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Effect of Salinity on Some Fruit Quality Attributes and Sugar Composition of *Satsuma mandarin* cv. Owari

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Abstract: The aim of the present study was to determine the effect of salinity on total soluble solids and acidity as citric acid and sugar composition of fruits under saline conditions. It had been observed in the study that total soluble solids and acidity of fruits were least affected by the salinity, sugar contents most affected. Total sugar contents and all sugar fractions of fruits were increased by the salinity. The increase in sucrose was higher compared with other sugar fractions.

Key words: Salinity, citrus, *Satsuma mandarin*, fruit quality, sugar fractions

INTRODUCTION

In Turkey, citrus fruits with 1.4 million tons of production have an important position within total agricultural production and exportation. The Mediterranean region, the southern part of the Turkey, contributes 86% of the citrus production, however, in terms of mandarin production. The Mediterranean is followed closely by the Aegean region. Due to earliness and high quality provided by the prevailing climatic conditions, *Satsuma mandarins* are mainly produced in the western Aegean region.

In many semi-arid and arid regions of the world, increasing salinity of the irrigation water subsequently increases the salinization of land under cultivation which decreases agricultural productivity. This type of salinization also exists in topographically low lands proximal to sea shores where seawater intrudes and mixes with fresh water coming from inland sources[1]. Around the Mediterranean, due to the shortages of water, quantity and quality of irrigation water create problems. A similar situation prevailing in the coastal part of İzmir (Seferihisar-Gümüldür) province of western Turkey, the main *Satsuma mandarin* producing region of the country.

Turkey is one of the countries which have been dominant for the *Satsuma mandarin* in the world trade and its growing area in the country is located along the coast of Aegean sea. Best quality mandarin is produced in Gümüldür and Seferihisar/İzmir and surroundings.

Citrus is a salt sensitive crop[2]. Compared to other agronomic and horticultural crops, citrus species are among the most sensitive to soil salinity[3]. Many researches have been conducted in order to determine the effects of salinity on citrus. In Büyükalan-Gümüldür, one of the leading *Satsuma* growing areas in Turkey, a great number of research have been done in order to reveal the level of salinity and its effects on quality, yield and tree characteristics. As a result of these studies, it was found that EC of the irrigation water in the area changed between 0.60-2.4 dS m^{-1} and its effects decreased towards inland from saline, salinity caused that decrease the vegetative growth of trees, leaf area, stomata number per unit area and yield[4] and negative affect the photosynthesis[4-7]. Its effect on fruit quality was less significant compared to other determined parameters. Among the quality attributes, fruit weight was decreased and especially crude fiber content was in the most affected one[5,8]. Shalhevet and Levy[9] reported that increase in the chloride content of fruit juice was an important symptom of the salinity[9]. In previous research carried out in Gümüldür-Büyükalan located in the central part of the Satsuma mandarin production area, significant correlation was found between the chloride content of the fruit juice and salinity parameters of water and leaf[8].

The water stress triggers the physiological function of osmoregulation[10]. Osmoregulation involves solute accumulation in cells sufficient to decrease the osmotic potential of cells when water potential of cells decreases at low water potential of the water source so that water can be absorbed from the water source by cells without losing cell turgor or decreasing cell volume[11]. Osmoregulation has been observed in leaves[12], stem and roots[11] and fruit[13].

Metabolism of sugars is adversely affected in plants growing under saline conditions[14]. In the leaves of glycophytes, content of soluble sugars increase under salinity[15], water stress[16] and chilling stress[17]. The soluble sugars along with other compatible solutes contribute to osmotic adjustment[15] and directly or indirectly modulate the expression of genes involved in various metabolic processes, storage functions and defence[18].

In this research, the sugar content and sugar fractions of fruits sampled from orchards in Gümüldür and Seferihisar area, of which the salinity problem due to seawater intrusion reported previously[19] was determined, because of their significant osmoregulatory role. In addition, Total Soluble Solids (TSS) and Titratable Acidity (TA) of fruit juice and TSS/TA ratio were determined.

