

Effects of Plastic Film Mulching on Quality and Appearance of Statuma Mandarin Fruit

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Abstract

Six-year Statuma mandarin (*Citrus unshiu* Marc. Cv. Miyagawa Wase) trees were used as materials to investigate the effects of plastic film mulching on quality and appearance of Statuma mandarin fruit during three periods of cell division, cell enlargement and mature stages. The results showed that mulching during the cell division and early-mature stages increased total sugar and reduced sugar content of fruit as well as the Vc content, compared to the control. However, the titratable acid content, fruit size, peel weight and single fruit weight were all lower than the control. Film mulching during the cell division phase resulted in higher edible fruit rate, while the fruit shape index was similar to the control. Mulching during the early-mature stage didn't affect the edible rate of fruit, but caused lower fruit shape index. Compared to the control, film mulching during the cell enlargement period caused lower total and reducing sugar content, titratable acid content and edible rate, while the Vc content was a little bit higher than the control. In addition, the fruit size, peel weight, single fruit weight and fruit shape index were all lower than the control. Mulching during the early-mature period effectively enhanced the content of total and reduced sugar and Vc and decreased the titratable acid content. Hence, it increased fruit quality but had negative effect on fruit appearance.

Keywords

Statuma Mandarin, Film Mulching, Fruit Quality, Fruit Appearance

1. Introduction

China is one of the main countries for citrus production and has No. 1 harvest area and No. 2 citrus production in the world [1]. The south hilly regions have rich light, heat and biological resources and the production poten-

tial is high. Therefore, these regions are the main citrus production area in China. However, more than 50% area is hillock land. Citrus is easily affected by water stress, which influences citrus yield and quality together with seasonal drought [2]. Plastic film mulching affects soil in different ways. It can increase soil temperature, have effect on water conservation and avoidance, enhance soil fertility and improve soil physical properties, so it has important impact on crop growth, development, yield and quality [3]. Studies show that mulching efficiently increases fruit sugar when citrus is mature. However, its effect on acid accumulation is controversial [4]-[8]. Currently, there are a lot of studies focusing on the effect of plastic film mulching on fruit quality, soil environment and light under the canopy [5]-[8], but studies on the effect of mulching on fruit appearance and quality during citrus fruit development are much less. In the present study, we used Statuma mandarin trees to investigate how film mulching during various stages affects appearance and quality of citrus fruit.

2. Materials and Methods

2.1. Materials

The experiment was performed in the citrus garden of Jishou, Hunan. Six-year Statuma mandarin (*Citrus unshiu*) trees were used as materials. Four trees whose growth and fruit amount were similar were selected for film mulching (distance: 1.5 m × 3.7 m). Four adjacent trees without mulching were used as controls. The treatment was performed on July 15th, 2011 (A, cell division phase of fruit), August 15th (B, cell enlargement stage) and September 15th (C, early-mature period), respectively. The double silver-black reflective film for mulching was from Jiangsu Mikedo Farm Plastic Film Ltd. The mulching ranged over 0.5 m of the canopy dripping line. After mulching, 4 fruits were randomly taken from different direction every 15 d.

2.2. Methods

After film mulching, a curved thermometer (Hebei Wuqiang Instrument Factory) and a soil tensiometer (TEN-40, Zhejiang Tuopu Instrument Ltd. Company) were set up 25 cm and 40 cm below the soil surface, respectively. Soil temperature and water potential results were collected on the sampling date from 8 am to 9 am.

The method proposed by Xuyan Lu *et al.* [9] was used to detect total and reducing sugar, titratable acid and Vc content of fruit. Fruit longitudinal and traverse diameters and peel thickness were measured using 1/1000 cm vernier caliper measurement and the accuracy was 0.01 cm. Fruit weight was determined using 1/100 electronic balance measurement and the accuracy was 0.01 g.

The SPSS software and the LSD method were used to analyze data. The Sigma Plot 10.0 software was used to make charts.

