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Postharvest Behaviour and Quality Characteristics of Mango (*Mangifera indica* L.) Fruit Grown under Water Deficit Conditions

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Abstract

Preharvest cultural practices affect the postharvest quality and behaviour of many fruits. In this study we compared the postharvest behaviour and quality of mango (*Mangifera indica* L. cv. 'Tommy Atkins') fruit from irrigated and non-irrigated trees. The trees were subjected to water stress (non-irrigated) up to 42 days after bloom (DAB) and control trees were irrigated throughout the year. The fruit were harvested at 168 DAB (mature stage). Ripening was conducted under ambient conditions of temperature and relative humidity. Fruit weight decreased with time and the loss was more pronounced in fruit from non-irrigated trees. Starch content and total titratable acidity decreased with increase in storage time. Total soluble solids (TSS) content increased during ripening and fruit from irrigated trees had higher TSS content. Respiration exhibited a true climacteric curve with ethylene production being detected at 11 days after fruit harvest. Fruit from irrigated trees reached climacteric peak almost five days earlier than those from non-irrigated trees. β-carotene content increased steadily with increase in time, decreasing at 9 days in storage. Although firmness and anthocyanin content decreased with time in fruit from both treatments, fruit from non-irrigated trees maintained higher values. Fruit from non-irrigated trees had a longer shelf life than those from irrigated trees due to a delayed climacteric peak and higher degree of firmness. These results indicate that irrigation influences fruit firmness, colour development and the postharvest shelf-life of mango fruit.

INTRODUCTION

Mangoes are the most popular and choicest of the commercial fruits produced in the tropics due to their extremely excellent flavor, attractive fragrance, beautiful colour, delicious taste and health-giving properties (Tasneem, 2004). However, any fruit quality and postharvest behaviour is affected by preharvest cultural practices among other factors. For instance, factors such as irrigation and water deficit have been reported to affect fruit composition and quality in various climacteric fruits such as 'Braeburn' apples (Mills et al., 1996) and mango (Lechaudel et al., 2005).

In Kenya farmers in the arid and semi-arid lands irrigate their mango trees, and it is important to investigate how this cultural practice influences fruit postharvest quality. Despite the important role of water in fruit growth and development, little information is available on the influence of water application on mango fruit quality at harvest and postharvest quality and behaviour. Indeed, retail traders in Kenya have indicated that, despite fruit from irrigated trees being bigger, they are inferior in terms of quality and postharvest behaviour. As a first step towards understanding the scientific basis of this claim we studied the postharvest behaviour of mango fruit from irrigated and non-irrigated trees.

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MATERIALS AND METHODS

Mango (*Mangifera indica* L. cv. 'Tommy Atkins') fruit were sampled from a commercial farm in Yatta District, a semi-arid region in Kenya. One set of trees was subjected to water stress until 42 days after bloom (DAB) when the rain season set in and another set of trees irrigated throughout the year. Fruit were harvested at 168 DAB and stored at ambient conditions of temperature and relative humidity.

Fruit weight was measured using a scientific balance (model Libror AEG-220, Shimadzu Corp., Kyoto, Japan). Flesh firmness along the equatorial region of the fruit was determined using a rheometer (model NRM-2010J-CW, Fudoh, Tokyo, Japan) fitted with an 8 mm probe and expressed in Newtons (N). Starch staining was done by taking a slice from the equatorial region of the fruit, dipping in I/KI (2 g/10 g) solution and rated as a percentage based on the Cornell Starch Chart. Individual sugars were analysed using high performance liquid chromatograph (HPLC). 10 g of fruit pulp was refluxed in ethanol for 1h. The sample was then concentrated by rotary evaporation and diluted with 75% acetonitrile. These individual sugars were analyzed using a HPLC (model LC-10AS, Shimadzu Corp., Kyoto, Japan) using a refractive index (RI) detector. Total soluble solids (TSS) content was determined using an Atago hand refractometer (Type 500, Atago, Tokyo, Japan). Total titratable acidity (TTA) was determined by titration with 0.1 N NaOH and results are expressed as % citric acid. β-carotene content was determined by a modified chromatographic method (Heionen, 1990) using HPLC (model LC-10AS, Shimadzu Corp., Kyoto, Japan) fitted with a UV detector and operated at an oven temperature of 35°C. Anthocyanin content was determined by the pH differential method (Ngo et al., 2007) by measuring the absorbance of extract in pH 1.0 and pH 4.5 buffers at 510 nm and 700 nm using a UV-Vis spectrophotometer (model UV mini 1240, Kyoto Shimadzu). For respiration and ethylene production rates, mango fruit were placed in plastic jars ranging in volume from 100 ml to12 L fitted with a self-sealing rubber septum for gas sampling. The fruit were incubated for 1h at room temperature. Gas samples from the headspace gas were removed using an airtight syringe and injected into two different gas chromatographs (model GC-8A, Shimadzu Corp., Kyoto, Japan). The gas chromatograph for CO_2 determination was fitted with a thermal conductivity detector and a Poropak Q column and that for ethylene determination fitted with an activated alumina column and a flame ionization detector.