MATERIALS AND METHODS

Fruit samples were taken from a total of 31 *Satsuma mandarin* orchards in the between Çile and Özdere/Gümüldür, Ürkmez/Gümüldür, Özdere/Gümüldür, Sığacık/Seferihisar, Azmak/Seferihisar and Sahilevleri. All orchards are located in the main and most intensive satsuma growing region in western part of Turkey. Trees were budded onto *Poncirus trifoliata* rootstocks. The orchards were selected with 750-1000 m intervals from saline to inland in the each survey area. The orchard with No.1 means that it is the nearest to the sea and the orchard with the last number means the farthest from the sea. Total soluble solids (%) and titratable acidity (as citric acid %) contents of the fruit juice were analysed. The fruit pulp was lyophilised and analysed for the sugar fractions, sucrose, fructose, α glucose, β glucose and galactose, by gas spectrophotometry (Carlo Erba Fractovap Model 2350). The samples were extracted by pyridine, BSTFA and trimethylchlorsilan and at 180°C for monosaccharides and 250°C for disaccharides using N_2 as the carrier[20].

The data of the areas were subjected to analysis of variance (ANOVA) and the means separated by Fisher's Protected Least Significant Difference (LSD) test. All the statistical analyses were performed with SPSS (SPSS Inc., USA).

RESULTS

Total Soluble Solids (TSS), Titratable Acidity (TA) and TSS/TA ratio of fruits: There were statistically significant differences between orchards in terms of Total Soluble Solids (TSS) in Azmak, Titratable Acidity (TA) in Özdere and Sığacık and both TA and ratio of TSS/TA in Ürkmez, while there were not statistically significant differences between orchards in terms of these parameters area that between Çile and Özdere and in Sahilevleri.

Titratable acidity of fruit juices decreased towards inland from saline in Özdere and Sığacık districts. There were statistically significant differences between orchards in both districts. It was 2.38% in the orchards near the sea (#1) and decreased to 1.24% in the farthest orchard (#3) to the saline in Özdere district and the highest TA was 2.08% in the second orchard, the lowest TA was 1.46% in the last one in latter district. In both districts, TSS were higher in the orchards which located near the saline than farther ones but these differences were not significant statistically (Table 1).

Table 1: TSS, TA and TSS/TA of fruit juice in the areas

Orchards	TSS (%)	TA (%)	TSS/TA	Orchards	TSS (%)	TA (%)	TSS/TA
Çile-Özdere/Gümüldür				Azmak/Seferihisar			
1	12.23	1.56	7.89	1	10.11	1.44	7.02
2	11.80	1.64	7.19	2	12.36	1.34	9.34
3	12.08	1.46	8.30	3	11.99	1.44	8.82
4	12.48	1.38	9.02	4	10.85	1.51	7.38
5	12.02	1.41	8.63	5	10.19	1.44	7.13
$LSD_{0.05}$	ns	ns	ns	6	12.20	2.08	5.86
Özdere/Gümüldür			7	11.16	1.44	7.97	
1	12.20	2.38	5.13	8	10.45	1.82	5.84
2	12.25	1.61	7.61	9	11.65	1.57	7.95
3	12.60	1.24	9.88	10	11.90	1.38	8.98
$LSD_{0.05}$	ns	0.181**	ns	11	10.06	1.33	7.56
Ürkmez/Gümüldür				$LSD_{0.05}$	0.878**	ns	ns
1	11.10	1.50	7.40	Sığacık/Seferihisar			
2	10.60	2.05	5.17	1	12.26	1.68	7.45
3	11.31	1.70	6.67	2	10.07	2.08	4.85
$LSD_{0.05}$	0.432*	0.221**	0.432*	3	9.40	1.51	6.23
Sahilevleri				4	9.45	1.46	6.50
1	9.28	1.44	6.50	5	10.24	1.40	7.37
2	9.25	1.66	5.58	6	9.43	1.16	8.24
$LSD_{0.05}$	ns	ns	ns	7	9.99	1.35	7.47
				$LSD_{0.05}$	ns	0.276**	ns

