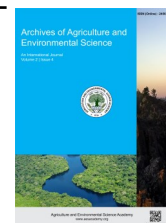




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## ORIGINAL RESEARCH ARTICLE



## Chemical quality attributes of mandarin (*Citrus reticulata* Blanco) as affected by altitude and fruit bearing position in Kavre, Nepal

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\*Corresponding author's E-mail: [kiran\\_freedom@live.com](mailto:kiran_freedom@live.com)**ARTICLE HISTORY**Received: 24 August 2019  
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Mandarin (*Citrus reticulata*)**ABSTRACT**

Mandarin (*Citrus reticulata* Blanco) occupies a prominent position in the total fruit sector of Nepal. A study was conducted to assess chemical quality parameters of mandarin in Kavre district of Nepal, during February 2018. Three altitudes (1410, 1540 and 1670 m.asl) and four bearing positions of fruits (East, West, North, and South) in each tree were taken, from southern facing slope of local mandarin orchard under normal farmer managed practices. Fruits from each sector were scored for TSS, pH, TA and ascorbic acid content. The result showed that the TSS (14.6°Brix), pH (3.37), and TA (0.06%) were recorded higher in the mandarin harvested at an altitude of 1410 m.asl. TSS/TA (23.81) and ascorbic acid content (35.96 mg/100g) were recorded highest in mandarin fruit harvested from 1670 m.asl altitude. Similarly, TSS/TA (21.13) was recorded higher in mandarin on eastern canopy of tree. TA (0.91%) and ascorbic acid content (37.54 mg/100g) were recorded higher in mandarin fruit harvested from western canopy. TSS (15.0°Brix) and pH (3.41) were highest in mandarin of southern canopy. The combined effect of altitude and fruit bearing position had significant effect on pH ( $P = 0.008$ ), TA ( $P = 0.012$ ), TSS/TA ( $P = 0.014$ ) and ascorbic acid content ( $P < 0.001$ ). Mandarins at southern bearing position located at 1540 m.asl and lower altitude were comparatively of good quality than of the upper altitude. Since the main chemical attributes for maintaining quality of mandarin, mandarin located at an altitude of 1540 m.asl followed by mandarin located at 1410 m.asl were promising than mandarin of higher altitude.

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**INTRODUCTION**

The main citrus type grown in Nepal is Mandarin with approximately 64.8% acreage of the total citrus area (40,554 hectare (ha)). The total area under mandarin in Nepal is 26,282 ha with the productive area of 16,248 ha and production of 146,690 Mt (MOAD, 2016). Cultivation of mandarin orange (*Citrus reticulata* Blanco) is one of the major economic activities in the mid-hills (550-1300 m) of Nepal (Lohar, 1995; Shimazaki et al., 2016; Timilsina, 2019). The mid-hill region of Nepal lying between 26° 45" to 29° 40" north latitude and 80° 15" to 88° 12" east longitude is quite suitable for mandarin cultivation (Shrestha and Verma, 1999). Kavre, the mid-hill district of Nepal is important

mandarin orange hub. The total area and productive area in Kavre district were respectively 1,365 ha and 914 ha. The production of Mandarin was 10,962 Mt (MOAD, 2016). It is the most important income generating fruit of Kavre. District earned 450 to 500 million rupees by selling 90-92% of their total production outside the district in 2015/16 (DADO, 2016). Mandarin orange cultivation provides nutrition, employment to the people, acts as source of income and maintains environmental harmony (Dhanraj et al., 1985; Tomiyashu et al., 1998; Timilsina, 2019).

