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Pre-harvest Treatments to Reduce Incidence of the Soft Scald and to Enhance Coloration of "Anna" Apple Fruits

Karim M. Farag and *Said M. Attia

Horticulture Department (Pomology), Faculty of Agriculture, Damanhour University, Egypt.
*Email: said.attia@agr.dmu.edu.eg

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Abstract:

Few attempts have been made to overcome problem of the soft scald. Many factors and conditions are associated with such physiological disorder. In this study, seven-years-old "Anna" apple trees were preharvest sprayed during 2016 and 2017 growing seasons with lisophos 1000mg/ litre, potassium sulphate 2%, calcium sulphate 2% and their combinations in order to investigate their influence on initiation of the soft scald and fruit quality especially fruit coloration at harvest as well as keeping fruit quality during storage for seven days on refrigerator. Lisophos alone or plus either calcium sulphate or potassium sulphate reduced initiation of the soft scald at harvest as compared with untreated fruits, in addition to retarding the loss of fruit firmness. The application of potassium sulphate alone or incorporated with lisophos treatment increased fruit diameter, fruit TSS, total sugars, peel anthocyanin and carotene contents but decreased fruit acidity, peel chlorophyll a and b as compared with control. After seven days of refrigerated shelf life, the application of lisophos plus calcium sulphate retarding the loss of flesh firmness, reduced weight loss% and incidence of the soft scald percentage. This study provided evidences about the possibility of reducing incidence of the soft scald in "Anna" apples by preharvest application of lisophos plus either calcium sulphate or potassium sulphate, while, enhancing fruit quality and coloration.

Keywords: *Soft Scald-Apple Fruits- Lisophos- Pre-harvest- Calcium- Potassium- Storage- Anthocyanin.*

Introduction

Soft scald of apple fruit is a physiological disorder that causes serious losses for growers in many countries especially after harvest (Johnston *et al*., 2002a). The symptoms of soft scald are soft brown lesion on the skin of the apple which extends into the flesh (DeEll, 2009). There were many factors affecting apple softening before and after harvest which also hasten the respiration climacteric rise apples including temperature during fruit growth especially warmer temperature (Bramlage, 1993: Emongor *et al*., 1994). There has been a lack for more research effort to overcome this problem or to alleviate the possible causes. The available data indicated to the involvement of many factors and conditions that lead to the incidence of soft scald such as late harvest or advanced maturity, mineral nutrition, light crop load, large fruit and vigorous trees (Snowdon, 1990). More the ethylene content in apple fruits after harvest more the incidence of soft scald (Farag, 2006). This disorder is also correlated with storage conditions (Johnston *et al*., 2002b). In addition, ethylene treatments which induce softening in apples by regulating expression of cell wall modifying enzymes such as polygalacturonase (Atkinson *et al*., 1998).

Good colors of apple fruit without physiological disorder determinants the value of many apple cultivars. Skin coloration of apples is directly related to the anthocyanin pigments (Lancaster *et al*., 1994: Li *et al*., 2008) or carotenes in some other cultivars. These pigments provide essential cultivar differentiation for consumers and are implicated in the health attributes of apple fruit including their roles as antioxidants. Under Egypt climatic conditions, "Anna" apple fruit has tendency not to develop good red color. Poor coloration has been a serious problem in affecting growers profit from these cultivars (Boyer and Liu, 2004).

Lysophosphatidylethanolamine (LPE) such as lisophos is a natural lipid has been used as a coloring and ripening agent in many fruit crops such as apple, cranberry, tomato and plum (Farag and Palta, 1989, 1992 and Farag and Attia, 2016) while keeping fruit quality by either lowering the respiration rate, inhibiting the activity of cell wall hydrolyses and by retarding senescence (Farag and Palta, 1993). On the other hand, calcium plays an important role in maintaining the quality and storability of fruit (Bhat *et al*., 2012: Wehr *et al*., 2004). Calcium-treated apple fruit have less disruption and degradation of the pectin-rich middle lamella, and have more cell-to-cell contact than non-treated fruit (Glenn and Poovaiah, 1990). Adequate levels of calcium are necessary for normal membrane function (Jaleel *et al*., 2007).

