V- SUMMARY AND CONCLUSION

This study was conducted on fruitful sweet orange trees of Washington navel and Tanarif cultivars grown in the Experimental Station of EL-Khairia Barrage during 2005-06 and 2006-07 two seasons. It was aimed to minimize an important disorder i.e, fruit creasing "albedo breakdown". So, the effect of foliar spray with some macro and micro elements (Ca, K, Zn, and Co) either solely or in chosen combinations, as well as GA\textsubscript{3} (growth promoter) and PP\textsubscript{333} (growth retardant) were investigated. These treatments were:

1. Water spray (control); 2. Ca-set; 3. ZnSO\textsubscript{4}; 4. KNO\textsubscript{3}; 5. CoCl\textsubscript{2}; 6. GA\textsubscript{3}; 7. PP\textsubscript{333}; 8. CoCl\textsubscript{2} + Ca-set + Ca-set; 9. CoCl\textsubscript{2} + ZnSO\textsubscript{4} + ZnSO\textsubscript{4}; 10. Ca-set + CoCl\textsubscript{2} + Ca-set and 11. ZnSO\textsubscript{4} + CoCl\textsubscript{2} + ZnSO\textsubscript{4}.

Along each experimental season, foliar application was carried out three times at 1.5 month intervals i.e, on May 30\textsuperscript{1}, July 15\textsuperscript{1b} and September 1\textsuperscript{8}, except both GA\textsubscript{3} and PP\textsubscript{333} treatments each was applied twice at two earlier dates.

Two factorial experiments were conducted (an experiment was devoted for each orange cultivar). The complete randomized block design with four replications was employed for arranging the aforesaid eleven spray treatments, where every replicate was represented by a single tree. In each experiment, specific effect of eleven spray treatments and either geographical direction (north & south), fruit development (age) or fruit state (normal & creased), as well as interaction effect of their combinations were evaluated regarding the response of creasing incidence; fruit quality; nutritional status (leaf & peel mineral composition); polygalacturonase (PG-ase) activity and fruit peel anatomical structure.

Measurements of the differential investigated characteristics in response to studied factors and their combinations were as follows:
V. I. Creasing incidence percentage:

In late September during both seasons creasing incidence was fortnightly examined up to November 15th when its visible morphological symptoms were observed, then its percentage in response to foliar spray treatments and geographical direction, as well as their combinations was periodically determined at one month interval till February 15th of 2006 and 2007 years during 1st and 2nd seasons, respectively.

V. II. Fruit quality:

On mid February of two seasons fruits were harvested, then both fruit physical and chemical properties i.e., (fruit weight, size, peel thickness, dimensions and shape index) and (TSS%; acidity %; and TSS/Acid ratio) in response to specific and interaction effects of spray treatments and fruit status (sound & creased) were determined.

V. III. Nutritional status (leaves & fruit peel mineral composition):

In this respect leaves and fruit peel N, P, K, Ca, Mg, Mn, Zn and Co content in relation to specific and interaction effects of two studied factors i.e, spray treatments and fruit state (creased or normal) from which peels and adjacent leaves were sampled for investigating the nutritional status response of two orange cultivars.

V. IV. Polygalacturonase (PG-ase) activity:

PG-ase activity was determined in albedo tissues were periodically sampled from sound (normal) fruits on mid September, November 1st 2006 and mid February 2007 during 2nd season to study the specific effect of spray treatments and fruit aging, as well as their interaction effect. Besides, PG-ase activity in response to specific and interaction effect of fruit state (normal & creased), spray treatments and their interaction were investigated in albedo sampled on February 15th 2007 year. Activity was determined by measuring the amount of galacturonic acid (as reducing groups) using the 3, 5- dinitrosalicylic acid method.
V. V. Anatomical studies:

Fruit peel anatomy of two sweet orange cultivars (Washington navel & Tanarif) was anatomically examined through two successive durations of fruit development in 1\textsuperscript{st} 2005-06 season. First duration was started 2 weeks after fruit set (April 15\textsuperscript{th}) and extended till starting of foliar application with spray treatments (May 30\textsuperscript{th}) where transverse sections were microscopically examined 3 times for fruit rind sampled on April 30\textsuperscript{th}; May 15\textsuperscript{th} and 30\textsuperscript{th}. However, 2\textsuperscript{nd} duration was dealing with that following starting foliar sprays treatments until morphological symptoms of creasing phenomenon was visually noticed in outer rind surface (November 15\textsuperscript{th}). So the initiation and development of creasing phenomenon in relation to both fruit age and various investigated foliar spray treatments was anatomically studied.