3. Results and Discussion

3.1. The Effect of Film Mulching on Soil Temperature and Water Potential

The results showed that film mulching increased soil temperature and reduced soil water potential (**Figure 1**). After mulching treatment, the soil temperature in the 25 cm region reached a peak on August 30th. It was about 2°C - 3°C higher than the control (**Figure 1(a)**). However, the water potential in the 40 cm region became lower than the control five days after mulching and reached the lowest potential on September 30th. Generally, it was about 15 - -10 kPa lower than the control (**Figure 1(b)**).

3.2. The Effect of Film Mulching on Fruit Quality

3.2.1. The Effect of Film Mulching on Total and Reducing Sugar Contents of Fruit

The results indicated that the accumulation trends of total sugar were similar between the treated and control trees during citrus fruit development (**Figure 2**). Before August 30th, the accumulation was fast. From August 30th to September 15th, the accumulation speed had a reducing trend, which may be due to high temperature stress. After September 15th, the accumulation was sharply increased. If film mulching was performed during the cell division phase (A), the total sugar content before September 6th was higher than the control; it was lower than the control between September 6th and October 15th; and it became higher than the control after October 15th. If film mulching was performed during the cell enlargement period (B), the total sugar content was lower than the control before September 30th and became higher than the control. It was a little bit lower than

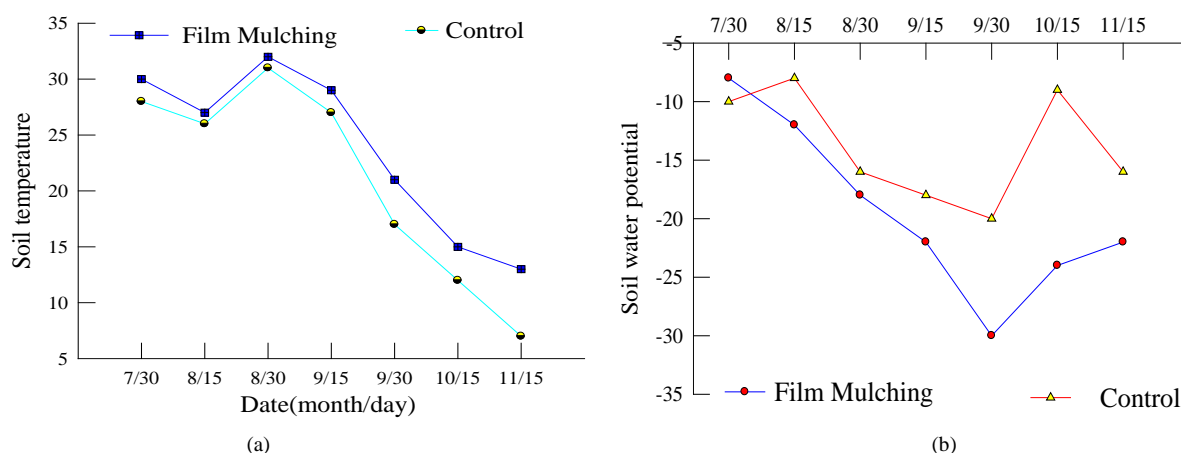


Figure 1. Effect on soil temperature (a) and soil water potential (b).

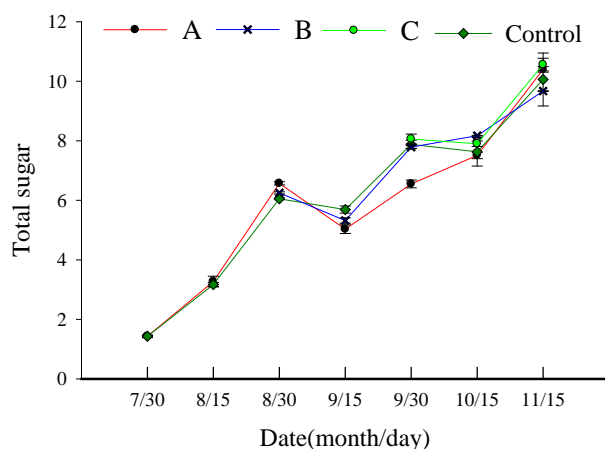


Figure 2. The effect of film mulching during different periods on total sugar content of fruit.

the control during the mature period. If film mulching was done during the early-mature period (C), the total sugar content was higher than the control.

