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Research on Effects of Plant Growth Regulators on Quality of Manicure Finger Grape

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Abstract: Total 13 quality characters of manicure finger grape which was treated by 21 different plant growth regulators in Pengshan county, Sichuan province were judged comprehensively according to the principle of fuzzy mathematics. The results indicated that the effects of growth regulators on the internal quality of manicure finger grape was larger than the external quality. In 13 quality indicators, the first four indicators which were vitamin C content, sugar acid ratio, soluble solid and total soluble sugar impacted greatly to the comprehensive characters. The best treatment on the comprehensive quality was the use of 5000 mg L^{-1} PBO on May 27 and 170 mg L^{-1} S-ABA on July 10 spraying on the trees and the best treatment on the external quality was the use of 5000 mg L^{-1} PBO +200 mg L^{-1} S-ABA spraying on the trees. The use of 10.0 mg L^{-1} Qibao spraying on the trees on May 27 was the best treatment on the internal quality.

Key words: Manicure finger, grape, quality, fuzzy mathematics, internal quality, plant growth

INTRODUCTION

Manicure finger grape whose parents were unikun and the 2nd Bala was cultivated diploid Eurasian species vine phytoplasma by Uehara Grape Research Institute in Japan. China introduced manicure finger grape etc., new varieties of grapes from Japan in 1990's (Chu and Li, 2001). The variety had entered the large-scale cultivation in Shangshui Henan, Changli Hebei, Zhuji Zhejiang, Rudong Jiangsu and Lingchuan Guangxi etc., planted areas at present (Meng *et al*., 2003; Wan-Hua, 2002; Wang *et al*., 2007; Wu *et al*., 2009) and the fruit showed medium-large, slender and bright red top as stained with red finger nails of the beauty's.

The appearance was very beautiful. Its fruit was crisp could be sliced, good flavor compact fruit. It was attractive and tasty. The variety has not been carried out in large scale in the Sichuan province. Although, solved the problem of cultivation of manicure finger grape in Pengshan Sichuan currently, there are still poor taste, not high yield. So, this study aims to use plant growth regulators to solve the problems and analyze quality indicators comprehensively according to the principle of fuzzy mathematics on the handled manicure finger grape to select the treatment of the best comprehensive quality of testing program. The study provide scientific guidance to the use of plant growth regulators for the production at the same time to provide theoretical basis for improving quality, standardization cultivation and management of manicure finger grape.

MATERIALS AND METHODS

Experimental material: In Orchard village, Guanyin Township, Pengshan county, Chengdu, choosed the same of 3 years old manicure finger grape trees which were planted in 2008 with leaving a flower for each fruit branch, staying about 10 inflorescences/plant. The posture was flat scaffolding and rain planting, the planting density was 3×1 m. Plant growth regulators Qibao was provided by the American Hualun Biological Sciences company.

Dinghao was provided by Lanyue technology development company in Sichuan province. S-ABA was provided by Lomon Fusheng Technology Co., Ltd in Sichuan. PBO was provided by institute of promoting and controlling the fruit production agents in Jiangyin city, Jiangsu province.

Field area: Guanyin Township, Pengshan county, Chengdu city, Sichuan province, humid subtropical climate zone, mild climate, abundant rainfall and four distinct seasons. There was not heat in summer and not cold in winter. The average of annual sunshine was 1293.7 h, the most of sunshine is in August, the least is in January and December. The average of annual temperature was 17.1°C, frost-free period is 308 days, rainfall was 983.4 mm and relative humidity was 82%. The altitude was about 600 m above sea level, experiment land was flat loam, pH 6.0. The test garden area was 10 acres, and management was better.

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Methods: The treatments with plant growth regulators on manicure finger grape in the consistent control and management of pest, fertilizer and water, carried out 21 different treatments with plant growth regulators on manicure finger grape (Table 1).

No. 1-15 treatments used different concentrations and the ratio of Dinghao and Qibao spraying on the trees on May 27. No. 16-21 used 5000 mg L^{-1} PBO spraying on the trees on May 27 and used different concentrations of S-induce resistance material spraying on the trees on July 10.

