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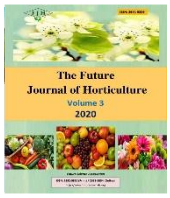

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REDUCING THE INCIDENCE OF RIND CREASING OF “NAVEL" ORANGES BY FOLIAR APPLICATION OF AN ANTI-ETHYLENE AND SOME NUTRIENTS

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ABSTRACT: The present study was conducted during 2017 and 2018 seasons on “Washington” navel orange trees to provide orange growers, with safe treatments that are applicable on field scale to reduce or prevent the incidence of rind creasing and to strengthen the structure of the albedo tissues by using calcium, molybdenum, or an anti-ethylene compound (AVG). The results of the present study indicated that ammonium molybdate (at 100 ppm) reduced creasing percentage. Moreover, the combination of AVG (at 50 ppm) plus ammonium molybdate (at 100 ppm) reduced creasing percentage, rind thickness and rind EC percentage. Moreover, enhanced rind and juice nutrient contents especially molybdenum and sulfur elements.

Key words: Creasing, orange, anti-ethylene, ammonium molybdate, nutrients.

INTRODUCTION

“Washington” navel orange is one of the most important citrus cultivars not only in Egypt but also in many countries around the Mediterranean region and parts of the USA. The quality criterion of the fruit attracts the consumers around the world to have the fruit especially the fresh ones. The fruits have a special lovely taste and aroma, In addition to its seedless uses in many production areas. No wonder there have an expansion in growing citrus trees in general and “Washington" navel particular over the last two decades. According to **FAO (2020)**, the total citrus production in Egypt increased from 3.724.900 tons in (2012) to 4.632.700 tons in (2019) . Even though citrus growing areas are mostly expanded from the Nile Delta to the newly reclaimed areas in arid environment, the growthers and producers still prefer to cultivate citrus trees especially "Washington" navel since it is profitable and marketable whether locally or by exporting to many markets around the world.

Rind creasing has been one of the major obstacles that face many citrus growers. The disorder causes the loosening of the albedo tissues in "Navelina" and "Valencia" orange fruit cultivars. This change reflects on forming groves on the flavedo tissue. The negative consequences of formation rind creasing have been documented over the years by many scientists. According to **Treeby and Storey (2002)** creasing is one of the most serious rind disorders that makes a large percentages of the crops invalid for fresh market. **Treeby *et al*. (2000)** found that creasing development is appearing as separations of the cells at the middle lamella of the albedo tissues. The appearance and rapid water less in addition to the short shelf life whether on the shelf at ambient temperature at refrigerated shelf Life or with cold storage. Moreover, the creased oranges were found to be more acceptable to the infection by some fungal diseases **(Eckert and Eaks, 1989)**. A high percentage of "Washington" navels are excluded during the screening process in the post-harvest stations before packing fruit for export. The excluded fruits are mostly due to having the disorder of rind creasing. The sale price of such creased fruits in of course much lower than the exported once, with high grade. There have been previous attempts to control the creasing problem under field conditions. To control the development of creasing it is recommended to select a rootstock which is not sensitive to creasing development. Rough lemon and Volkamer lemon (*Citrus Volkameriana*) are the most recommended rootstocks under the condition of South Africa **(du Plessis and Maritz, 2004).** Calcium is involved in the control the creasing **(Verreynne and Phiri, 2008)**. Creasing incidence was reduced by application of at Aminoethoxyvinylglycine (AVG) 20 – 60 mg /L (**Hussain and Singh, 2020**). Also, **Hussain and Singh (2015)** found that the foliar application of Cobalt sulphate ($CoSO_4$) at 125 -500 mg/L at golf ball stage was effective in controlling creasing.

Many attempts in the field were either too late or have not used the correct approach. In this study using early treatment, when the fruit just started to enter the phase of cell elongation, by a calcium application to strengthen cell wall and the membrane of albedo cells. Another approach we used ammonium molybdate to utilize molybdenum (Mo) as it has been reported strengthen the albedo cell walls which appeared or assessed from the detection of electrolyte leakage of the rind and the albedo tissue in a specific way. Mo is concept to be concerned in the pectin metabolism (**Verreynne, 2006). Bower, (2004**) suggested that Mo acts as a co-factor in ureide synthesis required in galacturonic acid formation. Mo is an essential element for denitrification process **(Mulder, 1948**). Furthermore, the climacteric nature likes behavior of the citrus peel must be exploited by using the anti-ethylene compound, namely aminoethoxyvinylglycine or AVG to inhibit ethylene production in the albedo tissues and to avoid its negative impacts on tissue degradation or breakdown since more the tissue damage means more the leakageof electrolytes and more creasing symptoms.