Values for the various treatments were compared using t-test; paired two samples for means using Genstat (13^{th} version) statistical method of analysis.

RESULTS AND DISCUSSION

Weight Loss and Starch Content

Weight loss was higher in fruit from non-irrigated trees (Fig. 1A). This is attributed to loss in moisture due to respiration, transpiration of water through peel and other biological changes taking place in the fruit (Rathore et al., 2007). Although moisture loss by fruit from irrigated trees was lower, they had a shorter shelf-life as evidenced by decay incidence. At harvest, fruit from non-irrigated trees had higher starch content (Fig. 1B). During storage starch content decreased rapidly during the first 7 days of storage irrespective of the treatment. Lima et al. (2001) found traces of starch in the pulp of over ripe 'Tommy Atkins' mango fruit and amylase activity was greatly reduced. In guava fruit starch content decreases with concomitant increase in alcohol-soluble sugars (Jain et al., 2005). We found a high correlation between the decrease in starch and increase in TSS content (r^2= 0.86 and 0.96) for the fruit from the irrigated and non-irrigated trees, respectively.

Pulp Sugar Content

Glucose and fructose content increased during storage to reach a maximum of 20 and 21 mg/100 g for glucose and 86 and 90 mg/100 g for fructose in the fruit from the irrigated and non-irrigated trees, respectively (Table 1). At 11 days after harvest, the maximum fructose content was 4 times that of glucose. The increase in reducing sugars is brought about by the hydrolysis of starch and sucrose (Lechaudel et al., 2005). Fructose and glucose come from sucrose hydrolysis, but glucose is also produced by starch hydrolysis. The decrease in the glucose content at the later stage could have been caused by its use in the respiratory metabolism. There was a marked increase in the conversion of sucrose to fructose and glucose at day 9 of storage in the fruit from non-irrigated trees than in the fruit from irrigated trees as had earlier been reported for apples (Mills et al., 1996). Plants can regulate their solute potential in tissues and organs to compensate for water stress, a process called osmotic adjustment, that results in a net increase in the concentration of a variety of solutes but primarily sugars (Lechaudel et al., 2005). The osmotic adjustment could have resulted in the increased sugar accumulation in the fruit from non-irrigated trees. A high sugar deposition due to high photosynthesis in these fruit could have resulted into the predominant red colour that is a protection mechanism imposed by sunlight exposure. A greater increase in sucrose level during storage in the fruit from the non-irrigated trees compared to those from irrigated trees may indicate a higher level of starch to sucrose conversion, probably due to increase in sucrose synthase activity.

Pulp Total Soluble Solids Content and Total Titritable Acidity

Total soluble solids (TTS) content was initially low until 4 days after harvest when the content increased to reach a peak of 14 and 12°Brix for the fruit from irrigated and non-irrigated trees, respectively (Fig. 2A). TSS content increased due to the alteration in cell wall structure and breakdown of complex carbohydrates into simple sugars during storage (Doreyappa-Gowda and Huddar, 2001; Rathore et al., 2007). The increase in TSS content is also attributed to partial breakdown of pectin and celluloses (Roe and Bruemmer, 1981). Total titratable acidity (TTA) decreased with increase in storage time to a minimum of 0.2% in fruit from irrigated trees and 0.11% in the fruit from non-irrigated trees (Fig. 2B). There was no significant difference ($p<0.05$) in TTA in the fruit from irrigated and non-irrigated trees as has previously been reported for mango (Doreyappa-Gowda and Huddar, 2001; Rathore et al., 2007). Reduction in acidity may be due to its conversion into sugars and their further utilization in metabolic process like respiratory climacteric in the fruit.

