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Full Length Article

Geographical Location and Agro-Ecological Conditions Influence Kinnow Mandarin (*Citrus nobilis* × *Citrus deliciosa*) Fruit Quality

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Abstract

This study evaluated the Kinnow fruit quality in relation to geo-ecological conditions in four main Kinnow producing districts of Punjab Province, Pakistan, including Toba Tek Singh (TTS), Khanewal (KHW), Vehari (VHR) and Sargodha (SGD). At commercial maturity, fruit were harvested from six commercial orchards of each district, and compared for cosmetic (mainly blemishes) and internal fruit quality. Wind^{+LGFI} (a complex of blemishes caused by wind and low grade fungal infection), mites and thrips were recognized as the key causal agents of Kinnow rind blemishes. Fruit harvested from district TTS and SGD exhibited highest proportion of A (13.33 and 10.22%) and grade B (25.79 and 17.77%) fruit respectively. Regarding physical quality attributes, rind smoothness was found significantly higher in fruit from district TTS followed by SGD. Among bio-chemical characters, SGD was on the top with respect to juice percentage (40.9%), TSS/TA ratio (14.5) and vitamin C content (67 mg/100 mL). TSS was significantly higher in fruit from VHR (11.2 °Brix), while, total sugars (8.4%) were maximum in fruit from TTS. Meteorological data showed that, TTS had lower while district KHW higher mean minimum monthly temperatures during most part of the year. Annual rainfall was higher in SGD, while lower in VHR. Average monthly RH was lower in VHR while higher in SGD. Soil and leaf nutrient analysis of the orchards revealed significantly higher soil potassium content (225.11 mg/kg), and favorable range of pH (7.61), leaf nitrogen (N, 1.98%), phosphorous (P,0.1%), potash (K, 0.61%), calcium (Ca,5.58%) and iron content (Fe, 155.04 mg/kg) in district VHR. Soil pH was lowest while leaf manganese (Mn) contents were significantly higher in SGD. TSS was correlated negatively with rain fall and RH.TSS/TA ratio and vitamin C were also correlated negatively with soil N. Disease incidence were negatively correlated with leaf P contents and positively correlated with rainfall. In conclusion, geolocation and agro ecological conditions have significant impact on Kinnow fruit quality. District VHR and TTS were found to be the potential pockets for obtaining good quality fruit along with district SGD for broadening the export base of Kinnow mandarin. © 2018 Friends Science Publishers

Keywords: Kinnow mandarin; Blemish; Fruit quality; Geographical locations

Introduction

Citrus holds a prominent position in fruit industry of Pakistan. During the year 2014, area under citrus in Pakistan was reported 193.6 thousand ha; producing total yield of 2167.7 thousand tones (FBS, 2014). The ‘Kinnow’ mandarin is leading cultivar among various cultivars being grown in Pakistan; contributing 70% share of the total citrus production (Khan *et al.*, 2010). Kinnow is also leading fresh fruit export from Pakistan, with earnings of 170.45US million dollars (FBS, 2014). Currently, most of the Kinnow production and export is from district Sargodha (SGD), (with production of 1025 thousand tones) despite of good share in production from some other districts of Punjab province such as Toba Tek Singh (TTS) (189 thousand tones), and Vehari (VHR) (78 thousand tones) (AMIS, 2012).

A number of abiotic (site, climate, soil structure, composition, and nutrition, irrigation management etc.) and biotic (rootstock, cultivar, inspect pest and diseases etc.) factors are responsible for quality yields in citrus (Davies and Albrigo, l994; Iglesias *et al*., 2007). A general perception of linking Kinnow fruit quality with ecological and geolocation of SGD district has narrowed the opportunity of sourcing fruit and setting up of Kinnow processing industry in other districts of Punjab. However, due to degradation in peel quality (incidences of blemishes) of Kinnow fruit in Sargodha (SGD) district in recent times, the industry is seeking for other Kinnow growing pockets, so that the export base can be stretched to increase and sustain exports. To achieve this, a complete quality profile of Kinnow fruit produced in different districts of Punjab, would be required. There was also a need to explore the factors including ecological and nutritional responsible for variation in fruit quality in different citrus growing districts as compared to SGD. It is well known that macro-nutrients; principally nitrogen (N), phosphorus (P) and potassium (K) play a pivotal part in fruit yield and quality (Albrigo, 2002; Storey and Treeby, 2002; Srivastava and Singh, 2009; Hammami *et al*., 2010). Particularly, N is obligatory for optimal vegetative and reproductive plant growth (Alva *et al.*, 2006).