Thus, the objectives of this study were to provide orange growers, especially "Washington" navel orange with safe treatments that are applicable on field scale to reduce or prevent the incidence of rind creasing, to strengthen the structure of the albedo tissues by using calcium, molybdenum, or an anti-ethylene compound and to provide navel orange growers with a production system that could be adopted on a field scale to increase their profits by keeping healthy fruits with better shelf life.

MATERIALS AND METHODS

This study was conducted in two successive seasons 2017 and 2018 using "Washington" Navel orange trees (*Citrus sinensis* L. Oesbeck). Fifteen years old and uniform Navel orange trees were grown in a sandy soil in a private orchard at Rashid region, EL Behira Governorate, Egypt. Tree spacing was 4 × 5 m grafted on sour orange rootstock. Trees were under standard cultural practices and under surface irrigation system. Treatments were conducted on May in both seasons, where each treatment had four replicates. Nine treatments were conducted in thirty-six optimal trees randomly selected and sprayed twice, the first at the golf ball stage of fruit and after 15 days. These treatments included:

1- Control.

2- Aminoethoxyvinylglycine (AVG) (50 ppm).

3- Aminoethoxyvinylglycine (100 ppm).

4- Ammonium molybdate (100 ppm).

5- Calcium sulphate (100 ppm).

6- Aminoethoxyvinylglycine (50 ppm) + Ammonium molybdate (100 ppm).

7- Aminoethoxyvinylglycine (50 ppm) + Calcium sulphate (100 ppm).

8- Aminoethoxyvinylglycine (100 ppm) + Ammonium molybdate (100 ppm).

9- Aminoethoxyvinylglycine (100 ppm) + Calcium sulphate (100 ppm).

The fruits were sampled at the mature yellow stage on the first of December in both seasons. Fifteen orange fruits were picked from each of the nine treatments, and were washed with tap water then dipped for 5 minutes in sodium hypochlorite for surface sterilization, and then fruits were divided into two groups. Ten fruits were used for assessment of fresh samples and five fruits for packing and storage for ten days at ambient temperature (22+2° C).

Physical properties

The average weight of fruits was determined using a digital analytical balance to estimate the fresh weight (g), The vernier caliper was used to estimate the diameter at the tropic of each fruit and rind thickness, fruit size was determined by using a graduated cylinder, In both seasons, 15 ripe fruits from each tree were randomly harvested around the tree canopy to examine the incidence of creasing on individual fruit and it was also estimated on fruits on all trees based on the appearance of fruit surface.

Creasing incidence (%) was calculated according to (**Hussain, 2015)** using the following equation **= {(Total number of creased fruit/ Total number of fruit assessed} x 100.**

Chemical properties

The acidity was determined based on the estimation of citric acid using five mL of fruit juice for each fruit sample and titrated with a known normal state sodium hydroxide solution using phenolphthalein as an indicator **(AOAC, 1985)**. The results of this titration were converted to a titrated pH using the following formula:

Percent of titratable acidity = {(N. NaOH * ml. NaOH * 0.064 * 100)/ (ml. Juice used)}, TSS (%) was determined in orange juice using the refractometer**,** TSS/Acidity was calculated as a ratio between TSS (%) and acidity (%). Beta-carotene was estimated according to **(Wintermans and Mats, 1965)**, Vitamin C was estimated as milligrams of ascorbic acid/100 ml of juice according to the method of **Egan *et al*. (1987)** and sugars were extracted from 10 ml of filtered juice of each sub-sample. The extraction was carried out by using distilled water according to **Loomis and Shull (1937)**. Total sugars were determined according to **Egan *et al*. 1987**. The electrical conductivity (EC) of both the rind and the albedo tissue were measured by using a conductivity meter.

The concentration of sulphur in the extract was determined turbidimetrically using a spectrophotometer. Turbidity was developed using barium chloride ($BaCl_2$, $2H_2O$) and was measured at wave length of 425 nm following ASI method **(Hunter, 1984),** Ca concentration of samples were determined in the previously filtrates by the flame photometer according to **Chapman and Pratt (1978)**. Spectrophotometric method has been developed for determination of molybdenum using surfactantmediated liquid–liquid extraction. Molybdenum (V) obtained by ascorbic acid reduction in 2.5 M $H_2 SO_4$ reacted spontaneously with thiocyanate and cetyl trimethyl ammonium bromide (CTAB), forming an intense orange yellow complex that was extracted quantitatively into 1, 2-dichloroethane and absorbed at 460 nm.' (**Dass *et al*., 2014**).

