Effects of Zinc Fertilizer on Photosynthetic Characteristics of 'Shine Muscat' Grape

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Abstract. Zinc is an essential nutrient for plant growth and development. Zinc deficiency affects plant photosynthesis and nitrogen metabolism. In this experiment, 'Shine Muscat' grape was used as experimental material. Three soil application levels of zinc sulfate were set up, which were 2 kg/667 m², 3 kg/667 m² and 4 kg/667 m², respectively. The time of applying zinc fertilizer in soil was 10 days after flowering, and the time of spraying zinc fertilizer was divided into 21 days after flowering, 35 days after flowering, 21 days and 35 days after flowering, respectively, once (twice in total), with no zinc fertilizer as control (CK). The results showed that the application of zinc sulfate 3 kg/677 m² on soil 10 days after flowering, 0.3% zinc sulfate fertilizer on leaves 21 days after flowering and 35 days after flowering increased zinc content in grape leaves and fruits, and significantly increased net photosynthetic rate of grape leaves.

1 Introduction

'Shine Muscat' is a diploid fresh-eating grape variety [1]. It first appeared in Japan and belongs to a mid-late maturing European-American hybrid grape variety. It was bred by the Japanese Institute of Phytogeny by crossing Anrujin 21×Bainan. The variety registration was carried out on March 9, 2006 [2]. Because of its good fruit setting and non-cracking, strong rose fragrance and crisp flesh, durable storage and transportation, it is favoured by many grape producers and consumers. It has developed rapidly in southern China and enlarged cultivation area.

Grape, as one of the most important cultivated fruit trees in the world, plays an important role in the fruit market. How to improve the quality of grape fruit has always been the focus of scientific research. In recent years, people only pay attention to the application of nitrogen, phosphorus and potassium fertilizers, while neglecting the application of medium and trace elements, leading to soil compaction, insufficient supply of trace elements in grape fruits, and declining fruit quality, which cannot meet the demand of consumers for products. Studies have proved that zinc is an essential element for normal growth and development of plants, and zinc plays an important role in agricultural production [3]. Zinc is a necessary trace element to maintain the normal growth of animals, plants and humans [4-5]. Insufficient supply of available zinc can

lead to adverse effects such as reduced yield and quality of agricultural products [6-7]. At present, the effects of zinc fertilizer on physiological indexes and fruit quality of apples, pears and other fruit trees have been systematically studied at home and abroad, but the effects of Zinc Fertilizer on grape were seldom reported. In this experiment, the 'Shine Muscat' grape was used as the test material. The effects of zinc fertilizer on the photosynthetic characteristics of 'Shine Muscat' grape leaves were studied by soil zinc application and grape leaf spray. The aim was to provide theoretical basis for the high-quality production of 'Shine Muscat' grape.

2 Materials and methods

2.1. Materials

The experimental base is located in Qiquan Town, Chongzhou City, and the modern agricultural research and development base of Sichuan Agricultural University. The base is all for shelter cultivation. The background value of soil in the experimental plot is shown in Table 1, and the classification standard of grape leaf nutrition is shown in Table 2 [8]. The selected materials were the same tree potential in vineyard, the same soil, fertilizer and water management in field, no pests and diseases, and the strong three-year-old 'Shine Muscat' grape. The row spacing was 1.5m ×3.0m, 150 plants per mu were planted.

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Table 1. Test soil background value.

The organic matter (%)	pH	Alkali hydrolysable N (mg/kg)	The effective P (mg/kg)	Available K (mg/kg)	Water-soluble calcium (mg/kg)	Water-soluble magnesium (mg/kg)	The effective Fe (mg/kg)	The effective Mn (mg/kg)	The effective Zn (mg/kg)
2.38	7.95	65.22	25.69	105.95	364.85	23.82	3.86	23.36	1.94

Table 2. Chinese grape leaf nutrient element classification criteria.

Leaf nutrient	The lack	Low levels	A moderate amount	High quantity
Total Zinc (mg/kg)	<11	11~24	25~50	>50

2.2. Experimental design

Three soil levels of zinc sulfate were set up, which were 2 kg/667 m², 3 kg/667 m², 4 kg/667 m², respectively (Table 3).

Table 3. Experimental design of soil and foliar spraying with Zinc Fertilizer.

