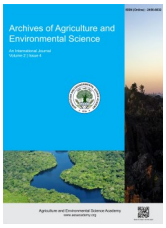
Archives of Agriculture and Environmental Science 4(3): 319-325 (2019)
https://doi.org/10.26832/24566632.2019.0403010

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: www.aesacademy.org



ORIGINAL RESEARCH ARTICLE

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

Kiran Timilsina* and **Kalyani Mishra Tripathi**

Department of Horticulture, Agriculture and Forestry University, Rampur, Chitwan, NEPAL
*Corresponding author's E-mail: kiran_freedom@live.com

ARTICLE HISTORY

Received: 24 August 2019
Revised received: 01 September 2019
Accepted: 06 September 2019

Keywords

Altitudinal effects
Chemical quality
Fruits bearing position
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.

Citation of this article: Timilsina, K. and Tripathi, K.M. (2019). Chemical quality attributes of mandarin (*Citrus reticulata* Blanco) as affected by altitude and fruit bearing position in Kavre, Nepal. *Archives of Agriculture and Environmental Science*, 4(3): 319-325, https://dx.doi.org/10.26832/24566632.2019.0403010

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; Verreynne *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_2 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 tan 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).

Titratable acidity

The altitude had very high significant (*P≤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 titratable 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.

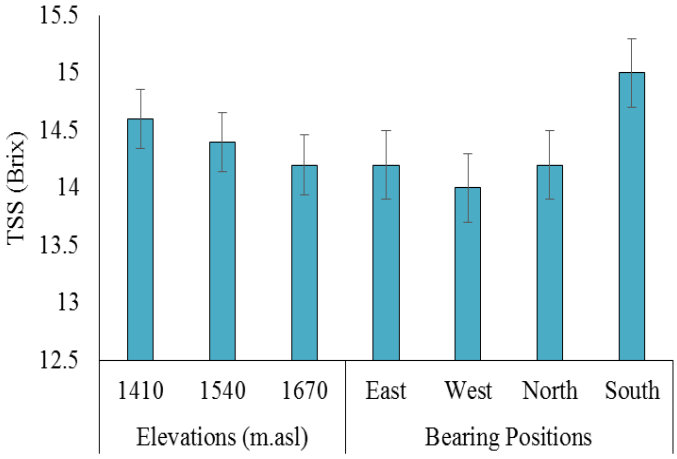


Figure 1. *Effect of altitude and bearing position on TSS of mandarin in Dhulikhel, Kavre, 2018.*

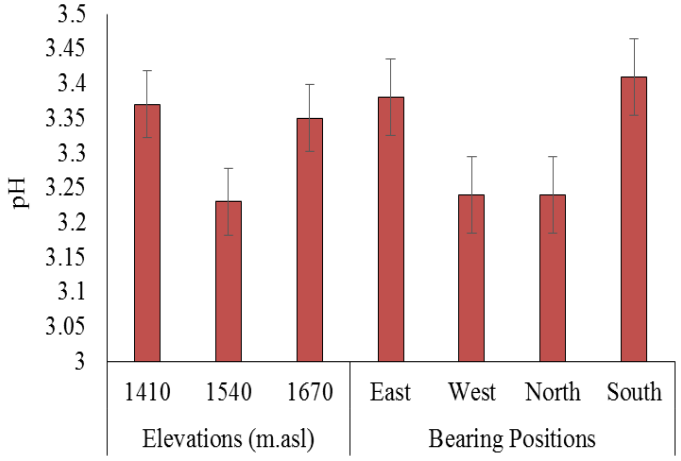


Figure 2. *Effect of altitude and bearing position on pH of mandarin in Dhulikhel, Kavre, 2018.*