The paramount significance should be given for the production of better quality fruits in the consumer point of preference. The position of the fruit and aspect of the fruit on a particular tree

has considerable influence on the quantity and quality of fruit (Jifon and Syvertsen, 2001). The quality traits of fruits are affected by the number of factors. Among this orientation of the fruit on the tree plays a marvelous role in influencing the quality of the fruit (Rehman *et al.*, 1982; Rehman *et al.*, 1984; Gosh and Mitra, 1990; Underhill and Chadha, 1990; Mitchell *et al.*, 1992; Baidiyala, 1993; Ray and Munshi, 1990). Mandarin orange grown at higher altitudes of Kavre district is not as good regarding quality as they are in lower altitudes (Shrestha and Shrestha, 1999). Fruit quality is mainly determined by fruit color, fruit size, juice content (%), total soluble solids (TSS), titratable acidity (TA) and the total soluble solids (TSS): TA ratio (Yakushiji *et al.*, 1998; Verreyne *et al.*, 2004). Environmental factors such as light and temperature will influence citrus juice quality concerning TSS (Levy *et al.*, 1978; Erez *et al.*, 1986; Olabinjo *et al.*, 2017).

Differences in TSS are associated with positional differences in canopy micro-climate and exposure to light and temperature individual fruit (Sites and Reitz, 1950; Lawallen and Marini, 2003; Schrader *et al.*, 2003). All quality is influenced by factors such as fruit size, harvest date, position in the tree, rootstocks and climatic conditions. Each of these factors contributes to the variation in quality among fruit from same tree (Fishler *et al.*, 1983; Timilsina, 2019). Fruit from the southern side (northern hemisphere) of the tree had lower juice content (%) than from the northern side of the tree (Cohen, 1998). Orange from southern canopy sectors (northern hemisphere) tends to have higher concentrations of soluble solids (Syvertsen and Albrigo, 1980). The microclimatic conditions such as the level and intensity of light or the higher temperatures to which fruits are exposed results to more advanced (TSS: TA ratio) (Kimball, 1984; Timilsina, 2019). The study aims was to determine chemical quality differences of mandarin between the fruit from different bearing positions of tree canopy at different altitudes of Kavre, Nepal.

## MATERIALS AND METHODS

### Site selection

The study on the effect of altitude and fruit bearing positions on fruit quality attributes was conducted at three villages viz., Sharadhabatashe, Eklekhent and Sankhu of Kavre district during 2018. In these villages location were identified based on altitudes (around 1410 meter above sea level (m.asl), around 1540 m.asl and around 1670 m.asl) with four fruit bearing positions (viz. East, West, North, and South) were taken for evaluation. Southern facing local mandarin tree with uniform size, age, vigor and under common farmer management were selected by Global Positioning System (GPS) and were marked.

### Sample collection

Forty eight fruits representing the single tree (12 from each bearing positions (4 fruits at 50 cm interval height from inner canopy to outer canopy)) were collected and a replica containing 4 mandarins of each bearing positions were packed in sealed

plastic bags and collected for physiochemical analysis. Fruits were harvested in first week of February.

### Quality attributes assessment

Different chemical parameters i.e. TSS, TA, pH and ascorbic acid content were scored. TSS was measured by hand held refractometer, pH was measured by digital pH meter at 27°C and TA and ascorbic acid were measured as per the methods outlined in AOAC (2016).

### Statistical analysis

The data were recorded, tabulated in MS Excel and statistically analyzed using GenStat following the methods mentioned by Gomez and Gomez (1984).

## RESULTS AND DISCUSSION

### Effects of altitude and fruit bearing position on chemical properties of mandarin

#### TSS

The higher TSS (14.6°Brix) was observed in mandarin at an altitude of 1410 m.asl and lower (14.2°Brix) was observed in mandarin at an altitude of 1670 m.asl; which were no significantly different. In general trend with the advancement of altitude TSS was found to be decreasing. The highest TSS (15.0° Brix) was observed in mandarin fruit at southern bearing position and lowest TSS (14.0° Brix) was observed in mandarin fruit harvested from western canopy but they were significantly indifferent. This findings coincide with the findings of Rehman *et al.* (1982) who reported non significant results for the traits under consideration for the orientation factor. The treatment effect of the increase of SSC in the present study may be attributed to the smaller fruit size. Smaller fruits tend to have higher soluble sugar content (SSC) (Albrigo, 1978). The influence of fruit position seemed to have little influence on TSS. The response is probably related to microclimatic conditions such as the amount of light and higher temperature to which different canopy positions are exposed. Higher CO<sub>2</sub> assimilation rates, higher leaf to fruit ratio, and efficient transport of photosynthetic products to fruit in external canopy positions; and/or that fruit from internal canopy positions are closer to the main limbs (main xylem tissue) may receive more water, resulting in more dilution in SSC compared to the external fruit, might account for higher SSC of fruit from external canopy positions. Also temperatures of sun exposed leaves are usually above air temperature, and 90% of irradiance on a clear day is absorbed in the outer 1m of the canopy depth of mature orange tree (Green and Gerber, 1967). Thus the core temperature of the canopy is lower than outer canopy positions in accumulating SSC in fruit. No significant effect of fruit position was observed on total sugar content in 'Kinnow' mandarin (Khalid, 2012). Citrus fruit harvested from the southern top canopy position had higher TSS (Izumi *et al.*, 1990).

