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Tree age and fruit size in relation to postharvest respiration and quality changes in 'Kinnow' mandarin fruit under ambient storage

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ABSTRACT

The conducted research focused on the impact of tree age and fruit size on postharvest respiration as well as changes in physico-chemical quality of 'Kinnow' mandarin fruit, stored in ambient conditions (20 ± 2 °C). Fruit from three different tree age groups (6, 18 and 35-years) and fruit size (large, medium and small) groups were analyzed for respiration and fruit quality during seven days ambient storage. Fruit from tree age group of 35-years surpassed the fruits from tree age group of 6-years in carbon dioxide (CO_2) production, while fruit size had non significant influenced CO_2 production following ambient storage. Ethylene production was predominantly more in fruit from tree age group of 35-years, while fruit of small size irrespective of tree age group had significantly higher ethylene production. In general, CO_2 production indicated a non-climacteric pattern, while ethylene production followed climacteric pattern, with two peaks. As regards fruit quality, fruit of tree age group of 35-years, had more TSS (10.6°Brix) titratable acidity (TA) (0.81%), sugars {reducing (1.9%), non reducing (5.3%) and total sugars (7.5%)} as compared to tree age group of 6 and 18-years. Final fruit quality data after seven days of ambient storage showed more decrease in TA (0.1%) and reducing sugars (0.26%) and increase in ascorbic acid (AA) (3.38 mg 100 mL^{-1}) and non reducing sugars (0.61%) in fruit of trees age group of 35-years. Fruit from 18-years old trees had higher mass loss (8.39%), irrespective of fruit size and the interactive response of tree age and fruit size revealed that more mass loss (11.71%) was observed in small sized fruit from 18-year-old trees. Ethylene production was positively correlated with mass loss ($r = +0.734$) in fruit from 18-year-old trees and negatively ($r = -0.692$) in fruit from 6-year-old trees. Irrespective of tree age and fruit size ethylene and CO_2 correlated positively with TSS, titratable acidity and total sugars and negatively with rind thickness.

1. Introduction

Fruit are living entities and continue to respire for some time (till senescence) once detached from the plant (Ranganna, 2008) and the rate of respiration predicts their potential storage life (Varoquaux and Ozdemir, 2005). Respiration is the chemical process by which stored organic substrates (carbohydrate, proteins, lipids, fats and organic acids) are broken down into simple products accompanied by production of heat (Workneh and Osthoff, 2010). Hence, it is important that fruit tissues must have sufficient organic materials at the beginning of the postharvest period to ensure optimum storage life (Cronje and Barry, 2013). In-sufficient carbohydrate concentration result in lower fruit quality (Holland et al., 2002). A commodity with high carbohydrate contents and low respiratory rate would last longer after harvest (Shah, 1998) and vice versa.

Number of factors contributes in accumulation of organic substances (carbohydrate, proteins, lipids, fats and organic acids) in a fruit (i.e. growth regulators, cultural practices, fertilizers, tree age and fruit size etc.) and these factors were well documented in lit-

Abbreviations: TA, titratable acidity; AA, ascorbic acid; TSS, total soluble solids; TS, total sugars; RS, Reducing sugars; NRS, non reducing sugars; S, Small; M, Medium; L, large; D, day; CO_2, Carbon dioxide.

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erature. Earlier study from Hearn (1993) revealed that fruit from young and fast growing citrus trees exhibited less TSS, acids and more solid to acid ratios. Similarly, in apple fruit, lower acids to solid ratios were obtained from young (4–6 year old) trees (Tahir et al., 2007). Our recent study also confirms this finding (Khalid et al., 2012b). According to DongHui et al. (2005), more ascorbic acid was recorded in fruit from young (5–10 year-old) *Prunus saliciana* trees as compared to fruit from relatively old (20–30 year-old) trees. However, the relationship of stored organic substances in fruit and more particularly in citrus and their postharvest respiration is rarely documented, to the best of our knowledge. It has been reported that fruit with more substrates (carbohydrate and organic acid contents) for respiration have higher respiration rate (Kramer, 2012). Similarly, Tahir et al. (2007) stated that apple fruit acquired from young trees with higher soluble solids showed earlier and higher ethylene production. However Asrey et al. (2007) found no definite pattern of respiration in guava fruit obtained from plants of different age groups.

Similarly, accumulation of organic substances in fruit also varies with fruit size. In larger size grapefruit, higher juice (%) and lower mass loss (%) was recorded, however, biochemical attributes of fruit were non significantly influenced by fruit size during storage (Paily et al., 2004). Increased fruit size was associated with decreased percentage of total soluble solids and acidity, as observed in 'Kinnow' mandarin (Malik et al., 2007; Sandhu, 1992; Jawandha et al., 2015), tangerine cv. *Sai Nam Phueng* (Boonyakiat et al., 2012) and apple (De Salvador et al., 2006). Fruit size has no relation with ascorbic acid contents in 'Kinnow' mandarin (Sandhu, 1992) and tangerine (Boonyakiat et al., 2012). Similarly, Fleancu (2007) reported a negative correlation between fruit diameter and fruit respiration in apple cultivars. Day (1993) reported that small potatoes have higher respiration rate than large potatoes. Ijabo et al. (2012) reported no significant effect of fruit size on heat of respiration in African pear (*Dacryodes edulis*) fruit.

