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Productivity, Fruit Quality and Nutritional Status of Washington Navel Orange Trees as Influenced by Foliar Application with Salicylic Acid and Potassium Silicate Combinations

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Abstract: The effect of foliar application with salicylic acid (0.0, 100 and 200 ppm) in combination with potassium silicate (0.05, 0.1, 0.15 and 0.2 %) solutions were investigated on 10 year-old Washington navel orange trees budded on sour orange rootstock grown in loamy sand soil under surface irrigation system at a private orchard, Tough region, Kalubia Governorate, Egypt during 2014 & 2015 seasons. The influence was evaluated through the response of the different (fruiting aspects, fruit quality and nutritional status) to the specific and interaction effects of both investigated factors. The obtained results revealed that all investigated measurements i.e., 1- fruiting aspects (fruit set, fruit retention and yield as No. or weight of harvested fruits per trees, 2- fruit quality (physical properties (average fruit weight, fruit dimensions, shape index, peel thickness and fruit juice weight) and chemical properties (TSS%, total acidity %, TSS/Acid ratio, total sugars and vitamin C contents) and 3- nutritional status (leaf total chlorophyll, N, P, K, Ca, Mg, Fe, Mn and Zn contents) responded specifically to each investigated factor. However, the response to potassium silicate was more pronounced and differences between its four concentrations were significant as compared each other from one hand and the highest one (0.20%) was the most effective. Meanwhile, with the salicylic acid concentrations the response was relatively slight and difference between its concentration were in most cases too few to reach level of significance. Such trend was true during both seasons, but the trend of response varied slightly or moderately from one measurement to another. As for the interaction effect between potassium silicates x salicylic acid concentrations, it was cleared that specific effect of each investigated factor directly reflected on its own combinations. Anyhow, both combinations representative of the highest potassium silicate (0.20%) in combination with two salicylic acid concentrations (100 & 200 ppm) particularly higher one were the most effective for most measurements of fruiting aspects, fruit quality and nutritional status, except with leaf Fe, Mn and Zn contents, whereas the combination of potassium silicate (0.15%) x lower salicylic acid concentration (100ppm) was statistically the superior.

Key words: Washington navel orange · Salicylic acid · Potassium silicate · Foliar application · Nutritional status · Fruit quality · Fruiting aspects.

INTRODUCTION

Citrus is considered to be one of the world's most common popular and favorite fruit. In Egypt, (420333.6 faddans = one faddan = 0.42ha) (more than 39% from total fruit area) are planted with citrus trees. The production of citrus in Egypt was increased to 3980151 tonnes in 2012[1]. Thus, Egypt is considered to be one of the ten largest producers of citrus in the world. Thereby, strenuous efforts have always been exerted for increasing production of citrus through a better understanding of its reaction to environment and mineral nutrition. Salicylic acid (SA) was first discovered as a major component in the extracts from Salix (willow) whose bark from ancient time [2]. Also, plant growth and development are greatly affected by various biotic and a biotic stresses factors. Detection of compounds of reducing these stresses is great important. Previous studies emphasized the beneficial effects of salicylic acid in reducing biotic stress sensitivity in plants. It was also shown to influence a number of physiological processes including flowering, ion uptake and transport, photosynthesis rate and stomatal conductance [3, 4, 5]. Using salicylic acid had beneficial effects on growth and fruiting of evergreen

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fruit crops [6-12]. Potassium silicate is a source of highly soluble potassium and silicon. It is used in agricultural production systems primarily as a silica amendment and has the added benefit of supplying small amounts of potassium. The National Organic Programme (NOP) has no prior ruling on the use of this substance. The national list allows the use of some synthetic silica-based fertilizers, but they are allowed only as micronutrient amendments as a means to deliver trace metals and are not intended as silica fertilizers per se. The list also allows the use of silicon dioxide in food processing. Silicon is one of the abundant elements in the lithosphere and it is the most abundant element in soil next to oxygen and comprises 28 per cent of its weight and 3-17 percent in soil solution [13]. It is most commonly found in soils in the form of solution as Silicic acid (H_4SiO_4) and plants take up directly as Silicic acid [14].

Therefore, the present study aims to investigate the effect of salicylic acid and potassium silicate on the productivity, fruit quality and nutritional status of Washington navel orange trees.

