Effects of Different Concentrations of Methyl Jasmonate on Fruit Quality of Citrus Huangguogan

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Abstract: In this study, methyl jasmonate (MeJA) was sprayed on the fruits of Huangguogan in shimian county in two different ways (whole tree spraying and fruit spraying) to study the effect of MeJA on the postharvest quality of the fruits of Huangguogan. The consequence showed that, compared with check (CK), each treatment could improve the fruit quality, 10 μmol·L⁻¹ MeJA sprayed on Huangguogan performed best. It significantly increased the sugar content, Vc content, total soluble solid (TSS in short) content and the sugar acid ratio of the Huangguogan, meanwhile decreased the content of titratable acid. These consequences indicated that preharvest MeJA treatment could improve the fruit quality of Huangguogan.

1. Introduction
Huangguogan is a Rutaceae Aurantioidea plant, originates in liyu village, xinmian town, shimian county, sichuan province. It has been cultivated locally for more than 300 years [1-2], and has characteristics as extremely late ripening, seedless, high quality, early harvest, high yield and strong adaptability [3]. Its ripening period is from March to May of the next year, which is the season with little fruit, and the market prospect is very broad, making it a rarity among hybrid citrus [4]. However, the Huangguogan has a slightly sour flavor [5], which restricted its economic benefit. Therefore, people pay more and more attention to improve its quality.

Methyl jasmonateis a kind of jasmonates (JAs for short), which is a natural physiological active substance in plants, non-toxic and pollution-free [6]. In the production, MeJA can be used to improve fruit color, aroma, and fruit quality, reduce chilling damage, and improve storage quality [7]. Due to the volatility of methyl jasmonate, bagging is usually carried out after spray treatment to prolong its effect [8].

Recent studies suggestthatafter treating plum with MeJA, Vc content increased, and fruit quality improved [9]. After harvest, treatment of loquat and pomegranate with MeJA could significantly increase the content of total phenol and flavonoids, and improve the nutritional quality of fruits [10-11]. In addition, the contents of total phenols, anthocyanins and Vc in raspberries and blackberries treated with MeJA before harvest increased [12]. MeJA treatment can also improve resveratrol content in grape fruits, promote the synthesis of lycopene and vitamin E, and improve the quality of horticultural crops [13].

In this experiment, the effects of methyl jasmonate of different concentrations on fruit quality
single fruit weight, length, diameter, sugar, acid, vitamin C, sugar acid ratio, TSS) of Huangguogan were investigated, and the optimal concentration to improve fruit quality was selected. Furthermore, it provides theoretical and practical basis for improving fruit quality.

2. Materials and methods

2.1 Experimental material
The test site is Huangguogan garden, songlin village, shimian county. The annual temperature is 17.1 °C, the accumulative temperature is 5468 °C, the extreme low temperature is 4.1 °C, the extreme high temperature is 38.1 °C, and the average frost-free period is 326 days. The average annual sunshine duration is 1242.9h, and the average annual rainfall is 777.4mm. The soil is slightly acidic and the climate is dry and hot. The test plants were robust Huangguogan with tree age (9 years old), tree potential, tree crown (diameter 3.5-4.5m), and no pests and diseases at the same management level in the early stage.

2.2 Experimental design
Thirty plants of Huangguogan were selected, methyl jasmonate was sprayed, 15 of which were sprayed on the fruit part, and the remaining 15 were sprayed on the tree crown. With the treatment of spraying clear water as CK, 4 treatments with different concentrations were performed: 1 μmol·L⁻¹, 10 μmol·L⁻¹, 50 μmol·L⁻¹, 100 μmol·L⁻¹ methyl jasmonate (MeJA). Methyl jasmonate was sprayed evenly for 3 times, developing fruit period, turning stage and dormancy. Take single plant as a plot, and repeated for 3 times. Bagging the fruit immediately after spraying (with single-part stationery bag in yellow), removing the fruit bag before spraying in the turning period and dormant period, and bagging immediately after spraying. After ripening in March of the next year, 4 fruits were randomly selected from the east, south, west and north directions of the outer middle and upper part of the tree canopy for picking, placed in an ice box, and immediately brought back to the laboratory for quality determination.

