

# Postharvest Quality of Red-fleshed Watermelon Affected by Fruit Position in Vine

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Effect of different fruit position on postharvest quality of F1 hybrid red-fleshed watermelon Hi-U 16 was examined. In this study only one main vine was trained and maintained. The plants were allowed to set three fruits naturally at the first (8<sup>th</sup> – 11<sup>th</sup> nodes), second (13<sup>th</sup> – 16<sup>th</sup> nodes) and third (18<sup>th</sup> – 21<sup>th</sup> nodes) position. Fruits were harvested at 35 days after anthesis. Fruit weight, diameter, skin glossiness, skin and flesh colour, soluble solids concentration, firmness, pH, titratable acidity and vitamin C were determined. Fruit from second position was heavier and larger than fruit at first position followed by third position. Fruit position affected watermelon flesh lightness where flesh of first fruit position was darker than second and third position. Soluble solids concentration and firmness of fruits decreased as fruit position increased. Fruit pH decreased with increasing fruit position order while titratable acidity showed contrary trend. In addition, fruit position had no significant ( $p > 0.05$ ) effect on skin color and glossiness and vitamin C of the fruit. In conclusion, the results indicated that different fruit positions affected postharvest quality of watermelon and the greatest effect was on soluble solids concentration and fruit weight which was the important characteristic for high quality of watermelon.

Abstract

**Keywords:** *Citrullus lanatus* (thunb.), Colour, Fruit position, Postharvest, Soluble solids concentration, Titratable acidity, Watermelon.

## INTRODUCTION

Watermelon, *Citrullus lanatus* (thunb.) Matsum and Nakai, is an annual plant of the cucurbitaceous family. Watermelon is one of the most widely cultivated crops in the world and its global consumption is greater than that of any other cucurbit (Gichimu *et al.*, 2008). It accounts for 6.8% of the world area devoted to vegetable production (Guner and Wehner, 2004; Goreta *et al.*, 2005). Watermelons rank top in Malaysia fruit export. Malaysia exports watermelons to Singapore, Hong Kong, Middle East and Europe. In 2008, Malaysia exported 43,489 ton of watermelon which worth USD 11,962,000.

From a consumer behaviour purchase study found out that good taste is the most important reason for buying a watermelon (Research, 2006). Consumers require minimum soluble solids concentration (SSC) of 10% to indicate the fruit is high quality (Rushing *et al.*, 2001). According to Genard and Bruhou (1992) fruit positioning can affect several aspects of peach quality such as colour and flavor. Pyke *et al.*, (1996) reported that SSC of kiwifruit tended to be higher in fruit from the ends of the leader than in fruit from nearer to the centre of kiwi fruit vine.

Watermelon size is also an important consideration since there are different market requirements for particular groups of shippers and consumers (Rushing *et al.*, 2001). Supermarket in Malaysia prefers fruit of 2-5 kg (Goh personal communication). Fruit out of this size range was sold at lower price in fruit stall near to road side. According to Alan and Eser (2007) fruit weight and diameter of hot pepper were significantly affected by fruit position. In cucumber, fruit position did not affect fruit weight (Marcelis, 1994). Previous study in evaluation of the number and position of watermelon fruits cultivated in a greenhouse showed that the position of the fruit in plant can affect fruit size and SSC (Seabra *et al.*, 2003). In Malaysia, watermelons are mainly planted in open field as intercropping cash crop with oil palm while waiting for young palm to grow up. However, there are some growers plant watermelon as mono crop in open field. Watermelon has never been planted under rain or protected shelter in Malaysia. Growing systems could affect fruit growth and quality as observed in field and greenhouse grown cucumber (Nerson, 2008). Therefore this study was carried out to determine the effect of different positions of field grown watermelon along a vine on fruit quality.