Potassium is one of the essential nutrients described as the quality element for fruit crop production. It wasreported to improve fruit quality, fruit coloration, shipping quality and shelf life (Lester *et al*., 2007). Preharvest application of potassium sulphate positively enhanced physical and chemical quality of many fruit species such as apples, grapes, nectarines and guava (Nava *et al*., 2007; Anjum *et al*., 2008; Gill *et al*., 2012; Yang *et al*., 2008). Soares *et al*. (2005) showed that preharvest application of potassium on pineapple fruit reduced internal browning physiological disorder.

Aforementioned, the objectives of this study were to investigate the effect of preharvest spray of lisophos, calcium sulphate and potassium sulphate on the incidence of soft scald disorder and to enhance coloration of "Anna" apple fruits.

Materials and Methods

1- Experimental design:

The present study was conducted during two seasons, 2016 and 2017 on seven-years-old "Anna" apple trees (*Malusdomestica* L). The description of the experiment was recorded in Table (1).

Cultivar	Rootstock	Study location	Irrigation system	Soil type	Distance between trees
Anna	Balady	Private orchard at Elboustan region, Emam Huseinyvillage, Behira, Egypt.	Drip irrigation	Sandy soil	4× 4 m

The study layout was randomized complete block design (RCBD) and the following seven foliar treatments were carried out with three replicates for each treatment and one tree represented one replication;

1- Untreated trees (sprayed water only as control).
2- Lisophos at 1000 mg/L (Phospholipid 70%).
3- Potassium Sulphate (PS) at 2%.
4- Calcium Sulphate (CS) at 2%.
5- Lisophos + Potassiumsulphate.
6- Lisophos + Calciumsulphate.
7- Potassiumsulphate+ Calciumsulphate.

The trees received the treatments once application time during 11, 7 June through 2016 and 2017, respectively. The surfactant Top film was added to all treatments at the rate of 0.5 cm^3/litre solution. The trees were sprayed directly with treatments solution with hand pump sprayer to runoff in the morning.

2- Physical and chemical analyses:

At harvest, a sample of 10 fruits of each replicate was randomly selected in both seasons to determine the following characteristics:

Fruit weight (g), fruit volume (cm^3), fruit diameter (cm) and fruit length (cm), fruit firmness (Ib/$inch^2$) was recorded using Effigi pressure tester (mod. FT 327) scale of, 3-27 Lbs. and incidence of the soft scald was visually estimated. Moreover, in fruit juice, percentage of the total soluble solids (TSS%) was measured by a hand refractometer, titratableacidity as grams of malic acid per 100 g juice was determined by titration with 0.1 N NaOH according to AOAC (1985) and TSS/Acidity ratio was estimated. Fruit total sugars were extracted from the fruit according to (Egan *et al.*, 1981) and total sugars were determined calorimetrically using phenol sulphuric acid method according to(Smith, 1956). In addition, chlorophyll a, b and carotene were determined according to (Lichtenthaler and Wellburn, 1985), Anthocyanin was determined according to Fuleki and Francis (1968) while L-ascorbic acid was determined according to AOAC (1985).

3- Shelf life assessment:

In order to investigate the effect of the different treatments on the development of soft scald, physical and chemical characteristics of apples, a sample of five fruits from each replicate was kept at refrigerator at (4 - $5C^{\circ}$) for seven days. Then, fruits were put at room temperature (20 ± $2C^{\circ}$) for two days to determine the development of incidence of the soft scald. Fruit weight loss%, fruit firmness, TSS%, acidity%, also, total sugars%, L-ascorbic acid, chlorophylls a, b, carotenes and anthocyanin were determined by using the same aforementioned methods and procedures.

4- Statistical analysis:

The investigation was analyzed using Statistical Analysis System (SAS, 2000). Treatments were arranged in a randomized complete block design (RCBD). Three replications were used with each treatment and one tree represented one replication. The least significant differences (LSD) at 0.05 levels according to Sendecor and Cochran (1980) were used to compare treatments means.

