The influence of 20% white shade nets on fruit quality of 'Nadorcott' mandarin

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Abstract

The external and internal quality of citrus fruit determines consumer acceptance, thereby driving the consumption and demand for fresh fruit. Emphasis is placed on producing a high volume of fruit of good quality, and it is known that light intensity is especially important in influencing sugar content, rind color, and blemish incidence. Extreme environmental conditions are challenging controllable factors. Therefore shade netting is used especially on fruit crops for protection against dramatic climatic events that affect the appearance of the fruit, i.e., excess sunlight, wind, and hail. The study was conducted on 'Nadorcott' mandarin trees planted in 2012 in a commercial orchard in Citrusdal, Western Cape province, South Africa. The aim of this study was to determine the influence of 20% white shade nets on the quality of 'Nadorcott' mandarin fruit. Monthly evaluation of fruit size, rind color, internal quality parameters (°Brix/citric acid ratio) and the incidence of sunburn was performed. The fruit diameter was not influenced by shade net in 2016; however, in 2017 a larger fruit diameter was measured for shade net fruit. Rind color development and internal quality were not influenced negatively by the treatment. Shade net was effective, reducing the incidence of sunburn significantly in both seasons, 2016 and 2017. Moreover, postharvest fruit quality was not negatively affected by the shade net treatments. In summary, our results indicate that shade-netting is a potential preventative technology ensuring unblemished and high quality in 'Nadorcott' mandarins, but further studies are required to evaluate the influence of tree age and microclimatic effect on fruit production and postharvest storage behavior in other citrus cultivars.

Keywords: *Citrus reticulata*, light intensity, Brix, fruit size, rind color

INTRODUCTION

In citrus fruit size and external appearance, including rind coloration and the absence of blemishes are important to determine market value. Additionally, the sugar to acid ratio is the critical internal quality parameter influencing continued purchasing. In citriculture environmental factors such as temperature and light intensity influence fruit size (Moon et al., 2011), acidity, soluble solid content (SSC) (Verreynne et al., 2004) and rind color (Cronje et al., 2013). The influence of the canopy positions was mainly due to the change in light spectral quality as it penetrates into the canopy, resulting in lower photosynthetic active radiation (PAR) levels inside the canopy (Cronje et al., 2013). However, micro-climatic factors, such as air temperature and relative humidity, also differ between canopy positions and will affect fruit quality. The SSC in citrus fruit is the result of the translocation and accumulation of leaf photosynthates in the juice sacs (Yakushiji et al., 1998). Therefore factors such as light and

other environmental factors that influence photosynthesis play an important role in the fruits SSC. Sites and Reitz (1949) established a correlation with SSC in the fruit pulp, and the amount of light received, and this is also evident from studies which reported a higher SSC for outside canopy fruit (Verreyne et al., 2004).

Light levels and low temperature are known to influence the chloroplast-chromoplast conversion associated with color development. The characteristic green color of immature fruit is due to the abundant chlorophyll pigment located in the chloroplast, while carotenoids which provide the yellow-orange coloration of mature citrus fruit is present in the chromoplast (Gross, 1987). The rate of chlorophyll production is reduced at a low light intensity, with enhanced chlorophyll degradation under cool temperatures (Meredith and Young, 1969), while for carotenoids, light promotes the carotenoid levels and results in improved rind coloration (Cronje et al., 2013). In contrast to the low light levels, excessive solar radiation levels alone or in combination with high air temperatures have been shown to cause sunburn (Ketchie and Ballard, 1968), which result in the yellow rind discoloration or in some cases necrotic tissue, thereby affecting the rind appearance and reducing the fruit value. Extreme environmental stress conditions are difficult to predict and control. However, shade nets, a relatively new introduction in citriculture is being implemented in orchards as protection against such climatic events (Rajapakse and Shahak, 2007). However, the impact of netting on citrus internal and external fruit quality aspects has not been as clear as its documented success in reducing sunburn (Syvertsen et al., 2003; Wachsmann et al., 2014). The aim of this study was to determine the influence of 20% white permanent shade netting on the quality aspects critical for fruit export of 'Nadorcott' mandarin (*C. reticulata* Blanco) at harvest and during long-term cold storage at -0.6 and 4°C.