## MATERIALS AND METHODS

### Plant material

The experiment was conducted in University farm (3° 2' N; 101° 42' E) with Serdang series of soil which is fine loamy, kaolinitic and isophyperthermic. The experiment began in March 2010 and end in August 2010 and the average daily maximum and minimum air temperature were 32.8° C and 22.5° C, respectively with average rainfall 250 mm/month. Malaysia is an equatorial country and as a result has a uniform temperature throughout the year. The variation in temperature annually is less than 2°C with average daily relative humidity of 80%.

The watermelon seeds of variety F1 hybrid watermelon Hi-U 16 were sown using peat moss under shade. The seedlings were transplanted into field after 12 days on 1 April 2010. The planting distance was 2.5 m between rows and 1 m between plants. Silvershine plastic mulch was applied to the raised beds. Composted chicken dung (2 t/ha) and bio-organic fertilizer (2 t/ha) were applied before installation of the plastic mulch. NPK 15:15:15 (400 kg/ha) was incorporated into the planting holes after installation of the plastic mulch. Plants were fertilized with NPK 12:12:17:2 (240 kg/ha) during growing season using pocket fertilization. Each plant was given 5 L water per plant per day in non-raining days and watering was not carried out during raining days. The experiment was carried out in a randomized complete block design with four replicate plants per treatment. The plants were grown in four rows of 16 plants. Each row represented a block.

In this fruit positioning experiment, only one vine was trained and maintained. The treatments were represented by three fruit positions and fruit was set on the same vine as follows: (a)

first position, on the 8<sup>th</sup>-11<sup>th</sup> nodes (average vine length was 75 - 100 cm from the main vein); (b) second position, on the 13<sup>th</sup>-16<sup>th</sup> nodes (average vine length was 135 – 150 cm from the main vein); and (c) third position, on the 18<sup>th</sup>-21<sup>th</sup> nodes (average vine length was 250 – 350 cm from the main vein). Pistillate flowers were pollinated naturally and were allowed to develop three fruits per plant at 2 to 3 days interval. All lateral branches and new fruits were continuously removed.

Each fruit was tagged during anthesis and harvested at 35 days after anthesis. Watermelon was harvested by cutting the fruit from the vines using secateurs. After harvesting, the fruits were sent to laboratory. Fruit weight and diameter, skin glossiness, skin and flesh colour, flesh firmness, soluble solids concentration (SSC), pH, titratable acidity (TA) and vitamin C content were determined using total of 48 fruits.

#### **Determination of fruit weight and diameter**

Fruit was weighed using a weighing scale. Then the fruit diameter was measured using a measuring tape at the mid region of the fruits where it was biggest part of the fruit.

#### **Determination of skin and flesh colour**

Skin and flesh colour was determined using Minolta CR-300 Chroma Meter (Minolta Corp., Osaka, Japan) and results were expressed as lightness ( $L^*$ ), chroma ( $C^*$ ) and hue ( $h^\circ$ ). The  $L^*$  values ranging from 0 = black to 100 = white. The  $h^\circ$  is an angle in a colour wheel of 360°, with 0, 90, 180 and 270° representing the hues red, yellow, green and blue, respectively, while  $C^*$  is the intensity or purity of the hue. Measurements at the stem end, mid region and floral end of skin and flesh were made on two faces and a mean value was obtained.

#### **Determination of skin glossiness**

Skin glossiness was measured using a Rhopoint Novo-Curve™ Glossmeter (East Sussex, United Kingdom) and expressed as gloss units (GU) at an angle of 60°. Average of reading at 10 positions along stem end, mid region and floral end of each fruit replicate was taken.

#### **Determination of flesh firmness**

Flesh firmness was evaluated using the Bishop Penetrometer FT 327 (Alfonsine, Italy). The force required for an 11-mm probe to penetrate the cut surface in two opposite locations to a depth of 5 mm was recorded. The penetration force was expressed in kg/cm<sup>2</sup>.

#### **Determination of SSC**

Ten gram of fruit was macerated and the tissue was homogenised with 40 ml of distilled water by using a kitchen blender. The mixture was filtered with cotton wool. A drop of the filtrate was then placed on the prism glass of refractometer (Model N1, Atago Co., Ltd., Tokyo, Japan) to obtain the %SSC. The readings were corrected to a standard temperature of 20°C by adding 0.28% to obtain %SSC at 27°C.