Results

The effect of preharvest treatments with some safe compounds such as lisophos, potassium and calcium sulphate or their combinations on incidence of the soft scald disorder in "Anna" apples was reported in Table 2. Data indicated reduction in the percentage of the soft scald at the harvest time with varying degrees of efficacy. The least value was obtained by the combination of lisophos plus calcium sulphatein both seasons ranging between 10.0 to 11.7% while the highest incidence of soft scald occurred in the control ranging between 23.3% to 26.7% in the two studied seasons, respectively. Meanwhile, many other applications were also successful in reducing soft scald comparing with the control. It seemed that the presence of calcium sulphateas single treatment or when combined with lisophos was necessary to minimize the incidence of soft scald in "Anna" apples in a consistent manner in both seasons. Meanwhile, flesh firmness was also significantly influenced by various used treatments as reported in Table 2. The data revealed that the greatest flesh firmness of "Anna" apples was obtained again with the combination of calcium sulphateplus lisophos as compared with the control (Table 2). Even when either lisophos or calcium sulphate was solely used each one of them was able to retard the loss of flesh firmness relative to the control while potassium sulphate actually caused a significant reduction in flesh firmness relative to the control in both seasons. However, combination of both compounds with lisophos, resulted in greater flesh firmness than that found with the sole application of potassium sulphate alone. Thus, the inclusion of lisophos in the treatment solution was able to mitigate the adverse influence of potassium sulphate on "Anna" apples in both seasons. When both potassium and calcium sulphates were applied as single solution induced no significant influence on flesh firmness in a consistent manner in both seasons.

Table 2. Effect of pre-harvest treatments of lisophos, potassium sulphate and calcium sulphate on soft scald percentage and flesh firmness of "Anna" apples at harvest during 2016 and 2017, seasons.

Treatments	Season 2016		Season 2017	
	Soft scald (%)	Flesh firmness (Ib/ inch^2)	Soft scald (%)	Flesh firmness (Ib/ inch^2)
Control (water only)	23.33 a	9.03 d	26.67 a	8.70 de
Lisophos at 1000 mg/L	13.33 bc	9.40 c	15.00 bc	9.23 ab
Potassium Sulphate (PS) at 2%	16.67 b	8.60 e	18.33 b	8.57 e
Calcium Sulphate (CS) at 2%	11.67 bc	9.93 b	13.33 bc	9.07 bc
Lisophos +Potassium Sulphate	13.33 bc	9.10 d	16.67 bc	8.93 cd
Lisophos + Calcium Sulphate	10.00 c	10.23 a	11.67 c	9.47 a
Potassium Sulphate + Calcium Sulphate	13.33 bc	9.22 cd	16.67 bc	8.93 cd

*Values, within each column, of similar letter (s) were not significantly different according to the least significant difference (LSD) at 0.05 levels.

Regard to the influence of various preharvest field applications on some physical characteristics of "Anna" apples, the data reported in Table 3 revealed that there was no significant alteration in fruit weight due to all used treatments in both seasons. Consequently, that was also the general trend for fruit size in both seasons except with fruit size in the second season that was significantly increased relative to the control by the application of potassium sulphate. A typical trend of results was found for fruit length of "Anna" apples that was similar for all treatments and the control except with an increase obtained with potassium sulphate in the second season as compared with the control (Table 3). In addition, fruit diameter was not significantly affected by various applied treatments in both seasons except with the application of potassium sulphate that resulted in a significant increase in fruit diameter in both seasons when compared with the control.

Table 3. Effect of pre-harvest treatments of lisophos, potassium sulphate and calcium Sulphate on some physical characteristics of "Anna" apples at harvest during 2016 and 2017, seasons.

Treatments	Season 2016		Season 2017		Season 2016		Season 2017	
	Fruit weight (g)	Fruit size (cm^3)	Fruit weight (g)	Fruit size (cm^3)	Fruit length (cm)	Fruit diameter (cm)	Fruit length (cm)	Fruit diameter (cm)
Control (water only)	132.79 ns	142.01 ns	137.31 ns	140.02 b	6.49 ns	6.09 bc	6.84 b	6.14 b
Lisophos at 1000 mg/L	135.35 ns	138.92 ns	138.88 ns	142.27 ab	7.12 ns	6.00 c	6.86 b	6.20 ab
Potassium Sulphate (PS) at 2%	144.56 ns	140.55 ns	140.49 ns	149.32 a	7.14 ns	6.33 a	6.59 ab	6.25 a
Calcium Sulphate (CS) at 2%	145.05 ns	146.63 ns	139.34 ns	143.06 ab	7.00 ns	6.23 ab	7.06 a	6.21 ab
Lisophos +Potassium Sulphate	140.63 ns	142.81 ns	140.70 ns	143.29 ab	7.00 ns	6.04 bc	6.90 ab	6.16 ab
Lisophos + Calcium Sulphate	138.37 ns	145.13 ns	137.41 ns	141.61 ab	6.76 ns	6.18 abc	6.90 ab	6.16 ab
Potassium Sulphate + Calcium Sulphate	138.11 ns	140.27 ns	137.39 ns	142.13 ab	6.84 ns	6.00 c	6.95 ab	6.21 ab

*Values, within each column, of similar letter (s) were not significantly different according to the least significant difference (LSD) at 0.05 levels.