All data obtained during both season were subjected to statistical analysis and could be summarized as follows:

V. I. Creasing percentage:

A. Specific effect of investigated factors:

With regard to the specific effect of geographical direction, data obtained during both seasons revealed that fruits of the northern half of tree periphery were more susceptible to creasing phenomenon. However, differences were not significant at two earlier measuring dates (mid November & December), while as the season was advanced variances became more pronounced and significant with two orange cultivars.

Referring the specific effect of foliar spray treatments with mineral and growth regulators solutions, it was quite clear that all investigated treatments reduced creasing % and delayed date of its morphological incidence, especially in Washington navel orange cv. than the control (water sprayed trees) with one and two months during 2\textsuperscript{nd} and 1\textsuperscript{st} seasons, respectively. However, foliar spray with any of four CoCl\textsubscript{2} combinations i.e, (foliar spray with CoCl\textsubscript{2} once + foliar spray twice with either Ca-set or ZnSO\textsubscript{4}) were obviously the most effective in this concern. Taking into consideration that
both combinations of CoCl$_2$ + Ca-set were the superior, especially (Ca-set on late May + CoCl$_2$ on mid July + Ca-set on September 1$^a$). On the other hand, spray with ZnSO$_4$, KNO$_3$, GA$_3$ and PP333 solutions, each solely were the least effective. Meanwhile, foliar spray with either Ca-set or CoCl$_2$ (each solely) were in between the aforesaid two extremes.

B. Interaction effect:

Data obtained during two seasons displayed that the specific effect of each investigated factor had been reflected directly on their combinations. Herein, the least fruit creasing % was usually in concomitant to those fruits borne on southern half of tree periphery for sprayed trees with Ca-set + CoCl$_2$ combinations, followed by those sprayed with Ca-set + ZnSO$_4$ combinations.

V. II. Fruit quality:

Fruit physical (average fruit weight, volume, dimensions, peel thickness and shape index) and chemical properties (TSS, acidity and TSS/Acid ratio) in response to specific and interaction effects of foliar spray treatments, fruit status (sound & creased) and their combinations were investigated for Washington navel and Tanarif orange cvs. during both 2005-06 and 2006-07 experimental seasons.

V. II. 1. Fruit physical properties:

A. Specific effect:

Referring the specific effect of spray treatments, data obtained displayed that average fruit weight, size and dimensions (polar & equatorial diameters) followed to great extent the same trend of response. Hence, foliar spray with either ZnSO$_4$; KNO$_3$ or GA$_3$ solutions each solely resulted significantly in the greatest values of these four measurements. However, with fruit peel thickness KNO$_3$ and GA$_3$ were the superior descendingly followed by ZnSO$_4$. The reverse was true with CoCl$_2$ spray solely where the least values of all investigated physical properties were exhibited with both orange cultivars. Moreover, other spray treatments were in between with a noticeable
tendency of variance, especially treatment of Ca-set spray solution solely which showed its superiority over other members of such intermediate category. In addition, the response of fruit shape index to the specific effect of spray treatments was too slight or absent to be taking into consideration for Washington navel and Tanarif orange cvs., respectively.

As for the specific effect of fruit status, it was quite evident that sound fruits surpassed significantly the creased ones as values of all investigated fruit physical properties were concerned except fruit shape index of Tanarif orange fruits, where variance was too little and consequently could be easily neglected.

