

Short Communication

The influence of different agrochemicals foliar sprays on postharvest fruit quality of Navel orange

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Abstract: The present investigation was carried out during the two successive growing seasons of 2003 and 2004 on Washington Navel orange trees grown at El-Tarh region, El-Behera Governorate, in order to study the effect of spraying orange trees with different agrochemicals on fruit quality. For the present study, 96 trees were selected as uniform as possible and divided into two groups. The first group was subjected to the foliage treatments when the fruit reached pea size (5mm in diameter) and the second at marble size (15mm in diameter). Fruit weight was significantly increased in both seasons by spraying 2,4-D + boric acid at the pea or marble stages. In addition, spraying 2,4-D + boric acid at the marble stage only increased fruit length. Vitamin C content was not affected by all sprays at the pea stage, whereas it was significantly increased in the first season by spraying 2,4-D, 2,4-D + calcium chloride, 2,4-D+ calcium acetate, urea or boric acid alone at the marble stage. In the second season, fruit acidity was increased by spraying boric acid at both pea and marble stage, whereas, it was decreased by spraying 2,4-D + calcium chloride (pea stage) and 2,4-D + boric acid (marble stage). Spraying 2,4-D + calcium super phosphate at pea or marble stage significantly increased TSS percent. In addition, all treatments enhanced fruit color in both pea and marble stages over the control, especially, treatments that included foliar spray of 2,4-D. In general, most 2,4-D sprays combined with other compounds had significant influence on fruit quality characteristics.

Keywords: Navel orange, agrochemicals, fruit quality, postharvest, foliar sprays.

تأثير الرش الورقي ببعض الكيماويات الزراعية علي جودة ثمار البرتقال أبو سرّة بعد الحصاد

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المخلص: أجريت هذه الدراسة خلال عامي 2003 و2004 على أشجار البرتقال أبو سرّة في أحد مزارع محافظة البحيرة بمنطقة الطرح. وذلك بغرض دراسة تأثير الرش الورقي في مرحلتي نمو الثمار (حجم البسلة وحجم البلية) ببعض الكيماويات الزراعية على صفات جودة الثمار، وقد أجريت الدراسة على 96 شجرة متماثلة وموزعة عشوائياً في الحقل مقسمة إلى مجموعتين، رشّت المجموعة الأولى في مرحلة حجم البسلة (قطر 5مم)، و رشّت المجموعة الثانية في مرحلة حجم البلية (قطر 15مم)، ويمكن تلخيص النتائج كما يلي: الرش بحامض البوريك + 2,4-D في مرحلتي النمو سبب زيادة معنوية في وزن الثمار في كلا الموسمين، بينما زاد طول الثمار برش حامض البوريك + 2,4-D في مرحلة البلية فقط. لم يتأثر محتوى الثمار من فيتامين ج برش جميع المركبات في مرحلة البسلة، بينما إزداد في الموسم الأول برش كل من اليوريا، حمض البوريك، 2,4-D، خلات الكالسيوم + 2,4-D، كلوريد كالسيوم + 2,4-D في مرحلة البلية. إزداد محتوى حموضة الثمار في الموسم الثاني عند الرش بحامض البوريك في كلا المرحلتين، بينما إنخفض عند رش 2,4-D + كلوريد الكالسيوم (في مرحلة البسلة) و 2,4-D + حمض البوريك (في مرحلة البلية). أدت الرش بسوبرفوسفات الكالسيوم + 2,4-D في كلا المرحلتين إلى زيادة معنوية في محتوى الثمار من المواد الصلبة الكلية. أدت جميع معاملات الرش في مرحلتي النمو إلى تحسين لون الثمار. عموماً فإن معاملات الرش بالـ 2,4-D مصحوباً بالمركبات الأخرى كان الأكثر تأثيراً على صفات جودة الثمار.