MATERIALS AND METHODS

This study was carried out during 2014 & 2015 seasons on 10-year-old Washington navel orange trees budded on Sour orange rootstock grown at 5.0 meters a parts in loamy sand soil under surface irrigation of a private orchard at Manzala village, Tough region, Kalubia Governorate, Egypt. All trees were subjected to the same horticultural practices (irrigation, fertilization, weeds & pest control) adopted in the region according to the recommendation of the Ministry of Agriculture. It was devoted to investigate the influence of foliar application with salicylic acid (SA) (0.0, 100 and 200 ppm) in combination with potassium silicate (PS) (0.05, 0.1, 0.15 and 0.2 %) in addition to tap water as control treatment. The treatments used in this study as follow:

- Tap water (control).
- SA (0.0) x PS (0.05%)
- SA (0.0) x PS (0.10%)
- SA (0.0) x PS (0.15%)
- SA (0.0) x PS (0.20%)
- SA (100 ppm) x PS (0.05%)
- SA (100 ppm) x PS (0.10%)
- SA (100 ppm) x PS (0.15%)
- SA (100 ppm) x PS (0.20%)
- SA (200 ppm) x PS (0.05%)
- SA (200 ppm) x PS (0.15%)
- SA (200 ppm) x PS (0.15%)
- SA (200 ppm) x PS (0.20%)

The experiment was laid out in randomized complete block design with three replications (single tree per each replicate) was employed for arranging these treatments. Devoted trees for each treatment were sprayed five times with the corresponding solution (at the rate of 5 liters per each) five times at one-month interval starting from early March till early June during each season. The following characters were measured:

Productivity Aspects: fruit set%, fruit retention % and yield expressed as either number or weight in Kg of harvested fruits per each tree.

Fruit Quality

Fruit Physical Properties: average fruit weight (g), fruit dimensions (polar & equatorial diameters), fruit shape index (polar: equatorial diameters), rind thickness and fruit juice weight.

Fruit Chemical Characteristics: Were determined according to AOAC [15] for fruit juice TSS% using hand refractometer, fruit juice total acidity as citric acid by titration against NaOH (0.1N), TSS/Acid ratio, total sugars % were determined after the method described by Smith *et al.* [16] and fruit juice Vitamin C (ascorbic acid) content (mg/100ml juice) by titration with 2-6 dichlorophenol indophenol pigment.

Photosynthetic Pigments: total chlorophyll contents in fresh leaves were determined by using Minolta meter SPAD-502.

Macro and Micronutrients Contents in Leaves: Total leaf (N) was determined by the modified micro Kjeldahl method mentioned by Pregl [17]. Total leaf (P) was determined by wet digestion of plant materials after the methods described by Piper [18]. Total leaf (K) was determined photometrically according to the method described by Brown and Lilliand [19]. Calcium and Magnesium percentages as well as Iron, Manganese and Zinc were determined using the Atomic absorption spectrophotometer "Perkin Elmer -3300" according to Chapman and Pratt [20].

Statistical Analysis: All data obtained during both seasons were subjected to analysis of variance and significant differences among means were determined according to Snedecor and Cochran [21]. Capital and small letters were used for distinguishing between means of specific effect of two investigated factors i.e. salicylic acid & potassium silicate concentrations and interaction between them, respectively, according to Duncan's multiple test range [22].

RESULTS AND DISCUSSIONS

Some Fruiting Aspect in Response to Foliar Application with Salicylic Acid and Potassium Silicate: Data obtained of fruit set %, fruit retention % and yield per tree (expressed either as number and weight in Kg of harvested mature fruits) as productivity measurements, as well as some fruit quality pertaining their physical & chemical characteristics (average fruit weight, fruit dimension i.e. polar & equatorial diameters, fruit shape index, peel thickness and juice weight) & (fruit juice TSS%, total acidity%, TSS/Acid ratio, total sugars and vitamin C content) in response to specific and interaction effects of the two investigated factors during 2014 and 2015 seasons are presented in Tables 1-3.

Specific Effect: It is quite clear that all the above-mentioned fruiting measurements responded specifically to each investigated factor. However, the grade of response varied not only from one fruiting measurement to another, but also the rate of differences in each investigated measurement exhibited by potassium silicate was more pronounced than the analogous ones resulted by salicylic acid. However, in general the four potassium silicate spray solutions (0.05, 0.10, 0.15 and 0.20%) increased significantly all fruiting measurements as compared to control (water spray). Such trend was true with all fruiting measurements during two seasons with only two exceptions i.e. with fruit shape index, whereas a significance difference between all potassium silicate concentrations was absent and fruit juice total acidity which its trend took the other way around. Anyhow, the response of these fruiting measurements to the specific effect of potassium silicate concentration pointed out clearly that the greatest values of such measurements were significantly in closed relationship to the highest potassium silicate spray solution (0.2%). Moreover, potassium silicate spray at 0.15% concentration ranked statistically 2nd, followed by 0.1% spray solution. However, the lightest increase over control was always in concomitant to the lowest potassium silicate spray (0.05%). Differences between such four categories of response to specific effect of potassium silicate concentration were significant during both seasons with few exceptions particularly in some cases when comparing spray solutions of either (0.15 & 0.10%) or (0.10 & 0.05%) concentration each other pertaining their influence on equatorial diameter, fruit juice weight, total sugars and vitamin C, whereas, differences didn't reach level of significances. As for the exception dealing with the response of both fruit shape index (polar: equatorial diameters) and fruit juice total acidity, it may be logically explained depending upon the two facts: with the fruit shape index it may be attributed to the similar rate of the response exhibited with both fruit dimensions to a given spray treatment. While, fruit juice total acidity considered as dilution effect due to the increase exhibited in fruit juice content or sign of earlier maturation by all spraying treatments. The present results are in general accordance with those previously found by Kanto [23] on salicylic acid and Gad El- Kareem [24], Al-Wasfy [25] and Roshdy [26], they emphasized the importance of using silicon sources on growth and fruiting aspects of different fruit crops. Also, Ibrahim and Al-Wasfy [27] reported that using of potassium silicate at 0.1 improving yield and fruit quality of Valencia orange trees.