All treatments were sprayed on the leaves and the ears with a small watering can until the small water drops from the trees. In Table 1, A represented Dinghao, B represented Qibao, C represented Dinghao+Qibao, S represented different concentrations of PBO+S-ABA.

Determination of fruit quality: Selected randomly 100 fruits on the middle and lower parts of the ears from the harvested fruits for each treatment then selected randomly 20 fruits to measure the fruit fresh weight, soluble solids, titratable acidity, total soluble sugar and Vc content. The weight of fruits and ears were measured by the precision of 0.1 g balance; soluble solids content of berries were measured by WYT-4 handheld detector for determination of sugar; anthocyanin was measured by colorimetric method with hydrochloric acid andmethano (Qing-e, 2003), titratable acid was measured by acid-base titration method (GB 12293-90, 1990). Total soluble sugar was measured by anthrone spectrophotometric determination (GB 6194-86, 1986). Total soluble sugar was measured by anthrone spectrophotometric determination (GB 6194-86, 1986). Vitamin C was measured by 2, 6-dichloro-i ndophenol method (GB 6195-86, 1986). The standard of fruit tight was putting ears flatly: all branches were in a plane (1 point); shape changed significantly (2 points); shape changed slightly (3 points); shape were not change (4 points); shape changed and fruit deformation due to the squeezing each other (5 points).

Table 1: The treatments with plant growth regulators on manicure finger grape

Treatments	Ratio of treatments (mg L^{-1})
A1	2.5
A2	5.0
A3	7.5
A4	10.0
A5	12.5
B1	50.0
B2	40.0
B3	30.0
B4	20.0
B5	10.0
C1	2.5+10.0
C2	2.5+20.0
C3	5.0+10.0
C4	5.0+20.0
CK	0.0
S-1	5000+200
S-2	5000+170
S-3	5000+150
S-4	5000+130
S-5	5000+100
S-CK	0.0

10 ears per treatment, repeated 3 times. Plant community, a total of 63 quarters

$$\text{Uniformity} = \frac{\text{50 smallest grapes weight}}{\text{50 largest grapes weight}}$$

RESULTS

Evaluation index system designed: In order to evaluate the treatments effect on quality of manicure finger grape objectively and scientifically, we need to design a set of index system which is scientific, complete can be from all round view reflecting the quality of manicure finger grape. According to the principles of scientific, objective, systematic, feasible and authenticity based on domestic and international scholars, this study designed the 13 indicators from two aspects of the internal quality and external quality in order to reflect the impact of each treatments on manicure finger grape quality comprehensively (Table 2).

Evaluatin model: The comprehensive evalutaion of different treatments on the quality of manicure finger grape was conducted using Fuzzy comprehensive evaluation method, the method could determine the influence degree of different plant growth regulators on the quality indicator of manicure finger grape. By the standardized assessment matrix R and the weight vector w, the comprehensive evaluation model was conducted using fuzzy mathematical theory:

Table 2: Evaluation index system on quality of manicure finger grape

Elements	Contents of evaluation index	Index
Internal quality	Fruit weight/g	X_1
	Fruit longitudinal diameter/cm	X_2
	Fruit diameter/cm	X_3
	Fruit shape index	X_4
	Panicle weight/g	X_5
	Uniformity	X_6
	Tightness (score)	X_7
	Anthocyanin/nmol g^{-1}	X_8
	Soluble solids/%	X_9
External quality	Total soluble sugar/%	X_{10}
	Titratable acid/%	X_{11}
	Ratio of sugar to acid	X_{12}
	Vc content/mg/100 g	X_{13}

$$B = (b_1, b_2, \cdots, b_j, \cdots, b_n) = w * R^T$$
$$= (w^1, w^2, \cdots, w^n) * \begin{bmatrix} r_{11} & r_{21} & \cdots & r_{m1} \\ r_{12} & r_{22} & \cdots & r_{m2} \\ \cdots & \cdots & \cdots & \cdots \\ r_{1n} & r_{2n} & \cdots & r_{mn} \end{bmatrix}$$

In the earlier equation, * was the weighted average model which was characterized by a comprehensive evaluation of each factor's contribution to the evaluation results. There were variety of fuzzy operators such as the ⊗ (full constraints model), • (taking the product of large-scale), ⊕ (average balance type), etc. But in order to use comprehensive information of matrix R and make the results comprehensively, this study used the weighted average-type * operator. According to this algorithm, the greater the value of b_j was in the name of the greater the influence degree of different growth regulators on the quality was the smaller conversely.