The results indicated that the accumulation of reducing sugar had two peaks during citrus fruit development (Figure 3). It reached a small peak on August 15th, and the big peak showed up on September 30th. If film mulching was performed during the cell division phase (A), the reducing sugar content was similar to the control before August 15th; it was lower than the control between August 15th and September 20th; and it became higher than the control after September 20th. If film mulching was performed during the cell enlargement period (B), the reducing sugar content was always lower than the control before August 15th and it was significantly higher than the control around September 30th. However, it was lower than the control after October 15th. If film mulching was done during the early-mature period (C), the reducing sugar content showed no difference within one month after mulching and was higher than the control in the late stage (after October 15th).

3.2.2. The Effect of Film Mulching on Titratable Acid and Vc Content of Fruit

The results implicated that the titratable acid changes during citrus fruit development were different between the treated and control trees (Figure 4). The control tree showed two peaks. It reached a small peak on August 15th, and the big peak showed up on September 15th. However, the film mulching trees only had one peak. If film mulching was performed during the cell division phase (A), the titratable acid content was similar to the control before August 15th; it was higher than the control between August 15th and October 30th; and it became lower than the control after October 30th. If film mulching was performed during the cell enlargement period (B), the

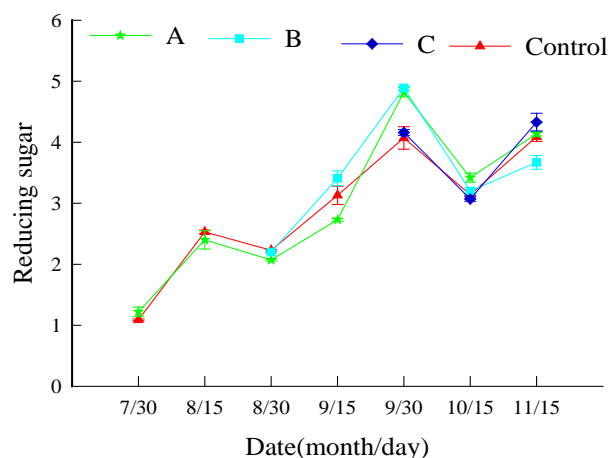


Figure 3. The effect of film mulching during different periods on reducing sugar content of fruit.

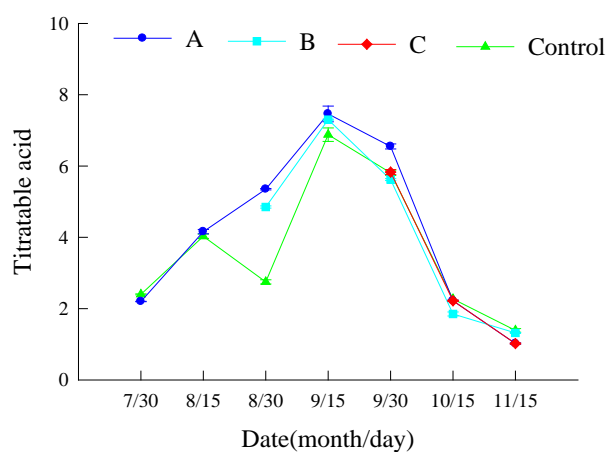


Figure 4. The effect of film mulching during different periods on titratable acid content of fruit.

titratable acid content was always higher than the control within one and a half months after mulching, and became lower than the control. If film mulching was done during the early-mature period (C), the titratable acid content showed no difference between the treated and control trees within one month after mulching and later, it was always lower than the control.

The results indicated that the changing trends of Vc content were similar between the treated and control trees during citrus fruit development (Figure 5). Before September 30th, the Vc content was stable, about 44 mg/100ml. After September 30th, it was sharply increased. If film mulching was performed during the cell division phase (A), the Vc content was similar in the early period and was slightly increased in the late period. If film mulching was performed during the cell enlargement period (B), the Vc content was higher than the control. If film mulching was done during the early-mature period (C), the Vc content was obviously higher than the control.