Statistical analysis

The data of the first part of this study was laid out and analyzed in randomized complete blocks design (RCBD), while the data of the second part was laid out as a factorial arrangement in a randomized complete block design where nine spraying applications represented the main plot and two dates (at harvest and 10 days later of shelf life at ambient temperature) were devoted as the sub plot. The analysis was done using **(SAS, 2000)** program version. The means were compared according to the least significant difference (**LSD**) at 0.05 levels.

RESULTS AND DISCUSSIONS

Physical characteristics

Changes in rind thickness in response to used applications are shown in Table (1). The data revealed that the control fruits had the greatest rind thickness while AVG (at 100 ppm) plus ammonium molybdate (at 100 ppm) had the smallest rind thickness. Moreover, the use of AVG alone (at 50 ppm) resulted in greater rind thickness than (at 100 ppm) alone. The application of calcium sulphate (at 100 ppm) also reduced rind thickness to a magnitude similar to AVG plus CaSO4 especially in the first season. While in the second season their difference was slight. Meanwhile, the combination of AVG (100 ppm) plus CaSO4 (at 100 ppm) resulted in a considerable reduction in the rind thickness since its magnitude was higher than that resulted from the use of CaSO4 individually.

The effect of various preharvest on the incidence of rind creasing of "Washington" navel orange was reported in Table (1). The data revealed that many treatments were successful in significantly reducing the incidence of creasing; among them was ammonium molybdate alone (at 100 ppm). Another effective treatment was combination of AVG (at 50 ppm) plus ammonium molybdate (at 100 ppm) in a consistent manner in both seasons. Moreover, calcium sulphate resulted in a remarkable reduction in the incidence of rind creasing as compared with control in both seasons. However, its combination with AVG (at 100 ppm) also caused a reduction in the percentage of creasing but with a large variation between the actual values of the two seasons. In general, the actual values of rind creasing in the second season was less that values obtained in the first season. Furthermore, the individual application of AVG (either at 50 ppm or at 100 ppm) each was effective on reducing the incidence of rind creasing in “Washington " navel oranges.

Table 1. Effect of aminoethoxyvinylglycine (AVG), ammonium molybdate and calcium sulphate on physical characteristics of “Washington navel” orange fruits during 2017 and 2018 seasons

Treatments	Rind thickness (cm)		Creasing %	
	2017	2018	2017	2018
Control	0.52 a	0.28 a	16.98 a	9.77 a
AVG (50 ppm)	0.28 b	0.26 b	12.07 c	6.97 cd
AVG (100 ppm)	0.25 c	0.24 c	8.85 e	6.24 d
Ammonium molybdate (100 ppm)	0.18 d	0.16 i	5.55 g	1.08 g
Calcium sulphate (100 ppm)	0.22 e	0.20 g	6.98 f	3.93 e
AVG (50 ppm) + Ammonium molybdate (100 ppm)	0.20 f	0.18 h	6.36 fg	2.13 f
AVG (50 ppm) + $CaSO_4$ (100 ppm)	0.22 e	0.21 f	10.83 d	6.70 cd
AVG (100 ppm) + Ammonium molybdate (100 ppm)	0.22 e	0.22 e	12.66 c	7.48 c
AVG (100 ppm)+ $CaSO_4$ (100 ppm)	0.24 d	0. 23 d	15.25 b	8.87 b
LSD 0.05	0.0084	0.0024	1.107	0.8801

*Values within a column of similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.

The effect of various applications on the fruit size of “Washington” navel orange was reported in Table (2). The data indicated that fruit size of the control fruits was similar to all other applications in both seasons. However, little variation was obtained with same treatments. For example, AVG (at 100 ppm) had significantly greater fruit size than that found with AVG (at 50 ppm) plus ammonium molybdate (at 100 ppm) in the first season. Similar trend was found with AVG (at 100 ppm) when compared with AVG (at 50 ppm) plus $CaSO_4$ (at 100 ppm) in the first season only. In a similar manner, ammonium molybdate (at 100 ppm) resulted in greater fruit size than AVG (at 50 ppm) plus ammonium molybdate at (100 ppm) and the same sole treatment gave greater fruit size than that obtained with AVG (at 50 ppm) plus $CaSO_4$ (at 100 ppm) in the second season.