No scientific work has been done previously on identification of additional pockets for quality Kinnow fruit for export and Kinnow fruit quality profile being grown in major Kinnow growing districts is also missing. We hypothesized that besides district SGD, other Kinnow growing districts also have potential for Kinnow export along with district SGD and ecological factors does influence Kinnow fruit quality. Keeping above mentioned observations in view, a comprehensive study was intended: i) to assess Kinnow fruit quality of major growing districts (Toba Tek Singh, Khanewal, Vehari and Sargodha of Punjab, ii) to explore the ecological factors affecting Kinnow mandarin (*Citrus nobilis* Lour × *Citrus deliciosa* Tenora) fruit quality, and iii) to identify other Kinnow growing pockets (along with SGD) to broaden Kinnow export base, for the benefits of industry and country.

Materials and Methods

Orchard Selection

Six commercial orchards were selected in each district [Toba Tek Singh (TTS), Khanewal (KHW) Vehari (VHR) and Sargodha (SGD)]. Medium sized (25 to 50 acres) orchards with good management practices were selected. After selection of orchards, the soil and leaf analysis data (Fig. 5 and 6), environmental data (Fig. 7 and 9) and data of agronomic practices (Table 1) was recorded. Fruit was harvested at optimum maturity (mid-January) to compare for quality attributes (external and internal).

Fruit Blemish Data

At harvest, fruits were evaluated for nature and extent of blemishes. Nature of fruit blemishes was determined on the basis of symptom described earlier (Beattie and Gellatley, 2003; Cardwell *et al.,* 2003; Schubert and Sun, 2003). Categorization of fruit were done according to the nature [biotic factors (anthracnose, thrips, mites, red scales); abiotic factors (*wind+LGFI, styler end deformity/SED, nutrition)] and extent of blemishes (<1 cm^2, 1–5, 6–10, 11–25, 26–50 and >50% blemished area) on fruit peel as defined by Ahmed (2005).

*a complex of wind and some unidentified factors including low grade fungal infections

Fruit percentage was calculated carefully in each category of blemish. Data was recorded on 210 fruit randomly picked from 10 trees in each orchard of individual district (total of 1260 fruit from each district) (total of 5040 fruit from all four districts).

Fruit Harvesting for Physico-chemical Quality Attributes

For this purpose, 45 uniform sized fruit were harvested randomly at optimum commercial maturity from eight healthy and uniform trees at each orchard, pooled together, and transported to Postharvest Research and Training Centre (PRTC) after packing in corrugated boxes (270 fruit from one district and 1080 fruit from all districts). The fruit from each orchard were divided into three repetitions containing 15 fruit for further studies. Fruit were analyzed for physico-chemical characters (peel smoothness, rind colour, fruit firmness, fruit diameter, total soluble solids (TSS), titratable acidity (TA), TSS/TA ratio, vitamin C, sugars (reducing, non-reducing and total).

External Fruit Quality

To determine the various external fruit quality parameters, following rating scales were used described earlier by Khalid *et al.* (2012).

Peel smoothness: The ranges for this attribute were as: 1 = very rough, 2 = rough, 3 = slightly smooth, 4= smooth and 5 = very smooth

Rind color: This parameter was graded as given: 1 = 100% green, 2 = 75% green; 25% orange, 3 = 50% green; 50% orange, 4 = 25% green; 75% orange and 5 = 100% orange.

Fruit firmness: This character was determined in the range: individual fruit firmness was valued as 1 (hard) to 5 (very soft) manually. Fruit was taken in palm and then pressing slightly and average was taken calculated for the replication.

Fruit diameter: Digital vernier caliper (Mitutoyo 500-171-20, Japan) was used for measuring fruit diameter and average was taken.