#### **Determination of TA and pH**

The remainder of the juice from the SSC determination was used to measure TA by titrating with 0.1 mol/L NaOH using 1% phenolphthalein as indicator. The results were calculated as a percentage malic acid [(ml NaOH × 0.1 mol/L ÷ weight of sample titrated) × 0.06705 × 100].

The pH of the juice was measured using a glass electrode pH meter model Crison Micro pH 2000 (Crison Instruments, S.A., Barcelona, Spain). The pH meter was calibrated with buffer at pH 4.0 and 7.0 before being used.

### Determination of vitamin C content

Ten gram of watermelon flesh was well homogenized with 3% cold metaphosphoric acid using a kitchen blender. The volume was made up to 100 ml and filtered with cotton wool. Then 5 ml of the aliquot was titrated with 2,6-dichlorophenol-indophenol solution to a pink end-point. The vitamin C content was determined according to Ranganna (1977) method.

### Statistical analysis

Data were analysed using the analysis of variance (SAS Institute, Cary, NC) and means were separated by Duncan's multiple range test at the level of  $P \leq 0.05$ . Correlation analysis by using Pearson's correlation matrix was also performed.

## RESULTS

The weight of fruit increased significantly ( $p \leq 0.05$ ) as fruit position progressed from 1 to 2, then followed by significant decreased ( $p \leq 0.05$ ) as fruit position progressed from 2 to 3 (Fig. 1). The diameter of fruit showed similar trend as fruit weight where it increased then decreased significantly as fruit position progressed from 1 to 2, and 2 to 3, respectively (Fig. 1). The correlation between watermelon fruit weight and its diameter can be confirmed with the significant positive correlation ( $p \leq 0.05$ ) (Table 1).

Skin glossiness of watermelon was not affected by fruit position (Fig. 2). Similar finding was found in skin colour where no significant ( $p \leq 0.05$ ) difference in  $L^*$ ,  $C^*$  and  $h_o$  values was noticed (Fig. 2 and 3). The  $C^*$  and  $h_o$  values of watermelon flesh was not affected by fruit position too, however,  $L^*$  values of flesh showed significant increase ( $p \leq 0.05$ ) throughout fructification, from the first to the third position (Fig. 4).

The firmness of watermelon decreased significantly ( $p \leq 0.05$ ) throughout fructification, from the first to the third position (Fig. 5). The SSC of watermelon also showed similar trend where the concentration decreased significantly as the fruit position progressed far from main vein (Fig. 5). The pH of the watermelon fruit was significantly affected by different fruit position as noted in Figure 6. Contrary to pH, the TA of fruit increased significantly ( $p \leq 0.05$ ) as the node order of the vine increased (Fig. 6). The vitamin C content of watermelon was not affected by fruit position even though there was a decreasing trend as fruit position progressed (Fig. 7).

## DISCUSSION

In this study fruit at second position has heavier weight and larger diameter than other positions. Fukuoka *et al.*, (2009) found out cells in intermediate and outer regions of heavy watermelon were larger and longer than those light fruit. In cherimoya, a contrary finding to this study was reported where fruits at basal position (arising from nodes 1-4) were heavier than other position which arises from nodes beyond 5 (Gonzalez and Cuevas, 2008). Similar finding was also found in hot pepper where fruit weight decreased throughout fructification, from the position near to ground to position further from ground (Alan and Eser, 2007). Fruit position along the shoot are known to affect assimilate movement and fruit growth of kiwi (Pyke and Alspach, 1986; Lawes *et al.*, 1990). The development of a new fruit on a plant that already bears one or more older fruit increases the competition for assimilates and, as older fruits are stronger sinks, this competition mainly reduces growth in the younger fruits. In plant species that shows indeterminate growth, such as watermelon, the buds, flowers and fruits develop progressively on the same plant due to continuous flowering and fructification. Thus, the fruits on a plant compete strongly with each other for the available assimilate (Ali and Kelly, 1992). This competition for available assimilates affects subsequent fruit size.