The data of fruit weight at harvest as responded to various applications is also reported in Table (2). The data indicated that in the first season all treatments had similar fruit weight to that of the control. Only AVG (at 50 ppm) plus ammonium molybdate (at 100 ppm) had smaller fruit weight than the control. Meanwhile, in the second season the control fruits had similar fruit weight to all other used treatments.

With regard to the fruit Diameter in response to used preharvest applications. The data in Table (2) also showed that there was no difference in fruit diameter between the control and all other treatments especially in the first season. Meanwhile, in the second season per treatments had greater fruit diameter than others such as ammonium molybdate alone (at 100 ppm) and AVG (at 100 ppm) plus ammonium molybdate (at 100 ppm).

Table 2. Effect of aminoethoxyvinylglycine (AVG), ammonium molybdate and calcium sulphate on fruit size, fruit weight and fruit diameter of "Washington navel" orange fruits during 2017 and 2018 seasons

Treatments	Fruit Size (cm^3)		Fruit weight (g)		Fruit Diameter (cm)	
	2017	2018	2017	2018	2017	2018
Control	382.76 abc	484.75 ab	375.00 a	434.55 ab	8.97 ab	8.85 ab
AVG (50 ppm)	367.35 abc	511.50 ab	342.88 ab	451.65 ab	8.64 abc	9.02 ab
AVG (100 ppm)	413.00 a	468.25 b	380.63 a	418.63 b	8.99 a	8.91 ab
Ammonium molybdate (100 ppm)	404.50 ab	554.50 a	380.88 a	505.35 a	8.89 ab	9.39 a
Calcium sulphate (100 ppm)	355.75 abc	494.25 ab	346.25 ab	437.18 ab	8.54 bc	8.98 ab
AVG (50 ppm) + Ammonium molybdate (100 ppm)	350.00 bc	476.50 b	323.13 b	458.35 ab	8.38 c	9.07 ab
AVG (50 ppm) + $CaSO_4$ (100 ppm)	332.75 c	471.25 b	342.00 ab	413.08 b	8.58 abc	8.02 b
AVG (100 ppm) + Ammonium molybdate (100 ppm)	394.35 ab	535.75 ab	379.63 a	467.25 ab	8.72 abc	9.34 a
AVG (100 ppm)+ $CaSO_4$ (100 ppm)	401.00 ab	472.25 b	379.38 a	402.70 b	8.82 ab	8.86 ab
LSD 0.05	59.35	74.44	47.67	77.79	0.4424	0.7083

*Values within a column of similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.

Chemical characteristics

The response of "Washington navel" to various used applications with regard to electrolyte leakage of the rind was shown in Table (3). The data stated that the highest leakage was obtained with the control in a significant manner as compared with all applications. Meanwhile, the lowest value of such leakage was found with ammonium molybdate (at 100 ppm) in a consistent manner in both seasons. Moreover, many other treatments were able to reduce electrolyte leakage of the rind in considerable magnitude such $CaSO_4$ (at 100 ppm). Meanwhile, all other used treatments were able to cause a significant reduction of such leakage with varying influence especially $CaSO_4$ (at 100 ppm) and AVG alone at 100 ppm. However, the combination of AVG plus $CaSO_4$ did not cause. Further reduction in electrolyte leakage as compared with the use of each component individually. None of the treatments was not able to positively reduce such leakage but with the control.

Since loosening and breakdown of the albedo tissues has been as the main symptoms of creasing, it was essential to assess the integrity of the albedo tissue in response to used treatments. The data indicated that there were many variations in such leakage with the least percentage obtained with the combination of AVG (at 50 ppm) was less effective on the reduction of rind leakage of electrolytes than the former combination. Meanwhile, the individual treatment of ammonium molybdate was remarkably effective on the reduction of albedo electrolyte leakage relative to the control and to other applications. Furthermore, when AVG (at 100 ppm) was combined with $CaSO_4$ (at 100 ppm) their effectiveness on rind leakage was lower than when AVG was combined ammonium molybdate especially in the first season.

The effect of various treatments on the total Soluble Solids (TSS) of the juice was reported in Table (3). The data showed that the highest significant TSS with the sole application of ammonium molybdate (at 100 ppm) when compared with the control or with other treatments. The application of calcium sulphate alone (at 100 ppm) also resulted in a significant increase in TSS relative to the control in both seasons. The anti-ethylene including treatments namely AVG had in general lower TSS values than the control especially when combined with CaSO4 or with ammonium molybdate. The application of AVG either (at 50 ppm) or (at 100 ppm) resulted in a significant reduction in the TSS as compared to with the control in the two seasons. Moreover, the combination containing AVG (at 50 ppm) plus ammonium molybdate (at 100 ppm) had more TSS value than the same combination but with 100 ppm of AVG during both seasons.