Internal Fruit Quality/Bio-chemical Characters

Regarding internal fruit quality, total soluble solids (TSS), titratable acidity (TA), TSS/TA ratio, vitamin C and sugars (reducing, non-reducing and total) were determined. Digital refractometer (Atago-PAL-1, Tokyo, Japan) was used to determine TSS and was expressed as ^{o}Brix at room temperature. Titratable acidity (TA), was determined by following the procedure described earlier by Khalid *et al.* (2012) and expressed as percent citric acid. TSS/Acid ratio was calculated by dividing TSS with TA. Vitamin-C contents of fruit juice were determined following a method defined by Ruck (1969). Sugars in juice were determined as total sugars following the

Table 1: Comparison of cultural practices adopted by Kinnow fruit growers in different districts of Punjab

	No. of irrigations/year	Amount of N kg/tree/year	Amount of P kg/tree/year	Amount of K kg/tree/year	No. of plowing/year	No. of pruning/year	No. of insecticides/year	No. of fungicides sprayed/year
Toba Tek Singh	11.16b	2.66b	6.0a	0.91c	1.00c	1.16b	4.33a	2.66ab
Khanewal	16.66a	2.25b	2.33b	1.00bc	2.33b	1.33b	4.00a	3.33a
Vehari	18.0 a	3.16a	6.33a	1.66 a	4.16a	2.00a	4.33a	3.00a
Sargodha	13.0 b	2.33b	1.16c	1.41ab	1.16bc	1.00b	2.16b	1.50b
LSD Value	*1.445*	*0.208*	*0.515*	*0.197*	*0.609*	*0.199*	*0.290*	*0.637*

Means not sharing any letter are significantly different ($P \leq 0.05$); NS = Non-Significant; n=6

method earlier out lined by Khan *et al.* (2009) and expressed as percentage.

Analysis of Soil and Leaf Samples

Soil and leaf samples were collected from individual orchard of respective district to evaluate the status of nutrients. Samples (soil and leaf) were collected at the same time when the fruit samples were collected i.e. in mid-January.

For leaf analysis, disease and insect pest attack free (50–60) mature leaves were randomly collected at shoulder height from three trees and placed in paper bags. The leaves were then shifted to Postharvest Research & Training Centre (PRTC), University of Agriculture Faisalabad and analyzed after washing and drying according to the method previously defined by Chapman and Parker (1961).

Similarly, with the help of augur, soil samples were taken from three different sites randomly, in each block from where the fruit was harvested. Samples were collected from three different depths, (1–15 cm, 16–30 cm and 31–45 cm). The labeled samples were shifted to the Soil and Water Testing facility, Sargodha for further estimations.

Environmental Profile of Individual Districts

Environmental profile comprising of i. Temperature ii. Relative humidity (RH) and iii. Rainfall of individual districts was obtained from various sources. Data for district VHR was acquired from a local Punjab Agriculture Extension Department Office, whereas data of district SGD and TTS were obtained from Punjab Metrological Department, Lahore. Data for district KHW was acquired from a local grower association (British Cotton Growing Association).

Statistical Approach

Experiment was carried out under Randomized Complete Block Design (RCBD) arrangement. Analysis of variance and correlation techniques were employed to test the overall significance of the data using statistix v® 8.1 software. Correlation studies were determined to find out the relationship between fruit quality with environmental factors, existing soil and leaf nutrient contents.

Results

Kinnow Fruit Quality Comparison among Four Districts

Nature and extent of blemishes in kinnow fruit among four districts: Overall, wind^{+LGFI} (the blemish complex) was found as a main causative agent followed by mites. Blemished fruit due to wind^{+LGFI} were significantly higher (88.51%) in district Khanewal (KHW) followed by Sargodha (SGD) (86.67%) (Fig. 1), while the lowest percentage of wind^{+LGFI} affected fruit was found in district Vehari (VHR). Mites related blemishes were found in all locations with non-significant difference. Styler end deformity (SED) was also witnessed during recent survey with significantly higher percentage (23.77%) of fruit affected in district SGD followed by KHW (9.68%), while minimum incidence were recorded in fruit from Toba Tek Singh (TTS) (Fig. 1). Styler end deformity (SED) was found negatively correlated with soil nitrogen content. Anthracnose incidence on fruit was positively correlated with rainfall and RH, while found negatively correlated with leaf P content.

Regarding extent of blemishes, blemish category with $<1cm^2$ area affected of fruit (A grade fruit) was significantly higher in district TTS (13.33%) and district SGD (10.22%) fruit, however, both were statistically at par with each other. Similar results were obtained in case of B grade fruit (1–5% area affected), as well (Fig. 2), with TTS (25.79%) and SGD (17.77%) being the leading districts.

Physical Characters

Firmness was recorded significantly higher in fruit from district VHR (2.3 score) followed by SGD and KHW (2.1 each). Fruit from district VHR and KHW presented higher peel colour score of 5 each (Fig. 3). Rind smoothness was significantly higher in fruit from district TTS (3.5 score) and SGD (3.2 score), while remain at par to each other. Peel thickness was significantly greater (4.9 mm) in fruit from TTS while lower in VHR (3.7 mm). SGD (40.9%) and KHW (37.7%) was on the top with respect to juice percentage, while remain at par to each other (Fig. 3). Fruit firmness was found positively correlated with soil saturation capacity and leaf nitrogen contents.