Determination of weight: Weight to determine had direct impact on the results of model evaluation. To make the weight more objective, more scientific, the entropy method to determine the index weight was used in this study. The earliest concept of entropy was from thermodynamics that the system state was a measure of uncertainty. In information theory, the entropy value reflected the degree of disorder of information which could be used to measure the amount of information. Entropy-weight reflected the degree of competition of the information between the same index if the information was same that the advantages and disadvantages between the different evaluations on this indicator was not reflected. This method of determining weights of each index was to avoid the influence of human factors as possible so that the evaluation was more scientific. Entropy could be used to measure the size of Information, the more information an index carried and transmitted that the greater role of the index on decision-making was (Zhou *et al*., 2008) the entropy of the evaluation object j was defined as:

$$H_j = -k\sum_{i=1}^{m} f_{ij} \ln f_{ij} \quad (j = 1, 2, \cdots, n)$$

in which;

$$f_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}, \quad k = \frac{1}{\ln m}$$

and assume that when $f_{ij} = 0$, f_{ij}, $\ln f_{ij} = 0$ the entropy-weight of object j was defined as:

$$w^j = \frac{1 - H_j}{\sum_{j=1}^{n} (1 - H_j)}$$

by the size of the weight, the role size of different indicators in decision-making information was reflected. The weight vector of each evaluation index could be drawn by each weight:

$$w = w^1, w^2, ..., w^n$$

Original data: By measuring and analysis, the original datas of indicators of quality about each treatment on manicure finger grape were obtained (Table 3 and 4).

Quality evaluation results

Weight of the quality indicators: The survey datas in Table 3 and 4 were standardized using EXCEL 2010 edition and then calculated the quality index weight by the entropy method, the evaluation index weight vector obtained was:

$$w = (0.0428, 0.0231, 0.0837, 0.0240, 0.0757, 0.0660, 0.\ 0625, 0.0802, 0.0944, 0.0848, 0.1195, 0.1017, 0.1416)$$

Thus, showed in 13 internal and external quality indicators, the descending order of their comprehensive quality influence on manicure finger grape were Vc content, titratable acid, ratio of sugar to acid, soluble solids, total soluble sugar, fruit diameter, anthocyanin, panicle weight, uniformity, tightness, fruit weight, fruit shape index and fruit longitudinal diameter; the top five were all indicators of internal quality; the weight of internal quality was 0.6223, the weight of external quality was 0.3777, clearly visible, influence of growth regulator on the internal quality of manicure finger grape was much bigger than the external quality's.

The impact of different treatment of growth regulators on the comprehensive quality of manicure finger grape. The overall evaluation of 21 treatment methods showed the data in Table 5, based on the indicators calculated, an overall evaluation of the 21 different treatments was conducted, the results was:

$$B = w * R^T = (0.2597, 0.3134, 0.3444, 0.3394, 0.3307, 0.2933, 0.3473, 0.4158, 0.4026, 0.\ 5440, 0.4389, 0.5853, 0.5446, 0.5107, 0.1766, 0.6229, 0.7386, 0.5685, 0.5084, 0.5566, 0.2039$$

Table 3: Original data of indicators of external quality on about each treatment on manicure finger grape