Furthermore, the effect of applied treatments before harvest on some chemical characteristics of "Anna" apples was reported in Table 4. It was evident that total soluble solids (TSS) were increased by many treatments especially those that included lisophos either alone or when combined with potassium sulphate or plus calcium sulphate. However, calcium Sulphate alone was not able to cause a significant change in TSS% as compared with the control in both seasons, while potassium sulphate resulted in a significant increase in TSS% either alone or when combined with calcium sulphate. On the other hand, total acidity% in "Anna" apples juice was significantly reduced relative to the control by all lisophos sprayed either alone or as combination with either potassium sulphate or calcium sulphate. However, the individual application of calcium sulphate resulted in similar total acidity in apple juice that found in the control as well as its combination with potassium sulphate in both seasons. Even the application of potassium sulphate alone caused a reduction in fruit acidity% similar to that obtained by lisophos. Meanwhile the TSS to acidity ratio was significantly affected by many treatments whether individually as the case with lisophos or potassium sulphateor in combinations as occurred with the application of lisophos plus potassium sulphate or plus calcium sulphate. However, calcium sulphate again was not able to increase such ratio as compared with the control consistently. Regarding to total sugars% the data in Table 4 indicated that all applied treatments resulted in total sugars% relative to the control with greater magnitude of increase as with lisophos alone, potassium sulphate alone or their combination in both seasons. Even the combination of potassium sulphate plus calcium sulphate was able to cause a significant increase in total sugars% as compared with the control (Table 4). The changes in vitamin C in response to various applied treatments seemed to take a different trend since potassium sulphate alone or its combination with lisophos were not effective in increasing vitamin C content. However, the significant increase in vitamin C was obtained with either lisophos solely or its combination with calcium sulphatein both seasons (Table 4).

Table 4. Effect of pre-harvest treatments of lisophos, potassium sulphate and calcium sulphate on some chemical characteristics of "Anna" apples during 2016 and 2017, seasons.

Treatments	Season 2016		Season 2017		Season 2016		Season 2017		Season 2016	Season 2017
	TSS (%)	Acidity (%)	TSS (%)	Acidity (%)	TSS/ Acidity %	Total sugar %	TSS/ Acidity %	Total sugar %	Vitamin C mg/100g	Vitamin C mg/100g
Control (water only)	13.60 c	1.01 a	13.80 d	0.98 a	13.53 d	8.13 e	14.11 e	8.90 g	5.66 c	5.33 d
Lisophos at 1000 mg/L	15.10 a	0.81 c	15.20 b	0.79 c	18.98 a	9.16 a	19.23 b	9.82 c	7.02 b	7.23 b
Potassium Sulphate (PS) at 2%	15.10 a	0.80 c	15.40 ab	0.77 c	18.78 a	9.09 a	19.82 ab	9.99 b	5.27 c	5.14 d
Calcium Sulphate (CS) at 2%	13.90 c	0.99 a	14.00 d	0.98 a	14.02 cd	8.41 d	14.32 de	9.04 f	9.10 a	8.84 a
Lisophos +Potassium Sulphate	15.20 a	0.79 c	15.50 a	0.76 c	19.24 a	9.15 a	20.32 a	10.14 a	5.85 c	5.89 c
Lisophos + Calcium Sulphate	14.50 b	0.93 b	14.60 c	0.88 b	15.47 b	8.77 b	16.51 c	9.43 e	9.10 a	9.04 a
Potassium Sulphate + Calcium Sulphate	14.40 b	0.99 a	14.70 c	0.98 a	14.53 c	8.57 c	15.04 d	9.63 d	7.35 b	6.37 c

*Values, within each column, of similar letter (s) were not significantly different according to the least significant difference (LSD) at 0.05 levels.