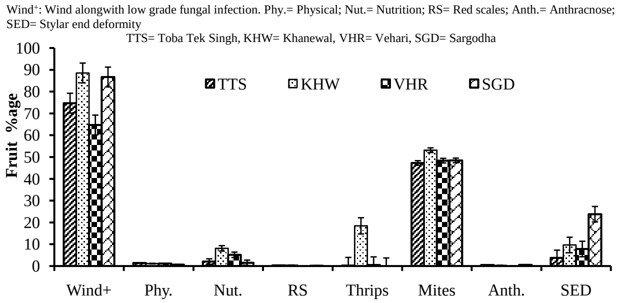

Fig. 1: Nature of Kinnow skin blemishes in four districts of Punjab; *n=6*
(Vertical bars represent ± S.E. of treatments means)

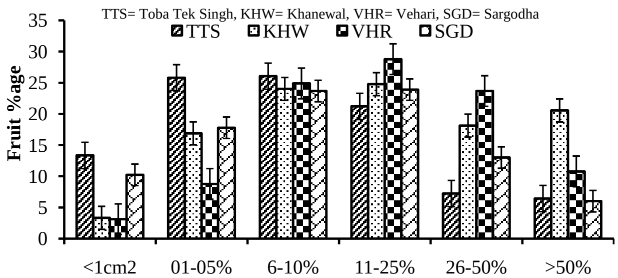

Fig. 2: Extent of Kinnow skin blemishes in four districts of Punjab; *n=6*
(Vertical bars represent ± S.E. of treatments means)

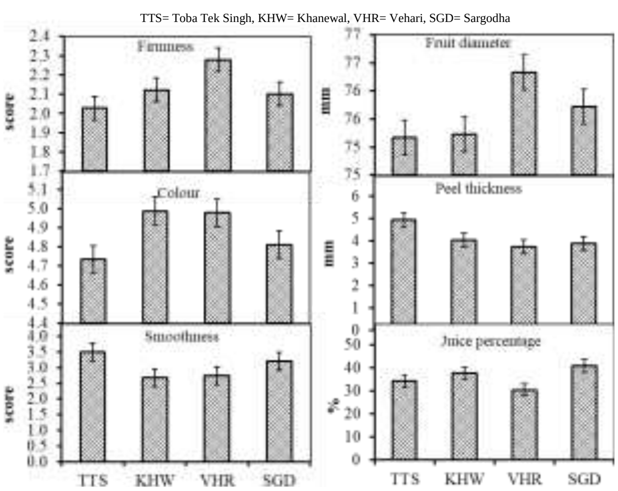

Fig. 3: Physical fruit quality in relation to different geographical locations *(n=270 as 45 fruits were harvested from each orchard of each district)*
(Vertical bars represent ± S.E. of treatments means)

Biochemical Characters

Fruit from district Toba Tek Singh (TTS) showed significantly higher total soluble solids (TSS) (11.2 ºBrix) followed by KHW (10.6 ºBrix). Significantly, greater titratable acidity (TA) (0.82%) was recorded in fruit from district VHR followed by TTS and KHW with 0.78% TA each (Fig. 4). However, TSS/TA ratio was significantly higher in fruit from district SGD (14.5) followed by KHW (14.1). Same was the case with vitamin C which was 67 mg/100 mL, significantly higher in fruit from district SGD followed by KHW (56.8 mg/100 mL). Total sugars were found significantly higher in fruit from district TTS (6.3%) compared to other districts, followed by SGD district, while non-significant difference was found among reducing sugars (Fig. 4). TSS was found negatively correlated with RH and rainfall whereas vitamin C and TSS/TA ratio are found negatively correlated with soil nitrogen contents.

Soil Nutrient Analysis

Electrical conductivity (EC) was recorded significantly higher (1.44 mS/cm) in soils from district VHR followed by from district TTS (1.37 mS/cm) (Fig. 5). Nitrogen and phosphorous were found significantly higher (0.16% and 11.13 mg/kg) in soils from district TTS, respectively while potassium was significantly higher (225.11 mg/kg) in soils from VHR. Soil pH was significantly higher (7.72) in orchards of TTS, while lowest in district SGD (7.56). Soil saturation capacity was significantly greater in district VHR (37.77%) (Fig. 5).