	External quality						
Treatments	Fruit weight/g	Fruit longitudinal diameter/cm	Fruit diameter/cm	Fruit shape index	Panicle weight/g	Uniformity	Tightness /score
A1	9.2	4.20	2.03	2.07	953.2	0.57	4
A2	11.2	4.42	2.03	2.18	1014.6	0.59	4
A3	9.6	4.14	2.10	1.97	1241.7	0.58	4
A4	10.2	4.29	2.09	2.05	1460.5	0.61	4
A5	10.2	4.27	2.05	2.08	885.5	0.62	4
B1	9.2	3.99	2.06	1.94	800.4	0.65	3
B2	10.0	4.40	2.00	2.20	854.2	0.67	3
B3	11.0	4.35	2.33	1.87	897.5	0.71	3
B4	10.5	4.48	2.01	2.23	876.2	0.68	3
B5	9.8	4.36	1.99	2.19	798.5	0.70	3
C1	9.3	4.26	2.00	2.13	898.7	0.72	4
C2	10.3	4.28	2.04	2.10	932.1	0.74	4
C3	11.6	4.40	2.37	1.86	965.9	0.75	4
C4	11.6	4.35	2.40	1.81	943.7	0.70	4
CK	8.9	3.88	1.90	2.04	845.6	0.61	3
S-1	12.5	4.48	2.22	2.02	1761.0	0.74	4
S-2	11.8	4.46	2.03	2.19	1243.9	0.79	4
S-3	10.5	4.13	2.01	2.05	1169.5	0.72	4
S-4	9.9	4.09	1.98	2.07	891.1	0.71	4
S-5	12.4	4.38	2.31	1.90	1320.2	0.73	4
S-CK	9.0	3.87	1.91	2.03	832.4	0.63	3

Table 4: Original data of indicators of internal quality on about each treatment on manicure finger grape

	Internal quality					
Treatments	Anthocyanin/ nmol g^{-1}	Soluble solids/%	Total soluble sugar/%	Titratable acid/%	Ratio of sugar to acid	Vc content/ mg/100 g
A1	204.77	15.09	11.04	0.572	19.301	2.73
A2	301.68	15.07	11.96	0.503	23.777	2.62
A3	381.33	15.67	12.06	0.482	25.021	3.58
A4	314.63	14.50	10.93	0.557	19.623	3.32
A5	259.10	15.73	11.28	0.559	20.179	3.47
B1	909.00	16.27	12.23	0.394	31.041	3.69
B2	550.64	16.63	12.33	0.363	33.967	4.73
B3	448.34	16.70	12.38	0.336	36.845	5.12
B4	493.09	16.87	12.67	0.335	37.821	5.68
B5	1339.56	17.73	12.51	0.314	39.841	7.45
C1	379.63	16.13	11.93	0.414	28.816	6.92
C2	740.35	17.83	13.48	0.402	33.532	7.36
C3	390.75	16.53	12.05	0.385	31.299	6.76
C4	289.29	16.03	12.16	0.398	30.553	6.69
CK	253.25	15.17	11.32	0.569	19.895	2.88
S-1	305.50	16.80	14.03	0.431	32.552	5.62
S-2	461.53	18.30	16.82	0.477	35.262	7.41
S-3	345.84	17.77	16.57	0.525	31.562	5.86
S-4	546.19	17.17	14.82	0.492	30.122	5.33
S-5	363.93	17.01	13.70	0.479	28.601	4.21
S-CK	249.12	15.33	11.81	0.587	20.119	2.91

According to B values, the influence size of different treatments on the comprehensive quality of manicure finger grape are shown in Table 5. In Table 5, the comprehensive effects of all plant growth regulators treatments on comprehensive quality were better than the control.

In the five treatments of Dinghao, the best treatment on quality of manicure finger grape was A3 (7.5 mg L^{-1} Dinghao). In the five treatments of Qibao, the best treatment on quality of manicure finger grape was B5 (10 mg L^{-1} Qibao). In the treatments of Dinghao+Qibao, the best treatment on quality of manicure finger grape was C2 (2.5 mg L^{-1} Dinghao+20.0 mg L^{-1} Qibao). In the treatments of PBO+S-ABA, the best treatment on quality of manicure finger grape was S-2 (5000 mg L^{-1} PBO+170 mg L^{-1} S-ABA) in all the 21 treatments, the best treatment on quality of manicure finger grape was 5000 mg L^{-1} PBO+S-ABA 170 mg L^{-1} each indicators of quality was fruit weight 11.8 g, fruit longitudinal diameter 4.46 cm, fruit diameter 2.03 cm, fruit shape index 2.19, panicle weight 1243.9 g, uniformity 0.79, tightness 4 scores, anthocyanin 461.53 nmol g^{-1}, soluble solids

