Effect of Plastic Film Mulching on Fruit Quality of *Citrus grandis* cv. 'Hongroumiyou' and 'Sanhongmiyou'

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**Abstract.** Plastic film mulching (PFM) around fruit trees could effectively improve fruit quality by promoting fruit coloration and sugar accumulation. 'Hongroumiyou' and 'Sanhongmiyou' are mutated from *Citrus grandis* cv. 'Guximiyou' possessing attractive appearance, rich nutritional ingredients. When they are introduced into Sichuan Province, the fruits revealed lower sugar accumulation and higher acid content than that in Fujian Province. We compared the fruit quality by mulching at 55, 85, 115, 145, 175 days after flowering. The results showed that mulch treatment had no significant effect on the external quality of 'Hongroumiyou' and 'Sanhongmiyou'. While it could effectively improve the internal fruit quality, including promotion of total soluble solid and vitamin C, and decrease of total acid. The best effect on the improvement of fruit quality was mulched at 115 days after flowering for 'Hongroumiyou' and 145 days after flowering for 'Sanhongmiyou'. In addition, mulching cultivation also avoided tree death resulted from the rootrot atrophy because of a long-term flooding. It is important to promote film mulching cultivation in the pummelo production in Sichuan Province.

1. Introduction

In 1970s, plastic film mulching (PFM) around fruit trees started to apply in the production of fruit trees. Reflecting plastic film could effectively improve fruit quality by promoting fruit coloration and accumulation of total soluble solid [1-5]. Compared with bare land cultivation, film mulching cultivation can improve light, temperature and water retention, as well as the physical and chemical properties of soil. On the other hand, it can avoid accumulation of redundant rain in the orchard in South China. The improvement of light not only increased the photosynthetic efficiency, but also regulated the sucrose metabolism and anthocyanin synthesis related enzyme activities, which significantly promoted sugar accumulation and fruit coloring [5].

Pummelo (*Citrus grandis* (L.) osbeck) belongs to genus *Citrus* L., family Rutaceae, which is an important fruit tree endowed with high economic and nutritional values [6]. China is one of major centers of origination and genetic diversity, possessing abundant pummelo germplasms. The cultivation history of pummelo can be traced back to 3000 years ago [7], including three major cultivation areas, Southeast coastal, South China and Southwest China [8]. Until now, more than 200 pummelo varieties have been selected and cultivated in China [9]. 'Hongroumiyou' [10] and
'Sanhongmiyou' [11] are mutated from 'Guanximiyou', which have been widely cultivated in Fujian and Sichuan Provinces because of their attractive appearance, rich nutritional ingredients and trace elements.

When we introduced the new cultivars 'Hongroumiyou' and 'Sanhongmiyou' into Sichuan Province, the fruits revealed lower sugar accumulation and higher acid content than Fujian Province due to the lower annual average temperature and less mean annual sunshine durations. In this study, we compared the fruit quality by plastic film mulching at different period to determine the best time for mulch treatment. The results will provide guidance for high-quality and high-efficient production of pummelo in Sichuan Province.

2. Materials and methods

2.1. Plant materials

*Citrus grandis* cv. 'Hongroumiyou' and 'Sanhongmiyou' (5a) rootstocked by wild *C. grandis* were used in this study. The experiments were carried out in the orchard in Pengshan County, Meishan, Sichuan Province. We set five mulch periods at 55, 85, 115, 145, 175 days after flowering. No mulch treatment was used as CK. Silver black reflective film was covered to 0.5 m outside the canopy drip line of trees. Three trees were treated for each treatment with three repeats per treatment. The mature fruits were harvested at 205 days after flowering.

2.2. Fruit quality detection

Vernier caliper was used to detect the peel thickness, longitudinal and transverse diameter of fruits. Fruit and flesh weight was measured by an electronic balance. According to these data, fruit shape index and edible rate were calculated. Granulation index = \( \frac{(a_1 + 2a_2)}{2 \times (a_0 + a_1 + a_2)} \), where \( a_0 \), \( a_1 \), and \( a_2 \) indicate the number of segment without granulation, the number of segment with less than half of granulation, and the number of segment with more than half of granulation, respectively.