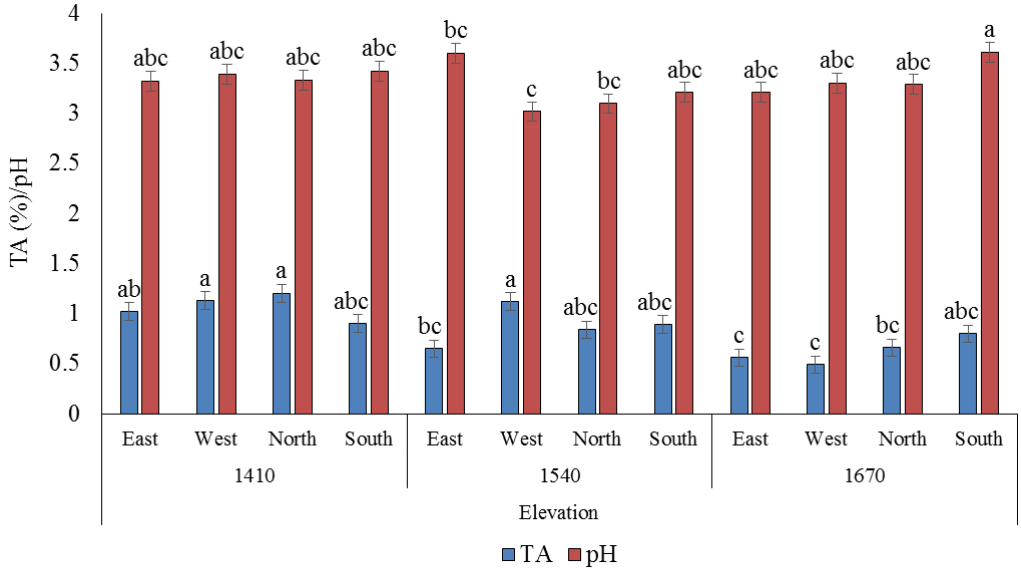


Figure 3. *Interaction effect of altitude and bearing position on TA and pH of mandarin in Dhulikhel, Kavre, 2018.*

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 perceptive 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.

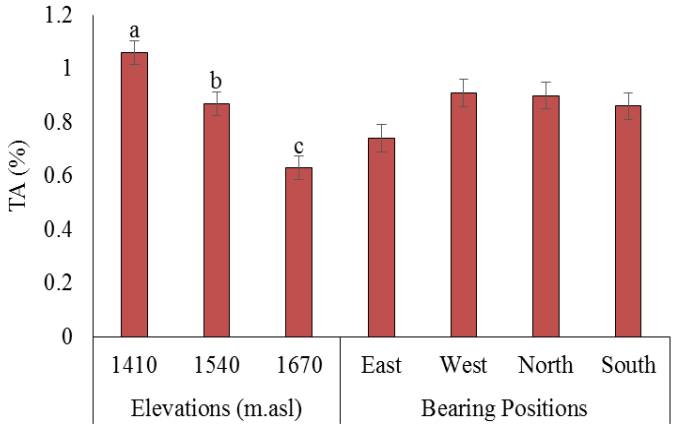


Figure 4. *Effect of altitude and bearing position on TA of mandarin in Dhulikhel, Kavre, 2018.*

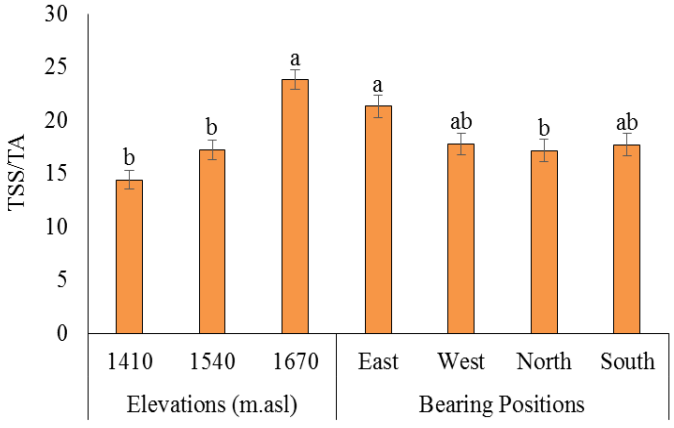


Figure 5. *Effect of altitude and bearing position on TSS/TA of mandarin in Dhulikhel, Kavre, 2018.*