Table 5: The results of comprehensive quality of different treatments on manicure finger grape

Treatments	Overall evaluation	Ranking
A1	0.2597	19
A2	0.3134	17
A3	0.3444	14
A4	0.3394	15
A5	0.3307	16
B1	0.2933	18
B2	0.3473	13
B3	0.4158	11
B4	0.4026	12
B5	0.5440	7
C1	0.4389	10
C2	0.5853	3
C3	0.5446	6
C4	0.5107	8
CK	0.1766	21
S-1	0.6229	2
S-2	0.7386	1
S-3	0.5685	4
S-4	0.5084	9
S-5	0.5566	5
S-CK	0.2039	20

Table 6: Indicators weight of evaluation according to elements

Elements	Elements share	Index	Indicators weight according to elements
External quality	0.3777	A_1	0.1133
	-	A_2	0.0612
	-	A_3	0.2216
	-	A_4	0.0634
	-	A_5	0.2003
	-	A_6	0.1747
	-	A_7	0.1655

Table 7: The effects on external quality of different treatments of manicure finger grape

Treatments	Evaluation on external quality	Ranking
A1	0.3371	15
A2	0.4674	9
A3	0.4276	12
A4	0.5385	6
A5	0.4116	14
B1	0.1759	19
B2	0.2820	17
B3	0.4456	11
B4	0.3272	16
B5	0.2780	18
C1	0.4498	10
C2	0.5193	8
C3	0.6972	4
C4	0.6536	5
CK	0.0773	21
S-1	0.8488	1
S-2	0.6983	3
S-3	0.5233	7
S-4	0.4242	13
S-5	0.7577	2
S-CK	0.0955	20

Table 8: Indicators weight of evaluation according to elements

Elements	Elements share	Index	Indicators weight according to elements
Internal quality	0.6223	A_8	0.2123
	-	A_9	0.1517
	-	A_{10}	0.1363
	-	A_{11}	0.1921
	-	A_{12}	0.1635
	-	A_{13}	0.2276

18.3%, total soluble sugar16.82%, titratable acid 0.477%, ratio of sugar to acid 35.262, Vc content 7.41 mg/100 g, contracted with control S-CK in addition to titratable acid which decreased 18.74%, the other 12 quality indicators increased 31.11, 15.25, 6.28, 7.88, 49.44, 25.40, 33.33, 19.37, 42.42, 75.27, 154.64% in order. In summary, the manicure finger grape in the use of 5000 mg L^{-1} PBO on May 27+170 mg L^{-1} S-ABA on July 10 spraying on the trees could not only meet the needs of the people about the external quality but also meet the needs of their internal quality. The impact of different treatment of growth regulators on the external quality of manicure finger grape: For the analysis of the influence degree of different treatment on the external quality of manicure finger grape, now consolidated the external target weight, the result was shown in Table 6. According to evaluation indicators weight gained by elements separated, the fuzzy comprehensive evaluation was conducted by elements, the results were shown in Table 7.

In Table 7, the comprehensive effects of all plant growth regulators treatments on external quality were better than the control. In the 5 treatments of Dinghao, the best treatment on the external quality of manicure finger grape was A4 (10.0 mg L^{-1} Dinghao). In the five treatments of Qibao, the best treatment on the external quality of manicure finger grape was B3 (30 mg L^{-1} Qibao). In the treatments of Dinghao+Qibao, the best treatment on the external quality of manicure finger grape was C3 (5.0 mg L^{-1} Dinghao+10.0 mg L^{-1} Qibao).