3.2.3. The Effect of Film Mulching on Edible Rate of Fruit

The results indicated that the changing trends of edible rate were similar between the treated and control trees during citrus fruit development (Figure 6). On August 15th, the edible rate of fruit reached a small peak and it was decreased after the peak. It was increased after August 30th and became stable after September 30th. If film mulching was performed during the cell division phase (A), the edible rate was lower than the control before August 20th (the early stage); it was higher than the control between August 20th and September 10th; and it

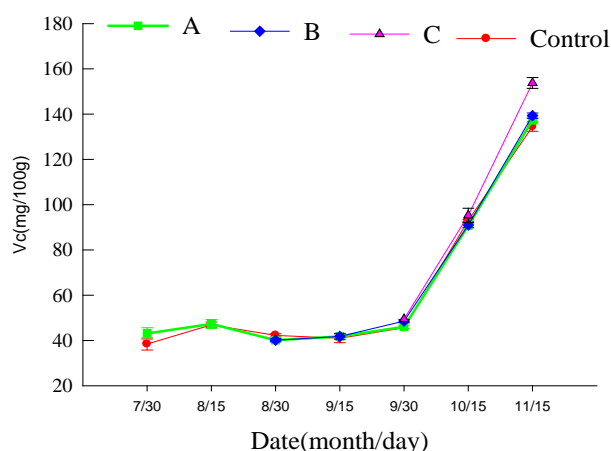


Figure 5. The effect of film mulching during different periods on Vc content of fruit.

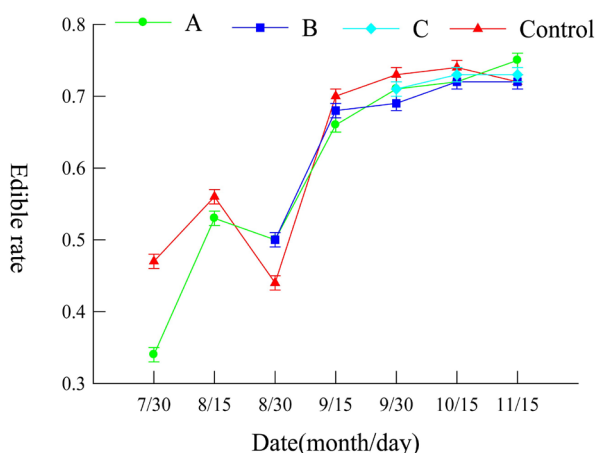


Figure 6. The effect of film mulching during different periods on edible rate of fruit.

was similar to the control after September 10th (the late stage). If film mulching was performed during the cell enlargement period (B), the edible rate was higher than the control in the early stage and lower than the control in the late stage. If film mulching was done during the early-mature period (C), the edible rate had no difference between the treated and control trees.

3.2.4. The Effect of Film Mulching on Fruit Appearance

We detected the effect of film mulching during different periods on five fruit appearance indexes like longitudinal diameter, transverse diameter, etc. (Table 1). The results showed that film mulching influenced fruit appearance during citrus fruit development. Among these five indexes, the longitudinal of treat A and B were all smaller than the control after mulching treatment. Before the end of cell enlargement period, the peel weight was significantly higher than the control (except the weight on August 15th). It was obviously lower than the control after enlargement period. The single fruit weight was dramatically lower than the control (except the weight on August 30th). However, the fruit shape index of different treatments was similar.

4. Discussions

4.1. The Effect of Film Mulching on Soil Temperature and Water Potential

In the present study, we detected the changes of soil temperature and water potential after plastic film mulching.

Table 1. The effect of film mulching during different preiodson fruit appearance.