According to Njoroge and Reighard (2007) source limitation may lead to smaller fruits. Sink strength of growing cantaloupe was related to fruit number on leaf area and photosynthetic

activity of the plant (Valantin *et al.*, 1998). In addition, El-Keblawy and Lovett-Doust (1996) presented corroborating evidence where developing fruit sinks inhibiting new leaf production of melon fruit. Roberts *et al.* (2006) reported any reduction of watermelon plant leaf or leaf area could reduce fruit yield. Most probably the leaf number or area at position 2 of this study was higher than leaf at position 1 and thus producing heavier fruit. Unfortunately in this study leaves area and its photosynthetic activity were not determined to postulate this hypothesis.

The skin glossiness of watermelon was not affected by fruit position indicating the composition and structure of watermelon epicuticular wax at each position are the same. Skin glossiness of watermelon is cultivar-dependant as reported by Corey and Schlimme (1988). In addition to skin glossiness, the skin colour of watermelon was also not affected by fruit position. However, the flesh L\* values of watermelon was affected by fruit position where fruit at first position has the lowest values as compared to other positions. This indicated flesh lightness getting lighter as fruit getting further away from main vein. This will affect consumer preference as consumers buy with their eyes especially when fruits are sold as minimally processed product by exposing flesh colour.

Red-fleshed watermelon is a good source of lycopene which act as an antioxidant by quenching free radicals formed during normal metabolism and may deactivate DNA chain-breaking agents that are implicated in some cancers (Perkins-Veazie and Collins, 2004). They reported that L\* values and lycopene level of fresh-cut watermelon was negatively correlated indicating the darker the flesh colour, the higher the lycopene level. In this study the L\* values of first position watermelon was the lowest and this could indicate lycopene level in first position of watermelon might be highest as compared to other position fruits.

In watermelon the texture and sweetness of edible flesh largely determine fruit quality (Fukuoka *et al.*, 2009). In this study both firmness and SSC of watermelon decreased as the node order of the vine increased. A firm texture of watermelon can also be stored for longer period as it softens much slower than those with low firmness. The high SSC in watermelon was mainly due to the high fructose and sucrose (Fukuoka *et al.*, 2009).

As the fruit-set of watermelon increased from first to third position, the pH decreased significantly ( $p \leq 0.05$ ). A contrary finding was found in TA and both of them were negatively correlated ( $p \leq 0.05$ ) (Table 1). The increase of TA in watermelon as fruit position increased was in agreement with cherimoya (Gonzalez and Cuevas, 2008). This showed that fruit of first and second positions was low in organic acid as compared to the fruit of third position. Organic acids are utilized as respiratory substrates and as carbon skeletons (from their carboxyl groups, -COOH) for the synthesis of new compounds (e.g. flavour compounds) (Zomajski, 1997). High TA in fruit of third position indicates low metabolism and less aromatic as compared to fruit in first and second positions. Watermelon located at third position tend to be smaller and lighter, due to less number of cells and low capacity to compete for photo-assimilates thus leading to low metabolism (Guillaspy *et al.*, 1993). In addition, the pH of watermelon was positively correlated ( $p \leq 0.05$ ) with weight and diameter (Table 1) indicating bigger fruit was less acidic than smaller fruit.

The vitamin C content in red-fleshed watermelon of this study was about 6 mg/100 g fresh weight. As compared to other tropical fruits like papaya and guava, watermelon is not a good source of vitamin C. Both 'Eksoitika' papaya (Ding and Ng, 2008) and 'Kampuchea' guava (Ding and Ong, 2010) contained 20-28 and 40-45 mg vitamin C/100 g fresh weight, respectively.