In the treatments of PBO+S-ABA, the best treatment on the external quality of manicure finger grape was S-1 (5000 mg L^{-1} PBO+S-ABA 200 mg L^{-1}) which was the best treatment on external quality in all the 21 treatments, meanwhile its each indicator of external quality was fruit weight 12.5 g, fruit longitudinal diameter 4.48 cm, fruit diameter 2.22 cm, fruit shape index 2.02, panicle weight 1761 g, uniformity 0.74. tightness 4 scores, contracted with control S-CK in addition to fruit shape index which decreased 0.49%, the other six external quality indicators increased 38. 98, 15.76, 16.23, 111.56, 17.46, 33.33% in order. In summary from the ornamental side, the best treatment was that spraying on the trees with 5000 mg L^{-1} PBO on May 27+200 mg L^{-1} S-ABA on July 10 on the external quality of manicure finger grape.

The impact of different treatment of growth regulators on the internal quality of manicure finger grape: for the analysis of the influence degree of different treatment on the internal quality of manicure finger grape, now consolidated the internal target weight, the result was shown in Table 8. According to evaluation indicators

Table 9: The effects on internal quality of different treatments of manicure finger grape

Treatments	Evaluation on internal quality	Ranking
A1	0.0418	21
A2	0.1532	16
A3	0.2626	15
A4	0.0768	19
A5	0.1329	17
B1	0.4959	13
B2	0.5356	8
B3	0.5767	5
B4	0.6320	4
B5	0.9325	1
C1	0.5078	11
C2	0.7392	3
C3	0.5578	7
C4	0.5041	12
CK	0.0737	20
S-1	0.5206	10
S-2	0.7441	2
S-3	0.5643	6
S-4	0.5262	9
S-5	0.3059	14
S-CK	0.0808	18

weight gained by elements separated, the fuzzy comprehensive evaluation was conducted by elements, the results was shown in Table 9. In Table 9 in addition to the treatment of A1 using 2. 5 mg L^{-1} Dinghao, the other treatments on the internal quality of manicure finger grape were better than the control. In the five treatments of Dinghao, the best treatment on the internal quality of manicure finger grape was A3 (7.5 mg L^{-1} Dinghao). In the five treatments of Qibao, the best treatment on the internal quality of manicure finger grape was B5 (10.0 mg L^{-1} Qibao). In the treatments of Dinghao+Qibao, the best treatment on the internal quality of manicure finger grape was C2 (2.5 mg L^{-1} Dinghao+20. 0 mg L^{-1} Qibao). In the treatments of PBO+S-ABA, the best treatment on the internal quality of manicure finger grape was S-2 (5000 mg L^{-1} PBO+170 mg L^{-1} S-ABA). The best treatment on the internal quality of manicure finger grape in all the 21 treatments was B5 (10.0 mg L^{-1} Qibao), its each indicator of internal quality was anthocyanin 1339.56 nmol g^{-1}, soluble solids 17.73%, total soluble sugar 12.51%, titratable acid 0.314%, ratio of sugar to acid 39.841, Vc content 7.45 mg/100 g, contracted with control S-CK in addition to titratable acid which decreased 46.51%, the other five internal quality indicators increased 437.72, 15.66, 5.93, 98.03, 156.01% in order. In summary from the consumption side, the best treatment was that spraying 10.0 mg L^{-1} Qibao on May 27 on the manicure finger grape.

DISCUSSION

The key point of fuzzy mathematics comprehensive evaluation is the establishment of evaluation model and the determent of weight; previous methods in determining the weight were generally expert scoring which often make the evaluation results more subjective, lack of certain scientific. In this study in order to make the weight more objective, more scientific, the entropy method to determine the index weigh was used.

The influence of the internal quality was larger than extemal quality on manicure finger grape in the use of plant growth regulators. The first four indicators in 13 quality indicators were vitamin C content, sugar acid ratio, soluble solid and toal soluble sugar which greatly impacted on the comprehensive quality characters.

CONCLUSION

In this study, according to the principle of fuzzy mathematics with various quality indicators, selected out the best treatment of the best comprehensive quality on the manicure finger grape was the use of 2000 mg L^{-1} PBO on May 27 and 170 mg L^{-1} S-ABA on July 10 spraying on the trees. The best treatment on the external quality was the use of 2000 mg L^{-1} PBO on May 27+200 mg L^{-1} S-ABA on July 10 spraying on the trees. The use of 10.0 mg L^{-1} Qibao on May 27 spraying on the trees was the best treatment on the internal quality.

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