In a finding from Sites and Reitz (1950); a trend to higher soluble

solids in the top of tree as compared to the lower part of the tree. Fruit classified as inside fruit had considerably lower value of TSS. The fruits taken from north - northeast section of the trees were lower in soluble solids than fruits taken from any other sectors of the tree. There was gradual but definite increase in the average soluble solids value toward the south side of the tree, where soluble solids value are generally equally high.

### pH

The altitude had no significance effects on pH of mandarin juice (Figure 2). The highest pH (3.37) was observed in mandarin fruit harvested from an altitude of 1410 m.asl followed by mandarin harvested from an altitude of 1670 m.asl (3.35) and least pH (3.23) was observed in the juice of mandarin fruit harvested from 1540 m.asl. These results were insignificantly different. Similarly, the bearing position of fruit had no significant effects on pH of juice. The highest pH (3.41) was observed in mandarin harvested from southern bearing position and least pH (3.24) was observed in the juice of mandarin fruit at western and northern bearing position but was significantly indifferent. A comparison among the studied mandarin trees on fruit quality

was made for fruit harvested from Dhulikhel, where all mandarin tree might have received different cultivation practices because of which a contrasting result obtained before may have been obtained. The measurement of pH has been found to yield useful information for quality control in the production of citrus juice products (Kilburn, 2002).

### Titrateable acidity

The altitude had very high significant ( $P \leq 0.001$ ) effect on TA of mandarin (Figure 4). The maximum TA (1.06%) of juice was obtained in mandarin fruit harvested from an altitude of 1410 m.asl. The minimum TA (0.63%) of the juice was observed in mandarin fruit at an altitude of 1670 m.asl. In general trend TA was found to be decreasing with the increase in altitude significantly. The fruit bearing position had no significant influences on titrateable acidity of juice. The highest TA (0.91%) was observed in juice extracted from mandarin fruit harvested from western bearing position followed by mandarin juice extracted from fruit harvested from northern bearing position (0.90%). The lowest TA (0.74%) of the juice was obtained from mandarin harvested from eastern bearing position. These results were insignificantly different.

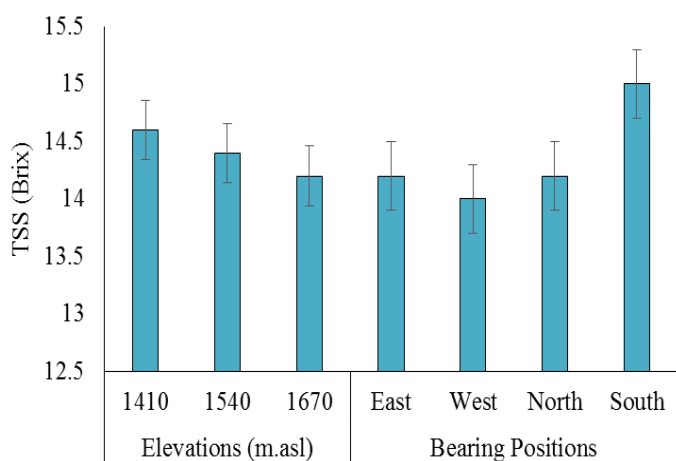


Figure 1. Effect of altitude and bearing position on TSS of mandarin in Dhulikhel, Kavre, 2018.