Leaf Nutrient Analysis

Regarding leaf nutrient analysis, nitrogen (N), phosphorous (P), potassium (K), calcium (Ca) and iron (Fe) were found significantly higher in leaves from district VHR with value of 1.99%, 0.098% 0.62%, 5.58% and 160.54 mg/kg, respectively. Manganese (Mn) was significantly higher in leaves from district SGD (36.64 mg/kg) and VHR (36.0 mg/kg) while at par to each other (Fig. 6), while Ca was also higher and at par in leaves of districts VHR (5.58%) and SGD (5.51%) while significantly differed from other two districts (TTS and KHW).

Orchard Cultural Profile

Significantly lower quantity of irrigations (11) per annum was applied to the orchards in TTS and SGD (13), compared to maximum (18) in KHW. Quantity of fertilizer (N, P and K) applied to the orchards, pruning and number of ploughings in orchards in a growing season; were also recorded significantly greater in district VHR (Table 1). P application was lowest in district SGD (1.16 kg/tree) compared to TTS and VHR (≥6 kg/tree). K application was significantly lower (0.9 kg/tree) in TTS compared to other districts, which were at par. Pesticides applications (insecticides and fungicides) were also significantly lower in SGD.

Environmental Profile of Four Districts

Environmental data of all four locations was acquired for

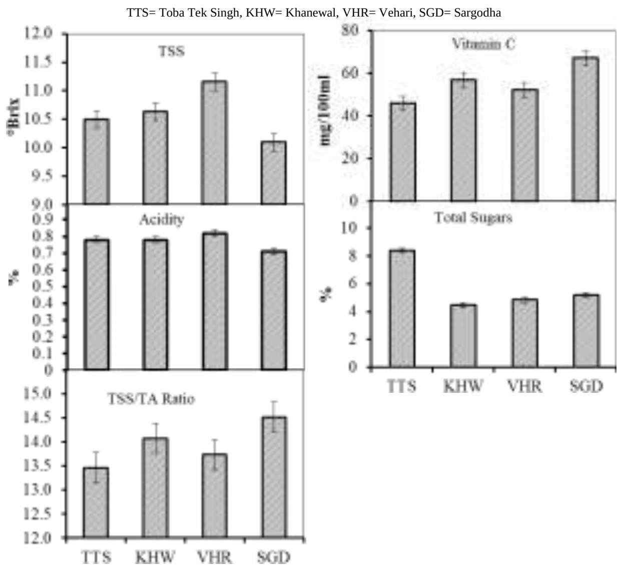

Fig. 4: Biochemical fruit quality in relation to different geographical locations *(n=270 as 45 fruits were harvested from each orchard of each district)*
(Vertical bars represent ± S.E. of treatments means)

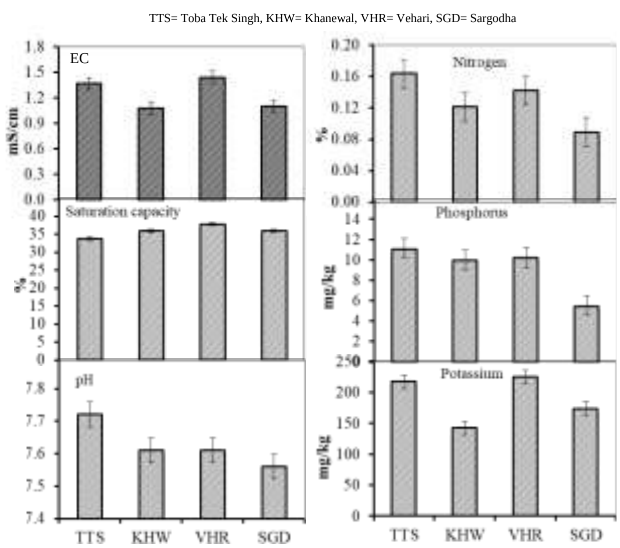

Fig. 5: Soil nutrient status in different Kinnow growing districts; *n=6*
(Vertical bars represent ± S.E. of treatments means)

the entire growing season during 2010. Data included temperature (monthly mean minimum and mean maximum temperatures), monthly average relative humidity (RH) and monthly total rainfall.