At the meantime, there was a significant in anthocyanin content in the apple skins by all used treatments except the application of calcium sulphate at 2% (w/v), relative to the control in both seasons. Meanwhile, the application of lisophos plus potassium sulphate resulted in a significant increase in anthocyanin formation followed by the sole treatment of potassium sulphate in a consistent manner. The application of lisophos alone was able to significantly increase anthocyanin in apples, such increase was higher than that obtained by its combination with calcium sulphate. Thus, it was evident that calcium sulphate had an influence on coloration of apples (Table 5). Moreover, chlorophyll a in fruit skin was at the highest content in the control and in calcium sulphate treated fruits that did not differ significantly in their chlorophyll a content. Meanwhile, many used treatments were able to reduce chlorophyll a content in apple skins especially with the application of the combination of lisophos plus potassium sulphate followed by the individual application of potassium sulphate. The presence of calcium sulphate along with lisophos or even plus potassium sulphate caused an increase in chlorophyll a content in the skin of fruits. Similar trends of results were obtained with chlorophyll b since the greatest content was found in the control fruits especially in the second season, however, the combination of lisophos plus either potassium sulphate or calcium sulphate had an equal effect on chlorophyll b and had similar content to that obtained in the control fruits. Thus, the consistent reduction in chlorophyll b was only obtained with the application of potassium sulphate relative to the control. With regard to carotene content in fruit skin at harvest, it was found that there was a significant increase in carotene by the application of the combination of lisophos plus potassium sulphate in addition to the application of each compound individually. However, the application of calcium sulphate alone caused a significant reduction in carotene content while when it was applied along with potassium sulphate resulted in a slight increase in carotenes as compared with the control (Table 5).

Table 5. Effect of pre-harvest treatments of lisophos, potassium sulphate and calcium sulphate on skin pigments of "Anna" apples during 2016 and 2017, seasons.

Treatments	Season 2016		Season 2017		Season 2016		Season 2017	
	Anthocyanin mg/ 100g	Chlorophyll a mg/ 100g	Anthocyanin mg/ 100g	Chlorophyll a mg/ 100g	Chlorophyll b mg/ 100g	Carotene mg/ 100g	Chlorophyll b mg/ 100g	Carotene mg/ 100g
Control (water only)	6.56 e	2.52 a	6.27 e	2.55 a	1.23 c	0.50 ef	1.26 a	0.47 e
Lisophos at 1000 mg/L	9.62 c	2.23 d	8.84 c	2.13 c	1.27 a	0.58 c	1.18 c	0.62 b
Potassium Sulphate (PS) at 2%	13.11 b	1.88 e	12.62 b	1.87 d	1.26 ab	0.64 b	1.18 c	0.69 a
Calcium Sulphate (CS) at 2%	6.20 e	2.54 a	6.49 e	2.57 a	1.24 abc	0.49 f	1.25 a	0.47 e
Lisophos +Potassium Sulphate	14.18 a	1.83 f	13.90 a	1.88 d	1.24 abc	0.67 a	1.24 ab	0.69 a
Lisophos + Calcium Sulphate	7.41 d	2.41 b	8.41 d	2.46 b	1.27 a	0.51 e	1.21 bc	0.54 d
Potassium Sulphate + Calcium Sulphate	8.84 c	2.38 c	8.48 d	2.45 b	1.25 abc	0.54 d	1.21 bc	0.57 c

*Values, within each column, of similar letter (s) were not significantly different according to the least significant difference (LSD) at 0.05 levels.

Post-harvest fruit assessment:

The data in (Table 6) provided evidence that it was possible to significantly reduce the incidence of soft scald percentage (Table 6) in the fruit by many used treatments. Such percentage in the control fruits ranged between 30% to more than 36% while in calcium-treated fruits, the incidence of soft scald ranged between 11% to 16% whether calcium sulphate was applied alone or in combination with lisophos. Meanwhile, incidence of the soft scald with the use of lisophos alone at 1000 ppm was also very effective on reducing soft scald formation in apple fruits. Furthermore, the application of potassium sulphate alone or in combination with calcium sulphate had an equal influence on reducing incidence of the soft scald in apples. Moreover, the application of lisophos plus potassium sulphate that had a significant influence on skin coloration was also effective on reducing the disorder of soft scald as compared with the control (Table 6). With regard to the response of flesh firmness to various applied treatments, the data in Table 6 revealed that even with the successful reduction of soft scald and the enhancement of coloration and skin tissues by many treatments, three was either an increase in flesh firmness caused by the combination of lisophos plus calcium sulphate or even the individual use of either one especially in the second season relative to the control. Moreover, lisophos plus potassium did not reduce flesh firmness in spite of its frequent-positive effects on color improvement and soft scald incidence (Table 6). Concerning the effect of various treatments on weight loss percentage after harvest, the data indicated that "Anna" apples had the least significant loss when was treated with either lisophos alone or lisophos combination with calcium sulphate in both seasons. The highest weight loss was found with the control fruit. However, several treatments resulted in similar weight loss percentage to that found in the control especially in the first season such as potassium alone or in combination with lisophos in addition to potassium sulphate plus calcium sulphate. Moreover, calcium sulphate alone was able to consistently reduce weight loss in both seasons relative to the control.