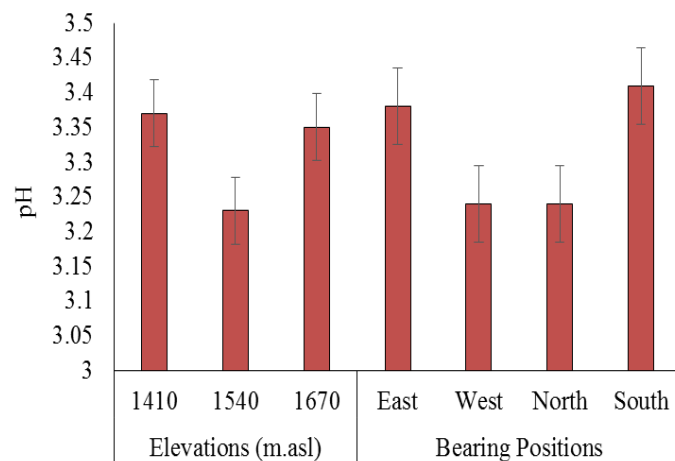


Figure 2. Effect of altitude and bearing position on pH of mandarin in Dhulikhel, Kavre, 2018.

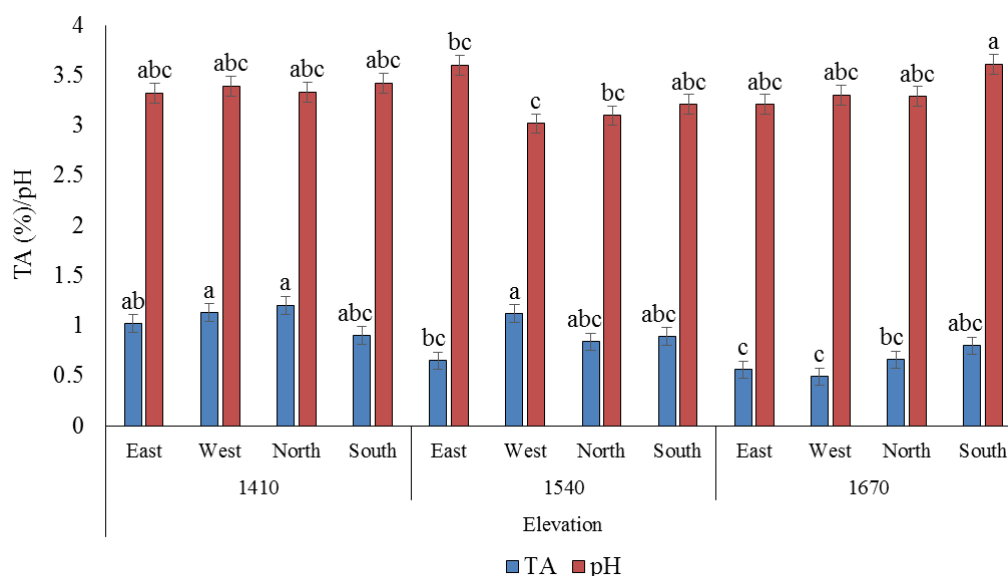
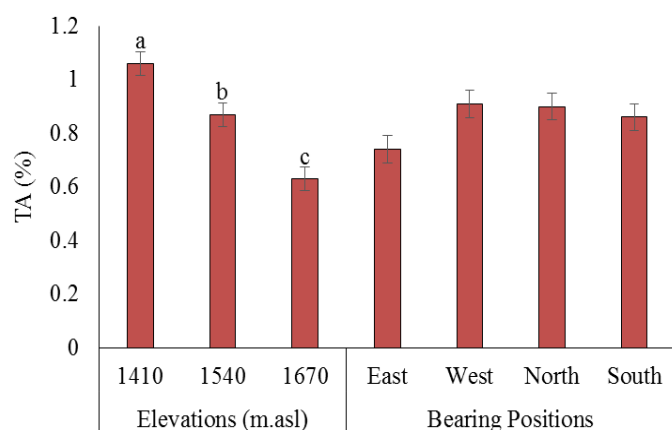
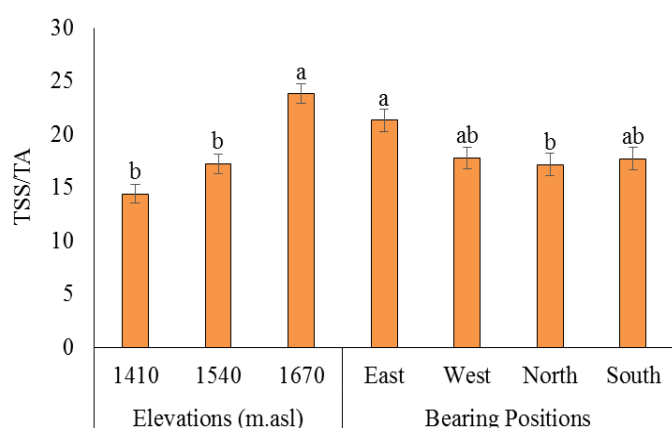