The influence of various treatments on juice acidity of "Washington "navel oranges at harvest were reported in Table (3). The data indicated that either AVG of 50 ppm or at 100 ppm resulted in a significant increase in juice acidity with greater acidity as the concentration increased. Ammonium molybdate, however, caused a significant reduction in such acidity when compared with the control in both seasons. Calcium sulphate on the other hand, caused a slight but still significant increase in the juice acidity as compared with ammonium molybdate. When the two combinations of AVG (at 100 ppm) plus ammonium molybdate or the combination of AVG (at 100 ppm) plus $CaSO_4$ where compared in terms of their influence of juice acidity, the use of $CaSO_4$ in the combination resulted in greater juice acidity than when ammonium molybdate was included in the combination in consistent manner in both seasons. The highest reduction in juice acidity was obtained with the combination of AVG (at 50 ppm) plus ammonium molybdate (at 100 ppm). It was generally obvious that the presence of ammonium molybdate in one of the used combinations was more beneficial in improving fruit quality than the presence of $CaSO_4$ in the combination as was consistently shown in Table (3).

Table 3. Effect of aminoethoxyvinylglycine (AVG), ammonium molybdate and calcium sulphate on chemical characteristics of "Washington navel" orange fruits during 2017 and 2018 seasons

Treatments	Rind electrolyte leakage (%)		Albedo Electrolyte leakage (%)		TSS (%)		Acidity (%)	
	2017	2018	2017	2018	2017	2018	2017	2018
Control	39.62 a	30.50 a	21.99 a	21.50 a	13.20 c	17.82 b	0.81 g	0.78 g
AVG (50 ppm)	34.95 d	27.08 d	17.93 d	17.96 a-d	12.45 f	17.15 e	0.89 d	0.83 d
AVG (100 ppm)	32.05 f	23.63 f	14.82 f	14.41 cd	12.05 g	16.61 f	0.94 c	0.86 c
Ammonium molybdate (100 ppm)	26.94 i	19.80 i	9.88 i	9.07 e	13.70 a	18.10 a	0.78 i	0.75 i
Calcium sulphate (100 ppm)	30.83 g	21.98 g	13.07 g	13.48 d	13.45 b	18.00 a	0.80 h	0.76 h
AVG (50 ppm) + Ammonium molybdate (100 ppm)	28.55 h	20.92 h	11.48 h	7.50 e	13.00 d	17.59 c	0.84 f	0.79 f
AVG (50 ppm) + $CaSO_4$ (100 ppm)	33.54 e	25.25 e	16.67 e	14.89 b-d	12.75 e	17.30d	0.85 e	0.81 e
AVG (100 ppm) + Ammonium molybdate (100 ppm)	37.37 c	28.41 c	19.90 c	18.97 a-c	11.75 h	16.58 f	0.97 b	0.89 b
AVG (100 ppm)+ $CaSO_4$ (100 ppm)	38.52 b	30.19 b	21.37 b	20.88 ab	11.15 i	15.88 g	1.01 a	0.91 a
LSD 0.05	0.326	0.2714	0.298	3.782	0.055	0.1033	0.0014	0.0020

*Values within a column of similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.

Changes in TSS to acidity ratio in response to preharvest treatments to "Washington" navel oranges were reported in Table (4). The data revealed that the greatest ratio at harvest was found with ammonium molybdate treatment as compared with the control and all other treatments. The two AVG concentrations had lower TSS/Acidity ratio than than that of the control in both seasons. Moreover, when each AVG concentration was applied in combination with ammonium molybdate further reduction occurred in such ratio. However, $CaSO_4$ resulted in greater TSS /acidity ratio when compared with its combination with AVG (at 50 ppm) or (at 100 ppm). Moreover, the combination of AVG plus ammonium molybdate resulted in greater ratio than AVG plus $CaSO_4$ at the same concentrations. Thus, the application of ammonium molybdates was beneficial to "Washington" navel orange whether applied individually or in a combination with AVG.