On the basis of respiration, Goldschmidt (1997) considered citrus fruit non-climacteric (due to slow release of ethylene) as well as climacteric (due to ripening related changes in response to exogenous ethylene production). Moreover, Katz et al. (2004) reported a climacteric-like rise in ethylene production in citrus fruitlets upon harvest which augmented by exogenous ethylene treatment whereas, low levels of ethylene production was exhibited by mature detached fruit and this production was not influenced by exogenous ethylene application. Tree age and fruit size significantly influence fruit quality and are important criteria for marketability of mandarin-type fruits (Iqbal et al., 2015; Khalid et al., 2012b). However, the effect of these two components on postharvest respiration and physicochemical fruit quality of citrus fruit during shelf-life is not well documented. Therefore current study was planned to ascertain influence of tree age and fruit size on respiration, ethylene production and qualitative changes in citrus fruit during shelf-life at ambient conditions.

2. Materials and methods

2.1. Plant material and site selection

The experiment was conducted on fruit sourced from a commercial 'Kinnow' mandarin orchard located in Sargodha district (latitude 32°03′ N, longitude 72°40′ E). Fruit were harvested from trees of three different age groups. Commercially mature fruit (when fruit color changes to 100% yellow) from each age group were randomly harvested at shoulders height and categorized into three groups based on fruit size i.e. small (S) 60–64 mm; medium (M) 65–69 mm and large (L) 70–74 mm, packed and transported to Postharvest Research and Training Centre (PHRTC), Institute of Horticultural Sciences (HIS), University of Agriculture Faisalabad (UAF). Fungicidal treatment (0.2% thiabendazole) was given for one min to fruit after being washed by tap water and then dried at room temperature (20 ± 2 °C). Each age and size group was divided into two fruit lots. Nine treatments (three age groups × three fruit size) with three replications were included in each lot, having sample size of 15 fruits per replication. One lot of fruit was analyzed immediately after harvest (day 1) and the other lot was kept at ambient conditions (20 ± 2 °C and RH 60–65%) and analyzed 7 days after harvest (day 7).

2.2. Respiration and ethylene production (m Mol kg^{-1} h^{-1})

Randomly selected two uniform sized fruit from each treatment were retained in a sealed plastic jar for one hour. CO_2 and ethylene concentrations were determined after an hour from the headspace. CO_2 analyzer (model VAISALA, MI 70) was used for determination of CO_2 concentration (m Mol kg^{-1} h^{-1}), while ethylene was calculated by ethylene meter (model ICA-56), as m Mol kg^{-1} h^{-1}.

2.3. Physical fruit quality

Fruit mass (g), fruit mass loss (%), rind mass (%), rag mass (%) and juice mass (%) were determined in fruit physical quality as described by Khalid et al. (2012b).

2.4. Biochemical fruit quality

TSS (°Brix), titratable acidity (TA) (%), ascorbic acid (AA) (mg 100 mL^{-1}), and sugars (reducing, non reducing and total sugars) (%) were determined in biochemical fruit quality parameters, according to methods given by Khalid et al. (2012b).

2.5. Standards and reagents

Analytical grade sodium hydroxide, oxalic acid and 2, 6-dichlorophenolindophenol, was obtained from Reidel deHaen.

2.6. Statistical analysis

The experiment was carried out in completely randomized design (CRD) with three factor (tree age, fruit size and shelf-life) factorial arrangement. MSTAT-C (Michigan State University, East Lansing, MI, USA) software was used for data analysis and means were compared by duncan's multiple range test (DMRT) at 5% level of significance.

3. Results

3.1. Respiration and ethylene production during shelf-life studies

Generally, higher CO_2 production was observed in all sized fruit from tree age group of 35-years during seven days shelf life studies (Fig. 1a–c), however the results were statistically similar on D-4 in all tree age groups.

Regardless of fruit size, higher respiration rate was recorded in fruit obtained from tree age of 35-years, whereas, lower CO_2 production was noticed in fruit obtained from trees of 6-years age (Fig. 2a). Fruit size had no significant impact on CO_2 production during shelf-life studies in individual tree age groups (Fig. 1d–f). Regardless of tree age, fruit size exhibited at par response for CO_2 production (Fig. 2b).

Large sized fruit group from tree age of 18-years exhibited higher ethylene production, while lower ethylene production in 6-year-old trees (Fig. 3a). Fruit size (medium and small) acquired from 35-year-old trees had higher ethylene production, whereas