MATERIAL AND METHODS

The experiment was carried out over two seasons (2016 and 2017) in a commercial orchard of 'Nadorcott' mandarin trees on *Carizzo citrange* (*Poncirus trifoliata* × *C. sinensis*) in Citrusdal (-32.542140, 19.011877), Western Cape Province, South Africa. The orchard was planted in 2012, with a tree spacing of 5.5 m between and 2.5 m within rows, in a north to south row orientation. The orchard management followed standard citriculture practices for both treatments. The experimental layout was a randomized complete block design (RCBD), where each experimental block was divided into two plots of 75×25 m ($n=4$). The treatments consisted of either the shade netting or the control (no netting), where the shade plots were covered at 5.5 m height over the trees by permanent 20% white shade netting (Plusnet, 13 Bussing Road, Aureus, Randfontein, 1759, Gauteng, South Africa) prior to the first season. In order to compensate for a border effect, trees in the first 10 m at either side of the rows and the first two rows from the sides of each plot were excluded from data collection. Two weeks prior to commercial harvest, 40 fruit were sampled in each replicate block from two adjacent trees of uniform size, health, and crop load. The fruit were selected mid-way of the tree canopy height, $\pm 1-1.5$ m from ground level, within the first 20 cm of the outer canopy boundary. The day after harvesting the fruit, the rind color, and thereafter the internal quality parameters were determined.

Fruit rind color was measured with a chroma meter (CR-400, Konica Minolta Sensing, Inc., Japan) on the sun-exposed side of each fruit and expressed as Hunter a/b ratio. Fruit diameter was determined with an electronic fruit size measure and data logger (GUÜSS Manufacturing (Pty) Ltd., Strand, South Africa). The juice of 10 fruit of each replicate was extracted (8-SA10, Sunkist®, Chicago, USA), strained through a muslin cloth, whereafter the soluble solid content (SSC), measured as °Brix, was determined with a digital refractometer (PR-32 Palette, ATAGO CO, Tokyo, Japan). From the extracted juice, a 50 mL sample was used to determine the citric acid content, with a potentiometric titrator (888 Titrando, Metrohm, Switzerland), using

Tiamo™ software. Due to citric acid being the major component of organic acids within *Citrus*, the percentage of citric acid was also used in calculating the sugar to the acid ratio (°Brix/citric acid percentage). The remaining 30 fruit per replicate were allocated to lots of 15 per replicate prior to cold storage at either 4 or -0.6°C for 32 days plus seven days at shelf life before evaluation for non-chilling rind disorders (staining) and chilling injury, (% incidence). The sunburn incidence was graded based on a visual scoring scale, after the color break, according to severity, ranging from 0 = no sunburn incidence, 1 = moderate to light yellow coloration to 2 = severe, bright yellow coloration, leathery and necrotic and used to calculate percentage incidence.

Mixed model repeated measures ANOVA was performed using Statistica 13's VEPAC module (TIBCO Software Inc., 2017). For post hoc testing, the Fisher least significant difference (LSD) post hoc test was used. Sunburn incidence was analyzed by means of a one-way ANOVA.

RESULTS

No significant difference in the fruit diameter between the shade net and control fruit was recorded during the first season. However, in the second season, the average fruit diameter for the shaded fruit was significantly larger at 68.8 mm compared to 66.2 mm, respectively. The yield (fruit tree-1 and kg tree-1) were not affected by the treatment (Table 1). Shade net did not influence rind color development as rind color development patterns were similar between control and shaded fruit, with no significant difference detected between the treatments, over both seasons (Table 2). However, it was visually noted that the color development in the season was not as progressed at harvest compared to the first season, which is reflected in the colorimeter values.

The internal quality parameters measured showed no significant difference between treatments at harvest (Table 2) as well as after cold storage (data not shown). Both treatments impacted on SSC (°Brix) and citric acid content in the juice, showing a similar trend over the developmental period (data not shown) but resulted in no significant difference at harvest. Furthermore, the ratio of the SSC to % citric acid ratio was not differently influenced for fruit grown under shade netting, compared to that of fruit grown without shading, over the fruit development period as well as at harvest (as no treatment differences occurred).

The presence of shade netting effectively reduced the percentage of sunburn incidence in both seasons (Table 3). In both seasons the 20% white shade netting significantly reduced the percentage of sunburned with 18 and 16% in the respective seasons. No significant difference in the incidence of chilling and non-chilling postharvest disorders occurred after cold storage due to the shade netting treatment (Table 4).