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

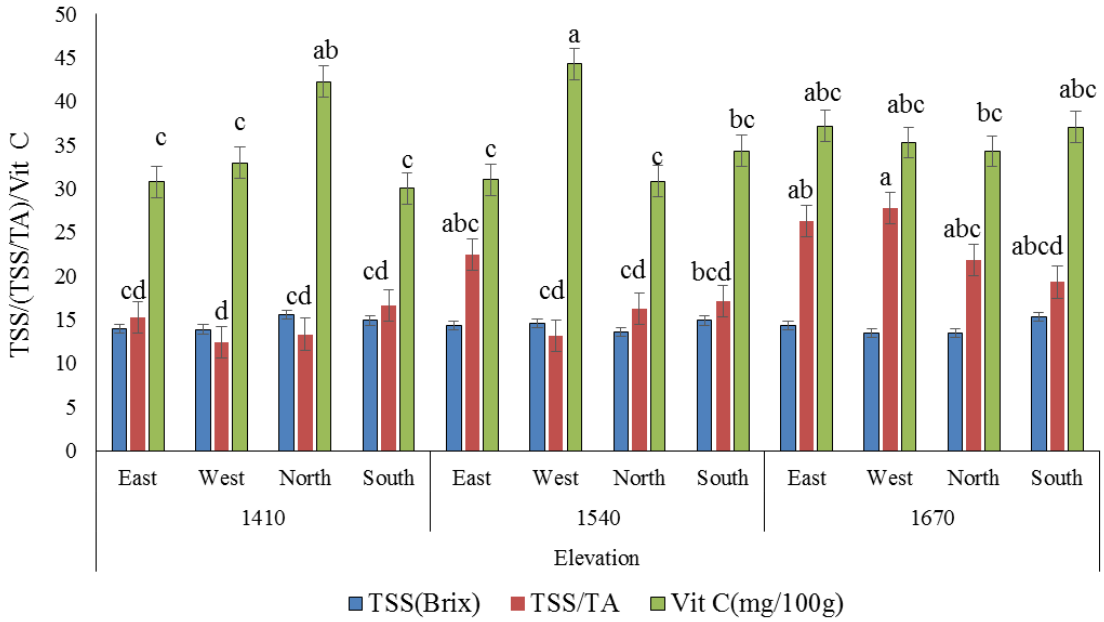


Figure 6. *Interaction effect of altitude and fruit bearing position on TSS, TSS/TA and ascorbic acid content of mandarin in Dhulikhel, Kavre, 2018.*

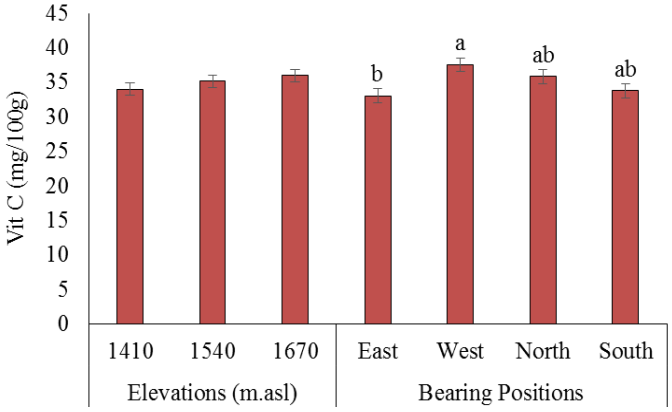


Figure 7. *Effect of altitude and bearing position on ascorbic acid content of mandarin in Dhulikhel, Kavre, 2018.*

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.

ACKNOWLEDGEMENTS

The authors are thankful to Food Research Division of NARC, Prime Minister Agriculture Modernization Project (PMAMP), Agriculture and Forestry University (AFU) and DADO, Kavre for the support provided for carrying out this research and for their co-operation.

REFERENCES

Albrigo, L.G. (1978). Rootstock affect 'Valencia' orange fruit quality and water balance. *Citrus Industry*, 59(9): 31.

AOAC. (1995). Official Methods of Analysis (16 ed.). Washington DC: Association of Official Analytical Chemists.

Baidiyala, S. D. (1993). Maturity standard for Muzaffarpur litchi fruits. *South Indian Horticulture*, 223-224.

Cohen, E. (1998). The chemical composition and sensory flavour quality of 'Minneola' tangerines I. Effects of fruit size and within tree position. *Journal of Horticulture Science*, 63(1): 175-178, https://doi.org/10.1080/14620316.1988.11515844

DADO, K. (2016). Yearly Agriculture development Programme and Statistics 2015/16. Kavre: District Agriculture Development Office.

Datio, H. and Tominaga, S. (1981). Organic acids and amino acids in the juice of fruit at various locations within the canopies of differently trained Satusma trees. *Journal of Plant Nutrition*, 12: 523-534.

de Wit, M., Nel, P., Osthoff, G. and Labuschagne, M.T. (2010). The effect of variety and loca-tion on Cactus Pear (*Opuntia ficus-indica*) fruit quality. *Plants Food for Human Nutrition*, 65(2): 136-145, https://doi.org/10.1007/s11130-010-0163-7

Dhanraj, S., Krishnaprakash, M.S., Arvindaprasad, B., Ananthakrishna, S.M., Krishnaprasad, C.A. and Narasimham, P. (1985,). Effect of orchard elevation on maturity and quality of apples. *Journal of Food Quality*, 9(3): 129-142, https://doi.org/10.1111/j.1745-4557.1986.tb00783.x

Erez, A. and Flore, J.A. (1986). The qualitative effect of solar radiation on 'Redhaven' peach fruit skin color. *HortScience*, 21: 1424-1426.