## CONCLUSIONS

Watermelon position in a vein affected postharvest quality of fruit. The greatest effect was showed in fruit weight and SSC which was the important characteristic for producer and consumer. Sugar content and sweetness were the critical factors in determining the quality of watermelons. In addition, high quality of watermelons should appear heavy for size. Since it is more common

to buy a whole, uncut fruit, consumer often look for one that is heavy for its size. Therefore, it is recommended to train and maintain plant having only 1 to 2 watermelon fruit to be set per vine to get the larger fruit and higher SSC. Leaf area has an important role in fruit development because leaves were the source for fruit. For further study, it is suggested to examine the leaf area and its photosynthetic activity in order to fully characterize the effect of fruit position on quality of fruit.

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## Tables

Table 1. Correlation coefficients (r) for fruit weight, diameter, pH and titratable acidity of watermelon fruits on different positions in a vine.

	<b>Weight</b>	<b>Diameter</b>	<b>pH</b>	<b>Titratable acidity</b>
Weight	--			
Diameter	0.89**	--		
pH	0.50**	0.40*	--	
Titratable acidity	-0.29*	-0.31*	-0.61**	--

n= 48

\*, \*\* significant or highly significant at  $p \leq 0.05$ .



## Figures

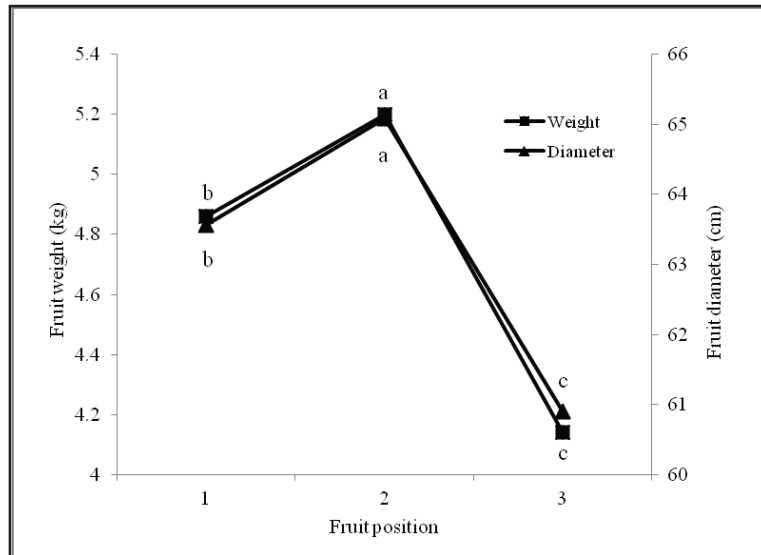


Fig. 1. Effects of fruit position on fruit weight and diameter of watermelon. Means in lines with different letters differ significantly at  $p \leq 0.05$ .

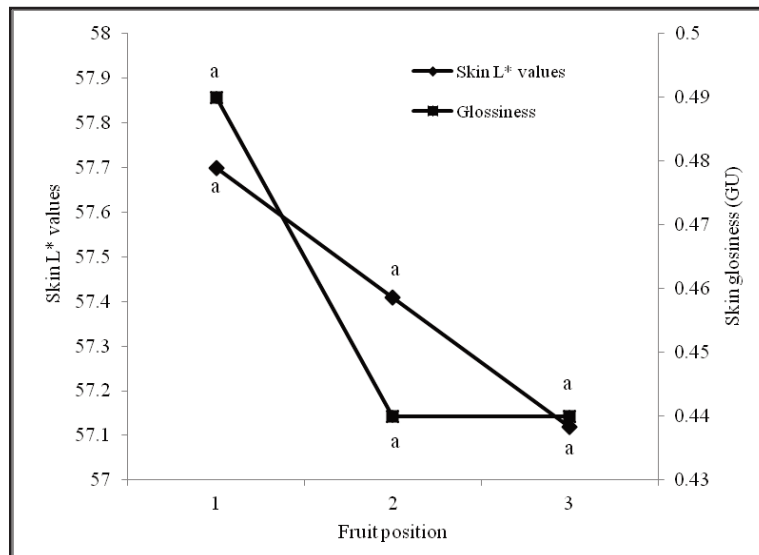


Fig. 2. Effects of fruit position on skin L\* values and glossiness of watermelon. Means in lines with different letters differ significantly at  $p \leq 0.05$ .