B. Interaction effect:

Concerning the interaction effect of two investigated factors (foliar spray treatments & fruit status), data obtained during both seasons displayed that specific effect of each investigated factor reflected on their combinations. However, different investigated fruit physical characteristics didn't completely coincide in their response, but it could be safely concluded that a general trend was approximately detected. Anyhow, average fruit weight, volume, dimensions (polar & equatorial diameters) and peel thickness exhibited the highest values with the sound fruits of foliar sprayed trees with ZnSO₄, KNO₃, GA₃ and to great extent Ca-set solutions (each solely) for two orange cultivars with some moderate shift in ranking the superiority of such four combinations, especially those related to the spray solution could be easily observed from one fruit physical measurement to another. The reverse was true with the creased fruits of sprayed trees three times with CoC₁₂ solution only. Other combinations were in between the aforesaid two extremes.

Meanwhile, variances in fruit shape index were either slight and didn't follow specific trend or completely absent from statistical point of view for Washington navel and Tanarif orange cultivars, respectively.
V. II. 2. Fruit chemical properties:

Fruit juice TSS%:

A. Specific effect:

Data obtained during two experimental seasons displayed that fruit juice TSS% of both orange cultivar responded specifically to the investigated foliar spray treatments. Herein, foliar spray with KNO₃, CoC₁₂ or PP₃₃₃ solutions (each solely) were statistically the superior for increasing TSS% in both sweet orange cultivars. The reverse was true with Ca-set, ZnSO₄ or GA₃ as they resulted generally in the least TSS%. In addition, four combinations of spray with CoC₁₂ plus either Ca-set or ZnSO₄ and control (water spray) were in between, however differences between treatments of the inferior category from one hand and those of intermediate members from the other were significantly absent with two orange cvs.

As for the specific effect of fruit status, it was too slight to be taken into consideration.

B. Interaction effect:

Data obtained during two experimental seasons displayed obviously that more pronounced variances due to specific effect of spray treatments as compared to the slight or absent effect of fruit status reflected obviously on fruit juice TSS% of two orange cvs. Herein, the sound fruits of foliar sprayed trees with either KNO₃, CoC₁₂ or PP₃₃₃ solutions (each solely) had statistically the richest fruit juice total soluble solids content for two orange cultivars. The reverse was true with the creased fruits of Ca-set, ZnSO₄ and GA₃ sprayed trees, beside sound fruits of Ca-set and GA₃ sprayed trees of both orange cvs. Other combinations were in between.

Fruit juice total acidity:

A. Specific effect:

Data obtained during both seasons revealed that juice acidity responded specifically to each investigated factor. Herein, sprayed trees with either
KNO₃, CoCl₂ exhibited the highest juice acidity %, however later solution was more effective with Tanarif cv. On the contrary, both ZnSO₄ and Ca-set treatments resulted generally in the least acidity %. Other treatments were in between. On the other hand the specific effect of fruit status was less pronounced, however sound fruits had relatively higher juice acidity than creased ones, especially in 2ⁿ season where difference was significant.

B. Interaction effect:

The sound fruits of CoCl₁₂ sprayed trees, descendingly followed by those of KNO₃ sprayed trees showed the highest fruit juice total acidity for 2 orange cvs. The reverse was detected by both Ca-set or ZnSO₄ treated trees regardless of fruit status for two orange cultivars. Other combinations were in between.

Fruit juice TSS/acid ratio:

A. Specific effect:

However, the specific effect of foliar spray treatments was not so pronounced and trend of response was relatively stable, but it could be generally concluded that fruits of sprayed trees with either Ca-set or ZnSO₄ solutions (two cvs.) and to great extent Washington navel orange treated trees with Pp₃₃₃ showed the highest TSS/ acid ratio, especially as an average of two seasons was concerned. The reverse was true with GA₃ or CoCl₁₂ treated trees, where the least TSS/ acid ratio was exhibited (GA₃ was more effective with Washington navel orange but with Tanarif trend took the other way around). Meanwhile, the creased fruits had significantly higher fruit juice TSS/ acid ratio than sound fruits of two orange cvs.