As for the specific effect of salicylic acid concentration, the obtained data presented in Tables 1-3 revealed that the rate of response was relatively not so pronounced to that previously discussed with potassium silicate concentration. Hence, the increase in most productivity and fruit quality measurements over control was significant in such parameters of 200 ppm salicylic acid sprayed Washington navel orange trees, except those dealing with fruit physical characteristics measurements. Moreover, differences between lower salicylic acid spray solution (100 ppm) and control plants were too few to be taking into consideration. These results are confirmed by those obtained by Eshmawy [10], Saied [11], Ahmed [12], Ibrahim and Al-Wasfy [27] and Ahmed *et al.* [28], who reported that using of potassium silicate improved yield and fruit quality of Valencia orange trees.

Interaction Effect Between Salicylic Acid and Potassium Silicate: Concerning the interaction effect of different combinations among salicylic acid and potassium silicate concentrations on the differential investigated fruiting parameters of Washington navel orange cv. Data presented in Tables 1-3 revealed that each investigated factor reflected directly its specific effect on the interaction effect of their combinations. Anyhow, all investigated fruiting parameters which had been responded specifically to any investigated factor were also influenced by their combinations. Consequently, the combinations of the highest potassium silicate concentration (0.2%) and to great extent those of 0.15% from one side and any of two salicylic acid levels (100 & 200 ppm) from the other exhibited statistically the greatest values of such measurements exactly (percentage of fruits set & retention), (yield either as number or weight of

Table 1: Some fruiting measurements (fruit set %, fruit retention%, yield/tree and average fruit weight of Washington navel orange cv. as influenced by specific and interaction effects of salicylic acid & potassium silicate concentrations during 2014 & 2015 seasons.

Spray treatments								
Salicylic acid (ppm)	Fruit set %				Fruit retention %			
Potassium silicate (%)	0.00	100	200	Mean*	0.00	100	200	Mean*
				2014 season				
Control (Tab water)	11.71h	11.74h	11.73h	11.72E	8.82i	8.81i	8.89i	8.84E
0.05	13.05g	13.24g	15.17f	13.82D	9.80h	9.65h	12.53cd	10.66D
0.10	15.80e	17.18d	17.36cd	16.78C	11.01g	13.13ab	11.45f	11.86C
0.15	17.88bc	17.43cd	17.44cd	17.58B	12.22de	11.92e	12.92bc	12.36B
0.20	18.09b	18.73a	17.75bcd	18.19A	13.00b	13.45a	13.35ab	13.27A
Mean**	15.31B	15.66AB	15.89A	--	10.97B	11.39B	11.83A	--
				2015 season				
Control (Tab water)	12.33e	12.35e	12.34e	12.34E	8.73j	8.71j	8.72j	8.72E
0.05	13.46d	13.91d	15.29c	14.22D	9.86h	9.83i	12.06e	10.44D
0.10	15.68c	17.79b	17.83b	17.10C	11.34g	13.08c	11.76f	12.06C
0.15	18.59a	17.80b	18.50a	18.30B	12.38d	12.22de	13.34bc	12.65B
0.20	18.93a	18.91a	18.44a	18.76A	13.24bc	13.65a	13.51ab	13.47A
Mean**	15.80B	16.15AB	16.48A	--	11.11B	11.41B	11.88A	--

Table 1: Continued

Spray treatments	Yield (harvested fruits per tree) as:											
Salicylic acid (ppm)	No. of fruits/tree				Fruits weight/tree (Kg)				Average fruit weight (g)			
Potassium silicate (%)	0.00	100	200	Mean*	0.00	100	200	Mean*	0.00	100	200	Mean*
					2014 season							
Control (Tab water)	99.00h	98.00h	100.3gh	99.11E	21.59j	21.57j	21.62j	21.59E	221.0ij	220.0i	221.7ij	220.9D
0.05	104.00f	102.3fg	122.7e	109.7D	23.30i	22.66i	29.95g	25.30D	224.0i	221.3ij	244.0f	229.8CD
0.10	122.0e	130.0d	124.0e	125.3C	28.15h	32.70e	29.47g	30.11C	230.7h	251.3e	237.7g	239.9C
0.15	130.3d	128.0d	142.0c	133.4B	32.51e	31.07f	37.13d	33.57B	249.3e	242.7f	261.3d	251.1B
0.20	153.7b	151.3b	160.0a	155.0A	41.68b	40.18c	45.60a	42.49A	271.0b	265.3c	284.7a	273.7A
Mean**	121.8B	121.9B	129.8A	--	29.45B	29.63B	32.76A	--	239.2B	240.1B	249.9A	--
					2015 season							
Control (Tab water)	105.0i	104.0i	106.0i	105.0E	23.56i	23.54i	23.54i	23.55E	227.4i	226.2i	226.8i	226.8C
0.05	109.3h	105.3i	126.7g	113.8D	24.82h	23.88i	31.22g	26.64D	227.0i	226.6i	246.3f	233.3BC
0.10	133.0e	136.0d	129.7h	132.9C	31.18g	34.57d	31.00g	32.25C	234.3h	254.0e	239.0g	242.4B
0.15	135.de	132.7e	145.0c	137.6B	33.51e	32.64f	37.96c	34.71B	248.2f	246.0f	261.7d	252.0B
0.20	157.0b	158.3b	162.0a	159.1A	42.25b	42.13b	47.20a	43.86A	269.0b	266.0c	291.2a	275.4A
Mean**	127.9B	127.3B	133.9A	--	31.07B	31.35B	34.18A	21.59E	241.2B	243.8B	253.0A	--