Treatments	Soil application of zinc sulfate	Spraying zinc sulfate concentration	Spraying period
1	2 kg/667 m ²	0.3%	21 days after flowering(once)
2	2 kg/667 m ²	0.3%	35 days after flowering (once)
3	2 kg/667 m ²	0.3%	21 and 35 days after flowering (twice)
4	3 kg/667 m ²	0.3%	21 days after flowering (once)
5	3 kg/667 m ²	0.3%	35 days after flowering (once)
6	3 kg/667 m ²	0.3%	21 and 35 days after flowering (twice)
7	4 kg/667 m ²	0.3%	21 days after flowering (once)
8	4 kg/667 m ²	0.3%	35 days after flowering (once)
9	4 kg/667 m ²	0.3%	21 and 35 days after flowering (twice)
CK	0	0	

The 'Shine Muscat' grapes were applied to the soil 10 days after blooming (May 5, 2017). The concentration of zinc sulfate solution was 0.3%. The spraying time was 21 days after full blossom (spraying zinc sulfate once on the leaves on May 16, 2017), 35 days after full blossom (spraying zinc sulfate once on the leaves on May 30, 2017), 21 days after full blossom and 35 days after full blossom (spraying zinc sulfate twice on the leaves). Spraying zinc fertilizer or clear water on the leaf surface was carried out on sunny days. Zinc fertilizer or clear water was sprayed uniformly on both sides of grape leaves with a portable sprayer and sprayed onto the leaves with drip water. No zinc fertilizer was used as control (CK). Random block arrangement was used in the experiment. Nine treatments were set up, three grapes per treatment were repeated three times, and three trees were repeated one time, total 81 grapes. The specific treatment is shown in Table 3 below.

2.3. Statistical analyses

Microsoft Excel 2016 was used in the statistical analysis of the experimental data, and related charts were drawn according to the analysis results, and variance analysis was carried out using SPSS23.0.

3 Results and Discussion

3.1 Effects of soil application and foliar zinc spraying on zinc content in leaves and fruits of 'Shine Muscat' grape

As seen as the table 4, CK leaves without zinc fertilizer at 100 days after flowering(fruit ripening stage) have the lowest zinc content, only 10.04 mg/kg, which is in deficiency level. After soil application and foliar spraying zinc sulfate, zinc content in leaves of all treatments increased significantly, reaching the appropriate standard. Zinc content in leaves of treatment 6 is the highest, reaching 49.65 mg/kg, which is significantly different from other treatments and control. The zinc content in leaves increased by 79.78%. When the amount of soil fertilizer is constant, the zinc content of two times of spraying zinc fertilizer treatment is relatively higher.

Zinc content in the fruit of 'Shine Muscat' grape was similar to that in the leaves. After soil application and foliar spraying of zinc sulfate, zinc content in the fruit of each treatment increased significantly. Zinc content in the fruit of treatment 6 was the highest, with a significant difference between treatment 6 and other treatments,

followed by treatment 9 and 1.06 mg/kg. Zinc content in treated 6 fruits was 72.48% higher than that in control fruits, and that in treated 9 fruits was 61.32% higher than that in control fruits. The content of zinc in the fruit of

treatment 7 was the lowest, only 0.76 mg/kg, but still higher than that of control. The content of zinc in the fruit of treatment 7 was 46.05% higher than that of control.

Table 4. Effects of soil application and foliar zinc spraying on zinc content in leaves and fruits in maturation period.

Treatments	Leaf zinc content (mg/g)	Fruit zinc content (mg/g)
1	33.093 d	0.793 cd
2	31.532 d	0.844 c
3	43.504 b	1.014 b
4	34.853 d	0.841 c
5	37.564 cd	0.962 bc
6	49.652 a	1.493 a
7	36.365 cd	0.761 cd
8	39.492 c	0.852 c
9	42.693 b	1.063 b
CK	10.044 e	0.411 e

Note: The lowercase letters in the table indicate the difference in the same column data at the 0.05 level.

3.2 Effect of Zinc Fertilizer on Chlorophyll Content of 'Shine Muscat' Grape Leaves

According to the table 4, the total chlorophyll a, chlorophyll b and chlorophyll contents in leaves of 'Shine Muscat' grapes treated with soil application and foliar spraying of zinc sulfate 100 days after flowering are significantly higher than those of the control. The content of chlorophyll a in treatment 6 was the highest (3 kg/677 m² zinc sulfate was applied on soil 10 days after flowering, 0.3% zinc sulfate was sprayed on leaves 21 days and 35 days after flowering). The content of chlorophyll a in treatment 6 was not significantly different from that in treatment 3, but was significantly

different from that in other treatments. The content of chlorophyll a in treatment 6 increased by 21.1% compared with the control. The content of chlorophyll b in treatment 6 was significantly different from that in other treatments. The content of chlorophyll b increased by 62.4% compared with the control. The total chlorophyll content of treatment 6 was not significantly different from that of treatment 3, but significantly different from that of other treatments. The total chlorophyll content of treatment 6 was 34.0% higher than that of control. In conclusion, appropriate soil application and foliar spraying of zinc sulfate could increase chlorophyll a content, chlorophyll b content and total chlorophyll content of 'Shine Muscat' grape leaves.

