Scientia Horticulturae 219 (2017) 31–36

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Effects of DuPont Tyvek® non-woven material mulching on fruit quality and chlorophyll fluorescence in Wanzhou Rose Orange

Jia Xuemei[a], Yang Qiong[a], Wang Ya[a], Liu Yanmei[b], Zheng Yongqiang[a,*], Xie Rangjin[a], He Shaolan[a], Deng Lie[a], Yi Shilai[a], Lv Qiang[a], Ma Yanyan[a]

[a] National Engineering Research Center for Citrus Technology/Citrus Research Institute, Southwest University-Chinese Academy of Agricultural Sciences, Chongqing 400712, China

[b] Economic Crop Technology Promotion Stations, Beibei District, Chongqing 400700, China

ARTICLE INFO

Article history:
Received 31 October 2016
Received in revised form 26 February 2017
Accepted 28 February 2017
Available online 7 March 2017

Keywords:
Citrus sinensis (L.) Osbeck *cv* Tarocco
Plastic film mulching
Total soluble soiled
Titratable acid
Weak daylight

ABSTRACT

To provide a theoretical basis for cultivation measures for alleviating the effects of weak daylight on citrus fruit quality, the effects of DuPont Tyvek® Non-Woven Material Mulching on Fruit Quality and Chlorophyll Fluorescence in Wanzhou Rose Orange [*Citrus sinensis* (L.) Osbeck *cv* Tarocco] was evaluated. At fructescence, soil surface of rose orange was applied full (FC) or half (HC) cover of DuPont Tyvek® non-woven materials, and relative light intensity, fruit quality, chlorophyll fluorescence, and other indexes were assessed. The experiment show that Tyvek® mulching significantly increased relative light intensity at different parts of the tree regardless of weather. Specifically, relative intensity of reflected light at the bottom was improved by more than 177.8%. In terms of fruit internal quality, the total soluble soiled (TSS) content of FC-treated trees was significantly increased compared with control values. However, titratable acid (TA) contents of HC-treated trees were significantly enhanced, delaying fruit ripening. Meanwhile, TA contents of FC-treated trees showed no significant changes, promoting fruit ripening. At the same time, FC and HC Tyvek® treatments significantly increased the final color index of fruits a/b. Both FC and HC treatments significantly improved peel uniformity and fresh coloring. Finally, HC and FC treatments significantly altered chlorophyll fluorescence transient and other leaf parameters; Fj, Vj, ABS/RC, RC/Cso and φ_{Do} in leaves of HC-treated trees were significantly increased, and ψo, φ_{Eo} and Fv/Fo markedly decreased. Meanwhile, ABS/RC, RC/Cso and φ_{Do} in the FC group were significantly reduced, and ψo, φ_{Eo} and Fv/Fo markedly increased, compared with control values. In conclusion, the FC method effectively decreases the effects of weak daylight on rose orange quality, and could improve its economic value.

1. Introduction

The most significant weather feature in autumn and winter in Chongqing is the high frequency of continuous rain that lasts for a long time, thus leading to low temperature and weak daylight; this causes great economic losses to agricultural production (Wang et al., 2014). Compared with other C3 plants, citrus has a lower photosynthetic capacity (usually less than 12 μmol m^{-2} s^{-1}), which constitutes a factor that limits tree growth as well as fruit yield and quality (Kriedemann, 1968; Jifon and Syvertsen, 2003). Fruit quality is closely associated with the strength of photosynthesis, and can be directly affected by sunlight intensity during citrus maturation (Chen et al., 2001). Studies have revealed that reflective mulching materials can improve light distribution at the canopy by increasing reflected light from the ground; this improves photosynthetic effectiveness, and regulates sugar metabolism as well as the activity of anthocyanin synthesis-related enzymes, thereby affecting fruit sugar accumulation and coloration (Bergqvist et al., 2001; Meinhold et al., 2011; Jiang et al., 2014). Therefore, it is of significant importance to develop plastic film mulching to improve citrus fruit quality in Chongqing.

Environmental conditions have important effects on yield and quality of fruit crops, and sunlight is a major climatic factor determining fruit yield and quality (Jifon and Syvertsen, 2001). Studies have demonstrated that reflective film mulching can improve light utilization in peach (Layne et al., 2001), apple (Layne et al., 2002; Iglesias and Alegre, 2009), plum (Melgarejo et al., 2012), grape (Leal,

* Corresponding author.
E-mail addresses: jiaxuemei1212@sina.cn (J. Xuemei), citruslab@163.com, zhengyq@swu.edu.cn (Z. Yongqiang).

http://dx.doi.org/10.1016/j.scienta.2017.02.049

2007) and citrus (Shi et al., 2011) trees, thereby increasing photosynthesis to improve fruit quality (Meinhold et al., 2010). In terms of citrus, studies have proposed to adopt the half cover pattern, where trees are mulched to near drip moulding of the canopy; this can effectively increase sunlight directed to citrus trees, enhance internal light intensity at the canopy, improve light conditions on leaf and fruit surfaces, increase chlorophyll content in leaves, and enhance photosynthesis (Zhou and Wang, 2009), thereby enhancing fruit sugar content and reducing fruit acidity (Wu et al., 2012), and ultimately improving fruit quality.

Currently, studies assessing film mulching for citrus are mainly focused on *Citrus unshiu* (Zhou and Wang, 2009), *Citrus poonensis* (Shi et al., 2011) and other early-maturing varieties. In the Three Gorges Reservoir of Chongqing, as a planned important late-maturing citrus belt, late-maturing varieties show even longer maturing periods compared with early-maturing ones due to low temperature, rains, and weak daylight in autumn and winter. However, the effects of plastic film mulching on the fruits of late-maturing varieties remain unknown.

