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Location, Soil and Tree Nutrient Status Influence the Quality of 'Kinnow' Mandarin

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ABSTRACT

The present study was conducted to determine the relationship of orchard location, soil and tree nutrient status with fruit quality of 'Kinnow' mandarin (*Citrus reticulata* Blanco.) in district Sargodha (major 'Kinnow' producing area), Pakistan. The district was divided in four locations comprising of its four tehsils i.e., Bhalwal, Kotmomin, Sargodha and Sillanwali, while from each location seven orchards were randomly selected for soil, leaf and fruit samples collection. Soils from all locations were found slightly alkaline having deficit organic matter and P contents, while optimum in K contents. Foliar N and K contents were within optimum range from Bhalwal and Kotmomin orchards, while foliar P contents were in deficient from all locations. Fruit harvested from Bhalwal exhibited higher juice contents, soluble solids concentration (SSC) and level of ascorbic acid with lowest peel weight and thickness owing to better soils and leaf nutrient contents as compared to other locations. The results show pronounced effect of the soil and leaf nutrient conditions on physico-chemical quality characteristics of 'Kinnow' mandarin fruit besides other un-foreseen factors at different locations. Over all, orchards at Bhalwal produced 'Kinnow' fruit with superior quality (higher juice contents, SSC, ascorbic acid & lower peel weight & thickness) in contrast to all other locations.

Key Words: Fruit quality; 'Kinnow' mandarin; Location; Relationship; Soil and foliage NPK

INTRODUCTION

Citrus occupies a prominent position in the fruit industry of the world, as well as in Pakistan. The area under citrus in Pakistan during 2008 was 199.4 thousand ha with total production of 2294.5 thousand tones and Punjab province contributes 95% of total citrus production (GOP, 2010). At present, among various citrus cultivars being grown in Pakistan, the 'Kinnow' mandarin is the leading citrus cultivar with 70% share of the total citrus production (Khan *et al*., 2010). Productivity of citrus trees depends on many abiotic (climate, site, soil, nutrition & irrigation management) and biotic (rootstock, cultivar, insect pest & disease management) factors (Davies & Albrigo, l994b; Iglesias *et al*., 2007). Among them adequate supply of plant nutrients is a very important factor to produce the good quality fruits (Iqbal *et al*., 1999; Raza *et al*., 1999; Ioannis *et al*., 2004).

The application of macro-nutrients particularly nitrogen (N), phosphorus (P) and potassium (K) plays important role in yield, as well as fruit quality (Albrigo, 2002; Storey & Treeby, 2002; Srivastava & Singh, 2009; Hammami *et al*., 2010; Lester *et al*., 2010; Liu *et al*., 2010), especially N is necessarily needed for optimum vegetative, as well as reproductive growth (Alva *et al*., 2006). The level of N fertility has more influence on the growth, yield and quality of citrus than any other single plant nutrient (Thompson *et al*., 2002). It is an essential ingredient of chlorophyll, proteins, growth hormones and enzymes and is a building block for fruit production (Huett, 1996). P performs many vital functions in the plant photosynthesis, enzyme activity, metabolism and movement of sugars (Davies & Albrigo, 1994b). It is also important for growth and development of flowers, as well as fruits. Low P contents in leaves have been reported to produce miss-shaped poor quality 'Kinnow' mandarin fruit with open centers, coarse and thickened peel, low and acidic juice contents (Raza *et al*., 1999). K plays a regulatory role in physiological and bio-chemical processes of citrus plant (Davies & Albrigo, l994a). It is involved in the formation

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and functioning of proteins, fats, carbohydrates, chlorophyll and maintaining the balance of salts and water in plant cells. The K application has also been reported to play important role in the acid metabolism of the citrus juice (Achilea *et al*., 2002). Hence, a balanced supply of N, P and K gives high yield with better citrus fruit quality (Albrigo, 2002).