Figure 3. Interaction effect of altitude and bearing position on TA and pH of mandarin in Dhulikhel, Kavre, 2018.

The results are in agreement with those found in the cactus pear fruit grown in different locations of South Africa (de Wit *et al.*, 2010). These authors showed that altitude was responsible for low rated acidity. Similarly, pomegranates cultivated in low altitude were more acids than fruits harvested from elevated zone leading to delayed maturity (Shulman *et al.*, 1984). Organic acid rates in the fruit are sensitive to altitude level (Trad *et al.*, 2013). In citrus citric acid was the predominant organic acid influenced by altitude in altitude. Citric acid that contributes for augmenting TA, is found slightly more concentrated in fruit situated in low sunlight perceptible area in previous researches (Datio and Tominaga, 1981). In findings from Sites and Reitz (1950); on the average acidity of inside fruit and top inside fruit increased with height, but acidity decreased with height of outside and top outside fruit. The difference in the acidity between inside, outside, and canopy fruit were also small, and failed to account for much of the variation in acidity. Direction of exposure to light was found to have some relationships to the level of acidity in the juice of fruit. The east section of the tree was considerably lower in acidity than any of the other sectors. The results obtained in this experiment are in variation with many of the findings before. It might be due to the fluctuated environmental components as well as fruit production units applied in the sample undertaken. In most of the experiment done before the highest altitude considered is lowest altitude in this experiment. The variation in the result might be due to the highest altitude and farmer management practices for each tree.



**Figure 4.** Effect of altitude and bearing position on TA of mandarin in Dhulikhel, Kavre, 2018.



**Figure 5.** Effect of altitude and bearing position on TSS/TA of mandarin in Dhulikhel, Kavre, 2018.

### Interaction effect of altitude and bearing position on TA of mandarin

The perusal from the data shown in Figure 3, the significant effect of altitude and bearing position of fruit was found on titratable acidity of mandarin fruit. The organic acids mainly citrus acids in citrus are the reserve source of energy (Rokaya *et al.*, 2016). The titratable acidity (TA) measured as percentage of citric acids was found highest (1.20%) in mandarin fruit of northern canopy at 1410 m.asl followed by mandarin fruit in western canopy at the same altitude (1.13%). The lowest titratable acidity (0.49%) was recorded in mandarin fruit of western bearing position of the canopy at 1670 m.asl followed by mandarin fruits in eastern canopy at the same altitude. The total acids in the fruits are negatively co-related to sunlight exposure (Robinson, 1983).