The effect of preharvest treatments on vitamin C of "Washington" orange juice was reported in Table (4). The data showed that the highest value was obtained with ammonium molybdate during the two seasons. Meanwhile, when AVG (at 50 ppm) was combined with ammonium molybdate, there was a reduction in vitamin C which was even greater with the combination of AVG (at 100 ppm) plus the same concentration of ammonium molybdate. Furthermore, the application of $CaSO_4$ was also effective on increasing vitamin C when compared with the control but to less magnitude than that obtained with ammonium molybdate in both seasons. In addition, AVG treatment (at 100 ppm) caused a reduction in vitamin c but still had greater vitamin C than that obtained with AVG (at 50 ppm).

With regard to the influence of used treatments on the percentage of total sugars in the juice of "Washington " navel oranges, the data in Table (4) indicated that ammonium molybdate still superior among all other treatments and the control in its total sugar content followed by $CaSO_4$ (at 100 ppm). Moreover, AVG treated fruits had less total sugars than the control. Furthermore, the combination of AVG (100 ppm) plus ammonium molybdate did not vary from AVG (100 ppm) plus $CaSO_4$ especially in the first season. Moreover, the combination of AVG (at 50 ppm) or (100 ppm) each of them, plus ammonium molybdate resulted in less total sugars as compared with the control. Thus, ammonium molybdate alone was more effective on enhancing total sugars of the juice than its combinations with AVG in both seasons.

The influence of various treatments before harvest on the content of carotenes in "Washington" navel orange was reported in **Table (4)**. The data revealed that the greatest content was found with the application of ammonium molybdate. It caused a significant increase in such carotenes more than $CaSO_4$. The individual application of AVG (at 50 ppm) resulted in a significant reduction of rind carotenes. In a similar the application of AVG (at 100 ppm) caused even a greater reduction in carotenes in the rind relative to AVG (at 50 ppm). The only combination of AVG (50 ppm) plus ammonium molybdate that increased rind carotenes as compared with the control. However, other combinations resulted in lower carotene content in the rind when compared with the control. Even the combination of AVG (at 100 ppm) plus $CaSO_4$ had lower carotenes in the rind relative to the control.

The effect of preharvest treatments on the content of juice carotene was also reported in Table (4). It was evident again that the sole application of ammonium molybdate was able to enhance fruit charactenstics as reported earlier including juice carotenes. Moreover, AVG (at 100 ppm) resulted in more reduction of such carotenes than AVG (at 50 ppm), meanwhile values of juice carotenes with both concentrations of AVG were lower than that of the control. Calcium Sulfate, on the other hand, resulted in lower carotenes than that obtained with the ammonium molybdate. The magnitude of the reduction of carotenes in the juice was higher when AVG (at 100 ppm) was combined with $CaSO_4$ when compared with AVG (at 100 ppm) plus ammonium molybdate.

Table 4. Effect of aminoethoxyvinylglycine (AVG), ammonium molybdate and calcium sulphate on chemical characteristics of "Washington "navel orange fruits during 2017 and 2018 seasons

Treatments	TSS/ acidity (%)		Vitamin C of juice (mg/100ml)		Total sugars of juice (%)		Carotene content of rind (mg/100g)		Carotene content of juice (mg/100g)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Control	16.33 c	22.93 c	48.77 d	58.04 d	14.28 c	15.89 c	30.45 d	31.93 d	23.15 d	29.93 c
AVG (50 ppm)	14.00 f	20.67 f	47.65 g	55.21 f	11.63 f	13.93 f	25.93 h	27.40 h	21.22 h	22.14 h
AVG (100 ppm)	12.90 g	19.32 g	48.34 e	57.28 e	11.48 f	13.13 g	24.98 i	26.24 i	20.45 i	20.74 i
Ammonium molybdate (100 ppm)	17.61 a	24.14 a	52.48 a	61.56 a	15.28 a	16.65 a	33.96 a	35.88 a	24.74 a	32.58 a
Calcium sulphate (100 ppm)	16.85 b	23.70 b	49.89 c	58.55 c	14.96 b	16.25 b	31.60 b	34.15 b	24.50 b	30.29 b
AVG (50 ppm) + Ammonium molybdate (100 ppm)	15.59 d	22.27 d	50.90 b	59.54 b	11.99 c	15.59 d	31.14 c	32.60 c	23.54 c	29.42 d
AVG (50 ppm) + $CaSO_4$ (100 ppm)	14.97 e	21.44 e	47.78 f	54.47 g	11.80 e	14.64 e	29.64 e	30.67 e	22.77 e	27.39 e
AVG (100 ppm) + Ammonium molybdate (100 ppm)	12.13 g	18.63 h	46.89 h	53.23 h	10.85 g	12.91 h	28.13 f	29.23 f	22.28 f	26.02 f
AVG (100 ppm)+ $CaSO_4$ (100 ppm)	11.11 i	17.45 i	46.36 i	52.04 i	10.80 g	12.63 i	26.43 g	28.07 g	21.70 g	24.50 g
LSD 0.05	0.06	0.15	0.02	0.01	0.17	0.08	7.7	1.03	0.01	0.07

*Values within a column of similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.