B. Interaction effect:

The highest juice TSS/ acid ratio was markedly coupled with the creased Washington navel orange fruits of Ca-set, ZnSO₄ and/ or Pp₃₃₃ treated trees, as well as the creased Tanarif fruits of Ca-set and ZnSO₄ sprayed trees. The reverse was found with sound fruits of GA₃ and CoCl₁₂.
sprayed trees of Washington navel and Tanarif orange cvs., respectively. In addition other combinations were in between.

V. III. Nutritional status (leaves & fruit peel mineral composition):

In this respect leaves and fruit peel N, P, K, Ca, Mg, Mn, Zn and Co contents of Washington navel and Tanarif orange cultivars in response to specific effect of two factors under study i.e., a - eleven foliar spray treatments with Ca-set, ZnSO$_4$, KNO$_3$, CoC$_{12}$, GA$_3$ and PP$_{333}$ solutions either each solely or combined plus other, b- fruit state (creased or normal), as well as interaction effect of various combinations between two studied factors were investigated during both 2005-06 and 2006-07 experimental seasons.

A. Specific effect :

Regarding the specific effect of differential eleven investigated spray treatments, data obtained during both 2005-06 and 2006-07 experimental seasons displayed the following :

1- Nitrogen content was decreased in leaves and fruit rinds of two sweet orange cultivars by all investigated treatments except foliar spray with KNO$_3$ and Ca-set (solely or plus CoC$_{12}$), where the level was significantly increased with former one but didn't respond by later one (in most cases). However, foliar spray with ZnSO$_4$ and to great extent GA$_3$ exhibited statistically the severest reduction in N level especially with fruit rind of two orange cultivars,

2- Phosphorus content: It was decreased also by most investigated spray treatments, especially Ca-set and CoC$_{12}$ as each was applied solely, where both exhibited statistically the least P % in two plant organs of both orange cvs. Meanwhile, KNO$_3$ and GA$_3$ spray treatments didn't significantly influence P level as compared to control (water spray).

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3. Potassium content: Most investigated spray treatments decreased leaf and fruit rind K% of two orange cultivars as compared to control (water spray) except foliar spray with KNO₃ (increased it significantly especially in leaves) and **PP333** which showed no significant effect. On the other hand, the least K level was associated with Ca-set and CoC1₂ spray treatments, especially as former one was applied solely.

4- Calcium content: All spray treatments increased it except both KNO₃ and GA3 spray treatments especially former one, besides ZnSO₄ particularly with Tanarif orange cv. which didn't show significant difference than control. On the other hand, foliar spray with Ca-set either solely or plus CoC1₂ (T₈ & T₁₀) exhibited statistically the highest increase in Ca % over control (water spray) especially former treatment (Ca-set solely).

5- Magnesium content: All spray treatments decreased leaf and fruit peel Mg content below control for two cultivars. However, the reduction was significant in two plant organs (leaf & fruit rind) of Washington navel and Tanarif orange trees sprayed with Ca-set, KNO₃ and ZnSO₄ (each solely), beside those of CoC1₂, GA₃ and **PP333** sprayed trees of Tanarif orange cv.

6- Manganese content: All investigated spray treatments increased significantly its level than control (water spray) except foliar spray with either GA₃ or KNO₃ solutions, both didn't significantly affect it. On the other hand, CoC1₂ plus either Ca-set (T₈ & T₁₀) or ZnSO₄ (T₉ & T₁₁) exhibited statistically the richest leaf and fruit rind Mn content especially former ones (T₈ & T₁₀).

7- Zinc content: All investigated spray treatments increased its content in leaf and fruit rind with variable degrees of influence except foliar

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**SUMMARY AND CONCLUSION**
spray with CoCl$_2$ plus Ca-set (T$_8$ & T$_{10}$) where both and in most cases didn't significantly vary than control (water spray). On the other hand, foliar spray with ZnSO$_4$ solution either solely (T3) or plus CoCl$_2$ were statistically the most effective treatments for raising zinc level in both plant organs (leaf & fruit rind) for two orange cultivars.