*&** refer to specific effect of potassium silicate &salicylic acid concentrations, respectively.
Means of specific and interaction effects followed by the same capital and small letters, respectively didn't significantly differ at 5% level.

Table 2: Fruit physical properties (fruit dimensions, shape index, peel thickness (mm) and juice weight (g) of Washington navel orange cv. as influenced by specific and interaction effects of salicylic acid & potassium silicate concentrations during 2014 & 2015 seasons.

Spray treatments								
Salicylic acid (ppm)	Polar diameter (cm)				Equatorial diameter (cm)			
Potassium silicate (%)	0.00	100	200	Mean*	0.00	100	200	Mean*
				2014 season				
Control (Tab water)	7.89jk	7.84kl	7.89jk	7.87E	7.89jk	7.87jk	7.90j	7.87C
0.05	7.90j	7.82l	8.31e	8.01D	7.91j	7.84k	8.33e	8.02BC
0.1	8.01i	8.43d	8.08h	8.17C	8.04i	8.45c	8.10h	8.19B
0.15	8.20f	8.15g	8.50c	8.28B	8.24f	8.16g	8.51c	8.30AB
0.2	8.45cd	8.58b	8.66a	8.56A	8.47cd	8.60b	8.67a	8.58A
Mean**	8.09A	8.16A	8.29A	--	8.11A	8.18A	8.30A	--
				2015 season				
Control (Tab water)	7.91m	7.90m	7.92l	7.91E	7.92h	7.94gh	7.97gh	7.94BC
0.05	7.97k	7.87n	8.41f	8.09D	8.01g	7.93gh	8.43d	8.12BC
0.1	8.10j	8.49e	8.20i	8.26C	8.18f	8.52c	8.23f	8.31B
0.15	8.30g	8.24h	8.54d	8.36B	8.38de	8.33e	8.57c	8.43AB
0.2	8.56c	8.68b	8.74a	8.66A	8.55c	8.67b	8.75a	8.66A
Mean**	8.17A	8.24A	8.36A	--	8.21A	8.28A	8.39A	--

Table 2: continued

Spray treatments: Salicylic acid (ppm)	Fruit shape index				Peel thickness (mm)				Juice weight (g)			
Potassium silicate (%)	0.00	100	200	Mean*	0.00	100	200	Mean*	0.00	100	200	Mean*
2014 season												
Control (tab water)	0.997a	0.997a	0.996a	0.997A	3.75gh	3.81fg	3.87f	3.81C	87.33i	88.33hi	89.33hi	88.33D
0.05	0.999a	0.997a	0.998a	0.998A	3.64i	3.68hi	4.50c	3.94C	91.0h	90.67h	99.33f	93.67CD
0.10	0.997a	0.998a	0.998a	0.998A	4.87a	4.10e	4.17de	4.38B	102.7e	96.0g	98.33fg	99.00BC
0.15	0.996a	0.998a	0.998a	0.998A	4.25d	4.25d	4.43c	4.31B	104.0e	105.0e	110.3d	106.4B
0.20	0.998a	0.998a	0.999a	0.998A	4.65b	4.47c	4.70b	4.61A	113.7c	117.0b	120.7a	117.1A
Mean**	0.997A	0.998A	0.998A	--	4.23B	4.06B	4.33A	--	99.73A	99.4A	103.6A	--
2015 season												
Control (tab water)	0.995a	0.995a	0.994a	0.994A	3.78g	3.80g	3.81g	3.79C	90.33i	91.33i	91.67ij	91.11D
0.05	0.996a	0.993a	0.997a	0.996A	3.64h	3.67h	4.40c	3.91C	96.0h	94.0hi	102.3g	97.44CD
0.10	0.990a	0.997a	0.996a	0.994A	4.63a	4.04f	4.10ef	4.26B	106.7ef	102.0g	105.0f	104.6BC
0.15	0.990a	0.989a	0.997a	0.992A	4.11ef	4.16e	4.39c	4.22B	108.3de	109.7d	115.0c	111.0B
0.20	1.002a	1.002a	0.999a	1.001A	4.55b	4.28d	4.60ab	4.48A	120.0b	123.3a	125.0a	122.8A
Mean**	0.994A	0.995A	0.997A	--	4.14B	3.99B	4.26A	--	104.3A	104.1A	107.8A	--

*&** refer to specific effect of potassium silicate &salicylic acid concentrations, respectively.
Means of specific and interaction effects followed by the same capital and small letters, respectively didn't significantly differ at 5% level.