The total soluble solid (TSS) content was detected by the hand-held refractometer. 2,6-dichloroindophenol titration method was used to detect vitamin C content [12]. Total sugar and acid was measured by using anthrone colorimetric [13] and acid-base neutralization method [13], respectively. The sugar contents were calculated according to Xiong et al. [14]: Reducing sugar = \( \frac{D}{V_1} \times 1000 \), Invert sugar = \( \frac{D}{V_2} \times 1000 \), Sucrose = (invert sugar − reducing sugar) × 0.95, Total sugar = reducing sugar + sucrose, where \( D \), \( V_1 \), and \( V_2 \) represent the glucose content corresponding to 10 mL of Fehling reagent, titration volume of reducing sugar solution and invert sugar solution, respectively.

2.3. Data analysis

Significant differences between the means of the treatments were determined with 95% confidence (\( p < 0.05 \)) limit by Duncan multiple range test using SPSS18.0 (IBM, USA). Data are shown as the means of three replicates.

3. Results

3.1. External fruit quality

The external fruit quality of two pummelo cultivars by mulch treatment was shown in the Table 1. For 'Hongroumiyou', the peel thickness revealed significant differences among different treatments. The minimum peel thickness was 1.13 cm by mulching at 115 days after flowering. While it showed no significant differences in 'Sanhongmiyou' among mulch treatments and control group. The longitudinal and transverse diameter ranged from 17.23 to 18.13 cm and 16.23 to 17.54 cm without obvious change in 'Hongroumiyou'. Similar results exhibited in 'Sanhongmiyou'. Mulch treatment decreased the weight per fruit of 'Hongroumiyou' with the range from 1.62 kg to 1.83 kg reflecting at 145 and 115 days after flowering, lower than that in the CK. The maximum and minimum weight per
fruit of 'Sanhongmiyou' was 1.80 kg and 1.29 kg by mulching at 175 and 55 days after flowering. No obvious change trends were observed among treatments. Similar results were showed in the segment number, flesh weight and edible rate. The minimum granulation index was 0.15 for 'Hongroumiyou' and 0.11 for 'Sanhongmiyou' mulching at 85 and 145 days after flowering. Therefore, plastic film mulch treatment had no obvious effect on majority of external quality of 'Hongroumiyou' and 'Sanhongmiyou'.

Table 1. Effect of plastic film mulching on external fruit quality of *Citrus grandis* cv. 'Hongroumiyou' and 'Sanhongmiyou'

| Cultivar     | Plastic film mulching /DAF | Peel thickness/cm | Longitudinal diameter/cm | Transverse diameter/cm | Fruit shape index | Fruit weight/kg | Flesh weight/kg | Edible rate/% | Segment | Granulation index |
|--------------|---------------------------|-------------------|--------------------------|------------------------|-------------------|----------------|----------------|---------------|---------|-------------------|
| 'Hongroumiyou' | 55                        | 1.43ab            | 17.50b                   | 16.23b                 | 1.08a             | 1.72b          | 1.37ab         | 0.80a         | 14      | 0.53a             |
|              | 85                        | 1.60b             | 17.53b                   | 16.77a                 | 1.05a             | 1.67b          | 1.24b          | 0.75a         | 13      | 0.15c             |
|              | 115                       | 1.13c             | 17.70a                   | 16.83a                 | 1.05a             | 1.83a          | 1.47a          | 0.80a         | 15      | 0.31b             |
|              | 145                       | 1.40bc            | 17.37b                   | 16.88a                 | 1.03a             | 1.62b          | 1.22b          | 0.76a         | 15      | 0.25bc            |
|              | 175                       | 1.93a             | 17.23b                   | 17.20a                 | 1.00a             | 1.72b          | 1.30ab         | 0.76a         | 15      | 0.35b             |
|              | CK                        | 1.37bc            | 18.13a                   | 17.54a                 | 1.03a             | 1.88a          | 1.48a          | 0.59b         | 15      | 0.34b             |
| 'Sanhongmiyou' | 55                        | 1.63a             | 15.40b                   | 16.12b                 | 0.96a             | 1.29c          | 0.99b          | 0.77ab        | 14      | 0.21bc            |
|              | 85                        | 1.73a             | 17.03ab                  | 16.90ab                | 1.01a             | 1.69ab         | 1.25a          | 0.74b         | 14      | 0.37a             |
|              | 115                       | 1.47a             | 15.63b                   | 17.33ab                | 0.90a             | 1.53bc         | 1.24a          | 0.81a         | 15      | 0.26b             |
|              | 145                       | 1.33a             | 17.73a                   | 17.15ab                | 1.03a             | 1.62ab         | 1.26a          | 0.78ab        | 15      | 0.11d             |
|              | 175                       | 1.70a             | 17.07ab                  | 17.88ab                | 0.95a             | 1.80a          | 1.36a          | 0.76b         | 15      | 0.15cd            |
|              | CK                        | 1.67a             | 17.70a                   | 18.35a                 | 0.96a             | 1.59ab         | 1.19a          | 0.75b         | 15      | 0.13d             |