Thus, we aimed to assess the effects of plastic film mulching on fruit quality of late-maturing citrus, as well as the kinetics of chlorophyll fluorescence in leaves of mulched citrus trees, thereby determining the optimal mulching method for late-maturing citrus varieties under natural rainfall conditions. In addition, the relevant physiological regulatory mechanism for fruit quality was explored, to provide a theoretical basis for regulatory measures for alleviating the negative effects of low temperature and weak daylight in autumn and winter in the Three Gorges Reservoir Region, improving orange orchard yield and fruit quality.

2. Materials and methods

2.1. Plant materials and treatment

The test variety was 8-year-old *Citrus sinensis* (L.) Osbeck *cv* Tarocco with basically consistent growth tendency, used in these experiments have been obtained from an Wanzhou Rose Orange Orchard at the Chongqing, China. Its flowering phase is in the second half of April, and the fruits mature in the first half of April in the following year under the weather conditions in Chongqing. The trees were aligned with a spacing of 3 m × 4 m under natural conditions with no extra irrigation and received standard local commercial practices. A total of 90 plants were randomly selected. In addition, the Tyvek® high-density non-woven polyethylene material (Dupont) used in this study was of high diffuse reflectivity, waterproof and breathable, strong and durable, soft and tough, safe, and environmentally friendly. Soil surface was applied half cover (HC, coverage to near drip moulding) and full cover (FC, entire canopy and bilateral gutters covered to prevent rainwater from leaking to the soil) with Tyvek® non-woven materials after rainfall during the late fruit swelling period (late December) in 2014. Meanwhile, trees without treatment were considered as controls (CK) (Fig. 1). 10 plants in one row from North to South were administered one treatment, and each treatment was repeated for 3 times. During picking time, rose orange fruits were collected from upper (U) and Downside (D) parts of each plant on March 24, 2015. Downside part fruits were collected at a distance of 0.6 ± 0.2 m from the ground, and the upper ones at >1.2 ± 0.2 m from the ground. Three fruits were collected along the North-South direction from each part of the assessed plants; 60 fruits were collected from each part for each group, with 3 repetitions. The fruits were immediately transported to the laboratory for determining external and internal properties.

2.2. Determination of tree reflectivity

Three plants were randomly selected from the CK, HC and FC groups, and the intensity of reflected light was measured at vertical distances of 0.6 m and 1.2 m on a TASI-631 luminometer (Suzhou Tasi Electronic Co., Ltd.), with the unobstructed ground considered a reference to evaluate relative reflectivity. In addition, the relative reflectivity was determinated at 12:00p.m. on sunny and cloudy day every one month during mulching period, respectively. Relative reflectivity (%) = (Illuminance of treatment group-reference Illuminance)/reference Illuminance × 100, in $\mu mol\ m^{-2}\ s^{-1}$ (Wu et al., 2012).

2.3. Determination of fruit quality

Determination of fruit external quality. Fruit color index was measured on a Konica Minolta colorimeter CR-10 (Japan). A total of 25 fruits from each part of each group were selected, and three points randomly selected from the equatorial part of each fruit. Then, a, b and L values were measured and averaged, respectively. Prior to measurements, calibration was performed using a white plate, followed by measurements of a value ("+" indicated redness, and the larger the value, the deeper the redness; "−" referred to greenness, and the smaller the value, the deeper the greenness), b value ("+" indicated yellowness, and the larger the value, the deeper the yellowness; "_" referred to blueness, and the smaller the value, the deeper the blueness) and L value (brightness; the larger the value, the higher the brightness). The measurements were repeated 3 times for each fruit (Singh and Reddy, 2006).

Determination of fruit internal quality. Fruits were squeezed using a juicer, and the resulting juice was filtered with a clean gauze into a clean 1000 ml beaker, followed by oscillation for subsequent usage. The total soluble solids content (TSS) and titratable acidity (TA) contents were determined according to the GB/T 8210-2011 *Method of inspection for fresh citrus fruit* (GB/T 8210; 2011).

2.4. Determination of chlorophyll fluorescence

Three plants were separately and randomly selected from the CK, HC and FC groups; the 3rd leaf of 2 spring tips from upper (1.2 ± 0.2 m) and downside parts (0.6 ± 0.2 m) at southern and northern directions were collected and clamped to perform dark treatment for 15 min, followed by determination of O-J-I-P fluorescence kinetics and extraction of chlorophyll fluorescence JIP-text parameters, on the Multi-Function Plant Efficiency Analyzer MPEA-2 (Hansatech, UK) (Baker and Rosenqvist, 2004; Stirbet, 2011), with $Vt = (Ft - Fo)/(Fm - Fo)$. In addition, chlorophyll fluorescence parameters were analyzed in terms of relative growth rate (%), defined as follows: relative growth rate (%) = (parameter value of treatment group-parameter value of control group)/parameter value of control group × 100.

2.5. Statistical analysis

Analysis of variance and a significance test were analyzed with the SPSS 20.0 software by one-way ANOVA with least significant difference (LSD) test at $P < 0.05$, and the results were expressed as means ± SD of three replicates of each treatment.

3. Results

3.1. Effects of plastic film mulching on relative light intensity at different tree parts

Fig. 2 shows the effects of Tyvek® mulching on relative intensities of incident and reflected lights at upper and downside parts of