Respiration and Flesh Firmness

The climacteric peak was attained at 19 ml per kg per hour and 17.2 ml per kg per hour in fruit from irrigated and non-irrigated trees, respectively (Fig. 3A). Ethylene was detected 11 days after harvest with the fruit from irrigated trees having a lower ethylene production rate (6.5 ηl per gram per hour) than the fruit from non-irrigated trees (13.3 ηl per gram per hour). The respiration peak preceded the ethylene peak as has been reported for avocado and mango (Tucker and Grierson, 1987) and soursop (Worrell et al., 1998). The fruit from irrigated trees reached a climacteric maximum earlier than the fruit from non-irrigated trees, which explains their shorter shelf-life. Fruit from non-irrigated trees can, therefore, store for a longer period of time, a characteristic that is desirable in the postharvest handling of mangoes destined for the export market.

Fruit firmness decreased with increase in storage days (Fig. 3B). Fruit from non-irrigated trees were firmer than those from irrigated trees. The fruit from irrigated trees might have had a lot of water due to increased degree of hydration in their cell walls resulting in the reduction in firmness. The disassembly of the fruit cell wall is largely responsible for softening and textural changes during ripening, but the precise roles of particular cell wall alteration and/or of cell wall-modifying enzymes that bring about these changes are not clearly understood (Tateishi et al., 2005).

Pulp β-Carotene and Peel Anthocyanin Contents

The β-carotene content of the pulp increased with increased storage up to day 9 in fruit from both treatments (Fig. 4A). β-carotene content has been shown to increase during storage of mango fruit (Rathore et al., 2007; Vazquez-Salinas and Lakshminarayana, 1985). Thereafter, the levels decreased to 0.67 and 0.51 mg/100 g on 11 days in storage in the fruit from irrigated and non-irrigated trees, respectively. Fruit from non-irrigated trees had higher anthocyanin content than those from irrigated trees (Fig. 4B). The decreased canopy in the fruit from non-irrigated trees may have contributed to increased anthocyanin content. Anthocyanin content in fruit depends on environmental conditions like temperature and light (Saure, 1990) and cultural factors are also thought to influence colour development in many fruits as has previously been reported for bagged 'Kent' mango fruit (Saengnil et al., 1997). Preharvest factors resulting in high carbohydrate content of fruit during growth tend to increase anthocyanin content (Mills et al., 1996). Therefore, the increase in the red colour development in the fruit from non-irrigated trees may be the result of a higher concentration of sugars, a desirable quality characteristic for consumers.

CONCLUSION

Mango fruit from non-irrigated trees had a longer shelf-life than those from irrigated trees due to delayed climacteric peak and had an attractive red colour mostly preferred by consumers. They are, therefore, good for salads, desserts and the export market. The fruit from irrigated trees were higher in total soluble solids and β-carotene but had a shorter life and reduced firmness that makes them suitable for the juice industry and local market. Irrigation, therefore, affects the quality of mango through reduction of firmness and postharvest shelf life.

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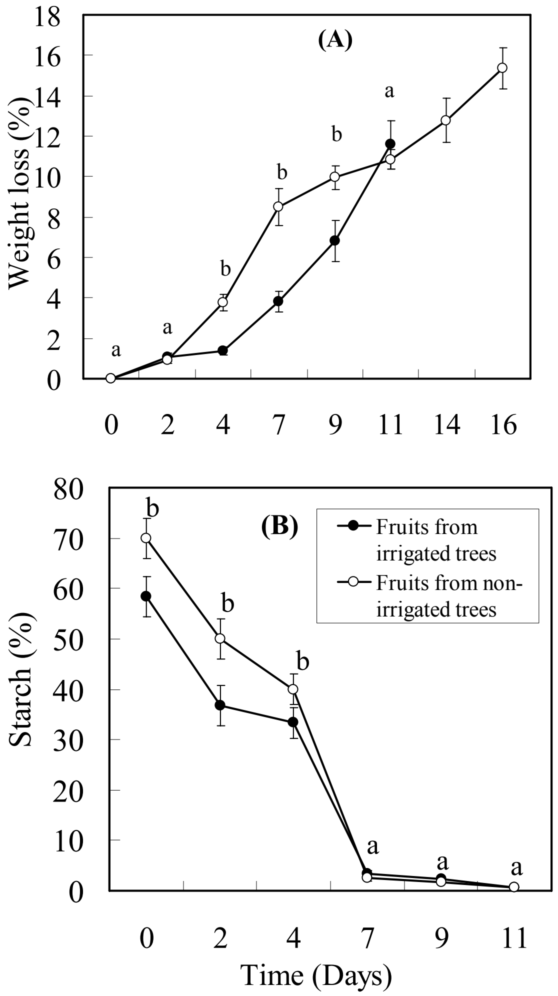
Tables