Monthly mean minimum temperature: Monthly mean minimum temperature of all locations is shown in Fig. 7. District TTS showed lower minimum monthly temperature during entire growing season except February and August in which VHR district showed minimum temperature. Among all four districts, high temperature was noted in

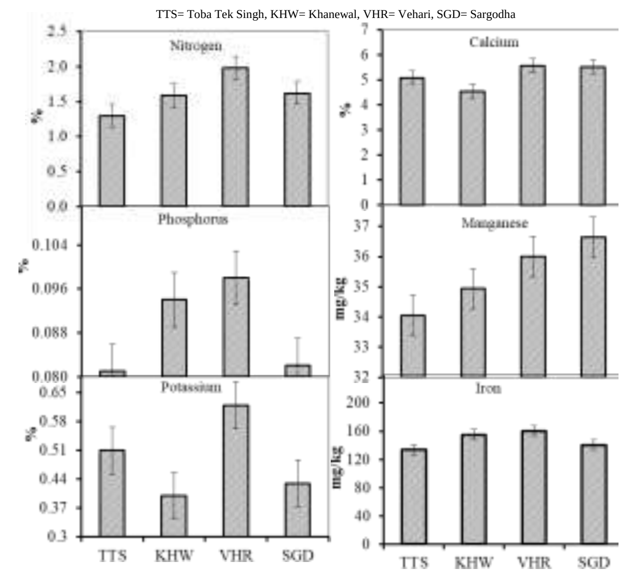

Fig. 6: Leaf nutrient status of Kinnow tree in different Kinnow growing districts; *n=6*
(Vertical bars represent ± S.E. of treatments means)

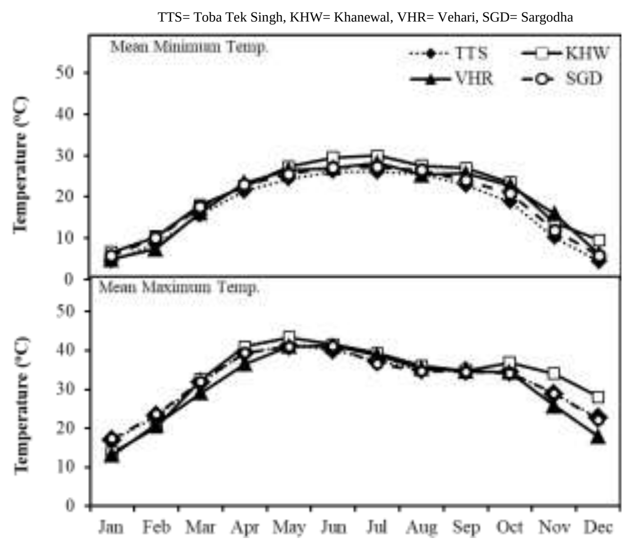

Fig. 7: Mean minimum and maximum temperature of four districts during Kinnow growing season (2010)

district KHW during entire growing season except April and November in which District VHR showed greater temperature.

Monthly mean maximum temperature: As regards monthly mean maximum temperature, district SGD showed higher in January and February while district KHW showed higher in all other months, as compared to other districts (Fig. 7).

Relative humidity (RH): Generally, RH was recorded higher in SGD during the months of January, February, July, August, September, October, November and

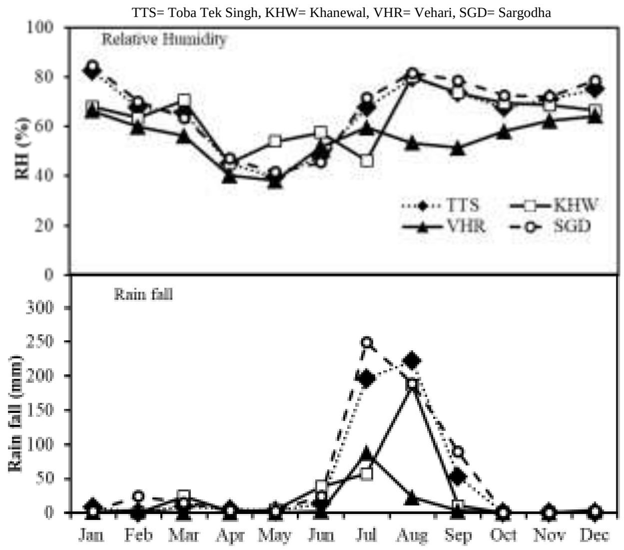

Fig. 8: Mean monthly relative humidity and rainfall in four districts during Kinnow growing season (2010)