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Introduction

Citrus in Egypt is a major export product. Egypt has the potential to export close to one million tons of fresh fruits by the year 2010 (Hofer, 2006). Today, Egypt stands at the tenth and fourth position among the top citrus producing and exporting countries, respectively (F.A.O., 2010). In Egypt Washington Navel orange is the most important and popular orange variety that is consumed and exported as fresh fruit. Recently, the production of high quality citrus crop for export purposes is highly awarded specially by Navel orange growers. Fruit size represents one of the most important quality characteristics for citrus fresh consumption (Agusti et al., 2002) as well as external features like fruit colour, size, and peel texture are the important parameters to estimate the quality of the fruit, while internal characters contributing to fruit quality include amount and quality of juice, seediness, vitamin C contents, total soluble solids (TSS), titratable acidity (TA) and TSS: TA ratio. (Ahmed, 2006). Improving citrus fruit quality can be achieved by several steps including; high quality nurseries, good agricultural practices and standardized citrus packing stations. The major agricultural practice that affects tree nutritional status and has strong impact on its fruit quality characteristics is fertilization. Both macro and micro- nutrients such as N, Ca and Bo are critical nutrients for fruit growth and quality (Shoeib and El-Sayed, 2003). Urea was reported to enhance fruit size, peel thickness and juice (El-Otmani, 2002). Its application as foliar sprays is reported to be absorbed rapidly and efficiently by leaves of most fruit crops (Johnson et al., 2001) and are commonly sprayed in citrus plantation without causing any phytotoxic effects (Alberigo, 2002). Also, foliar sprays of calcium, boron and zinc either alone or in combinations, have been shown to protect the plant against stress (Andrews, 2002). Stress (i.e. high temperature stress) disrupt tree metabolism and causes physiological damage. However, date and number of applications must be considered according to the purpose aimed to obtain best result. Also, 2,4-D is a synthetic auxin which

is known to be effective in enhancing Navel orange fruit quality such as weight and size (Ahmed, 2006 and Modise et al., 2009). It has been widely used as herbicide for several decades due to its relative moderate toxicity and biodegradability in plant and soil (National Research Council Canada, 1991 and Sterling and Hall, 1997). The world health organization (WHO) does not regard 2,4-D and its salts and esters as either genotoxic or carcinogenic, and established an acceptable daily intake (ADI) for 2,4-D of 0 to 0.01 mg /kg/day (USDA, 2006) which is far less from the concentration applied when it is sprayed as synthetic auxin on fruit trees.

From the previous above, the present study was carried out in order to investigate the influence of different agrochemicals foliar sprays either alone or in combinations to Washington Navel orange trees during two growing stages of the fruit (at pea and marble stages) on the different postharvest fruit quality characteristics.

Material and methods

Plant material and treatments

The effect of spraying Washington Navel orange trees with different agrochemicals on postharvest fruit quality was studied during 2003 and 2004 growing seasons. The present study was conducted in a private citrus orchard at El-Tarh region, EL- Behera Governorate. The soil was clay, well-drained with water table about 120 cm and pH 8. Twenty years old Washington Navel orange trees (*Citrus sinensis* L.), budded on sour orange rootstock were planted at 4x4 m apart and subjected to the same cultural practices usually done in the orchard.

In January of both seasons, calcium superphosphate (15.5% P₂O₅) was added at the rate of 500 kg per feddan. Ammonium nitrate (33% N) was applied at the rate of 300 kg in March, 250 kg in May and 300 kg in August of both seasons per feddan. In August of both seasons, 100 kg per feddan potassium sulfate (48% K₂O₅) was added. Trees were irrigated with Nile water every 15-20 days.

Ninety six trees were selected as uniform as possible and divided into two groups. The first group was subjected to the foliage treatments at the beginning of May when the fruit reached pea size (5mm in diameter), and the second at the end of May when the fruit reached marble size (15 mm in diameter). Trees were sprayed with, calcium chloride (0.5%), calcium acetate (0.5%), boric acid (150 ppm), urea (2%), calcium superphosphate (2%) and 2,4-D (20 ppm). 2, 4-D was sprayed alone or in combination with the previous mentioned compounds.