Table 6. Effect of pre-harvest treatments of lisophos, potassium sulphate and calcium sulphate on soft scald percentage, flesh firmness and weight lossof "Anna" apples after storage during 2016 and 2017, seasons.

Treatments	Season 2016		Season 2017		Season 2016	Season 2017
	Soft scald %	Firmness (Ib/ inch^2)	Soft scald %	Firmness (Ib/ inch^2)	Weight loss %	Weight loss %
Control (water only)	30.00 a	7.90 b	36.67 a	7.37 d	5.00 a	5.67 a
Lisophos at 1000 mg/L	15.00 bc	8.00 b	21.67 bc	7.53 bc	2.83 b	3.17 d
Potassium Sulphate (PS) at 2%	18.33 b	7.53 c	25.00 b	7.13 e	4.67 a	5.17 b
Calcium Sulphate (CS) at 2%	11.67 c	8.10 ab	16.67 c	7.57 bc	2.67 b	3.33 d
Lisophos +Potassium Sulphate	16.67 b	7.90 b	20.00 bc	7.40 cd	4.33 a	4.67 c
Lisophos + Calcium Sulphate	11.67 c	8.30 a	16.67 c	7.83 a	2.50 b	3.00 d
Potassium Sulphate + Calcium Sulphate	16.67 b	7.90 b	21.67 bc	7.33 d	4.13 a	4.53 c

*Values, within each column, of similar letter (s) were not significantly different according to the least significant difference (LSD) at 0.05 levels.

Some fruit parameters were also assessed after harvest (Table 7) in relation to preharvest treatments, the data of total soluble solids percentage (TSS) indicated that all applied treatments before harvest resulted in a significant increase TSS after harvest but varied in the magnitude of such increase. For example, the greatest increase in TSS was obtained with the applications of either lisophos plus potassium sulphate, followed by potassium sulphate alone, then lisophos at 1000 ppm. On the other hand, juice acidity was the highest at the control fruits in both seasons, and was similar to that acidity resuting from the application of calcium sulphate alone. Moreover, the least juice acidity of "Anna" apples was obtained with potassium sulphate alone or when was combined with lisophos. The application of lisophos alone at 1000ppm resulted also in reducing juice acidity when compared with the control. The changes in the TSS to acidity ratios were also influenced by various applied treatments prior harvest (Table 7). The data provided more evidence that the increase in TSS to acidity by lisophos plus potassium sulphate as well as potassium sulphate alone. However, calcium sulphate alone was as effective as the control. Furthermore, there were many other treatments that were equally effective on TSS to acidity ratio such as lisophos alone, lisophos plus calcium sulphate in addition to potassium sulphate plus calcium sulphate. The data in Table 6 also showed the changes in anthocyanin content after harvest in response to applied treatment before harvest, this data indicated that the greatest increase in anthocyanin was obtained with potassium sulphate alone or when was applied in combination with lisophos. The sole application of lisophos at 1000ppm was also able to increase anthocyanin content after harvest. However, the opposite trend was found with the application of calcium sulphate since there was less anthocyanin in the fruit relative to the control. Moreover the combination of lisophos plus calcium sulphate did not increase anthocyanin in the second season.

Table 7. Effect of pre-harvest treatments of lisophos, potassium sulphate and calcium sulphate on some chemical characteristics of "Anna" apples after storage during 2016 and 2017, seasons.

Treatments	Season 2016		Season 2017		Season 2016		Season 2017	
	TSS %	Acidity %	TSS %	Acidity %	TSS/ acidity %	Anthocyanin mg/ 100g	TSS/ acidity %	Anthocyanin mg/ 100g
Control (water only)	13.70 f	0.95 a	13.60 f	0.94 a	14.40 c	8.70 d	13.72 c	8.98 d
Lisophos at 1000 mg/L	15.00 bc	0.85 b	14.70 bc	0.87 b	17.50 b	10.84 b	16.88 b	10.91 c
Potassium Sulphate (PS) at 2%	15.30 ab	0.75 d	14.90 ab	0.79 d	20.40 a	15.18 a	18.86 a	15.68 b
Calcium Sulphate (CS) at 2%	14.20 e	0.93 a	13.90 e	0.98 a	15.40 c	8.20 e	14.21 c	7.63 e
Lisophos +Potassium Sulphate	15.40 a	0.79 cd	15.10 a	0.80 cd	19.49 a	15.04 a	18.78 a	16.11 a
Lisophos + Calcium Sulphate	14.70 cd	0.83 bc	14.60 c	0.87 b	17.71 b	9.77 c	16.77 b	9.13 d
Potassium Sulphate + Calcium Sulphate	14.60 d	0.85 b	14.30 d	0.84 bc	17.03 b	10.05 c	16.94 b	9.27 d