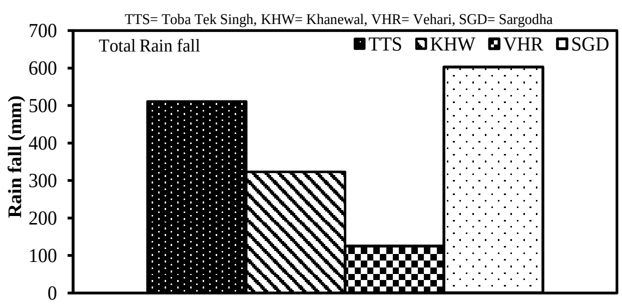

Fig. 9: Total rainfall in four districts during completely growing season (2010)

December (Fig. 8). Minimum RH was recorded in district VHR as compared to other locations during the entire growing season.

Rainfall: Data regarding distribution of rainfall is shown in Fig. 8, which clearly shows that the months of June, July, August and September are more prominent for rain than all other months of the entire growing season. Total rainfall during entire growing season in all four locations is presented in Fig. 9. Total rainfall was recorded higher in district SDG trailed by district TTS, while minimum was recorded in district VHR.

Discussion

Climatic conditions like temperature, rainfall and humidity significantly influence fruit physical and biochemical quality. Variation occurs in fruit quality, tree growth and development with respect to different geographical locations (Meena and Yadav, 2001). Similar results were found in the current study as the fruit obtained from different locations differed in terms of physical and biochemical quality parameters. Variation in nature and extent of blemishes was also found among fruit obtained from different locations. Wind^{+LGFI} blemishes (a complex of wind and low grade fungal infection) were found higher among all type of blemishes in all districts, suggesting that it is a common issue despite of difference in locations and cultural practices. However, among this category, a large proportion of fruit with low grade fungal infection developed at earlier stage was marketable locally. Gravina *et al.* (2011) proposed that wind blemishes are one of major issue in citrus groves. Among individual districts, wind^{+LGFI} blemishes were found significantly higher in district KHW, which might be due to the higher wind speed as well as higher fungal infection during early fruit development period. KHW orchards were having significantly higher number of irrigations. In another study, Malik *et al.* (2014) reported that such low grade fungal infection on Kinnow fruit have been much intensified in some orchards particularly in Tehsil Bhalwal, District Sargodha, and the symptoms were ascribed to pathogens causing scab and melanose. Lack of orchard hygiene, over irrigation, carryover plant debris and contaminated soil from orchard to orchards were noted as potential causes for widespread fungal infection. Blemishes from mites were another major cause, however results were found non-significant among districts. Blemishes caused by thrips were found only in KHW district. The reason might be the ineffective plant protection and cultural practices in the orchards of district KHW although the frequency of operations was comparable to other districts. Soon after petal fall, thrips can be seen on small citrus fruitlets, cause scarring on the small fruit and this thrips damage is associated with relatively hot climatic conditions during bloom in citrus (UC-IPM, 2017). Temperature during fruit setting and early fruit development is comparatively high in KHW as compared with other districts (Fig. 7). This could also be the reason for more thrips blemishes on fruit harvested from KHW district. Anthracnose blemishes correlated positively with rainfall and relative humidity and negatively with leaf P contents. Rainfall plays important role in dispersal of anthracnose spores (Peres *et al.,* 2002). Higher leaf P contents can reduce anthracnose susceptibility. In mango fungicides having phosphoric acid as active ingredient are used to control anthracnose disease (Nelson, 2008). Significantly higher percentage of A grade fruit (<1cm^2 area covered with blemish) and B grade fruit (1–5% area covered with blemish) were found in orchards from district TTS and SGD (Fig. 2). Overall good cultural and orchard management practices adopted by the growers of these districts might be the reason.

As regards fruit physical quality parameters, rind color, fruit diameter and fruit firmness were found significantly higher in district VHR. Climate has significant influence on citrus fruit quality. In dry climate, citrus fruit firmness was higher (Zekri, 2011). The climate of VHR is mostly dry as compared to other three districts (Fig. 8) and this could be the reason for more firm fruit in this area. Fruit diameter was also found higher in district VHR (Fig. 3). Soil and leaf N and K contents were found higher in district VHR (Fig. 5 and 6), which would have resulted in better growth of fruit. In earlier studies, these two nutrients were found related with more fruit size in citrus (Hamza *et al.*, 2012).