DISCUSSION

The shade net treatment did not influence the fruit development pattern, regardless of the season, with no fruit size difference reported in the first season. However, during the second season, the average fruit size for shaded-fruit was increased by 3.9%, resulting in these fruits being 2.6 mm larger at the end of the season. The data from the 2016 season concur with Wachsmann et al. (2014) where no influence of shade netting on 'Orri' mandarin fruit size was reported for 18% white, 25% red, 24% yellow or 13% transparent netting. The lack in yield (fruit and kg tree-1) difference between treatments could be explained by the relatively young orchard status (4th and 5th year of production) and it is possible that due to the increase vegetative growth under the shade net (Brown, 2018) an increase in yield tree-1 would become evident in subsequent season. However, the increased fruit size under the shade net had a positive commercial impact increase export volume as the shifted the fruit size

distribution toward the larger counts, and had a direct impact on an improved return on investment even at this early stage of the production of the orchard (Brown, 2018).

Shade nets or screens are known to reduce solar radiation (Jifon and Syvertsen, 2003; Lee et al., 2015) and light intensity that can also differ among canopy positions (Cronje et al., 2013). Verreyne et al. (2004) reported that light intensity influences the fruit size of mandarin types, with greater size for outside canopy, positioned fruit. However, in this study, a reduction of light intensity (17-20%) (Prins, 2018) by the shade net did not affect the fruit growth and size negatively.

The general reduction in photosynthetic photon flux (PPF) caused by shade nets, may result in higher photosynthesis due to a decrease in photo-inhibition which is associated with high light and leaf temperatures (Prins, 2018; Syvertsen et al., 2003). The inconsistent results obtained in our study regarding fruit size between seasons can therefore not directly be ascribed to the role of photosynthesis in providing carbohydrates to drive fruit development. Syvertsen et al. (2003) reported a higher photosynthesis rate under the 50% shade cloth, yet fruit size of 'Spring Navel' orange was not affected. Moon et al. (2011) suggest that fruit growth is not only dependent on the light intensity but aspects such as sink strength, hormone balance, fruit load, and leaf to fruit ratio all being influential. Possible climatic differences between the two seasons might be responsible for producing fruit size differences since high heat and humidity are known to lead to large fruit (Prins, 2018). However, it has been proposed that air temperature has a broad influence on fruit growth and that heat accumulation could be used as a better indicator to relate to fruit growth.

Rind color was not negatively affected by the shade net treatment in either season. Color development generally occurs during the end of the cell enlargement phase (Rodrigo et al., 2004). In this study, however, in both seasons, color change from green to yellow-orange only commenced between May and June. These results, however, do not concur with other studies where shade net treatment affected the rind coloration, either positively or negatively. Syvertsen et al. (2003) and Otero et al. (2011) reported that the rind coloration of 'Spring' navel orange was improved by a 50% shade cloth. In contrast, Jifon and Syvertsen (2003) found that rind coloration was delayed for 'Ruby Red' grapefruit and 'Hamlin' orange when exposed to a 50% reflective shade screen. It is thought that the shade percentage factor and type of netting product, along with the time of application and the tree age are critical to affect rind color. Light intensity is important for rind coloration, in and a reduction in light intensity reduce carotenoid levels (Cronje et al., 2013). However, in this study, the reduced light levels and the expected climatic alterations associated with shade nets was not detrimental to the rind coloration (Prins, 2018).

The shade netting was effective in reducing the percentage of sunburn in both seasons and sunburn is strongly linked to high sunlight exposure of fruit (Ketchie and Ballard, 1968) and concurs with results of Lee et al. (2015) on 'Ponkan' mandarin.