2.3 Determination of fruit quality and data processing
The single fruit weight, length, diameter, sugar, acid, vitamin C, sugar acid ratio, TSS of Huangguogan were determined referring to xiong's method [14]. Excel2016 was used for data processing, and significant differences were analyzed.

3. Results and analysis
It can be seen that, compared with the CK, different spraying sites and concentrations of methyl jasmonate had great influence on the fruit quality of Huangguogan, especially for the internal quality (Figures1 and 2).

3.1 Effect of methyl jasmonate on fruit of the quality of Huangguogan
The highest sugar content was in treatment B, which was 13.01 g · 100mL⁻¹, significantly higher than CK, while in treatment D, C and A, which were successively decreased. Treatment C had the lowest acid content (0.48 g · 100mL⁻¹), followed by B, D and A. The highest Vc content was 23.05 mg · 100g⁻¹ in treatment B, which was significantly higher than CK, while the Vc content in C, D and A decreased successively, respectively 22.86 mg · 100g⁻¹, 22.56 mg · 100g⁻¹ and 19.84 mg · 100g⁻¹. The highest TSS content was in treatment B (13.8%), which was significantly higher than CK, followed by in treatment D (13.2%), C (12.6%) and A (12.2%). The sugar-acid ratio was the highest in treatment B (25.1), which was significantly higher than CK, followed by treatment C, D and A (24.1, 19.8 and 15.9, respectively). In conclusion, the fruit quality of B was the best.
Table 1. Determination of fruit quality after spraying of methyl jasmonate with different concentrations on Huangguogan (spraying on fruit)

| Concentration (μmol·L⁻¹) | Weight (g) | Length (cm) | Diameter (cm) | Fruit shape index | Sugar (g 100mL⁻¹) | Acid (g 100mL⁻¹) | Sugar-acid ratio | Vc (mg·100g⁻¹) | TSS (%) |
|--------------------------|------------|-------------|---------------|------------------|-------------------|-----------------|-----------------|----------------|---------|
| CK                       | 142.49a    | 6.451a      | 7.515a        | 1.165a           | 9.62b             | 0.81a           | 11.9b           | 19.84b         | 11.4b   |
| 1(A)                     | 148.25a    | 7.515a      | 7.601a        | 1.011a           | 10.35de           | 0.65c           | 15.9e           | 20.68b         | 12.2d   |
| 10(B)                    | 141.68a    | 6.485a      | 7.501a        | 1.141a           | 13.01a             | 0.52b           | 25.1a           | 23.05a         | 13.8a   |
| 50(C)                    | 145.31a    | 6.689a      | 7.512a        | 1.123a           | 11.56c             | 0.46b           | 24.1ac          | 22.86ac        | 12.6d   |
| 100(D)                   | 149.87a    | 7.545a      | 7.703a        | 1.021a           | 12.25cd           | 0.62cd          | 19.8d           | 22.56cd        | 13.2c   |

Note: Significance analysis of lowercase letter annotation (P<0.05), similarly hereinafter.

3.2 Effect of methyl jasmonate on tree of fruit quality of Huangguogan

The treatment F with the highest sugar content was 13.15 g · 100mL⁻¹, which was significantly higher than CK, and G, H and E were successively decreased. The acid content of F was the lowest, 0.45g · 100mL⁻¹, followed by that of G, H and E. The Vc content of F was the largest, significantly higher than CK, followed by G and H. However, the Vc content of E was lower than CK. The highest TSS content was in treatment F (14.0%), which was significantly higher than CK, G, H and E. The sugar-acid ratio was the highest in treatment F (29.2), which was significantly higher than CK, followed by treatment G, H and E (23.9, 17.8 and 13.2, respectively). To sum up, the fruit quality of F was the best.