Table 3: Fruit chemical properties (fruit juice TSS %, total acidity %, TSS/Acid ratio, total sugars % and Vitamin C) of Washington navel orange cv. as influenced by specific and interaction effects of salicylic acid & potassium silicate concentrations during 2014 & 2015 seasons.

Spray treatments: Salicylic acid (ppm)	TSS (%)				Total acidity (%)			
Potassium silicate (%)	0.00	100	200	Mean*	0.00	100	200	Mean*
2014 season								
Control (Tab water)	10.05h	9.94 h	10.07h	10.02D	1.023b	1.004c	1.007bc	1.01A
0.05	10.39g	10.66g	11.61e	10.89C	1.014bc	1.073a	0.933fg	1.01A
0.10	12.19a-c	11.27f	11.32f	11.59B	0.918gh	0.941ef	0.957e	0.939AB
0.15	11.93cd	11.85de	12.43a	12.07A	0.978d	0.987d	0.995ij	0.953AB
0.20	12.02b-d	12.16a-c	12.22ab	12.13A	0.910hi	0.899ij	0.883i	0.897B
Mean**	11.32B	11.18C	11.53A	--	0.969A	0.981A	0.935A	--
2015 season								
Control (Tab water)	10.00i	10.03i	10.03i	10.02E	1.022b	1.007bc	1.002c	1.01A
0.05	10.48h	10.43h	11.65de	10.85D	1.013bc	1.097a	0.952ef	1.02A
0.10	11.99ab	11.11g	11.47f	11.53C	0.917g	0.943f	0.958def	0.939AB
0.15	11.53ef	11.75cd	12.03a	11.77B	0.968de	0.975d	0.889hi	0.944AB
0.20	11.83bc	11.97ab	12.00a	12.00A	0.905gh	0.890hi	0.881i	0.892B
Mean**	11.17B	11.06C	11.44A	--	0.965A	0.982A	0.936A	--

Table 3: Continued

Spray treatments: Salicylic acid (ppm)	TSS/acid ratio				Total sugars (%)				Vitamin C (mg/100 ml)			
Potassium silicate (%)	0.00	100	200	Mean*	0.00	100	200	Mean*	0.00	100	200	Mean*
2014 season												
Control (Tab water)	9.82h	9.90g	10.01gh	9.91E	7.30i	7.27m	7.31i	7.30D	51.96j	51.96j	51.97j	51.96D
0.05	10.24g	9.93gh	12.45d	10.87D	7.36k	7.44j	7.95g	7.58CD	53.04j	53.42i	60.96e	55.81CD
0.10	13.28c	11.98ef	11.83f	12.36C	8.18e	7.42j	7.49i	7.70BC	64.86d	57.47h	58.42g	60.25C
0.15	12.20de	12.01ef	13.89a	12.70B	7.81h	8.50f	8.31d	8.06B	63.63f	62.62f	71.61c	65.62B
0.20	13.21c	13.53bc	13.83ab	13.52A	8.40c	8.56b	8.75a	8.57A	72.79b	72.66b	73.49a	72.98A
Mean**	11.75B	11.47C	12.40A	--	7.81AB	7.75B	7.96A	--	61.66B	60.23AB	63.89A	--
2015 season												
Control (Tab water)	9.79h	9.96h	10.00g	9.92E	7.41h	7.40h	7.41h	7.41C	54.79gh	54.79gh	54.80gh	54.80D
0.05	10.35f	9.51i	12.24c	10.70D	7.56g	7.68fg	8.11de	7.78C	56.31h	56.33h	64.21e	58.95CD
0.10	13.08b	11.78e	11.98de	12.28C	8.26d	7.03i	7.79f	7.69C	70.66d	62.44fg	63.72f	65.60C
0.15	11.92de	12.05cd	13.54a	12.50B	7.98e	8.24d	8.47c	8.23B	68.27ef	67.90ef	76.26cd	70.81B
0.20	13.07b	13.44b	13.62a	13.38A	8.68b	8.98a	9.11a	8.92A	73.33bc	83.90a	74.46b	77.23A
Mean**	11.64B	11.35C	12.27A	--	7.98AB	7.86B	8.18A	--	65.07B	65.47B	67.09A	--

*&** refer to specific effect of potassium silicate &salicylic acid concentrations, respectively.
Means of specific and interaction effects followed by the same capital and small letters, respectively didn't significantly differ at 5% level.