Treatments were arranged in a complete randomized design with four replicates for each treatment and trees of both groups were treated with the following 12 foliage treatments (i.e., 4 x 12 = 48 trees/group):

T1= Water spray only (control).

T2= Calcium chloride (0.5%).

T3= Calcium acetate (0.5%).

T4= Boric acid (150 ppm).

T5=Urea (2%).

T6= Calcium superphosphate (2%).

T7= 2,4-D (20 ppm).

T8= 2,4-D (20 ppm) + calcium chloride (0.5%).

T9= 2, 4-D (20 ppm) + calcium acetate (0.5%).

T10 = 2, 4-D (20 ppm) + boric acid (150 ppm).

T11=2, 4-D (20ppm) + urea (2%).

T12 = 2, 4-D (20ppm) + calcium superphosphate (2%).

The surfactant Nourfilm (produced by Alam Chemca) at the rate of 40 cm/100 L water was added to all sprayed chemicals in order to obtain best results.

Fruit sampling

At harvest date (mid - December), 25 fruit were sampled per replication uniformly from all sides of each tree of both groups in both growing seasons for physico-chemical analysis.

Fruit physical analysis

The fruits were washed under tap water, dried under shade, in each fruit sample; fruit color was assessed visually according to the color chart of orange fruit, fruit weight (g), diameter (cm) and length (cm) were measured

using a manual vernier caliper. Fruits were peeled; peel and pulp were weighed (g) separately and juice was extracted in a beaker and juice volume (cm³) was estimated. A part of the juice was kept in sealed plastic container for biochemical analysis at the spot.

Fruit biochemical analysis

The fruit juice quality analysis including total soluble solids (TSS), acidity, TSS/acidity ratio and vitamin C were estimated. The percentage of total soluble solids was measured by hand refractometer. Acidity, as citric acid percentage, was calculated by titration with 0.1N sodium hydroxide. Vitamin C content (mg/100ml juice) was determined by titration with indophenol blue due.

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) using the statistical analysis system (SAS, 2003) and the results were considered to be significant at the 0.05 level of probability. Means were separated using the least significance differences (LSD) according to Snedecor and Cochran (1989).

Results

Fruit Physical analysis

Fruit weight

The data presented in Table (1) showed a significant increase in fruit weight compared to the control by spraying calcium chloride and 2,4-D + calcium superphosphate (in the first season), calcium acetate, boric acid, calcium superphosphate and 2,4-D + calcium chloride (in the second season) and 2,4-D + boric acid and 2,4-D + urea (in both seasons) at the pea stage.

With regard to the marble stage, fruit weight significantly increased in both seasons over the control by spraying boric acid, calcium superphosphate, 2,4-D + calcium chloride, 2,4-D + calcium acetate and 2,4-D + boric acid, with no significant differences among the mentioned treatments were obtained in the second season (Table 1).

Table 1. Effect of spraying different agricultural chemicals on physical fruit quality of Navel orange trees in 2003 and 2004 season.