Table 5. Effect of soil and foliar spraying zinc fertilizer on the content of chlorophyll in grape leaves in maturation period.

Treatments	Chlorophyll a content (mg/g)	Chlorophyll b content (mg/g)	Total chlorophyll content (mg/g)
1	1.167 bc	0.523 d	1.690d
2	1.186 b	0.563 c	1.749 c
3	1.231 a	0.671 b	1.902 a
4	1.190 b	0.569 c	1.759 bc
5	1.143 c	0.516 d	1.659 d
6	1.246 a	0.754 a	2.000 a
7	1.158 bc	0.517 d	1.675 d
8	1.200 b	0.572 c	1.772 b
9	1.198 b	0.602 bc	1.800 b
CK	1.029 d	0.464 e	1.493 e

3.3 Effects of Zinc Fertilizer on Photosynthetic Parameters of 'Shine Muscat' Grape Leaves

As can be seen from table 5, net photosynthetic rate (Pn), stomatal conductance (Gs), transpiration rate (Tr) and instantaneous water use efficiency (IWUE) of 'Shine Muscat' grape leaves at 100 days after flowering were higher than those of CK without zinc fertilizer, while intercellular CO₂ concentration (Ci) was lower. The

transpiration rates of treatment 1, treatment 6 and treatment 8 were significantly different from those of treatment 2, treatment 4, treatment 5, treatment 7 and treatment 9. The transpiration rates of treatment 1, treatment 6 and treatment 8 were 50.28%, 67.03% and 44.91% higher than those of control respectively. The net photosynthetic rate (Pn) of each treatment was significantly different from that of the control, and the net photosynthetic rate (Pn) of treatment 6 was the largest, which was significantly different from that of

other treatments. The stomatal conductance of treatment 2, treatment 4, treatment 6 and treatment 8 was significantly different from that of control. There was no significant difference among treatment 4, treatment 6 and treatment 8. The stomatal conductance of treatment 4 was the largest, followed by treatment 6. The intercellular CO₂ concentration of treatment 1, 6 and 8 was lower than that of control and other treatments, but

there was no significant difference among the three treatments. The intercellular CO₂ concentrations of treatment 1, 6 and 8 were 17.93%, 23.69% and 18.26% lower than those of control, respectively. The instantaneous water use efficiency of treatment 1 and 6 was significantly different from that of control, but there was no significant difference among treatments, which increased by 32.99% and 34.18% respectively.

Table 6. Effect of soil and foliar spraying zinc fertilizer on photosynthetic parameters of grape leaves in maturation period.

Treatments	Tr (mol·m ⁻² ·s ⁻¹)	Pn (μmol·m ⁻² ·s ⁻¹)	Gs (mol·m ⁻² ·s ⁻¹)	Ci (μmol/mol)	IWUE (μmol·mmol ⁻¹)
1	2.011 a	4.885 b	0.091cde	222.188 b	2.427 a
2	1.747 b	3.600 cd	0.102 bcd	232.308 ab	2.198 ab
3	1.916 ab	3.888 cd	0.092 cde	240.399 ab	2.020 ab
4	1.776 b	3.478 cd	0.157 a	241.222 ab	2.070 ab
5	1.548 b	3.169 d	0.071 de	242.858 ab	2.098 ab
6	2.082 a	5.103 a	0.130 abc	206.604 b	2.449 a
7	1.550 b	3.609 cd	0.070 de	237.507 ab	2.334 ab
8	2.003 a	4.254 bc	0.141 ab	221.284 b	2.208 ab
9	1.582 b	3.354 cd	0.066 de	240.479 ab	2.222 ab
CK	1.247 c	2.228 e	0.047 e	270.728 a	1.825 b

4 Conclusions

Applying zinc sulfate 3 kg/677 m² on the soil 10 days after flowering, spraying 0.3% zinc sulfate fertilizer on the leaves 21 days and 35 days after flowering increased zinc content of grape leaves and fruits. It could significantly increase the chlorophyll a content, chlorophyll b content and total chlorophyll content of 'Shine Muscat' grape leaves, and increase the stomatal conductance to promote the entry of CO₂ and water entering leaves. The net photosynthetic rate and transpiration rate of 'Shine Muscat' grape leaves were significantly increased, and the intercellular CO₂ concentration was decreased.

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