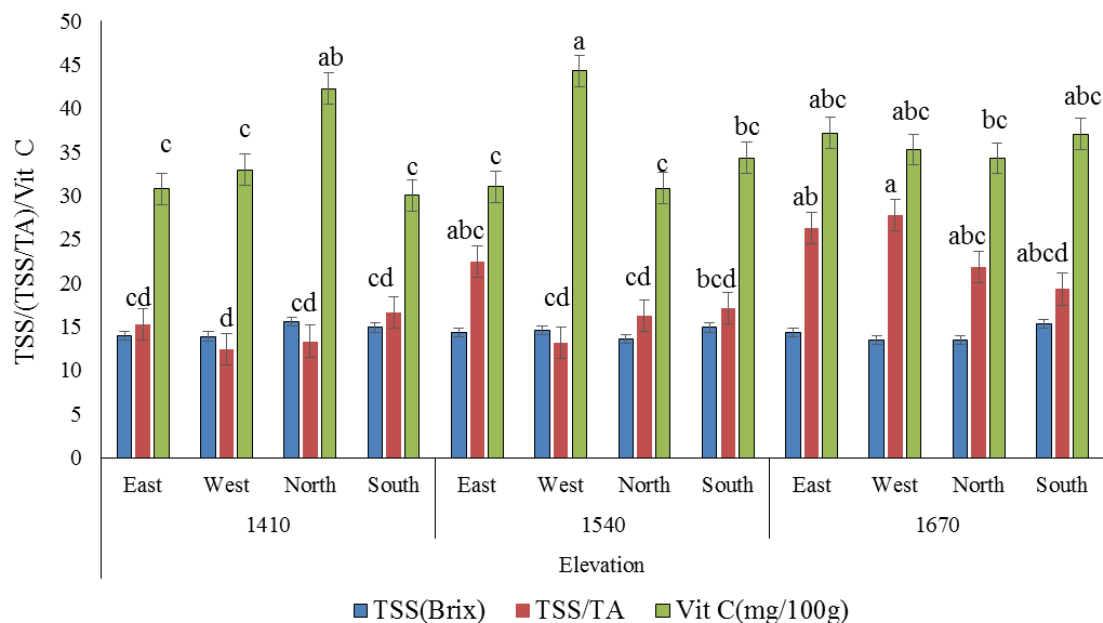
### TSS/TA

TSS/TA ratio reflects the proper blending of sugar and acid in the fruits. This is one of the important criteria standardizing fruits for consumer's acceptance. The TSS/TA was highly and significantly ( $P \leq 0.001$ ) affected by altitude (Figure 5). The highest TSS/TA ratio (23.81) was observed in juice of mandarin fruit harvested from an altitude of 1670 m.asl. The lowest TSS/TA ratio (14.43) was observed in juice of mandarin fruit harvested at an altitude of 1410 m.asl followed by fruit harvested at an altitude 1540 m.asl (17.24). In general, TSS/TA ratio was found to be increasing significantly with advancement of altitude. The fruit bearing position had significant effect ( $P = 0.038$ ) on TSS/TA ratio of mandarin juice. The highest TSS/TA ratio (21.33) was observed in mandarin fruit harvested from eastern bearing position of tree canopy. The lowest TSS/TA ratio (17.16) was observed in mandarin fruit harvested from northern bearing position. The intermediate result was found in mandarin fruit harvested from southern bearing position (17.78) and western bearing position (17.78).

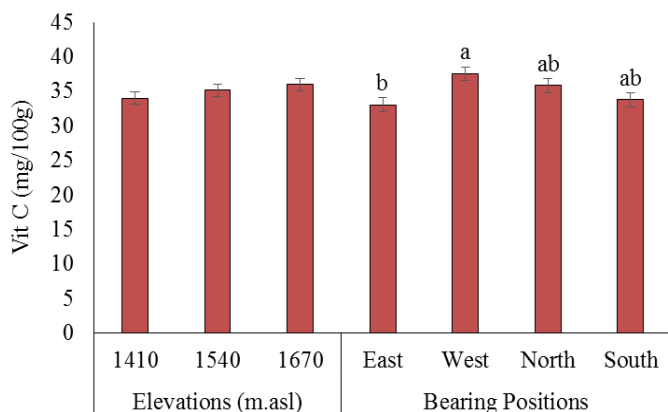
In findings from Sites and Reitz (1950); soluble solids/ acid ratios increased consistently with increase in height of the fruit from the lower canopy to the outer canopy. The increase in ratio with increase in height, occurred in all the light classes about equally, though in the top outside and top inside classification the ratio increased more rapid rate than in the other light classifications. The trend was most pronounced in the north part of the tree. No difference in SSC/TA had been found in 'Spring Navel' orange subjected to semi shading, full shading or full sun (Harrison *et al.*, 2013).