Table 1. Pulp sugar content during postharvest storage at ambient temperature of mango fruit from irrigated and non-irrigated trees.

	Sugar Content (mg/100g)								
	Glucose			Fructose			Sucrose		
Time (days)	Irrigated	Non-irrigated		Irrigated	Non-irrigated		Irrigated	Non-irrigated	
0	6.8±0.94[a]	8.3±0.53	NS	52.7±6.50	52.7±4.40	NS	85.1±5.48	90.8±3.62	NS
2	8.6±1.35	9.1±1.23	NS	59.5±0.50	60.3±4.29	NS	125.6±6.90	135.9±5.00	NS
4	ND	ND		ND	ND	-	ND	ND	
7	ND	ND		ND	ND	-	ND	ND[d]	
9	20.5±1.09	21.6±1.22	NS	82.8±4.10	88.9±2.46	NS	126.3±3.20	140.8±2.70	***[b]
11	20.2±1.05	21.5±1.07	NS	86.0±8.54	90.1±4.93	NS	118.3±13.1	125.8±9.30	NS[c]

[a] Data are means± SD of three replications.
[b] *** denotes highly significant difference (p<0..05) between fruits from irrigated and non-irrigated trees.
[c] NS denotes not significant
[d] ND denotes not determined.

Figures



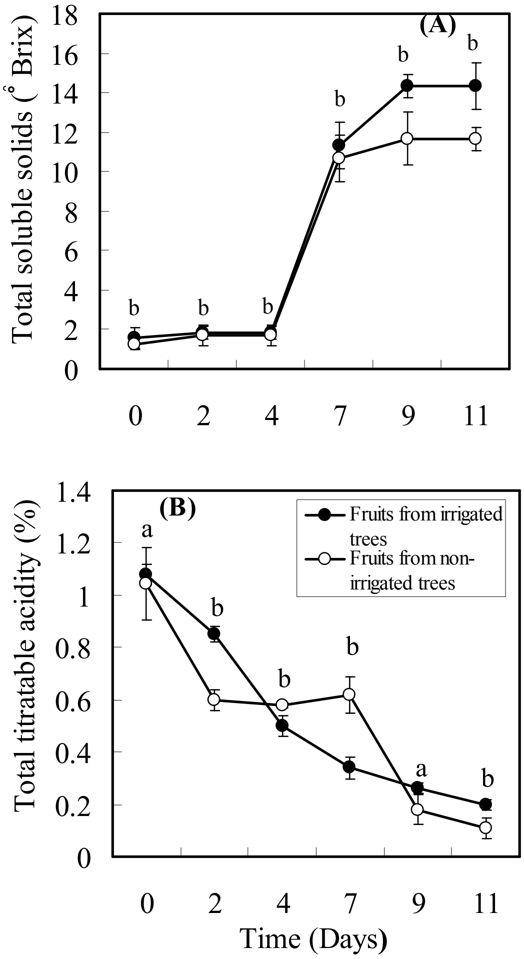


Fig. 1. Percentage weight loss (A) and starch content (B) in fruit from the irrigated and non-irrigated trees during postharvest storage at ambient condition. Vertical bars represent SE of the mean of six replications. When absent, the SE fall within the dimensions of the symbol 'a' denotes a period of no significant difference while 'b' denotes a period of difference between the fruit from irrigated and non-irrigated trees ($p<0.05$).

Fig. 2. Total soluble solids content (A) and total titratable acidity (B) in fruit from the irrigated and non-irrigated trees during postharvest storage at ambient conditions. Vertical bars represent SE of the mean of 18 replications. 'a' denotes a period of no significant difference while 'b' denotes a period of difference between the fruit from irrigated and non-irrigated trees ($p<0.05$).