Fishler, M., Goldschimt, E.E. and Monselise, S.P. (1983). Leaf area and fruit size on girdled grapefruit branches. *Journal of American Society of Horticulture Science*, 108(2): 218-221.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research (2nd Ed). John Wiley & Sons, New York. pp. 28-192.

Gosh, B. and Mitra, S. K. (1990). Effects of varying level of nitrogen, phosphorous and potassium on yield and quality of litchi (*Litchi chinensis* Sonn. I cv. *Bombai*. *Haryana Journal of Horticulture Science*, 19:1-2.

Green, B. A. and Gerber, J. F. (1969). Radiant energy distribution in Citrus trees. *Proceedings of American Society of Horticulture Science*, 90: 77-85.

Harrison, M.R., Spiers, J.D., Coneva, E.D., Dozier, W. and Woods, F.M. (2013). Orchard design influences fruit quality, canopy temperature, and yield of Satsuma mandarin (*Citrus unshiu* 'Owari'). *International Journal of Food Science*, 13(3): 334-344, https://doi.org/10.1080/15538362.2013.748376

Ishikawa, T., Dowdle, J. and Smirnoff, N. (2006). Progress in manipulating ascorbic acid biosynthesis and accumulation in plants. *Physiologia Plantarum*, 126(3): 343-355, https://doi.org/10.1111/j.1399-3054.2006.00640.x

Izumi, H., Ito, T. and Yoshida, Y. (1990). Changes in quality during storage of *Citrus unshiu* fruit according to fruiting position of inner and outer canopies. *Journal of Horticultural Society*, *58*(4): 885-893, https://doi.org/10.2503/jjshs.58.885

Jifon, J. L. and Syvertsen, J. P. (2001). Effects of moderate shade on citrus leaf gas exchange, fruit yield, and quality. *Proceedings of the annual meeting of the Florida State Horticultural Society*, 114: 177-181.

Kilburn, R.W. (2002). Relationship between brix, acid and pH. The Taste of Citrus Juice. *71*, pp. 251-254. Lake Wales: Florida State Horticultural Society.

Kimball, D.A. (1984). Brix/acid ratio correlation with climatic data for California navel and Valencia oranges [Titratable acidity measured as citric acid, sugar and acid balance]. *Citrus Industry*, 26-29.

Levy, Y., Bar-Akiva, A. and Vaadia, Y. (1978). Influnce of irrigation and environmental factors on grapefruit acidity. *Journal of American Society of Horticulture Science*, 103(1): 73-76.

Lewallen, K.S. and Marini, R.P. (2003). Relationship between flesh firmness and ground colour in peach as influenced by light and canopy position. *Journal of the American Society for Horticulture Science*, 128(2): 163-170, https://doi.org/10.21273/JASHS.128.2.0163

Lohar, D.P. (1995). Orchard soil moisture conservation and fruit drop studies in mandarin orange (*Citrus reticulata* Blanco) at LARC during 1991/92. [English].". LARC Working Paper (Nepal). no. 95/14.

Mitchell, G. E., McLauchlan, R. L., Isaacs, A. R., Williams, D. and Nottingham, S. M. (1992). Effect of low dose irradiation on composition of tropical fruits and vegetables. *Journal of Food Composition and Analysis*, 5(4): 291-311, https://doi.org/10.1016/0889-1575(92)90063-P

MOAD. (2016). *Statistical Information on Nepalese Agriculture*. Kathmandu, Nepal: Government of Nepal, Ministry of Agriculture Development, Agribusiness Promotion and Statistics Division.

Olabinjo, O.O., Ogunlowo, A.S., Ajayi, O.O. and Olalusi, A.P. (2017,). Analysis of physical and chemical composition of sweet orange (*Citrus sinensis*) peels. *International Journal of Environment, Agriculture and Biotechnology*, 2(4): 2201-2206, https://doi.org/10.22161/ijeab/2.4.80

Ray, D.P. and Munsi, P.S. (1990). A note on qualitative parameters and its association with leaf and soil nutrients litchi (*Litchi chinensis* Sonn.). *Orissa Journal of Horticulture*, 18(1-2): 80-85.

Rehman, S., Ahmad, I., Ghafoor, A. and Baloch, A. K. (1982). Quality of sweet oranges (*Citrus sinensis*) as influenced by the fruit orientation on the tree. *Pakistan Journal of Science*, 65-70.