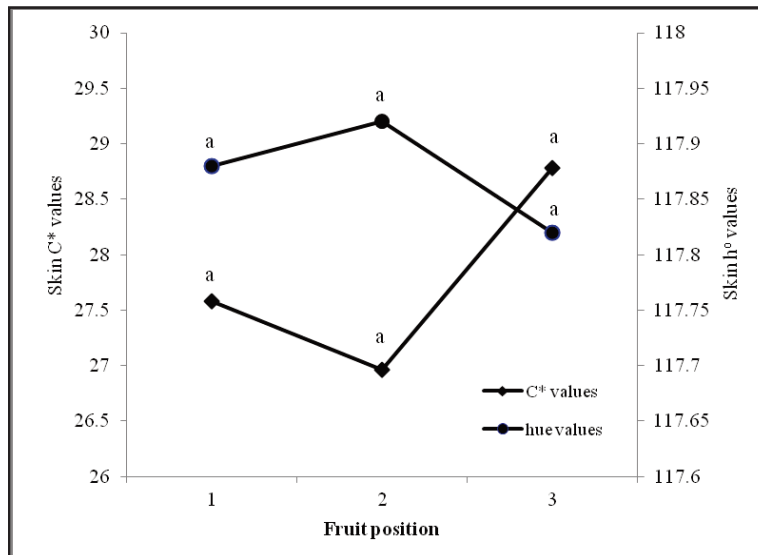


Fig. 3. Effects of fruit position on skin C\* and h° values of watermelon. Means in lines with different letters differ significantly at  $p \leq 0.05$ .

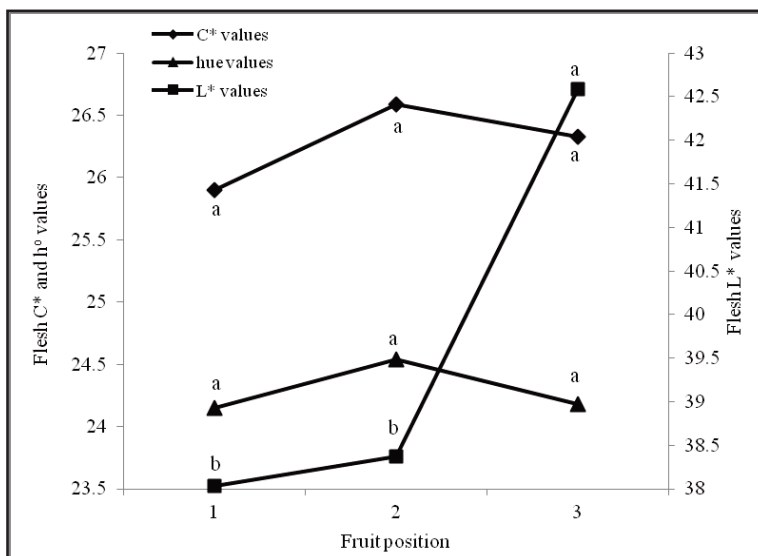


Fig. 4. Effects of fruit position on flesh L\*, C\* and h° values of watermelon. Means in lines with different letters differ significantly at  $p \leq 0.05$ .