harvested fruits per tree), (average fruit weight & dimensions), (peel thickness & fruit juice weight) and some fruit juice chemical properties (TSS%, TSS/Acid ratio, total sugars and vitamin C contents). On the contrary, the least values of the previous fruiting measurements were always in closed relationship with these combinations which are representative of the lowest potassium silicate concentration (0.05%) particularly as combined with salicylic acid at either (0) or (100 ppm). In addition, the other combinations were in-between the aforesaid extremes with a relative slight difference varied from one fruiting measurement to another. Such trend was true during both seasons with only two exceptions i.e., 1st dealing with fruit juice total acidity, whereas its trend took the other way around and 2nd dealing with fruit shape index which didn't significantly respond to all investigated combinations. These results could be logically explained on the base of following three facts:

- The more pronounced influenced of potassium silicate paralleled to the relative slight response to salicylic acid is a real reason for explaining the trend of response of most investigated fruiting measurements.
- The paralleled rates of response dealing with both fruit dimensions (polar & equatorial diameters) whereas both were approximately coincident in their trend of response to a given spray treatment (combination) and consequently considered as the main responsible mean of significance absent between different combinations.
- With fruit juice total acidity pertaining its decrease by different (potassium silicate conc. x salicylic acid conc.) combinations may be attributed to either the dilution effect resulted by increasing fruit juice weight by different spray treatments (potassium silicate x salicylic acid combinations) or may be due to such decrease in fruit juice total acidity usually associated to the earlier fruit maturity coupled with a noticeable acidity reduction.

In addition, earlier findings of several investigators gave support to the present results regarding the beneficial effect of potassium silicate x salicylic acid combinations on the differential investigated fruiting parameters. In this regard, Kanto [23], Gad El- Kareem [24], Abdel-Aal and Oraby [29] and Lalithya *et al.* [30, 31]. Moreover, Moawad *et al.* [32] they reported that foliar application of mixture of potassium silicate and boric three times improved yield and fruit quality of Succary Mango trees.

Total Chlorophyll, Macro and Micronutrients Contents in the Leaves: Data presented in Tables 4 and 5 indicated the total chlorophyll content and nutritional status of Washington navel orange trees (N, P, K, Ca, Mg, Fe, Mn and Zn) contents were influenced by specific and interaction effects by using different concentrations of salicylic acid and potassium silicate and its combinations during 2014 and 2015 seasons.

Specific Effect: As for the specific effect of potassium silicate spray solutions, data obtained during both seasons revealed that all concentrations increased significantly all investigated leaf chemical composition over the control. Such trend was true during both seasons, except the lowest potassium silicate concentration (0.05%), whereas the increase was so slight to reach level of significance in most cases with few exceptions related to the leaf Mg and Zn content (during two seasons) and leaf K, Ca and Mn content in the 2nd season. Moreover, the most effective potassium silicate was significantly coupled with its highest concentration (0.20%) as the response of leaf total chlorophyll, N, P, K, Ca and Mg contents was concerned. However, with the micro nutrient elements Fe, Mn and Zn the trend was modified, whereas two intermediate potassium silicate concentrations (0.15 & 0.10%) exhibited statistically the highest leaf Fe, Mn and Zn contents. Concerning the specific effect of salicylic acid concentration, the obtained results during both seasons displayed that differences in all investigated leaf chemical constituents were not so pronounced and the response to salicylic acid concentration didn't follow a firm trend similar to that previously detected with potassium silicate. Anyhow, the higher salicylic acid concentration (200 ppm) resulted in a slight increase in leaf total chlorophyll content and level of macro nutrient elements. Such increase didn't reach level of significance except with leaf K and Mg contents during both seasons as the higher salicylic acid concentration (200 ppm) was compared to the either its lower concentration (100 ppm) or to the free salicylic acid solution (0.0). However, with the leaf micro nutrient elements (Fe, Mn and Zn) the lower salicylic acid concentration (100 ppm) was more effective and differences were significant only with leaf Zn content during both seasons and Mn content in the 2nd season. On the other hand, differences between (0.0) and (100 ppm) salicylic acid sprayed solutions was not significant for leaf total chlorophyll content and leaf N, P, K, Ca, Mg and Fe content during both seasons, while reached to level of significance with leaf Mn & Zn contents during both seasons and 2nd season, respectively.

Table 4: Leaf total chlorophyll, N, P and K contents of Washington navel orange cv. as influenced by specific and interaction effects of salicylic acid & potassium silicate concentrations during 2014 & 2015 seasons.