Rehman, S., Baloch, A.K. and Ghaffor, A. (1984). The quality of sweet oranges (*Citrus sinsensis*) as influenced by exposure of sunlight. *Journal of Pure Applied Science*, 3: 1-5.

Robinson, T.L. (1983). Effect of light environment and spur age on 'Delicious' apple fruit size and quality. *Journal of American Society of Horticulture*, 108(5): 855-861.

Rokaya, P.R. (2017). *Effect of altitude and various and postharvest factors on quality and shelf life of mandarin (Citrus reticulata* Blanco*)*. Rampur, Chitwan, Nepal: Agriculture and Forestry University.

Rokaya, P.R., Baral, D.R., Gautam, D.M., Shrestha, A.K. and Paudyal, K.P. (2016). Effect of altitude and maturity stages on quality attributes of mandarin (*Citrus reticulata* Blanco). *American Journal of Plant Sciences*, 7, 958-966, https://doi.org/10.4236/ajps.2016.76091

Schrader, L., Zhang, J. and Sun, J. (2003). Environmental stress that cause sunburn of apple. *Acta Horticulture*, 618: 397-405.

Shimazaki, M. and Nesumi, H. (2016). A method for high quality citrus production using drip irrigation and plastic sheet mulching. *Japan Agricultural Research Quarterly: JARQ*, 50(4): 301-306, https://doi.org/10.6090/jarq.50.301

Shrestha, G.P. and Shrestha, G.K. (1999). An overview of fruit growing in Nepal. *Nepalese Horticulture*, 3: 36-40.

Shrestha, P.P. and Verma, S.K. (1999). Development and outlook of citrus industry in Nepal. *Proceedings of National Horticulture Workshop*. Kathmandu, Nepal: Nepal Horticulture Society, pp. 48-57.

Shulman, Y., Fainberstein, L. and Lavee, S. (1984). Pomegranate fruit development and maturation. *Journal of Horticutural Science*, 59(2): 265-274, https://doi.org/10.1080/00221589.1984.11515196

Sites, J.W. and Reitz, H.J. (1950). The variation in individual Valencia oranges from different locations of the tree as a guide to sampling methods and spot packing for quality. *Proceedings for the American Society of Horticultural Science*, 55: 73-1.

Syvertsen, J. P. and Albrigo, L. G. (1980). Some effects of grapefruit tree canopy position on microclimate, water relations, fruit yield, and juice quality. *Journal of American Society of Horticultural Science*, 105(3): 454-459.

Timilsina, K. and Tripathi, K.M. (2019). Effect of altitude and fruit bearing position on physical quality attributes of mandarin (*Citrus reticulata* Blanco) in Kavre, Nepal. *International Journal Of Horticulture, Agriculture And Food Science (IJHAF)*, 3(4): 232-242, https://doi.org/10.22161/ijhaf.3.4.12

Tomiyashu, Y., Verma, S.K. and Thapa, D.B. (1998). *Citrus Cultivation in Nepal.* Kirtipur, Nepal: Horticulture Development Phase-II, HMG/JICA.

Trad, M., Gaalliche, B., Renard, C.M. and Mars, M. (2013). Inter- and intra-tree variability in quality of figs. Influence of altitude,leaf area and fruit position in the canopy. *Scientia Horticulturae*, 162: 49-54, https://doi.org/10.1016/j.scienta.2013.07.032

Underhill, S.J. and Wong, L.S. (1989). A maturity standard for lychee (*Litchi chinensis* Sonn.). *Acta Horticulture*, 269(23): 181-188, https://doi.org/10.17660/ActaHortic.1990.269.23

USDA. (1944). *United States Standards for Grades (of various citrus juice products).* Florida: United States Department of Agriculture.

Verreynne, J. S., Rabe, E. and Theron, K. I. (2004). Effect of bearing position on fruit quality of mandarin types. *South African Journal of Plant and Soil*, 21(1): 1-7, https://doi.org/10.1080/02571862.2004.10635014

wang Ma, F. and Cheng, L. (2004). Exposure of the shaded side of apple fruit to full sun leads to up-regulation of both the xanthophyll cycle and the ascorbate-glutathione cycle. *HortScience*, 39(4): 887A-887, https://doi.org/10.21273/HORTSCI.39.4.887A

Yakushiji, H., Moringa, K. and Nonami, H. (1998). Sugar accumulation and partitioning in Satusma mandarin tree tissues and fruit in response to drought stress. *Journal of the American Society for Horticulture Science*, 123(4): 719-726, https://doi.org/10.21273/JASHS.123.4.719