In Pakistan, average life and production of citrus is far less than many other citrus producing countries of the world (Saleem *et al*., 2008; Khan *et al*., 2009). This reduction is mainly due to poor nutritional management of the citrus orchards being practiced in the country. In advanced countries, leaf tissue testing is a valuable tool to examine the tree nutritional status (Obreza *et al*., 1999), while soil analysis is common practice for evaluation of soil nutrients and planning for nutrient application to maintain high yield and good quality of citrus fruit (Albrigo, 2002; Hammami *et al*., 2010; Lester *et al*., 2010), which is rarely practiced in Pakistan. Although old information is available on leaf and soil analysis in citrus producing areas of Punjab, but it could not be adopted as a regular practice for designing a fertilizer application program (Ranjha *et al*., 2002). No such information is available to establish a relation between location of orchard, soil and leaf nutrition status with fruit quality of 'Kinnow' mandarin. We hypothesized that the adaptation of different cultural practices in major 'Kinnow' producing areas of Punjab may influence the level of N, P and K of trees, as well as soil and consequently the fruit quality. Therefore, the present study was conducted to investigate the relationship of soil and foliage nutrient status with fruit quality of 'Kinnow' mandarin at different locations in the Punjab, Pakistan. The information collected will be very beneficial for scientists, extension workers and citrus growers and exporters.

MATERIALS AND METHODS

Plant materials: The current research project was carried out in the commercial citrus orchards at Sargodha district (the main hub of 'Kinnow' production in the province), Punjab, Pakistan. Seven orchards with comparatively better agricultural practices were selected from four locations (tehsils) of Sargodha district including Kotmomin (lat. 32°13'N; long. 73°00'E), Bhalwal (lat. 32°15'N; long. 72°54'E), Sargodha (lat. 32°5'N; long. 72°40'E) and Sillanwali (lat. 31°49'N; long.72°32'E). Soil, leaf and fruit samplings were performed during peak harvesting period.

Soil sampling and analysis: Soil samples were collected randomly from three different depths of selected orchards i.e., 15-30 cm, 30-45 cm and 45-60 cm, labeled location wise and shifted to soil and water testing laboratory, Sargodha for analysis. The samples were pooled location wise and divided in three replicates. Soil samples analysis were performed according to the method described by Page (1982).

Leaf sampling and nutrient analysis: From each orchard, three plants of uniform size and grown under uniform condition were selected at random for leaf sampling. Leaf samples comprising of fully mature 100 leaves uniform size without any lesions or scars were collected randomly at shoulder height from four sides of experimental tree. The leaf samples were labeled location wise, then shifted promptly to Pomology Laboratory, Institute of Horticultural Sciences (IHS), University of Agriculture Faisalabad (UAF), for further analysis. The leaves were washed with the detergent, then tap water and finally distilled water were oven dried and grounded into fine powder, which were analyzed for determination of N, P and K according to the method described by Chapman (1960).

Fruit analysis: Fruit harvested from each orchard were immediately transported to Postharvest Research and Training Centre IHS, UAF for their physical [weight (g), diameter (mm), peel weight (%), peel thickness (mm), pulp: peel ratio, pulp weight (%) & juice weight (%)] and chemical [soluble solids concentration (SSC), titratable acidity (TA), ascorbic acid contents, reducing, non-reducing & total sugars] quality characteristics. Twenty fruit were collected from each orchard thus 140 fruit pooled for each location and were divided in three replications, consisted of 35 fruit each.

SSC, TA and SSC:TA ratio: Digital refractometer (Atago, RS-5000, Atago, Japan) was used to determine SSC of fruit juice. The reading was taken directly from refractometer and was expressed as Brix (%) at room temperature. To determine TA, 10 mL of fruit juice taken in 100 mL conical flask was diluted up to 50 mL with distilled water. The diluted sample was titrated against 0.1 N NaOH, using 2-3 drops of phenolphthalein as an indicator. TA was expressed as percent citric acid. The SSC: TA ratio was calculated in each sample by dividing the percentage of SSC with corresponding TA.

Ascorbic acid and sugars: Ascorbic acid contents of juice were determined following the method described by Ruck (1969). Ten mL of juice was taken in a 100 mL volumetric flask and volume was made by adding 0.4% oxalic acid solution. Five mL filtrated aliquot was titrated against 2, 6-dichlorophenolindophenol dye, to light pink colour end point (persisted at least for 15 seconds). The ascorbic acid contents were expressed as mg 100 mL^{-1}. Sugars in juice were determined as reducing sugars, non-reducing sugars, and total sugars following the method earlier out lined by Khan *et al*. (2009) and were expressed as percentage (%).