8- Cobalt content: Leaf and fruit rind cobalt content for both sweet orange cultivars was significantly increased by foliar spray with CoCl$_2$ solution either solely (T5) or plus one of Ca-set (T$_8$ & T$_{10}$) and ZnSO$_4$ (T$_9$ & T$_{11}$) as compared to control (water spray). Meanwhile, other investigated spray treatments didn't significantly differ than control.

As for the specific effect of fruit state (sound or creased), on leaf and fruit rind N, P, K, Ca, Mg, Mn, Zn and Co contents of Washington navel and Tanarif orange cultivars, data obtained during both 2005-06 and 2006-07 experimental seasons displayed that the following two conflicted trends were detected in this respect:

a- First trend of response dealing with Ca, Mg, Mn, Zn and Co contents, where fruit peel of sound fruits and adjacent leaves were richer in their content of such group as compared to the analogous ones of creased fruits and nearer leaves. However, specific effect of fruit state on both Mg and Co content was not so pronounced and in most cases didn't reach level of significance.

b- Second trend representative of the response of N, P and K contents, where their response took the other way around as compared to previously detected trend of the former group. Anyhow, creased fruits (peel) and adjacent leaves were richer in their (N, P, K) contents,
however K response was too slight and in most cases didn't reach level of significance, especially as fruit rind was concerned.

B. Interaction effect:

With regard to the interaction effect of the possible combinations between two investigated factors (spray treatments and fruit status) on leaf and fruit rind mineral composition, data obtained during both experimental seasons displayed that specific effect of each investigated factor reflected directly on their combinations. Consequently, it could be concluded the following points:

1- Nitrogen content: Rind of creased fruits and adjacent leaves sampled from sprayed trees with KNO₃, Ca-set (solely) or plus CoCl₂ were the richest and ranked 1ˢᵗ, 2¹⁴ᵗ and 3¹⁴ᵗ, respectively. However, the poorest leaves and fruit rind was those of normal fruits and nearer leaves collected from ZnSO₄ or GA₃ sprayed trees.

2- Phosphorus content: Creased fruits and adjacent leaves sampled from the KNO₃, GA₃ or water (control) sprayed trees showed significantly the highest P % in their tissues. The reverse was found with sound fruits and nearer leaves of sprayed trees with either Ca-set or CoCl₂ (each solely).

3- Potassium content: The highest leaf and fruit rind K content was significantly coupled with creased fruits and adjacent leaves of KNO₃ and (PP₃₃₃ / water) sprayed trees which ranked 1ˢᵗ and 2¹⁴ᵗ, respectively. The reverse was found by normal fruits and adjacent leaves of Ca-set and CoCl₁₂ sprayed trees (each solely or together).

4- Calcium content: Sound fruits and adjacent leaves of Ca-set (solely) or plus CoCl₂ sprayed trees had significantly the highest Ca %. The
opposite was true with creased fruits and nearer leaves of (water or KNO$_3$) and GA$_3$ or ZnSO$_4$ sprayed trees.

5- Magnesium content: Normal fruits and adjacent leaves of water sprayed trees (control) and to great extent those of PP333 and GA$_3$ exhibited generally the highest Mg %. However, differences was too slight to be significant especially with Washington navel orange cv. On the contrary, fruit rind of creased fruits and adjacent leaves of Ca-set or KNO$_3$ spray trees showed the least Mg % followed in most cases by creased ones of ZnSO$_4$ spray.

6- Manganese content: The highest leaf and fruit rind Mn content was in closed relationship to the sound fruits and adjacent leaves of sprayed trees with CoCl$_2$ plus either Ca-set (T$_8$ & T$_{10}$) or ZnSO$_4$ (T$_9$ & T$_{11}$). However, CoCl$_2$ + Ca-set especially T10 (Ca-set + CoC12 + Ca-set) sprayed trees was statistically the superior as Mn content of sound fruits (rind) and adjacent leaves was concerned. On the contrary, the least Mn level was found with fruit rind of creased fruits and adjacent leaves sampled from sprayed trees with water (control), KNO$_3$ or GA$_3$.