Mineral content of rind and juice

The data in Table (5) reveals the changes in molybdenum content of the rind in response to various preharvest applications. The data indicated that ammonium molybdate treated "Washington navel" had the highest molybdenum content in the rind while the control had the least. All other treatments resulted in significantly higher molybdenum in the rind than the control. The combinations that included ammonium molybdate all had higher Mo in the rind especially AVG (at 50 ppm) plus ammonium molybdate. Meanwhile, Mo content of the juice had similar treads to that obtained in the rind. Again it was found that the juice had the highest Mo content ammonium molybdate treated fruits followed by the combination of AVG (at 50 ppm) plus ammonium molybdate in the both seasons. The other two combinations of AVG (at 100 ppm) plus either ammonium molybdate or plus $CaSO_4$ followed the ammonium molybdate alone.

Changes in sulphur content in the rind and juice of "Washington navel" oranges as influenced by various treatments were reported in Table (5) and (6). The data indicated that the greatest sulphur content was found with the combination of AVG (at 100 ppm) plus $CaSO_4$ (at 100 ppm) followed in order with the individual application of $CaSO_4$ (at 100 ppm) these trends were valid for the rind and the juice. However, the application of AVG (at 50 ppm) plus $CaSO_4$ (at 100 ppm) it was less effective than the above treatments but led significant increase in sulphur content in the rind and in the juice as compared with the control. Moreover, ammonium molybdate alone resulted in a significant increase in sulphur content in the rind and in the juice.

Table 5. Effect of aminoethoxyvinylglycine (AVG), ammonium molybdate and calcium sulphate on chemical characteristics of "Washington "navel orange fruits during 2017 and 2018 seasons

Treatments	Mo content of rind (ppm)		Mo content of juice (ppm)		S content of rind (%)	
	2017	2018	2017	2018	2017	2018
Control	0.018 i	0.028 i	0.009 i	0.014 i	0.135 e	0.110 i
AVG (50 ppm)	0.020 h	0.055 h	0.012 h	0.019 h	0.160de	0.168 h
AVG (100 ppm)	0.067e	0.135 d	0.025 e	0.035 e	0.243 cd	0.320 d
Ammonium molybdate (100 ppm)	0.019 a	0.215 a	0.040 a	0.054 a	0.215 cde	0.195 g
Calcium sulphate (100 ppm)	0.025 g	0.075 g	0.021 e	0.022 g	0.355 ab	0.385 b
AVG (50 ppm) + Ammonium molybdate (100 ppm)	0.150 b	0.205 b	0.037 b	0.047 b	0.285 ab	0.240 f
AVG (50 ppm) + $CaSO_4$ (100 ppm)	0.055 f	0.105 f	0.024 f	0.030 f	0.353 ab	0.338 c
AVG (100 ppm) + Ammonium molybdate (100 ppm)	0.115 c	0.165 c	0.035 c	0.045 c	0.308 abc	0.300 e
AVG (100 ppm)+ $CaSO_4$ (100 ppm)	0.098 d	0.118 e	0.029 d	0.041 d	0.398 a	0.405 a
LSD 0.05	4.965	0.0083	5.254	0.0011	0.0972	0.0102

*Values within a column of similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.

The changes in calcium content of the rind and the juice of "Washington navel" oranges in response to various used treatments was documented in Table (6). The data revealed that the highest Calcium content was found with the individual treatment of $CaSO_4$ (at 100 ppm) followed in order with the combination of AVG (at 50 ppm) plus $CaSO_4$ (at 100 ppm). The rind had much higher calcium content than juice with all treatments and the control. The second combination that included AVG (at 100 ppm) plus $CaSO_4$ (at 100 ppm) also had a significant rise in calcium content as compared with the control. Moreover, with the individual treatment of ammonium molybdate the increase in Calcium content was found only in the juice relative to the control but not in the rind.