Statistical approach: The experiment followed two factors factorial arrangement under Randomized Complete Block Design (RCBD). Analysis of variance techniques were employed to test the overall significance of the data using MSTAT-C statistical software (Freed, 1994), while the Least Significant Difference (LSD) test ($P \leq 0.05$) was used to compare the differences among treatment means. All assumptions of the analysis were checked to ensure the validity of the statistical analysis. Pearson correlations were performed between soil and leaf mineral contents with physical and chemical fruit quality characteristics using SPSS software package v.18.0 for Windows, USA.

RESULTS

The soil analysis of the experimental orchards revealed that the soils from all locations of district Sargodha were deficient in organic matter (0.47-0.72%) and P (1.5-3.73 mg kg^{-1}) contents with significant differences among each other, while rich in K (2.23-2.80 mg kg^{-1}) contents with non-significant differences among locations (Table I). Maximum soil organic matter was found in Sargodha (0.72%), while minimum was in Sillanwali (0.47%). Maximum P (3.73 mg kg^{-1}) contents were recorded in soils of Kotmomin and minimum P (1.51 mg kg^{-1}) contents in Sillanwali soils. The soils from the all experimental locations were found slightly alkaline with pH ranging from 7.73-7.91. The soil EC and soil moisture contents were also found within low range in all soils (Table I).

Analysis of 'Kinnow' mandarin leaves collected from different orchards exhibited significant differences among locations with respect to their levels of N and K, while P contents were not significant (Table II). The N contents of 'Kinnow' mandarin leaves sampled from trees cultivated at Bhalwal and Kotmomin were significantly higher (2.43% & 2.44%) as compared to trees cultivated in Sargodha and Sillanwali (2.18% & 2.31%), respectively. The leaves of the 'Kinnow' trees from the Bhalwal and Kotmomin exhibited higher level of K (0.865% & 0.819%) as compared to Sargodha and Sillanwali (Table II).

Fruit harvested from orchards at different locations exhibited significant differences in fruit size and weight (Fig. 1A & 1B). The fruit diameter (70.4 mm) and weight (164.9 g) was found maximum in fruit harvested from Sargodha. The lowest fruit diameter (66.6 mm) and weight (140 g) was recorded in the fruit harvested from orchards at Kotmomin (Fig. 1). The peel thickness (2.29 mm) was also found maximum in the fruit harvested from Sargodha, whilst it was lowest (1.98 mm) in the fruit harvested from Kotmomin (Fig. 2A). Pulp:peel ratio was highest (1.5) in fruit harvested from Bhalwal as compared to all other locations (Fig. 2B). Whilst, the peel weight (28.03%) was maximum in the fruit harvested from Sillanwali (Fig. 3B). The juice contents (40.89%) were found maximum in the fruit harvested from Bhalwal, as compared to other three locations having almost same juice contents in their fruit (Fig. 3A). In the present study, regarding the physical fruit quality characteristics of 'Kinnow' mandarin: the fruit diameter was positively correlated with soil organic matter (r = 0.29), soil EC (r = 0.32), soil moisture contents (r = 0.39), leaf nitrogen (r = 0.33) and negatively correlated with soil P (r = -0.23). Fruit weight exhibited positive correlation with soil organic matter (r = 0.29), soil moisture (r = 0.39) and leaf N (r = 0.31) and negative correlation with soil P (r = -0.31). Peel thickness was positively correlated with soil EC (r = 0.39) and soil moisture (r = 0.34) and negatively correlated with soil P (r = -0.22). Whereas, peel (r = 0.22) and pulp (r =0.28), weight (%) showed positive correlation with soil EC (Table III).