7- Zinc content: Sound fruits and adjacent leaves of ZnSO$_4$ sprayed trees or ZnSO$_4$ + CoC12 sprayed trees (T$_9$ & T$_{11}$) exhibited statistically the highest Zn content. However, combination of ZnSO$_4$ spray solely was statistically the superior. The reverse was found with creased fruits and adjacent leaves of sprayed trees with either water (control), Ca-set or CoC12.

8- Cobalt content: Sound fruits and adjacent leaves of CoCl$_2$ treated trees either solely or plus one of Ca-set and ZnSO$_4$ exhibited statistically the highest cobalt content. On the contrary creased fruits

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and adjacent leaves sampled from sprayed trees with any of the
other investigated spray solutions had statistically the least leaf &
fruit rind Co content.

V. IV. Polygalacturonase (PG-ase) activity:

PG-ase activity in fruit rind (albedo tissues) of Washington navel and
Tanarif orange cultivars in response to differential spray treatments combined
with either fruit age of sound fruits (sampled on mid September, November 1^{8}
and February 15^{th}) or fruit state (normal and creased) were investigated.

A. Specific effect:

Obtained data displayed that PG-ase activity exhibited a gradual and
significant increase in albedo tissues of sound fruits with the advancement
of age from September till February. As for the specific effect of foliar spray
treatments, it was so clear that all spray treatments reduced PG-ase activity
below control. However, both combinations of either (CoC1_{2} + Ca-set) or
(CoC1_{2} + ZnSO_{4}) were the superior, especially two former ones. Moreover,
PG-ase activity responded specifically to fruit state, where activity was
significantly higher in albedo tissues of creased fruits than normal (sound)
ones.

B. Interaction effect:

Data obtained revealed that specific effect of each investigated factor
reflected directly on its own combinations. Herein, the highest activity was
coupled with the mid February sampled fruits from water sprayed trees
(control), while the reverse was true with sampled fruits on mid September
from (CoC1_{2} + Ca-set) sprayed trees. On the other hand creased fruits of
control trees showed the highest PG-ase activity in their albedo tissues.

V. V. Anatomical examination:

In 1^{8} 2005/06 experimental season, microscopic examination of
fruit rind for Washington navel and Tanarif orange cvs. was periodically
done to study anatomically the effect of fruit age and differential investigated spray treatments through two definite durations on the initiation and development of creasing phenomenon during $1^8$ and $2^4$ durations, respectively. It was quite evident through earlier 3 periodical dates of microscopic examination (April 30$^{th}$, May 15$^{1}$ and 30$^{th}$) that no sign of creasing initiation was observed, where both outer and inner mesocarp tissues were composed largely of thin walled parenchyma cells with no intercellular spaces in two orange cvs. The $1^2$ sign (initiation) of creasing symptoms was anatomically observed on June 15$^{1}$ as some narrow intercellular spaces scarcely scattered within the inner mesocarp tissue in fruits of water sprayed trees. However, fruits of other investigated treatments proved normality of their anatomical feature (devoid of intercellular spaces within the mesocarp tissues). By time, transverse sections prepared on August 1$^8$ in fruit rind of water sprayed trees (control) showed an excessive expansion of affected area and the originated intercellular spaces became wider. Such symptoms were also observed with fruit rind of most treatments, except that of sprayed trees with any of both (CoCl$_2$ + Ca-set combinations) i.e, T$_{10}$ & T$_{g}$ which delayed anatomical initiation of creasing till September 15$^{11}$. In addition, other foliar spray treatments resulted in a noticeable variations regarding their influence on creasing initiation and its development. Anyhow, two combinations of CoCl$_2$ + ZnSO$_4$ i.e., T$_9$ and T$_{11}$ delayed considerably creasing initiation, while ZnSO$_4$ solely was the least effective in this concern. As season was advanced up to 195 days from fruit set microscopic examination of fruit rind of control revealed that the adjacent affected area interlocked leading to wider intricate spaces. Interlocking of adjacent spaces resulted in intricated cavities below the flavedo zone which depressed the affected area of mesocarp leading to the formation of irregular grooves running in various directions over the outer peel surface.

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**SUMMARY AND CONCLUSION**