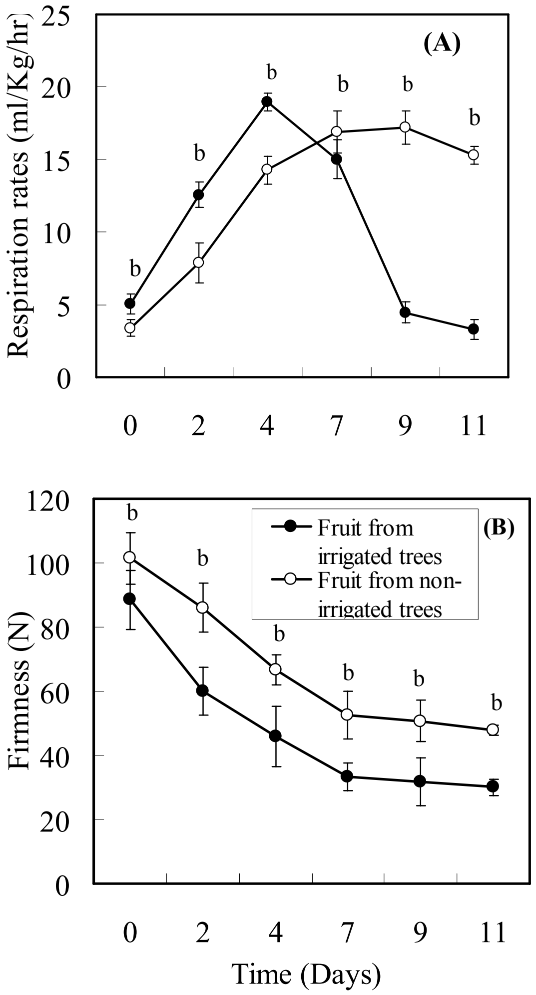


Fig. 3. Respiration rate (A) and firmness (B) in fruit from the irrigated and non-irrigated trees during postharvest storage at ambient conditions. Vertical bars represent SE of the mean of six replications. When absent, the SE fall within the dimensions of the symbol. 'a' denotes a period of no significant difference while 'b' denotes a period of difference between the fruit from irrigated and non-irrigated trees ($p<0.05$).

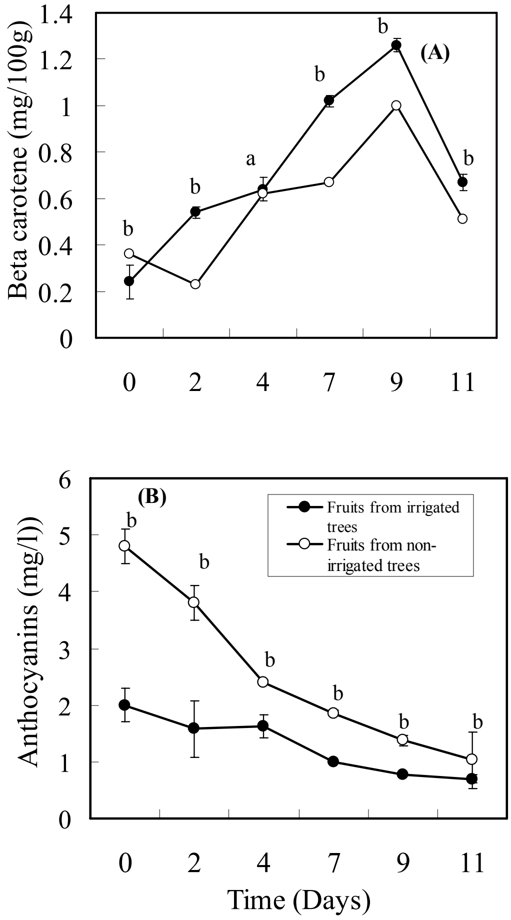


Fig. 4. β-carotene (A) and anthocyanins (B) in fruit from the irrigated and non-irrigated trees during postharvest storage at ambient conditions. Vertical bars represent SE of the mean of three replications. 'a' denotes a period of no significant difference while 'b' denotes a period of difference between the fruit from irrigated and non-irrigated trees ($p<0.05$).