Table 2. Determination of fruit quality of Huangguogan after spraying with methyl jasmonate at different concentrations (spraying on tree)

| Concentration (μmol·L⁻¹) | Weight (g) | Length (cm) | Diameter (cm) | Fruit shape index | Sugar (g 100mL⁻¹) | Acid (g 100mL⁻¹) | Sugar-acid ratio | Vc (mg·100g⁻¹) | TSS (%) |
|--------------------------|------------|-------------|---------------|------------------|-------------------|-----------------|-----------------|----------------|---------|
| CK                       | 142.49a    | 6.451a      | 7.515a        | 1.165a           | 9.62b             | 0.81a           | 11.9b           | 19.84b         | 11.4b   |
| 1(E)                     | 145.56a    | 7.015a      | 7.433a        | 1.060a           | 10.36e             | 0.80ac          | 13.2bd          | 18.12b         | 12.0e   |
| 10(F)                    | 148.65a    | 6.321a      | 7.525a        | 1.190a           | 13.15a             | 0.45b           | 29.2a           | 24.56a         | 14.0a   |
| 50(G)                    | 150.21a    | 6.463a      | 7.254a        | 1.122a           | 12.21c             | 0.51b           | 23.9c           | 22.01c         | 13.2c   |
| 100(H)                   | 149.19a    | 7.536a      | 7.533a        | 0.999a           | 11.56c             | 0.65d           | 17.8d           | 20.23cd        | 12.8cd  |

3.3 Comprehensive analysis of two different processing methods

The concentration of methyl jasmonate, which had the greatest influence on fruit quality, was 10 μmol · L⁻¹. After spraying the fruit with 10 μmol · L⁻¹ methyl jasmonate, the sugar content of the fruit was 13.01 g · 100mL⁻¹, the acid content was 0.52 g · 100mL⁻¹, the Vc content was 23.05 mg · 100g⁻¹, the TSS was 13.8%, and the sugar-acid ratio was 25.1. After spraying with 10 mol · L⁻¹ methyl jasmonate on tree, the sugar content of Huangguogan was 13.15 g · 100mL⁻¹, the acid content was 0.45 g · 100mL⁻¹, the Vc content was 24.56 mg · 100g⁻¹, the TSS was 14.0%, and the sugar-acid ratio was 29.2. Therefore, the fruit quality of Huangguogan treated with 10 μmol · L⁻¹ methyl jasmonate had the greatest influence on the fruit quality of Huangguogan, thus achieving the goal of increasing sugar and decreasing acid.

4. Discussion and conclusion

Fruit quality has a great impact on fruit commodity value, which has been the focus of fruit producers in China for a long time. The taste of Huangguogan is a little sour, which affects its economic benefit. In horticultural plant production, MeJA can be used to improve fruit color, aroma and fruit quality. In this study, methyl jasmonate was sprayed at different concentrations to explore the optimum concentration for production of Huangguogan. The results showed that the treatment with methyl jasmonate could effectively increase the total sugar content, TSS and Vc content, reduce the titratable acid content, and improve the fruit quality of the fruit. This is consistent with the research results of gong et al [15] that sprayed methyl jasmonate on mango. The fruit quality of Huangguogan with 10 mol · L⁻¹ methyl jasmonate was the best. This is consistent with the research results of wang et al [16]...
on grapes.

The results showed that the two different treatment methods could effectively improve the fruit quality of Huangguogan, with the highest sugar content, Vc content, TSS content, sugar-acid ratio, and the lowest titratable acid content. Therefore, the total tree spray of 10 mol \cdot L^{-1} methyl jasmonate had the greatest effect on fruit quality.

The results of this study showed that the different concentrations of methyl jasmonate improved the fruit quality and the economic benefit. Among them, the optimal concentration treatment was given by spraying the whole tree with 10 mol \cdot L^{-1} methyl jasmonate, which had the greatest effect on improving fruit quality. Therefore, according to the three key phenological periods of Huangguogan (developing fruit period, turning stage, and dormancy), the effect of spraying 10 mol \cdot L^{-1} methyl jasmonate on the whole tree was the best, and the selection of reasonable fruit bags and suitable orchard management had a great effect on the improvement of economic benefits of Huangguogan, which was worthy of promotion and application.

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