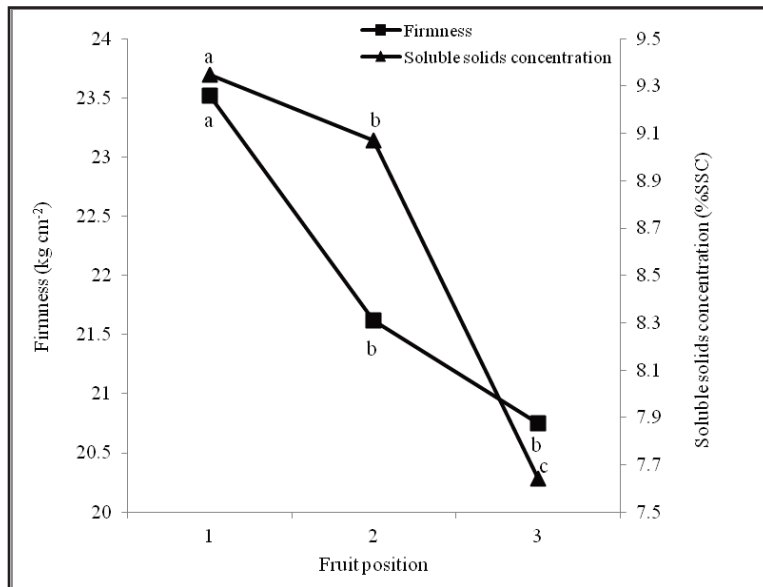


Fig. 5. Effects of fruit position on flesh firmness and soluble solids concentration of watermelon. Means in lines with different letters differ significantly at  $p \leq 0.05$ .

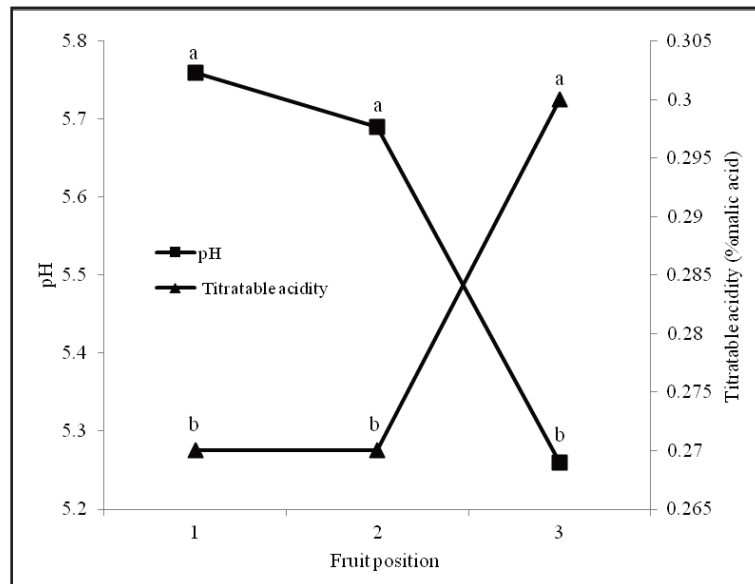


Fig. 6. Effects of fruit position on pH and titratable acidity of watermelon. Means in lines with different letters differ significantly at  $p \leq 0.05$ .

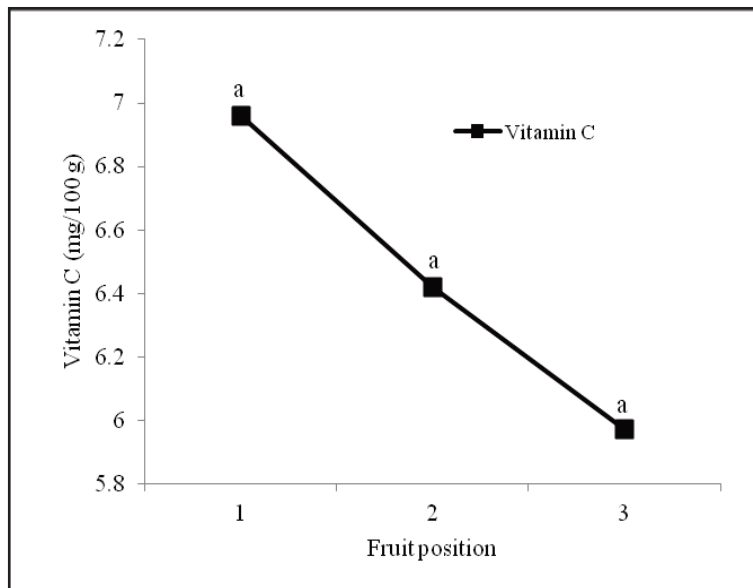


Fig. 7. Effects of fruit position on vitamin C content of watermelon. Means in lines with different letters differ significantly at  $p \leq 0.05$ .