ns, non significant **p<0.01 * p<0.05

Table 2: Contents of sugar fractions (mg g^{-1}) in the areas

Orchards	Sucrose	Fructose	α-Glucose	β-Glucose	Galactose	Total
Çile-Özdere/Gümüldür						
1	490.69	168.47	59.81	66.21	10.04	795.22
2	384.64	177.48	59.15	74.62	10.24	706.14
3	245.37	165.12	58.70	65.73	9.53	544.45
4	322.88	195.86	57.88	65.19	9.32	651.13
5	166.96	24.25	47.54	65.93	3.03	307.71
$LSD_{0.05}$	66.10**	40.13**	8.55*	ns	1.78**	79.73**
Özdere/Gümüldür	382.42	214.57	64.98	86.46	9.80	758.23
2	347.00	237.61	66.00	77.94	11.16	739.71
3	341.53	208.09	51.35	72.24	7.95	681.16
$LSD_{0.05}$	ns	ns	5.62**	7.71*	ns	ns
Ürkmez/Gümüldür						
1	317.43	140.12	48.20	54.32	9.77	569.84
2	164.64	126.93	37.65	55.30	5.03	389.55
3	236.46	108.17	40.72	41.18	9.12	435.65
$LSD_{0.05}$	21.82**	12.55**	7.52*	2.62**	0.91**	33.24**
Sahilevleri						
1	371.81	208.32	66.43	89.09	10.48	746.13
2	220.32	112.72	37.69	38.42	5.19	414.34
$LSD_{0.05}$	33.86**	20.45**	4.58**	5.29**	1.72**	42.55**
Azmak/Seferihisar						
1	429.42	159.51	54.42	56.81	12.96	713.12
2	343.85	209.14	63.34	81.77	9.78	707.88
3	343.35	181.80	47.41	69.49	7.76	649.81
4	191.35	301.58	76.79	83.67	16.52	669.91
5	296.58	172.73	42.48	60.54	7.12	579.45
6	360.81	152.19	58.38	67.54	9.94	648.86
7	350.37	165.25	46.57	64.05	9.22	635.46
8	315.45	157.19	49.30	63.14	10.50	595.58
9	286.49	173.76	55.80	52.62	11.17	579.84
10	115.30	129.18	41.96	45.98	6.62	339.04
11	206.53	148.33	52.67	62.38	8.69	478.60
$LSD_{0.05}$	29.75**	22.41**	7.64**	12.89**	2.57**	38.15**
Sığacık/Seferihisar						
1	217.42	113.38	36.30	55.89	5.66	428.65
2	297.87	114.31	32.58	47.60	6.66	499.02
3	394.86	150.95	45.37	61.88	8.95	662.01
4	296.94	181.98	66.03	80.25	7.76	632.96
5	326.73	244.05	74.38	99.38	10.55	755.09
6	228.60	212.93	63.62	70.34	12.30	587.79
7	208.49	142.82	38.35	51.72	5.86	447.24
$LSD_{0.05}$	21.99**	34.01**	6.14**	8.39**	2.17**	15.78**

ns, non significant **p<0.01 *p<0.05

There were significant differences between all criteri and orchards, but no relation was found related location of orchards it means salinity in the Ürkmez (Table 1).

In Azmak, TSS was high in the first five orchards, than decreases were observed in the following orchards towards inland. TSS was ranged between 11.65 and 12.36% in the first five orchards. They were varied between 10.06 and 11.16% in the inland orchards (Table 1).

Sugar composition of fruits: There were statistically significant differences between orchards and all sugar fractions, sucrose, fructose, galactose, α and β glucose and also total sugar contents of fruits. Since different results were obtained from the Sığacık/Seferihisar area, these results were examined separately.

Total sugar content of fruits was varied between 307.7 and 795.2 mg g^{-1} in area from Çile to Özdere, 681.1 and 758.2 mg g^{-1} in Özdere, 389.5 and 569.8 mg g^{-1} in Azmak, 414.3 and 746.1 mg g^{-1} in Sahilevleri and there were statistically significant difference between orchards in all areas (Table 2).

Total sugar amounts of fruits were higher orchards near the sea than in the inland orchards in the all districts.

The mean amounts of total sugar in all districts were evaluated, orchards in the Özdere took the first rank with 726.3 mg g^{-1}; followed by Çile-Özdere, Azmak, Sahilevleri and Ürkmez, respectively.