Treatments	Fruit weight (g)		Fruit length (cm)		Fruit diameter (cm)		Fruit diameter ratio		Peel weight (g)		Pulp weight (g)	
	Pea stage	Marble stage	Pea stage	Marble stage	Pea stage	Marble stage	Pea stage	Marble stage	Pea stage	Marble stage	Pea stage	Marble stage
2003 season												
T1	187	187	7.16	7.12	7.04	7.22	0.99	0.98	47.9	43.80	139.5	143.5
T2	217	209	7.42	7.33	7.26	7.55	1.01	0.96	48.9	46.70	168.8	162.6
T3	176	245	7.00	7.64	7.09	7.86	0.98	0.96	43.5	54.85	132.5	190.9
T4	195	217	7.07	7.42	7.08	7.62	0.99	0.96	46.6	48.25	147.7	168.7
T5	189	226	7.08	7.36	7.00	7.62	1.00	0.96	41.5	45.82	147.6	180.2
T6	193	207	7.18	7.41	7.20	7.43	1.00	0.99	43.9	47.17	149.8	160.0
T7	207	241	7.59	7.91	7.25	7.82	1.04	1.00	56.8	52.22	150.9	189.2
T8	197	203	7.26	7.30	7.07	7.48	1.02	0.97	46.3	47.77	151.4	155.3
T9	196	214	7.30	7.65	7.00	7.53	1.03	1.01	46.9	46.30	149.4	168.6
T10	218	231	7.55	7.84	7.38	7.75	1.01	1.00	49.1	51.85	169.2	179.5
T11	237	199	7.65	7.38	7.50	7.38	1.01	0.99	49.7	44.60	183.2	154.3
T12	247	200	7.85	7.38	7.62	7.35	1.02	0.99	36.5	47.27	205.6	153.2
L.S.D _{0.05}	26	16	0.70	0.55	0.45	0.33	0.04	0.05	19.7	8.29	45.6	34.4
2004 season												
T1	233	221	7.82	7.61	7.57	7.52	1.04	1.00	46.2	45.87	187.5	175.0
T2	243	245	8.07	7.92	7.65	7.85	1.05	1.02	47.4	50.05	195.5	194.7
T3	258	243	8.30	7.96	7.95	7.87	1.04	1.00	55.0	50.52	203.7	193.2
T4	271	277	8.22	7.32	7.95	8.10	1.03	1.02	46.1	54.52	217.8	222.0
T5	243	239	7.92	8.09	7.75	8.08	1.01	1.00	48.7	53.07	193.6	211.7
T6	269	266	8.22	7.99	8.12	7.99	1.01	0.99	69.0	51.77	200.6	214.5
T7	241	243	8.10	7.86	7.62	7.84	1.03	0.99	49.4	46.65	192.2	196.5
T8	257	262	8.85	8.10	7.82	7.95	0.99	1.01	49.1	58.42	208.2	204.0
T9	250	256	8.40	8.02	7.82	7.80	1.05	1.02	56.7	51.87	218.5	204.5
T10	256	256	8.02	7.99	7.95	7.84	1.02	1.01	33.5	53.27	227.9	203.5
T11	277	277	8.22	7.97	8.15	8.11	1.00	0.97	58.7	51.15	218.7	225.2
T12	230	262	8.00	8.21	7.57	8.02	1.05	1.01	47.9	57.25	182.1	204.7
L.S.D _{0.05}	22	30	0.59	0.24	0.59	0.58	0.06	0.06	18.9	8.96	47.9	56.9

Fruit color

As presented in Table (2), in general an enhancement in fruit color ranged from yellow to yellow -orange was achieved by all sprayed substances at both pea and marble stages, especially, treatments that included foliar spray of 2,4-D.

Fruit biochemical analysis

Vitamin C

With regard to the pea stage, the data of Table (2) showed that vitamin C content was not significantly affected by any of the treatments in both seasons as compared with the control.

Regarding the marble stage, the obtained data showed that foliar sprays of boric acid, urea, 2,4-D, 2,4-D + calcium chloride and 2,4-D + calcium acetate significantly increased vitamin C content as compared with the control in the first season. In addition, spraying 2,4-D + calcium acetate gave higher vitamin C content than boric acid, urea and 2,4-D (Table 2).

Acidity

Spraying 2,4-D + calcium acetate at the pea stage gave significantly lower fruit acidity than the control in the first season. Also, spraying urea and 2,4-D + boric acid at marble stage significantly decreased fruit acidity content in the second season. In contrast, a significant increase in fruit acidity content was obtained in the second season by spraying boric acid at both pea and marble stages as compared to the control. In addition, all other treatments did not significantly affect fruit acidity when sprayed at both pea and marble stages in comparison with the control in both seasons (Table 2).