### Interaction effect of altitude and bearing position on TSS/TA of mandarin

The perusal from the data shown in Figure 6, the significant effect of altitude and bearing position of fruit was found on ratio of TSS to TA of mandarin fruit. TSS/ TA ratio is considered to be one of the most reliable chemical properties of fruits. This ratio specifies the relation between sweetness to tartness (USDA, 1944). The TSS-TA ratio was observed maximum (27.78) in the fruits of western canopy at 1670 m.asl followed by mandarin



**Figure 6.** Interaction effect of altitude and fruit bearing position on TSS, TSS/TA and ascorbic acid content of mandarin in Dhulikhel, Kavre, 2018.



**Figure 7.** Effect of altitude and bearing position on ascorbic acid content of mandarin in Dhulikhel, Kavre, 2018.

fruits in eastern canopy at same altitude (26.29). The minimum TSS-TA ratio (12.42) was found in mandarin fruit along western canopy at an altitude 1410 m.asl followed by mandarin fruit in western bearing position at 1540 m.asl (13.12).

### Ascorbic acid

The altitude had no significant effects on ascorbic acid content in the juice of mandarin (Figure 7). Highest ascorbic acid content (35.96 mg/100 g) was observed in juice of mandarin at an altitude of 1670 m.asl and least ascorbic acid content (34.02mg/100g) was observed in mandarin at an altitude of 1410 m.asl that were statistically insignificant at 5% level of significance. In general trend ascorbic acid content was found to be increasing insignificantly with an increasing altitude. The fruit bearing position had significant effect ( $P = 0.022$ ) on ascorbic acid content. The highest ascorbic acid content (37.54mg/100g) was recorded in mandarin fruit harvested from western bearing position of tree canopy. The lowest ascorbic acid content (33.01mg/100g) was observed in mandarin fruit harvested from eastern bearing position of tree canopy. The intermediate ascorbic acid content was observed in northern bearing position (35.82mg/100g) and southern bearing position (33.81mg/100g).

In findings from Sites and Reitz (1950); highest value of ascorbic acid were found in the top outside fruit. The east part of the fruit had the lowest values. The result obtained in this experiment are in confirmation with this findings. In regards to ascorbic acid; sun exposed peel had significantly higher concentration than peels of shaded region (wang Ma and Cheng, 2004). The exposure of shaded peel to full sunlight led to an up regulation of the ascorbate glutathione cycle, which is an important pathway for the recycling of ascorbic acid (Ishikawa *et al.*, 2006).

### Interaction effect of altitude and fruit bearing position on ascorbic acid content of mandarin

The interaction effect of altitude and fruit bearing position on ascorbic acid content of mandarin fruit was found very highly significant (Figure 6). Vitamin C was found higher (44.76mg/100g) in the fruits of western canopy at 1540 m.asl followed by mandarin fruit located along northern canopy at an altitude of 1410 m.asl (43.24mg/100g). The lower ascorbic acid content (27.03mg/100g) was observed in mandarin fruit in southern canopy at 1410 m.asl followed by mandarin fruit in northern bearing position at an altitude of 1540 m.asl (30.48mg/100g).

### Conclusion

The microclimatic differences affect the composition of fruits as different biochemical pathways are responsive to light and temperatures. The pronounced differences in fruit quality are related to their position of fruit within the tree. The difference in chemical properties of mandarin is probably related to microclimatic condition such as amount of light and higher temperatures to which different bearing positions are exposed at each altitude. The influence of fruit position seemed to have major impact on TSS/TA ratio ( $P=0.038$ ), ascorbic acid content ( $P=0.022$ ) and less impact on pH, TSS and TA of mandarin.



Similarly different altitudes seemed to have major impact on TSS/TA ratio ( $P < 0.001$ ) and TA ( $P < 0.001$ ) and less influence on TSS, pH and ascorbic acid content of juice. The interaction effect of both altitude and bearing position was pronounced in pH ( $P = 0.008$ ), TA ( $P = 0.012$ ), TSS/TA ( $P = 0.014$ ) and ascorbic acid content ( $P < 0.001$ ). Therefore, considering the main chemical attributes for maintaining quality of mandarin, mandarin located at an altitude of 1540 m.asl followed by mandarin located at 1410 m.asl were promising than mandarin of higher altitude.

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