Sucrose was dominant in fruits in all orchards except two of them which number 4 and 10 in Azmak district. In two orchards, fructose content was 301.58 and 129.18 mg g^{-1} and sucrose content was 191.35 and 115.98 mg g^{-1}, respectively (Table 2).

Sucrose content of fruits decreased with increasing distance from the sea. It was 490.69 mg g^{-1} in the orchards near the saline, declined to 166.96 mg g^{-1} in the inland

orchards between Çile and Özdere area. Similarly, sucrose content was 382.42 and 341.53 mg g^{-1} in the Özdere; 429.42 and 206.53 mg g^{-1} in the Azmak; 371.81 and 220.32 mg g^{-1} in Sahilevleri at the orchards which were located near to sea and the inland, respectively. In Ürkmez, the highest sucrose content was also obtained from the orchard which was nearest to the sea, however, lowest value was obtained from the second orchard from the sea (Table 2).

The second dominant sugar fructose, changed with the increasing distance from the sea. Generally, in orchards that are far from the sea, in which the effect of salinity is low, the lowest fructose content was obtained.

The amount of β-glucose was found 2 to 15 times higher than the amount of α-glucose. Both α and β glucose and the total glucose increased, with one or two exceptions, towards to the sea, like the other sugar fractions (Table 2).

The galactose content was the lowest among the sugar fractions. Statistically significant relationships were found between galactose content and the distance to the sea; the galactose content decreased as the distance from the sea increased. Generally the amount of galactose changed between 3.03 and 16.15 mg g^{-1} according to the areas.

In Sığacık/Seferihisar area, of which the results differed from the others, the lowest values of total sugar was obtained in the orchards both the nearest and the farthest to the sea. The highest total sugar content of fruits was obtained from orchards, which are located in the middle zone.

DISCUSSION

The concentrations of total soluble solids and titratable acidity as citric acid in the citrus juice are important parameters for fruit quality. Besides, the ratio between TTS and TA are the most important factor in determining fruit quality. Generally saline conditions cause an increase TSS and acid concentrations in the fruits juice. Francois and Clark[21], reported that salinity caused a delay in the ripening of the fruit of Valencia orange, but did not cause any significant decrease of the fruit quality. Bielorai *et al.*[22] found the slight increases in TSS and contents of sucrose and in TSS/TA ratios in Shamouti oranges, while other researches declared that salinity caused an increase only in TSS and that it was not effective on TA[8]. In this research work, there were some differences between TSS, TA and ratio of TSS /TA with salinity in the areas. But these did not appear to be a typical effect of salinity in the whole of the areas. Salinity caused an increase in TSS of the fruits in Azmak and an increase citric acid concentration of fruits in districts of Özdere and Sığacık.

Sugars are among the most significant compounds in the fruits. Although sugar concentrations of a particular species may vary with the variety, rootstock and soil and climatic conditions, in citrus fruits, fructose is reported as the second most abundant sugar fraction after sucrose[23,24]. In this study, sucrose was found the dominant sugar in all orchards except two and followed by fructose as a second dominant sugar. Hepaksoy *et al.*[8], found similar results in terms of sugar contents in another study, which was conducted in district close to area of the present research.

Reduction of growth caused by high salinity is possibly related to osmotic effects as low soil water potentials and ionic imbalances as induced toxicities or induced deficiencies[25]. It is reported that in plant tissues salinity affects different metabolic processes such as CO_2 assimilation, protein synthesis, respiration or photohormone turnover[26]. To some degree, plants can cope with salinity through some regulatory processes like excluding the uptake of excessions or secreting it into vacuoles[27]. For this reason, plants subjected to salinity require additional energy and deplete storage carbonhydrates. That is why plants suffering from salinity are poor in energy status and have an impaired CO_2 assimilation[26].

Sugar is the main organic compound as osmotic regulation in glycophytes under the salt stress conditions[28]. Both reduced and non-reduced sugars with nitrogen compounds accumulate in cells under stress conditions and they play a role as osmotic regulators[29]. It has been stated that, in stress conditions, the most increasing type of sugar is sucrose and the second is fructose[24]. Especially sucrose has an important role in adapting to stress conditions. Sucrose provides protection by replacing water in the structure of membrane phospholipids in crystalline phase. Besides, it prevents structural changes in water-soluble proteins. The roles of reduced sugars (fructose, glucose and galactose) are more complicated in adaptation mechanism. In some cases, their accumulation might reach a harmful level in many respects. Monosaccharides which play an important role in respiration, increase the rate of respiration, help metabolism by providing the transfer of mitochondrial electrons and energy production. Besides being a carbonhydrate source, fructose plays an important role in the metabolic processes during stress conditions[30].