Table I: Status of soil organic matter, P, K, pH, EC and moisture contents at four locations of district Sargodha

Location	Organic matter (%)	P (mg kg^{-1})	K (mg kg^{-1})	pH	EC (mS cm^{-1})	Moisture (%)
Sargodha	0.72a	2.16ab	231.07	7.91a	2.46	36.57
Sillanwali	0.47b	1.51b	244.00	7.91a	2.20	34.57
Bhalwal	0.55b	3.13a	223.29	7.73b	2.52	35.14
Kotmomin	0.58b	3.73a	280.00	7.73b	3.07	32.86
Mean ($P \leq 0.05$)	*	*	NS	*	NS	NS

Any two means not sharing same letter differ significantly at 5% level of probability. NS = not signifiant. * = signifiant at P ≤ 0.05. n = 3 replicates.

Table II: Status of leaf N, P and K contents of 'Kinnow' mandarin trees at four locations of district Sargodha

Nutrients (%)	Location (Tehsils)				
	Sargodha	Sillanwali	Bhalwal	Kotmomin	Mean ($P \leq 0.05$)
N	2.18b	2.31b	2.43a	2.44a	*
P	0.016	0.018	0.016	0.016	NS
K	0.693b	0.607b	0.865a	0.819a	*

Any two means not sharing same letter differ significantly at 5% level of probability. NS = not signifiant. * = signifiant at $P \leq 0.05$. n = 3 replicates

Table III: Relationship between levels of OM, P and K in the soil and N, P, K in leaf with physical and chemical quality characteristics of 'Kinnow' mandarin fruit

	Fruit diameter	Fruit wt	Peel thickness	Peel wt	Pulp wt	SSC	AA	RS	NRS	TS
Soil OM	0.29**	0.29**	NS	NS	0.29**	NS	NS	NS	NS	NS
Soil P	-0.23**	-0.31**	-0.22*	NS	NS	NS	0.25*	0.42*	0.68**	0.65**
Soil K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Soil EC	0.32**	NS	0.39**	0.22*	0.28*	NS	NS	NS	-0.52**	-0.56*
Soil moisture	0.39**	0.39**	0.34**	NS	NS	-0.29**	NS	-0.52**	NS	NS
Leaf N	0.33**	0.31**	NS	NS	NS	NS	NS	NS	NS	NS
Leaf P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Leaf K	NS	NS	NS	NS	NS	NS	NS	NS	0.31**	0.28*

*, ** = significant at $P \leq 0.05$ or 0.01 respectively. OM = organic matter. wt = weight. SSC = soluble solids concentration. TA = titratable acidity. AA = ascorbic acid. RS = reducing sugar. NRS = non-reducing sugar. TS = total sugar. NS = not significant. n = 84

Fig. 1: Diameter (A) and weight (B) of 'Kinnow' mandarin fruit harvested from four locations of district Sargodha. Vertical bars indicate ± SE of means. Any two means not sharing same letter differ significantly at 5% level of probability. SGD = Sargodha. SLW = Sillanwali. BHL = Bhalwal. KTM = Kotmomin. n = 3 replicates

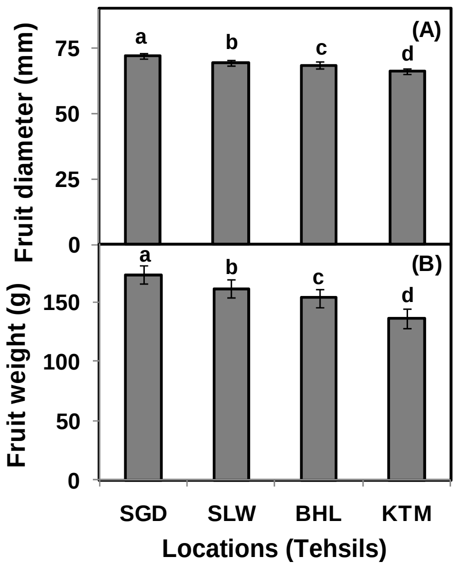


Fig. 2: Peel thickness (A) and pulp:peel ratio (B) of 'Kinnow' mandarin fruit harvested from four locations of district Sargodha. Vertical bars indicate ± SE of means. Any two means not sharing same letter differ significantly at 5% level of probability. SGD = Sargodha. SLW = Sillanwali. BHL = Bhalwal. KTM = Kotmomin. n = 3 replicates