Total soluble solids

With regard to the pea stage the data presented in Table (2) showed that fruit total soluble solids (TSS) increased significantly by spraying calcium chloride, 2,4-D, 2,4-D + urea and 2,4-D + calcium superphosphate in both seasons as compared to the control, with no significant differences among them were obtained.

Regarding the marble stage, spraying 2,4-D alone and 2,4-D + calcium acetate resulted in higher TSS content than the control in both seasons, with no significant difference obtained between both treatments (Table 2).

TSS/acid ratio

The data presented in Table (2) showed that in general, all sprayed substances caused an increase in the value of TSS/acid ratio over the control at the pea stage but the differences were not significant except spraying calcium superphosphate, 2,4-D + calcium chloride and 2,4-D + calcium acetate in the first season and calcium acetate in the second season.

Regarding the marble stage, the TSS/acid ratio was significantly increased over the control by spraying 2,4-D and 2,4-D + calcium acetate in the first season and, urea and 2,4-D + boric acid in the second season.

Discussion

Similar enhancement in fruit physical and biochemical characteristics obtained in the present study by the different sprayed substances specially fruit weight and size, and peel weight is also reported (Agusti et al., 1994; Alberigo, 2002; El-Otmani et al., 2002; Harty et al., 2004). Marzouk and Kassem (2002) reported an increase in fruit length/diameter ratio in Washington Navel orange trees by spraying 2,4-D, in both pea and marble stages and calcium chloride at the marble stage only. Qin XuanNan (1996) reported that spraying orange trees with H₃BO₃ increased TSS/acidity ratio. On the other hand, Marzouk and Kassem (2002) reported that spraying Washington Navel orange trees with calcium chloride, calcium acetate, urea and 2,4-D, at pea and marble stages, did not affect TSS/acid ratio. The foliar sprays of phosphoric acid recorded the highest value of TSS, total sugars, reducing sugars and carotene contents (Kassem et al., 2010). Fruit size and weight can be improved by increasing carbohydrates availability to fruit or by increasing fruit sink strength.

Table 2. Effect of spraying different agricultural chemicals on chemical fruit quality of Navel orange trees in 2003 and 2004 season.

Treatments	Juice volume (cm ³)		V. C content (mg/100 ml juice)		Acidity (%)		T.S.S. content (%)		T.S.S./acidity ratio		Fruit colour*	
	Pea stage	Marble stage	Pea stage	Marble stage	Pea stage	Marble stage	Pea stage	Marble stage	Pea stage	Marble stage	Pea stage	Marble stage
2003 season												
T1	60.0	61.5	37	23	1.27	1.29	11.7	11.47	9.25	8.94	F	H
T2	72.3	69.0	38	24	1.14	1.22	12.2	11.90	10.86	9.48	J	I
T3	53.0	90.0	36	23	1.24	1.34	11.9	11.45	9.67	8.55	I	H
T4	71.5	70.0	41	27	1.18	1.12	11.9	11.90	10.17	10.65	G	I
T5	61.8	76.7	36	26	1.30	1.20	12.2	11.90	9.64	10.02	I - H	I
T6	67.3	72.5	37	24	1.11	1.41	12.4	11.55	11.16	8.16	H	H
T7	66.3	83.7	37	27	1.21	1.13	12.4	13.00	10.28	11.50	H	H
T8	68.8	64.0	36	29	1.07	1.41	11.7	11.95	11.06	8.63	G	I
T9	62.0	69.7	36	30	1.05	1.11	12.1	12.65	11.58	11.39	I	I
T10	77.0	76.7	34	24	1.21	1.31	11.3	11.95	9.42	9.13	F	H
T11	84.8	66.7	39	22	1.32	1.29	12.3	11.65	9.62	9.13	G	H
T12	81.5	65.5	40	23	1.18	1.26	12.2	12.65	10.40	10.12	I	H
L.S.D _{0.05}	20.8	17.3	4.6	2.9	0.22	0.20	0.42	0.77	1.72	1.90		
2004 season												
T1	82.5	83.0	52	40	1.40	1.64	13.5	13.35	9.68	8.41	G	J
T2	77.8	82.7	53	37	1.40	1.57	14.1	13.60	10.05	8.00	J	I
T3	83.0	92.5	51	42	1.17	1.89	13.4	13.55	11.49	7.16	I - H	J
T4	97.5	99.5	56	39	1.72	1.91	13.3	13.55	7.82	7.58	J	J
T5	86.0	101.0	52	39	1.47	1.25	13.3	13.25	9.00	10.92	H	J
T6	87.0	104.2	45	37	1.45	1.67	13.8	13.15	9.41	7.84	H	I
T7	81.3	95.5	56	24	1.42	1.52	14.2	14.00	9.97	9.22	J	J
T8	90.5	91.7	50	40	1.52	1.49	14.3	13.65	9.74	9.26	I - J	J
T9	89.0	88.0	50	40	1.45	1.79	14.2	14.20	9.75	7.94	I	J
T10	88.5	86.0	45	40	1.45	1.22	13.8	13.25	9.72	11.14	I	J
T11	94.0	100.7	55	36	1.60	1.55	14.1	13.25	9.18	8.70	I	J
T12	77.8	87.0	56	39	1.47	1.71	14.2	13.60	9.71	7.90	J	J
L.S.D _{0.05}	25.0	27.8	8.6	5.7	0.26	0.27	0.59	0.51	1.36	1.96		