Note: The different normal letters in rows indicate significant difference at 0.05 level. DAF: days after flowering.

3.2. Internal fruit quality

The Figure 1 revealed the effect of plastic film mulching on external fruit quality of two pummelo cultivars. The total soluble solid content revealed an increase - decrease trend with the delay of mulch treatment, which were all significantly higher than that in the control group. The maximum TSS content reached 10.30% for 'Hongroumiyou' and 10.80% for 'Sanhongmiyou' by mulching at 115 and 145 days after flowering, respectively. After mulch treatment, the total acid content revealed as "U" pattern change, decreasing to 0.8% mulching at 115 days after flowering in 'Hongroumiyou'. Mulching at 55, 115, and 145 days after flowering, the acid content ranged from 0.78% to 0.89% in 'Sanhongmiyou'. TSS-acid ratio revealed an increase - decrease change with the delay of mulch treatment, reaching the maximum value of 13.50 mulching at 115 days in 'Hongroumiyou', and 12.56 mulching at 145 days in 'Sanhongmiyou'. Similar change trends were observed in the vitamin C content with the maximum of 40.00 and 35.00 mg•100mL⁻¹ in 'Hongroumiyou' and 'Sanhongmiyou'. The sugar content revealed a fluctuation change after mulch treatment. It reached 7.50 and 7.30 g•100mL⁻¹ for 'Hongroumiyou' and 'Sanhongmiyou' by mulching at 145 days after flowering.
4. Discussion

Plastic film mulching applying to fruit trees originated from Japan. Yakushiji et al. [15] firstly determined the sugar content of fruit, water status of soil, fine roots, pericarps, and juice vesicles in Satsuma mandarin in mulch treatment. As the severity of water stress increased, both water potential and osmotic potential of fine roots and pericarps significantly decreased in plants grown under mulch cultivation compared to well-watered trees. Furthermore, the total sugar content per fruit of water stressed trees was significantly higher than in fruit of well-watered trees. The results suggested that sugar accumulation in Satsuma mandarin fruit was not caused by dehydration under water stress but rather that sugars were accumulated by active osmoregulation in response to water stress. This was further confirmed by many other studies, that is, light or moderate water stress at maturity period did not significantly affect fruit size and fruit juice content, but effectively increased the total sugar of fruit [16-21]. Jiang et al. [5] proposed that plastic film mulching caused water deficit stress, which induced osmotic adjustment and then to enhance sugar accumulation of fruits.

In this study, plastic film mulch treatment had no obvious effect on the fruit weight. This was consistent with previous study on citrus [4]. As for the internal fruit quality, mulch significantly increased the accumulation of total soluble solid, and decreased total acid content, which was consistent with the studies on peach, grape and loquat [2-5]. In addition, mulch treatment could promote the accumulation of vitamin C. According to the results, the approximate mulch period was at 115 and 145 days after flowering for 'Hongroumiyou' and 'Sanhongmiyou', respectively. In the orchard in South China, mulching cultivation also avoided tree death resulted from the rootrot atrophy because of a long-term flooding. Therefore, it is important to promote film mulching cultivation in the pummelo production in Sichuan Province.
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