Spray treatments Salicylic acid (ppm)	Total chlorophyll. (mg/g FW)				N (%)			
Potassium silicate (%)	0.00	100	200	Mean*	0.00	100	200	Mean*
				2014 season				
Control (Tab water)	8.94b	8.94b	8.93b	8.94D	2.16jk	2.17j	2.20i	2.17C
0.05	8.94b	8.95b	9.70ab	9.20CD	2.10l	2.15k	2.34e	2.19C
0.10	10.07ab	9.52ab	9.60ab	9.73BC	2.43d	2.19i	2.22h	2.28BC
0.15	9.72ab	9.74ab	10.53a	10.0AB	2.26f	2.24g	2.48c	2.33B
0.20	10.64a	10.53a	10.83a	10.67A	2.53b	2.53b	2.60a	2.55A
Mean**	9.66A	9.54A	9.92A	--	2.30AB	2.26B	2.37A	--
				2015 season				
Control (Tab water)	9.01f	9.01f	9.03ef	9.02D	2.19k	2.19k	2.21j	2.20C
0.05	9.65c-f	8.96f	9.74b-f	9.45CD	2.13m	2.17l	2.36f	2.22C
0.10	10.09a-e	9.56d-f	9.74b-f	9.79BC	2.42e	2.27h	2.25i	2.32BC
0.15	9.85b-f	9.74b-f	10.55a-d	10.05B	2.29gh	2.30g	2.52d	2.37B
0.20	10.75ab	10.63a-c	10.91a	10.76A	2.58c	2.60b	2.63a	2.60A
Mean**	9.87A	9.58A	9.99A	--	2.32B	2.31B	2.40A	--

Table 4: Continued

Spray treatments Salicylic acid (ppm)	P (%)				K (%)			
Potassium silicate (%)	0.00	100	200	Mean*	0.00	100	200	Mean*
				2014 season				
Control (Tab water)	0.122g	0.122g	0.124fg	0.123C	1.30i	1.30i	1.31i	1.30D
0.05	0.124fg	0.125e-g	0.140b-g	0.130C	1.30i	1.31i	1.51e	1.37CD
0.10	0.144a-f	0.133d-g	0.140c-g	0.139BC	1.54d	1.38h	1.40h	1.44BC
0.15	0.145a-e	0.149a-d	0.156a-c	0.150AB	1.44g	1.48f	1.59c	1.51B
0.20	0.157a-c	0.161ab	0.163a	0.160A	1.62b	1.63b	1.67a	1.64A
Mean**	0.138A	0.138A	0.145A	--	1.44B	1.42B	1.50A	--
				2015 season				
Control (Tab water)	0.120d	0.120d	0.122d	0.121D	1.32j	1.32j	1.33j	1.32D
0.05	0.126cd	0.129cd	0.143a-d	0.133CD	1.36i	1.36i	1.54f	1.42C
0.10	0.146a-d	0.134b-d	0.142a-d	0.141BC	1.59e	1.41h	1.41h	1.47BC
0.15	0.147a-d	0.151a-c	0.159a-b	0.153AB	1.47g	1.53f	1.61d	1.54AB
0.20	0.161ab	0.164a	0.144a-d	0.157A	1.63c	1.66b	1.71a	1.67A
Mean**	0.140A	0.140A	0.142A	--	1.47B	1.46B	1.52A	--

*&** refer to specific effect of potassium silicate &salicylic acid concentrations, respectively.
Means of specific and interaction effects followed by the same capital and small letters, respectively didn't significantly differ at 5% level.

Table 5: Leaf Ca, Mg, Fe, Mn and Zn of Washington navel orange cv. as influenced by specific and interaction effects of salicylic acid & potassium silicate concentrations during 2014 & 2015 seasons.

Spray treatments Salicylic acid (ppm)	Ca (%)				Mg (%)			
Potassium silicate (%)	0.00	100	200	Mean*	0.00	100	200	Mean*
				2014 season				
Control (tab water)	4.21l	4.21l	4.22l	4.21 CD	0.370j	0.374j	0.374j	0.373D
0.05	4.29a	4.63i	4.56f	4.41C	0.393i	0.413h	0.533e	0.447C
0.10	4.57f	4.31j	4.42h	4.43C	0.567d	0.467g	0.500f	0.511B
0.15	4.54g	4.60e	4.90d	4.68B	0.537e	0.537e	0.577d	0.550B
0.20	4.94c	5.06b	5.17a	5.06A	0.593c	0.617b	0.640a	0.617A
Mean**	4.51A	4.51A	4.66A	--	0.492B	0.482C	0.525A	--
				2015 season				
Control (Tab water)	4.18k	4.19k	4.19k	4.17D	0.397j	0.400j	0.398j	0.393D
0.05	4.28j	4.34i	4.53f	4.39C	0.420i	0.440h	0.550e	0.470C
0.10	4.54f	4.28j	4.37h	4.40C	0.583d	0.487g	0.503f	0.524B
0.15	4.51g	4.57e	4.85d	4.64B	0.547e	0.553e	0.590d	0.563B
0.20	4.90c	5.01b	5.13a	5.01A	0.617c	0.633b	0.657a	0.636A
Mean**	4.48A	4.48A	4.62A		0.513AB	0.503B	0.540A	