In terms of export value, in addition to the external appearance, the taste of the fruit as expressed by the SSC, acids, and the sugar to acid ratio, is also of the utmost importance. The internal quality development of shaded fruit was not affected, which is in agreement with Cohen et al. (2000), where the sugar and acids in 'Marsh' grapefruit juice were not influenced by the application of either 30 or 60% shade. However, both concurring and contradicting findings to the current study were reported by Jifon and Syvertsen (2003). In their study, shade screens (50%) applied either early (after the bloom-peak 'May-June drop') or continued (after bloom to harvest) or late (only in August to harvest) did not affect the Brix of 'Hamlin' sweet orange, whereas continued shade application decreased the °Brix/acid ratio. Otero et al. (2011) reported that the use of 50% shading cloth on 'Spring' navel oranges, reduced the total soluble solids, but without affecting the ratio. In addition, Wachsmann et al. (2014)

documented that 'Orri' mandarin under 18% white shade net to have had significantly higher sugar to acid ratio, therefore reaching commercial maturity earlier, due to the desired reduced acid levels. A lack of postharvest physiological disorders is in addition to good rind coloration key to determine the market value of the fruit. An undocumented postharvest disorder for this cultivar did occur i.e., rind staining at both cold storage temperatures but was not affected by shade netting. The absence of any negative impact of the shade netting with regard to inducing postharvest disorders in 'Nadorcott' mandarin is of great commercial significance and is considered a key result from this study.

To conclude, the 20% white shade netting had a positive influence on the fruit size in the second season that could indicate a possible advantage for increases in export volumes. The shade net was effective in reducing the percentage of sunburn, without affecting the rind coloration. Furthermore, the maturity of the fruit grown under the shade net was not influenced. Therefore the internal quality was not affected.

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Table 1. The influence of 20% white shade netting on 'Nadorcott' mandarin fruit diameter and yield (fruit and kg tree⁻¹), during two consecutive seasons, 2016 and 2017 in Citrusdal South Africa.

	2016			2017		
	Fruit diameter (mm)	Fruit tree ⁻¹	kg tree ⁻¹	Fruit diameter (mm)	Fruit tree ⁻¹	kg tree ⁻¹
Control	48.1 ^{ns}	367 ^{ns}	31.89 ^{ns}	51.6 b	550 ^{ns}	55.31 ^{ns}
Shade net	48.8	432	40.19	53.7 a	526	58.69
<i>P</i> -value	0.648	0.384	0.218	0.034	0.790	0.712

^{ns} Denotes non-significant difference at 5% significant level.

Different letters denote significant difference between means within a column for at $P \leq 0.05$ according to Fisher's LSD test ($r=4$).

Table 2. The influence on rind color and internal quality at harvest, of 20% white shade netting on 'Nadorcott' mandarin fruit compared during two consecutive seasons, 2016 and 2017 in Citrusdal, South Africa.

	2016				2017			
	Rind color (a/b)	TSS (°Brix)	Citric acid (%)	Ratio (Brix/C-acid)	Rind color (a/b)	TSS (°Brix)	Citric acid (%)	Ratio (Brix/C-acid)
Control	-0.35 ^{ns}	14 ^{ns}	1.3 ^{ns}	10.5 ^{ns}	-0.59 ^{ns}	12.2 ^{ns}	1.1 ^{ns}	10.8 ^{ns}
Shade net	-0.34	13.6	1.3	10.8	-0.59	11.9	1.1	11.1
<i>P</i> -value	0.697	0.436	0.415	0.481	0.980	0.591	0.451	0.401

^{ns} Denotes non-significant difference at 5% significant level ($r=4$).

Table 3. The influence on sunburn incidence of 20% white shade netting on 'Nadorcott' mandarin fruit during two consecutive seasons, 2016 and 2017 in Citrusdal, South Africa.

	Treatment	Percentage (%)
2016	Control	23.7 a
	Shade net	5.75 b
	<i>P</i> -value	0.002
2017	Control	20.8 a
	Shade net	5.00 b
	<i>P</i> -value	0.031

Different letter denotes significant difference between means within a column for each season at $P \leq 0.05$ according to Fisher's LSD test ($r=4$).

Table 4. The influence on the incidence of postharvest disorders of 20% white shade netting on 'Nadorcott' mandarin fruit during two consecutive seasons, 2016 and 2017 in Citrusdal South Africa. Fruit were stored for 32 days at 4 or -0.6°C plus 7 days at ambient conditions before evaluations.

Storage temperature	4°C	-0.6°C
	Staining (%)	Chilling injury (%)
Control	26.9 ^{ns}	3.25 ^{ns}
Shade net	26.9	4.75
<i>P</i> -value	1.000	0.680

^{ns} Denotes non-significant difference between means within a column according to Fisher's LSD test at $P \leq 0.05$ ($r=4$).