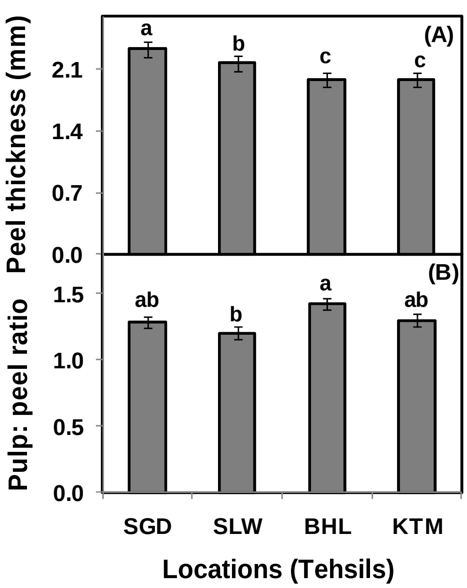


Fig. 3: Juice (A), peel (B) and pulp (C) weight percentages of 'Kinnow' mandarin fruit harvested from four locations of district Sargodha. Vertical bars indicate ± SE of means. Any two means not sharing same letter differ significantly at 5% level of probability. SGD = Sargodha. SLW = Sillanwali. BHL = Bhalwal. KTM = Kotmomin. n = 3 replicates

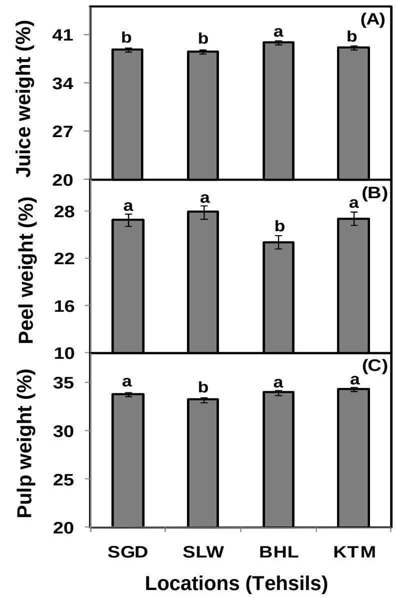


Fig. 4: SSC (A), TA (B) and SSC: TA ratio (C) of 'Kinnow' mandarin fruit harvested from four locations of district Sargodha. Vertical bars indicate ± SE of means. Any two means not sharing same letter differ significantly at 5% level of probability. SGD = Sargodha. SLW = Sillanwali. BHL = Bhalwal. KTM = Kotmomin. n = 3 replicates

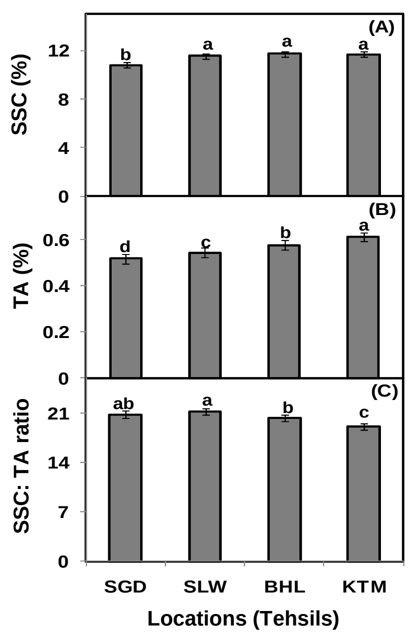


Fig. 5: Ascorbic acid concentration of 'Kinnow' mandarin fruit harvested from four locations of district Sargodha. Vertical bars indicate ± SE of means. Any two means not sharing same letter differ significantly at 5% level of probability. SGD = Sargodha. SLW = Sillanwali. BHL = Bhalwal. KTM = Kotmomin. n = 3 replicates

