationship is close. The single plant fresh weight of angelica is positively correlated with the total N, quick-acting K and organic matter content in soil, while it is negatively correlated with the quick-acting P content in soil. In particular, the correlation with the total N and quick-acting K reaches the extremely significant level.

Table 3 Correlation of soil fertility factors with major indicators of angelica quality and yield

Soil fertility indicators	Ferulic acid mg/g	Average single plant fresh weight//g
Total N	0.072 38	0.707 44
Quick-acting P	−0.288 91	−0.397 9
Quick-acting K	0.327 95	0.684 16
Organic matter	0.036 34	0.456 38

2.3 Path analysis on factors soil fertility and major indicators of angelica quality and yield To make clear the influence of soil fertility factors on angelica quality and yield, we carried out path analysis on major factors of soil fertility and content of ferulic acid and the single plant fresh weight (shown in Table 4 and Table 5).

2.3.1 Analysis on path coefficient of soil fertility factors and content of ferulic acid. From Table 4, it is known that the influence degree of major factors of soil fertility on content of ferulic acid is quick-acting K > total N > quick-acting P > organic matter. The direct influence of quick-acting K in soil on content of ferulic acid of angelic is positive, while the direct influence of total N, quick-acting P and organic matter in soil on content of ferulic acid is negative. The influence degree of major factors of soil fertility on the content of ferulic acid is as follows: quick-acting P > total N > quick-acting K > organic matter. The indirect influence of content of quick-acting P and quick-acting K in soil on the content of ferulic acid is positive; the indirect influence of total N and organic matter content on the content of ferulic acid is negative; the indirect influence of quick-acting P content on ferulic acid content is higher than the direct influence.

Table 4 Analysis on path coefficient of soil fertility factors and content of ferulic acid

Soil fertility indicators	Direct action	Indirect action				
		Total	Total N	Quick-acting P	Quick-acting K	Organic matter
Total N	−0.3178	−0.315 6		0.141 0	−0.229 1	−0.227 5
Quick-acting P	−0.142 9	0.718 8	0.586 6		0.087 6	0.044 6
Quick-acting K	0.456 2	0.286 6	0.328 9	−0.279 7		0.237 4
Organic matter	−0.032 9	−0.030 4	−0.023 5	0.010 2	−0.017 1	

2.3.2 Analysis on path coefficient of soil fertility factors and single plant fresh weight of angelica. From Table 5, it is known that the direct influence degree of major factors of soil fertility on single plant fresh weight is total N > quick-acting K > organic matter > quick-acting P. The direct influence of total N, quick-acting P and quick-acting K content in soil on the single plant fresh weight of angelica is positive, while that of organic matter on the single plant fresh weight is negative. The influence degree of major factors of soil fertility on the single plant fresh weight of angelica is as follows: total N > quick-acting K > organic matter > quick-acting P. The indirect influence of total N and quick-acting K in soil on the single plant fresh weight of angelica is positive, while that of organic matter on the single plant fresh weight is negative.

Table 5 Analysis on path coefficient of soil fertility factors and single plant fresh weight of angelica

Soil fertility indicators	Direct action	Indirect action				
		Total	Total N	Quick-acting P	Quick-acting K	Organic matter
Total N	0.521 7	0.518 1		−0.231 4	0.376 1	0.373 4
Quick-acting P	0.037 0	−0.019 8	−0.016 4		−0.022 6	0.019 2
Quick-acting K	0.386 3	0.242 8	0.278 5	−0.236 8		0.201 1
Organic matter	−0.106 5	−0.098 3	−0.076 2	0.033 3	−0.055 4	

3 Discussion

The correlation between the quick-acting K content in soil and the ferulic acid content in angelica is extremely significant. Its influence is the largest, while the indirect influence of quick-acting P on ferulic acid content in angelica is the largest, indicating that both the quick-acting K and quick-acting P are major factors influencing content of ferulic acid in angelica. With increase of the quick-acting K in soil, the content of ferulic acid in angelica increases; if the content of quick-acting P is low, it will influence the increase of ferulic acid content, because lack of P in soil will lead to poor growth of root system, reduction of lateral bud, short and small plant. However, the excessive increase of quick-acting P in soil will reduce the ferulic acid content of angelica. Therefore, it is required to increase application of potash fertilizer and control phosphorus fertilizer during angelica planting. There are few researches on influence of soil fertility on content of ferulic, so we made an analysis on this from experimental results.

The correlation between the total N and quick-acting K in soil and single plant fresh weight of angelica reaches extremely significant level, and both the direct and indirect influence is the highest, indicating that the total N and quick-acting K content have greater influence on the angelica yield. With increase of total N and quick-acting K content, the single plant fresh weight of angelica also increases. It proves that increasing application

of nitrogen fertilizer and potash fertilizer, especially the potash fertilizer, can increase angelica yield and improve angelica quality, which is consistent with researches of He Guiwen (2007).

In addition, the increase of organic matter in soil plays certain role in increasing the angelica yield. Organic fertilizer can compensate lack of soil fertility in the late period of angelica growth, and provide necessary nutrients for material production during the whole growing period, to guarantee adequate nutrient supply in middle and later period of angelica growth, which are consistent with researches of Qiu Daiyu *et al.* (2005) on the effect of high effective organic fertilizer on increase of angelica yield. Therefore, it is required to increase application of organic fertilizer during angelica planting.

4 Conclusions

Our research indicates that the content of angelica ferulic acid and angelica single plant fresh weight are positively correlated with the content of total N, quick-acting K, organic matter, whereas negatively correlated with the content of quick-acting P. The most direct factor that influences the content of the angelica ferulic acid is the quick-acting K, and the least direct factor is organic matter; the most direct factor that influences the single plant fresh weight of angelica is the total N, while the least direct factor is the quick-acting P. The maximum direct influence of soil fertility factor influencing the single plant fresh weight of angelica is total N, and the minimum is the quick-acting P, and the highest indirect influence comes from the total N. The soil fertility indicators that have great influence on quality and yield of angelica are the quick-acting K, total N, quick-acting P and organic element. In angelica production, it is preferred to apply potash fertilizer and nitrogen fertilizer to improve angelica quality and increase its yield.

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line, and difficulty in mortgage credit. In order to solve these problems, we should adopt the following measures to adapt to rural economy's needs for credit funds and increase farmers' income: improving the credit mode; lowering the credit threshold; innovating upon the credit products.

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