Table 5: Continued

Spray treatments Salicylic acid (ppm) Potassium silicate (%)	Fe (%)				Mn (%)				Zn (%)			
	0.00	100	200	Mean*	0.00	100	200	Mean*	0.00	100	200	Mean*
2014 season												
Control (Tab water)	67.32l	67.33l	67.35l	67.33C	30.95k	30.97k	30.96k	30.96C	22.77i	22.78i	22.78i	22.78D
0.05	67.56l	69.46k	71.17j	69.40BC	31.55j	32.54i	38.67h	34.25BC	23.88h	23.77h	26.34g	24.66C
0.10	72.78i	83.10d	83.91c	80.00A	40.91g	52.23d	52.81c	48.65B	27.28f	35.22c	35.48c	32.66A
0.15	87.47b	90.53a	74.79h	84.26A	54.52b	56.20a	45.76f	52.16A	36.13b	36.53a	28.34e	33.67A
0.20	75.90g	76.78f	77.48e	76.72B	47.59e	46.18f	47.56e	47.14B	28.64e	27.34f	29.57d	28.52B
Mean**	74.24A	77.44A	74.94A	--	41.10A	43.62A	43.17A	--	27.74C	29.13A	28.50B	--
2015 season												
Control (Tab water)	66.36l	66.37l	66.38l	66.37C	30.38m	30.40m	30.40m	30.39D	23.30h	23.32h	23.30h	23.30D
0.05	67.37k	70.50j	72.00i	69.95C	32.05l	34.44k	39.52j	35.33C	24.67g	24.57g	27.50f	25.58C
0.10	73.28h	83.07d	84.08c	80.14AB	40.53i	51.48d	51.97c	48.00B	27.57f	35.58b	35.72b	32.95A
0.15	86.07b	89.59a	75.39g	83.68A	54.67b	56.40a	46.51h	52.53A	35.59b	36.20a	29.49d	33.76A
0.20	76.52f	76.73f	78.23e	77.16B	48.41e	47.22g	48.00f	47.88B	29.61d	28.65e	30.51c	29.59B
Mean**	73.92A	77.25A	75.22A	--	41.21B	43.99A	43.28AB	--	28.15B	29.66A	29.31A	--

*&** refer to specific effect of potassium silicate &salicylic acid concentrations, respectively.
Means of specific and interaction effects followed by the same capital and small letters, respectively didn't significantly differ at 5% level.

These results are confirmed by those obtained by Eshmawy [10], Saied [11] and Ahmed [12], Gad El- Kareem [24], Ahmed *et al.*[28] and Abdel-Aal and Oraby [29]. They found that using of silicon and salicylic acid promoting production of Hindybisinnar Mango trees. Similar results were obtained by Ibrahim and Al-Wasfy [27] on Valencia orange trees and Moawad *et al.* [32] on Succary Mango trees.

Interaction Effect Between Salicylic Acid and Potassium Silicate: With regard to the interaction effect among potassium silicate concentration x salicylic acid concentration on the total leaf chlorophyll and nutritional contents in the leaves of Washington navel orange cv., data presented in Tables 4 and 5 indicated that different combinations varied obviously pertaining their effect on leaf chemical composition of Washington navel orange trees. However, the most effective combinations were generally in closed relationship to those between two higher concentrations of potassium silicate (0.20 & 0.15%) from one hand and any or both salicylic acid concentrations (100 & 200ppm) from the other. While, the trend of response varied greatly or slightly from one leaf chemical constituent to another. Anyhow, the highest leaf N, K, Ca and Mg contents were significantly coupled with the treatment of 0.2% potassium silicate x 200 ppm salicylic acid in both seasons. However, with three micro-elements (Fe, Mn and Zn) an obvious modification in the trend of response was detected whereas the spray solution representative of the (0.15% potassium silicate x 100 ppm salicylic acid) combination exhibited statistically the highest leaf Fe, Mn and Zn contents during both seasons of study. On the other hand, with both leaf total chlorophyll and P contents the combination between three higher concentrations of Potassium silicate particularly two higher ones (0.20&0.15%) combined with both salicylic acid concentrations (100 & 200 ppm) were statistically the most effective ones from one hand and they didn't significantly differ as compared each other during two seasons of study. On the contrary, the least values of all or most leaf chemical constituents were usually in concomitant to such combinations between the lowest potassium silicate concentration (0.05%) and any of both salicylic acid concentrations (100 & 200 ppm). In addition, other combinations were in between the aforesaid two extremes. The obtained results could be logically explained on the base of the more pronounced response of various nutritional status measurements to the specific effect of potassium silicate concentration rather than to the specific effect of salicylic acid concentration. In other words, potassium silicate plays a real role in nutritional status measurements and consequently it may be reflected on its combination. These results are in harmony with those obtained by Eshmawy [10], Saied [11], Ahmed [12], Gad El- Kareem [24], Roshdy and Ahmed *et al.* [28]. Also, Ibrahim and Al-Wasfy [27] suggested that using of potassium silicate at 0.1% improved leaf chemical composition of Valencia orange trees.

CONCLUSION

Conclusively, from the obtained results, it can be concluded that spraying Washington navel orange trees grown under similar environmental conditions and horticulture practices adopted in present experiment with

0.20% potassium silicate x 200 ppm salicylic acid is a beneficial mean in order to improve productivity, fruit quality and nutritional status of such favorite sweet orange cultivar.

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