Table 6. Effect of aminoethoxyvinylglycine (AVG), ammonium molybdate and calcium sulphate on chemical characteristics of "Washington "navel orange fruits during 2017 and 2018 seasons

Treatments	S content of juice (%)		Ca content of rind (mgs/100 ml)		Ca content of juice (mgs/100 ml)	
	2017	2018	2017	2018	2017	2018
Control	0.075 i	0.035 i	83.49 d	75.38 d	6.50 h	6.69 h
AVG (50 ppm)	0.105 h	0.065 h	79.95 f	71.40 f	7.11 e	7.24 e
AVG (100 ppm)	0.228 d	0.188 d	82.92 e	73.75 e	4.11 i	6.14 i
Ammonium molybdate (100 ppm)	0.153 g	0.108 g	73.41 i	64.89 i	7.34 d	7.87 d
Calcium sulphate (100 ppm)	0.278 b	0.243 b	93.45 a	86.66 a	8.98 a	9.02 a
AVG (50 ppm) + Ammonium molybdate (100 ppm)	0.175 f	0.130 f	75.09 h	70.50 h	6.69 g	7.20 g
AVG (50 ppm) + $CaSO_4$ (100 ppm)	0.240 c	0.230 c	92.49 b	84.40 b	7.98 c	8.87 b
AVG (100 ppm) + Ammonium molybdate (100 ppm)	0.208 e	0.163 e	76.89 g	70.65 g	6.89 f	7.22 f
AVG (100 ppm)+ $CaSO_4$ (100 ppm)	0.340 a	0.290 a	90.69 c	80.43 c	8.25 b	8.81 c
LSD 0.05	0.0069	0.0108	1.739	- -	- -	1.256

*Values within a column of similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.

DISSSCUSSION

Rind creasing is the formation of narrow sunken grooves in the rind, and in severe cases, the grooves intersect making the fruit appearance lumpy and soft. Attempts have been made to reduce the severity and the incidence of albedo breakdown. In this study molybdenum in the form of ammonium molybdate was used since its roles in increasing nitrate reductase acidity and increasing leaf nitrogen content and hence the yield were documented (**Kaiser *et al*., 2005**). The enzyme nitrate reductase catalyzes the first step in the conversion of N-Nitrate into plant N- compounds which means that more nitrogen will be available to the plant. The increase in nitrogen content means thicker rind which reduces creasing. In addition, more than 50 enzymes are known to be dependent on molybdenum in cell organism but only nitrate reductase and four others have been found in higher plants **(Mendel, 2013**). No wonder, the properties of the plant cell wall are dramatically affected by molybdenum applications and the symptoms of molybdenum deficiency and leaf dropping were relieved by Mo application **(Yang *et al*., 2021**). Thus when Mo is deficient chlorophyll synthesis was inhibited and photosynthesis rate was reduced, and yield declined **(Wu *et al*., 2014**). We also used calcium as an important factor that affect the cell wall integrity of the albedo tissue. Previous successful research attempts used calcium in form of carbonate chloride and nitrate when the fruit was small. These attempts need multiple applications (at least 5 times) where early and mid-season calcium spray was equally effective and tended to be marginally better than late season spray. In our study Calcium sulphate was used once since the weather is hot and growers will not follow the five times application. Thus, our calcium treatment was effective on reducing the albedo breakdown as shown in the Table (3) from the reduction of rind electrolyte leakage percentages. The repeated calcium application found the calcium nitrate was better than Calcium chloride that was better than Calcium carbonate. This study recommended using five application of Calcium nitrate since it did not result in leaf damage or leaf drop and many provide a small controlled nitrogen supplement to leaves and fruits. Furthermore, AVG was successful in reducing such leakage whether alone or in combinations with $CaSO_4$ or with ammonium molybdate in a consistent manner in the both seasons. The use of the anti-ethylene, namely AVG was helpful in reducing the albedo damage since it was important to reduce the enzymatic activity that could increase ethylene production. It is important to inhibit ethylene production in the orange peel since the rind physiology indicated that the rind behaves like climacteric fruits while the rest of the first is non-climacteric **(Sacher, 1973)**. On the other hand, summer application of GA_3 was used at 20 ppm when majority of fruits are between (30 – 50 mm) in diameter to reduce albedo breakdown such treatment was followed with GA_3 (at 10 ppm). Although GA_3 applications improved the firmness a quality at harvest and extended the shelf life but many orange producers are skeptic about the delay occurring in rind color development and the harvest delay (**Serreno *et al*., 2004)**.

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