Sampling date	Mulching	Longitudinal diameter/mm	Transverse diameter/mm	Fruit shape index	Peel weight/g	Single fruit weight/g
July 30th	A	27.83b	28.88*	0.96	8.75a	13.34
	control	29.86a	29.47	1.01	7.27b	13.64
Aug. 15th	A	33.58b*	34.51	0.97*	12.54	26.96b
	control	36.27a	35.71	1.02	12.67	29.49a
Aug. 30th	A	37.83	39.33*	0.96	17.01a	33.99a
	B	37.62b*	40.18*	0.94	17.50a	34.94a
	Control	39.74a	40.48	0.98	15.58b	33.18b
Sep. 15th	A	41.68b	44.28*	0.94	16.88a	49.59b
	B	41.69b	45.13*	0.92*	14.69b	56.11a
	Control	43.61a	45.48	0.96	17.30a	57.08a
Sep. 30th	A	43.23b*	46.41*	0.93	18.32b	63.32b
	B	43.19b	47.05*	0.92	16.82c	53.82c
	C	44.32a	47.17*	0.94	15.32d	52.48c
	Control	45.54a	47.63	0.96	20.15a	73.34a
Oct. 15th	A	45.72b	50.03	0.91	19.98a	71.83b
	B	45.72b	50.65	0.90	18.48b	64.98c
	C	47.36a	51.60*	0.92	18.33b	68.32bc
	Control	48.75a	52.29	0.93	19.96a	75.98a
Nov. 15th	A	49.35b	54.27*	0.91	18.32c	72.01b
	B	49.37b	54.87*	0.90	19.34b	70.02b
	C	50.81a	56.93	0.89*	18.27c	69.98b
	Control	52.34a	56.49	0.93	23.46a	84.02a

Different small letters mean significant difference at 0.05 levels with different treatments in the same time.

The results showed that film mulching in late July in Jishou region increased soil temperature and decreased soil water potential (**Figure 1**). It is consistent with the results obtained by Yakushiji *et al.* [4] and Haiwen Gao *et al.* [10].

4.2. The Effect of Film Mulching on Fruit Quality

During citrus fruit development, film mulching influences the changes of total and reducing sugar content, but different mulching time has different effects. Film mulching during the cell division phase elongated drought stress time and resulted in large change of total sugar content. Film mulching during the cell enlargement period showed lower total sugar content compared to the control. Mulching during the early-mature stage enhanced total sugar content of citrus fruit, which may be due to the increased activity of sucrose synthase (SS) and the reduction of juice pH caused by slight drought stress. Hence, it improves fruit sink strength [11]. The reducing sugar in Statuma mandarin fruit is mainly glucose and fructose. Mulching during different periods causes different drought stress to citrus and has different effects on reducing sugar content. It may be due to the change of transfer of reducing sugar to citrus juice sacs by osmotic adjustment under drought stress [12].

The studies on the effect of film mulching on citrus organic acid are controversial. Yakushiji *et al.* [4] and Liming Wu *et al.* [5] found that film mulching improves the accumulation of citrus organic acid, but Jun Huang *et al.* [6] revealed that film mulching decreases organic acid content. In addition, Xuegen Shi *et al.* [8] claimed film mulching has no obvious effect on organic acid accumulation of citrus fruit. In the present study, we found film mulching affected the content of titratable acid in the early stage of fruit development, but the effect was less in the mature stage. The lower titratable acid content (compared to the control) is good for improving fruit taste.

Citrus fruit is an important source for edible Vc. During citrus fruit development, Vc content changed within a small range in the early stage of fruit development. It sharply increased in the late stage of cell enlargement period. Especially, film mulching during the early-mature period made Vc content as high as 153.80 mg/100ml, which was significantly higher than the control. The change trend of Vc content is not consistent with the results proposed by Shengnan Shen [13] and Lijuan Wang [14]. The difference may be related to species, climatic conditions, soil elements and other factors, and it needs to be further studied.

Film mulching affects fruit appearance. The longer the mulching time was, the smaller the fruit size was. The longitudinal and transverse diameters of treated trees were significantly smaller than the controls. The mulching time was not related to the fruit shape index, but in the middle and late stage of fruit development, the index was obviously lower than the control. Film mulching made fruit peel thin, increased soluble solids and made fruit small. However, it did not affect edible rate during fruit mature period. It may be due to the change of endogenous hormones caused by mulching-induced water stress [15].

5. Conclusion

Film mulching significantly increases the quality of citrus fruit, but has negative effect on fruit appearance. As to the mulching time, the middle of September is a better time for Jishou region. It is not good to mulch before or after this time. If mulching in July or August, fruit is in the division or enlargement stages. It is bad for fruit growth. If mulching in a late time, it cannot improve fruit quality.

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