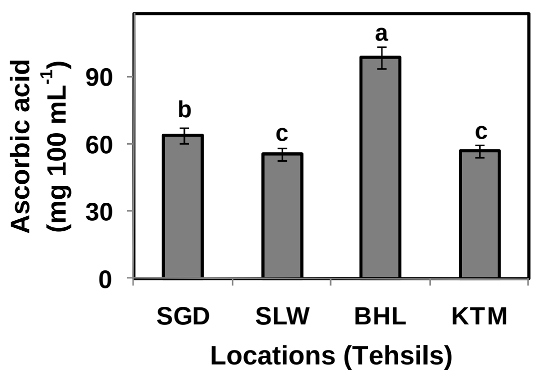
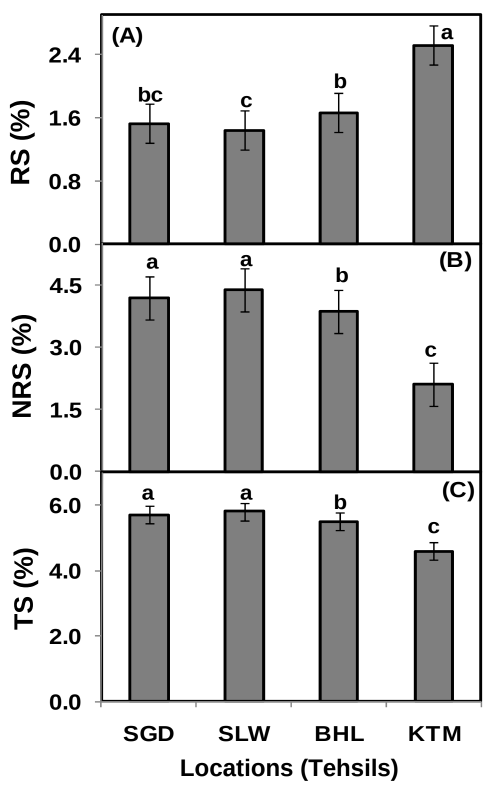


Fig. 6: Reducing sugars (RS) (A), non-reducing sugar (NRS) (B), and total sugars (TS) (C) of 'Kinnow' mandarin fruit harvested from four locations of district Sargodha. Vertical bars indicate ± SE of means. Any two means not sharing same letter differ significantly at 5% level of probability. SGD = Sargodha. SLW = Sillanwali. BHL = Bhalwal. KTM = Kotmomin. n = 3 replicates



The biochemical characters of fruit were significantly affected by the location of harvest (Fig. 4). The SSC of fruit was recorded maximum (11.86%) in the fruit harvested from Bhalwal (Fig. 4A), while TA was found maximum (0.62%) in the fruit harvested form Kotmomin (Fig. 4B). The fruit harvest from Sillanwali exhibited highest (21.23) SSC: TA ratio (Fig. 4C). The level of ascorbic acid in the juice of fruit harvested from the Bhalwal was highest (83.68 mg 100 g^{-1}) and was about 1.5-fold, 1.8-fold and 1.7-fold higher than fruit harvested from Sargodha, Sillanwali and Kotmomin, respectively (Fig. 5).

The fruit harvested from various locations also exhibited significant differences in the amount of sugars (Fig. 6). The level of reducing sugar was found maximum (2.58%) in fruit harvested from Kotmomin about 1.3-fold, 1.7-fold and 1.8-fold higher than fruit harvested from Bhalwal, Sargodha and Sillanwali, respectively (Fig. 6A). The non-reducing sugar was recorded maximum in the Sillanwali (4.39%) and minimum in the Kotmomin (2.12%) (Fig. 6B). The total sugars were found maximum in the fruit harvested from Sillanwali (5.8%), while it was found minimum in the Kotmomin (4.6%) (Fig. 6C). Ascorbic acid (r = 0.25), reducing sugars (r = 0.42), non-reducing sugars (r = 0.68) and total sugars (r = 0.65), were positively correlated with soil P contents. Soil EC exhibited negative correlation with non-reducing sugars (r = -0.52) and total sugars (r = -0.56). Similarly, soil moisture was negatively correlated with SSC (r = -0.29) and reducing sugars (r = 0.52). Non-reducing sugars (r = 0.31) and total sugars (r = 0.28) were positively correlated with leaf K contents (Table III).