* Fruit colour: F = light green, G = light yellow, H = yellow, I = full yellow, J = yellow-orange

Spraying synthetic auxins such as 2,4-D may act in these two ways specially when applied at the cell enlargement stage leading to enhancing cell expansion and increasing fruit size (Agusti et al., 2002). Similar influence might be obtained by urea sprays as it enhances vegetative growth (Kassem et al., 2010), thus, increases carbohydrates content in the fruits and encourages its growth. Calcium is a critical nutrient for citrus fruit quality and is known to be involved in many fundamental physiological plant processes involving cell walls, membranes and enzyme activity (Xu et al., 2009) which might have a direct effect on fruit growth. Also, an enhancement of fruit color was obtained. 2,4-D plays a role in encouraging fruit color break and enhancing peel color in citrus fruit (Agusti et al., 2002, Saleem et al., 2008). foliar urea applied increased the polyamine content, growth rate, and size of developing citrus fruit, as well as their potential to set (Corona, 1994 and Lovatt and Jaganath, 1998).

Moreover, an increase in fruit biochemical characteristics by spraying 2,4-D and urea was reported (Babu and Yadav, 2002, Gill et al., 2002; Kotsias, 2004; Saleem et al., 2008). The increase in juice volume by 2,4-D and urea sprays might be explained by their influence in enhancing cell expansion which increases vesicle capacity for juice accumulation (Agusti et al., 2002). A significant increase in orange fruit acidity by boric acid sprays was also reported by Qin XuanNan (1996). Moreover, the results of the present study are in line with those of Kim-YongHo et al. (2004) and Kotsias (2004) who found that calcium sprays increased TSS contents of mandarin and orange fruits. Kassem et al. (2010) reported that the foliar sprays of phosphoric acid recorded the highest value of TSS, total sugars, reducing sugars and carotene contents. phosphoric acid has a major role in the biosynthesis of nucleic acid, ATP molecules, and acts as co-enzyme for many enzymes (Kassem et al., 2010). Hegab et al. (2003) reported that the boron promotes starch transformation into saccharides in plant cells. The urea foliar spray increased juice content,

reduced acidity and increased the maturity index (El-Otmani et al., 2004).

Conclusion

From the investigations it is clear that with application of different agrochemicals at pea and marble stages, fruit quality can be positively manipulated in Washington Navel orange. The 2,4-D alone or combined with calcium compounds at the early stages of fruit growth (mainly the marble stage) could be useful in improving fruit quality.

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