In this research work, sucrose showed a greater increase than fructose in relation with salinity and had a greater portion in total sugars in most of the orchards.

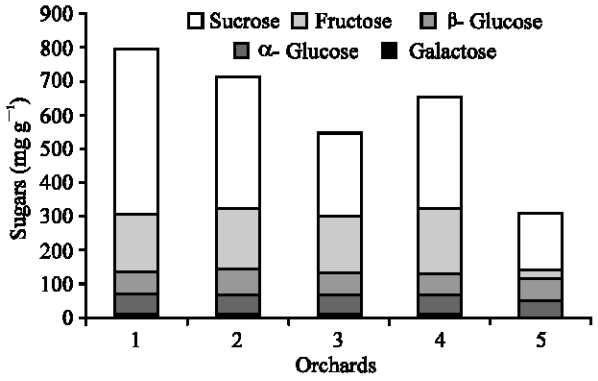

Fig. 1: Sugar fractions of orchards in the between Çile and Özdere area

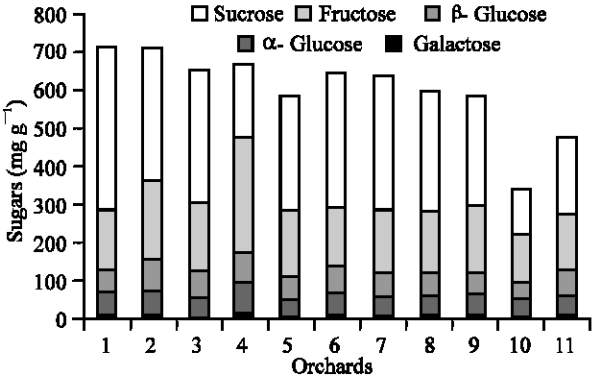

Fig. 2: Sugar fractions of orchards in Azmak/Seferihisar area

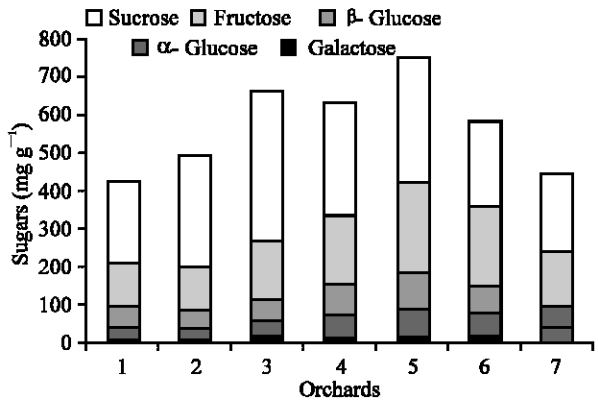

Fig. 3: Sugar fractions of orchards in Sığacık/Seferihisar area

Although not only the amount of sucrose, but also the amount of other sugar fractions (monosaccharides) rose by the increasing salinity, the ratio of monosaccharides in total sugar decreased (Fig. 1-3). In orchards which are near to the sea and on which salinity was more effective, the ratio of disaccharide/monosaccharide was above 1 and sometimes 1.5, or even 1.6, but in orchards which are far from the sea and thus the effect of salinity is low, this ratio was below 1.

Only in Sığacık/Seferihisar area, opposite of the expected results, sugar accumulation was lower in fruits of orchards that are close to the sea and their salinity level are known to be high[19], but sucrose had a bigger share in total sugars (Fig. 3). In the first three orchards from the sea, the ratio between disaccharide and monosaccharides was over 1, while inland orchards fell below 1.

These findings indicate that sugar accumulation in fruit grown under saline stress conditions increased and sucrose has a great portion of the total sugars, which suggests that disaccharides are largely responsible for active osmoregulation in fruit under saline stress conditions.

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