DISCUSSION

In the present study all the locations of district Sargodha exhibited differences in soil, as well as tree nutrients status. The soils of all experimental locations were found deficit in organic matter and P contents, while having higher levels of K contents (Table I). The optimum range of soil organic matter has been reported to range from 4-5% for better fruit crop management (OMAFRA, 2010). The soils from the all experimental locations were found slightly alkaline with low EC and moisture contents (Table I). The optimum range for soil P, K, pH, EC and moisture for better growth of citrus plants is ranged from 10-20 mg kg^{-1}, 150-200 mg kg^{-1}, 6-7.50, 10-15 mS cm^{-1} and 70-80%, respectively (Anonymous, 2004). The N contents of 'Kinnow' mandarin leaves sampled from trees cultivated at Bhalwal and Kotmomin were significantly higher (2.43% & 2.44%) and within the optimum range, respectively as compared to trees cultivated in Sargodha and Sillanwali (2.18% & 2.31%), which were in the deficient range, respectively (Fake, 2004). The leaves of the 'Kinnow' trees from the Bhalwal and Kotmomin showed an optimum range of the K (0.865% & 0.819%), respectively while the other locations (Sargodha with 0.693% &

Sillanwali with 0.607%) were found deficient for K contents in their 'Kinnow' mandarin leaves (Table II) (Fake, 2004).

Fruit harvested from orchards at different locations exhibited significant differences in physical fruit characteristics (Fig. 1-3). The higher fruit diameter and weight at Sargodha might be due to the availability of higher organic matter content (0.72%) in the soil as compared to all other locations (Table I). The reduced level of leaf and soil nutrient in the experimental orchards produced fruit with poor physical quality. As, consumer acceptance is mainly determined by the physical appearance of fruit; size and weight are the two main attributes attracting the consumers' decision for buying them. Earlier, Monga *et al*. (2004) also reported that the 'Kinnow' trees with higher N contents produced maximum fruit weight and diameter as compared to control. The higher juice contents and lower peel weight in fruit harvested from Bhalwal might be due to higher levels of soil and leaf nutrients as compared to other locations (Table I & II), which must be due to better fertilizer application at Bhalwal, which improved leaf nutrient contents as compared to Sargodha although with higher organic matter. In addition, positively correlations of fruit weight, fruit diameter and peel thickness with soil organic matter, soil EC, soil moisture contents and leaf nitrogen and negatively correlations of fruit weight, fruit diameter and peel thickness with soil P further confirms our results (Table III). Similarly, positive correlation between soil and leaf N, K and fruit juice and the peel thickness in citrus have been reported earlier by Davies and Albrigo (1994a).

The biochemical characters of fruit were also significantly affected by the location of harvest (Fig. 4). The higher SSC in fruit harvested from Bhalwal might be due to the comparatively higher levels of the macronutrients in these soils as compared to other locations. The lowest SSC: TA ratio was exhibited by fruit harvested from Kotmomin may be due to imbalance in the soil nutritional status due to ignored crop husbandry by growers. The concentration of SSC and SSC: TA ratio in the citrus juice decreased slightly by increase in the K, while the TA increased. Earlier, it was found that this decrease in SSC and SSC: TA ratio and increase in TA was primarily an effect of fruit size (Dou *et al*., 2005). Nasir *et al*. (1989) studied the effect of chemical fertilizer on the ascorbic acid contents of 'Kinnow' fruit and concluded that N and P carrying fertilizer had no significant effect on the accumulation of ascorbic acids in citrus juice and K fertilizer tended to increase the ascorbic acid content in citrus. This difference in the biochemical characters of fruits from all locations were due to difference in the availability of nutrients in soil and leaves and the difference in the cultural practices in all locations. The optimum level of N, P and K in the leaves of 'Kinnow' mandarin trees had been reported to improve the fruit quality parameters at harvest such as fruit volume, weight, total sugar, reducing and non-reducing sugars (Khan *et al*., 2009).

CONCLUSION

The physical and chemical characteristics of 'Kinnow' mandarin fruit are influenced by the location, soil and as well as tree nutrient status. The orchards with optimum soil and leaf nutrient levels produce fruit with better quality.

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