*Values, within each column, of similar letter (s) were not significantly different according to the least significant difference (LSD) at 0.05 levels.

Discussion

Poor coloration and soft scald disorder determinate the value and the best prices of apples in market. Therefore, the present study provided evidence that it was possible to significantly reduce the incidence of soft scald and enhance coloration of apples by some preharvest treatments. According to the data in Table 2, the applications of lisophos, calcium sulphate, potassium sulphate and their combinations lowered the percentage of soft scald at harvest as compared with control treatment. The positive role of lisophos on reducing soft scald might be attributed to its influence on membrane integrity and inhibited the enzyme activity leads to cell wall and membrane breakdown which reflects on reducing the physiological disorders (Farag and Palta, 1993; Ryu *et al.*, 1997). Attia and Farag, 2017 indicated that preharvest spray of either lisophos or $CaCl_2$ reduced water berry physiological disorder in Thompson seedless table grapes. Also, the positive effect of calcium on reducing soft scald disorder could be attributed to their effect on reducing softening and senescence of fruits (Barker and Pilbeam, 2007). In contrary, calcium deficiency causes bitter pit disorder in apples (Kader, 2002). Furthermore, preharvest application of potassium reduced internal browning disorder in pineapple fruit (Soares, 2005).

To explain the role of lisophos on apple fruit firmness, Farag and Attia, 2016 showed that preharvest spray of lisophos on plum fruit trees increased fruit firmness at harvest and keeping storability during storage. In the present study, lisophos spray showed positive effects on increasing fruit firmness (Table 2). Rato *et al.* (2004) found that plum fruits with higher calcium content showed higher firmness and lower ethylene production rates as compared with fruits with lower calcium content. The results of current study agreed with those obtained by (Roy, 1995, Jaleel *et al.*, 2007 and Bhat *et al.*, 2012). On the other hand, potassium fertilization negatively affected flesh firmness as a result of their expanded cell walls and smaller proportion of cell wall materials in relation to their total volume (Nava *et al.* 2007).

The data in Table 3 revealed that there was no significant alteration in some physical characteristics of Anna apples by preharvest treatments except with the application of potassium sulphte on fruit diameter. The non-significant effect of mentioned treatments could be attributed to the time of application after the completion of fruit growth. The positive effects of potassium on fruit diameter found in this study might be attributed to enhance formation and translocation of carbohydrates and osmoregulation which in turn improved fruit quality (White and Karley, 2010). Also, enhances cell hydration and its deficiency causes tissue dehydration (Menzel and Kirby, 2001). The results of present study agreed with those obtained by Divya Pandey, 2016 on Litchi fruit and Anjum *et al.* 2008 on apple fruit. The decrease in fruit TSS and total sugars found in this study caused by preharvest application of calcium agreed with the findings of others such as Attia, 2017 on pomegranates, Attia and Farag, 2017 on grapes and Attia, 2009 on apricot. They all found that calcium-treated fruits reduced TSS, total sugars and increased fruit acidity. Meanwhile, potassium foliar application increased TSS, total sugars and reduced acidity (Table 4).Foliar application of potassium improved TSS content due to its role in translocation of sugar from leaves to fruits, which resulted in better quality fruits in apple (Shirzadeh and Kazemi, 2012). These trends of results are in harmony with the findings of Anjum *et al.* 2008 on apple, Chanana and Gill, 2008 on grapes and Dutta and Banik, 2007 on guava.