Reduction in air and soil temperature in autumn is responsible for color change in citrus (Young and Erickson, 1961). Best quality citrus is produced in climate characterized with relative dryness (low rainfall), hot summer and cool winters at the time of fruit maturity (Ladaniya, 2008). Suitable climatic conditions (low rainfall, hot summer and significant temperature drop from September to December) at the time of fruit maturity and possibly high leaf Mn contents of district VHR might be the reason for better peel colour of fruit as compared to other districts. The results are also in accordance with Zekri and Obreza (2014), who revealed that Mn deficiency in citrus trees may greatly reduce fruit peel colour. Climatic conditions also influence peel thickness in citrus. Peel thickness was higher in TTS and lower in VHR. Climatic conditions like temperature and humidity influences peel thickness in citrus fruit. More rainfall during growing season (Chelong and Sdoodee, 2013) and thicker peel in citrus is due to lowering in minimum average temperature in winters (Juan and Jiezhong, 2017). These could be the reasons for more thick peel in fruit harvested from TTS as compared to other districts. Less peel thickness in VHR might be due to dry conditions prevailing in the area (Fig. 7). Juice percentage was found higher in fruit of district SGD, which might be due to more conducive climatic conditions (higher rainfall, RH), high leaf Mn and Ca contents of trees in this district. El-Sheikh *et al.* (2007) also reported similar results with regards to leaf nutrient contents and fruit juice. Fruit taste is reflected from ratio of TSS and acids in fruit juice and is a consumption attribute critical to consumer acceptability (Malundo *et al.*, 1996). Total soluble solids and acidity were found higher in fruit harvested from VHR district (Fig. 4). Total soluble solids were mainly influenced by fertilizer application and climatic conditions like rainfall and temperature. In district VHR low precipitation and humidity were recorded as compared to other three districts (Fig. 8). Nutritional status of plant (Fig. 6) and soil (Fig. 5) was also favorable in VHR district. These could be the reasons of higher TSS in fruit of VHR district. The fruit grown under hot tropical climate have the ability to produce high TSS (Zekri, 2011). Similarly, Chelong and Sdoodee (2013) also reported a higher TSS in Shogun (*Citrus reticulata* Blanco) fruit growing at Yala region in Thailand with lower rainfall. Moreover, a negative correlation was also found between TSS with rainfall ($r = -0.97$) and relative humidity ($r = -0.96$) in study area. Similar negative correlation between TSS, precipitation, acidity and precipitation in citrus were also previously reported (Ladaniya, 2008).

Nitrogen (N), phosphorus (P) and potassium (K) are important nutrients affecting fruit quality. Nitrogen (N) is responsible for the increase in juice contents whereas P reduces acid content, resulting increase in soluble solids:acid ratio. Potassium (K) boosts up fruit yield and size (Zekri, 2011). N, P and K were found higher in soils from district TTS and VHR as compared to other districts. On the other hand, soils from district VHR also possess good range of pH, saturation capacity and rich in leaf N P and K. For consistent and quality citrus production, K and certain micronutrients are considered essential (Ladaniya, 2008). This might be the reason for producing overall better quality fruit from district TTS and VHR. Vitamin C, an important parameter of fruit quality was negatively correlated ($r = -0.99$) with soil N contents and positively but non-significantly with leaf Mn contents. Similarly, several researchers have reported reduced levels of vitamin C contents in certain fruits and vegetables with the application of elevated levels of N (Lee and Kader, 2000; Musa and Ogbadoyi, 2012). Soil N contents were low in SGD and KHW (Fig. 5) and fruit obtained from these districts were high in vitamin C contents (Fig. 4). Leaf Mn contents were higher in SGD, which might have increased vitamin C contents in fruit. Moreover, irrigation frequency was also low in SGD (Table 1). Less irrigation frequency, higher Mn and low soil N contents could be the reason for high vitamin C in Kinnow fruit harvested from SGD as compared to other districts. Similarly, Lee and Kader (2000) reported that low N supply and less frequent irrigations could improve vitamin C contents in horticultural crops.

Conclusion

The study revealed that environmental factors, geographical location and cultural practices significantly influenced the external and internal fruit quality attributes of Kinnow mandarin. Soil pH, leaf Mn contents, climatic conditions including higher RH % and rain fall and cultural practices such as lower irrigation adopted in SGD were favorable for good physical and biochemical quality of fruit produced. District VHR also has the potential for good quality fruit production after SGD. In future fruit quality in VHR can be tested and compared with SGD by including micronutrient applications in cultural operations and by reducing irrigation frequencies. District TTS also produced less blemished fruit and has potential for producing better internal and external quality fruit by improving plant nutrition.

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