There was a significant increase in anthocyanin content in apple skins by all used treatments except the application of calcium sulphate as compared with control treatment (Table 5). The positive effect of lisophos on anthocyanin formation was previously reported (Farag and Attia, 2016, 2017; Ozgen *et al.*, 2015). The positive effects might be attributed to enhance ethylene production, carotenoid accumulation and enhance coloration enzymes such as (phenylalanine ammonium lyase, 1-aminocycloprpopane1-carboxylic acid and insoluble acid invertase) (Hong *et al.*, 2008; Farag and Palta, 1989 and Ozgen, 2004). Also, potassium treatment enhanced coloration of apples. Lester *et al.* (2005) observed that improvement of fruit color with potassium is attributed to their effects on carbohydrate influx as optimum K level enhanced phloem loading, nutrient transportation and unloading of sucrose. In addition potassium might be important in the anthocyanin pathway and could be a cofactor in the activation of some specific enzymes (Hunsche and Ernani, 2003). The positive effect of potassium on fruit coloration was previously reported on Nectarines (Yang *et al*., 2008) and on apple (EL-Gazzar, 2000). On the other hand, the present study showed that calcium treatment retard coloration of apples. These results were in agreement with Attia and Farag, 2017 on grapes and Attia, 2009 on apricots.

The data in Table 6 illustrated that it was possible to reduce the incidence of soft scald after storage also keeping fruit firmness and reducing weight loss of apples which reflects on keeping fruit quality after storage. The use of lisophos and calcium inhibited ethylene production in ripening fruits and maintain fruit firmness which reflects on extend apples shelf life (Hong, 2006). Also, retards the activity of enzymes such as polygalactourenase which reflect on retarding the cell wall hydrolysis (Wehr *et al*., 2004; Bhat *et al*., 2012). Kou *et al*. (2015) treated pear with $CaCl_2$ 2% inhibited the development of brown spots on ‘Huangguan’ pear by delaying the loss of the polyphenol substances (inhibited the activities of polyphenol-oxidase and peroxidase, increased the activities of catalase and superoxide dismutase) and maintaining the structural integrity of cell membrane.

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تقليل حدوث اللفحة الطرية وتحسين لون ثمار صنف التفاح الأنا بمعاملات ما قبل الجمع

كريم محمد فرج و سعيد محمد عطية

قسم البساتين (فاكهة)، كلية الزراعة-جامعة دمنهور -مصر.

الملخص:

بالرغم من وجود العديد من العوامل والظروف المرتبطة بحدوث مشكلة اللفحة الطرية، الا ان هناك القليل من المحاولات التى تمت للتغلب على هذا الاختلال الفسيولوجى، وقد أجريت هذة الدراسة خلال عامى ٢٠١٦، ٢٠١٧ حيث تم رش أشجار التفاح عمر ٧ سنوات بهذة المعاملات التالية قبل الجمع وهذة المعاملات كالتالى: الليزوفوس ١٠٠٠ مجم/لتر، سلفات البوتاسيوم ٢%، سلفات الكالسيوم ٢% والخليط بينهم وذلك لدراسة تاثير هذة المعاملات على حدوث اللفحة الطرية وجودة ثمار التفاح وخصوصا لون الثمار عند الجمع وأيضا المحافظة على جودة الثمار بعد الجمع بعد تخزينها لمدة أسبوع على درجة حرارة الثلاجة. حيث أدت المعاملة بالليزوفوس بمفردة أو مخلوطا بسلفات الكالسيوم أو سلفات البوتاسيوم الى تقليل حدوث اللفحة الطرية بالاضافة الى تاخير فقد صلابة الثمار عند الجمع مقارنة بالكنترول كما أدت المعاملة بسلفات البوتاسيوم بمفردها أو مخلوطة مع الليزوفوس الى زيادة قطر الثمار، محتواها من النسبة المئوية لكل من المواد الصلبة الذائبة الكلية%، السكريات الكلية% ومحتوى الثمار من صبغة الانثوسيانين بينما أدت الى تقليل الحموضة الكلية% ومحتوى الثمار من كلوروفيل أ و ب مقارنة بالكنترول. بعد أسبوع من حياة الثمار المبردة على الرف فى الثلاجة المنزلية، أدت المعاملة بالليزوفوس مخلوطا بسلفات الكالسيوم الى تاخير فقد صلابة لحم الثمار وتقليل كلا من الفقد فى الوزن وتطور اللفحة الطرية فى ثمار التفاح. وتوصى هذة الدراسة بامكانية تقليل حدوث اللفحة الطرية وتحسين صفات الجودة واللون فى ثمار التفاح باستخدام الليزوفوس مخلوطا مع سلفات الكالسيوم او سلفات البوتاسيوم.