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Available online free at www.futurejournals.org

The Future Journal of Biology

Print ISSN: 2572-3006 Online ISSN: 2572-3111

Future Science Association

Future J. Biol., 1 (2020) **35-44**

OPEN ACCES

DOI: 10.37229/fsa.fjb.2020.03.10

EFFECT OF LISOPHOS, SALICYLIC ACID AND POTASSIUM ON THOMPSON SEEDLESS GRAPE QUALITY

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Received: 4 Feb. 2020 **; Accepted:** 10 Mar. 2020

ABSTRACT: Fruit quality is one of the main fruit attributes that affect the marketability and attractiveness of Thompson Seedless grapes (*Vitis vinifera L.*). Grapevines were subjected to the following treatments: Lisophos (LPE) at 200 ppm, salicylic acid at 1 or 2 mM, potassium sulphate at 0.5% (w/v) and their combinations, in addition to the control (water spray). The vines received treatments as one application time on onset of veraison stage. This study aimed at investigating the effects of preharvest sprays of LPE, salicylic acid and potassium sulphate on clusters and berries quality at harvest. Furthermore, to provide grape producers with new-applicable safe, easy and cheap treatments and potential practical application to improve berries quality at harvest. The present study recommended using the formulations included in salicylic acid at 1 or 2 mM, Lisophos 200 ppm and potassium sulphate 0.5% to improve the overall quality of Thompson Seedless grapes.

Key words: Thompson Seedless- Lisophos- Salicylic acid- Potassium-Quality.

INTRODUCTION

Grape (*Vitis vinifera* L.) cv. Thompson Seedless is a member of the family Vitaceae, nearly the most widely cultivated fruit crop of the world and one of older cultivars between the varieties for the consumer and the export market. In Egypt, grape is the second fruit crop after citrus and the area of grape increased recently and reaches about 78,853 ha, which produces 1,759,472 tons with yield 223,134 hg/ha according to the **FAOSTAT (2018)**. Thompson Seedless considered a popular and common fruit in the world. This variety has the most delicious, refreshing and nourishing sub-tropical fruits. The berries are a source of nutrient elements and vitamins (B1, B2 and C). Grapes marketing value depends upon its appearance such as berry and cluster size, color and shape. Many efforts had been done to maintain the grape berries with high quality characteristics such as weight, size, firmness, color intensity for berry and cluster uniformity at harvest and during marketing, such attempts would be very important for the Thompson Seedless growers to obtain higher profit. So, the exogenous applications of different plant growth regulators (**PGRs**) to various stages of developing fruits and interior levels have showed their important for fruit development and quality parameters **(Srivastava and Handa, 2005)**.

Lysophosphatidylethanolamine (LPE) is a natural compound minor glycerolipid present in all extra-chloroplastic membranes. LPE has been shown to affect various physiological processes in plants.

It can change the physical properties of membranes to increase or decrease ion flux and membrane transport, vesicle formation and endo and exocytosis according to **Cowan (2006)**, maintenance of membrane integrity and reduction of the wound response, reduce ethylene production and extend shelf- life of many horticultural crops **(Amaro, 2012)**, which affect fruit quality of Thompson Seedless table grapes **(Hong *et al.*, 2007)**. LPE can retard senescence in attached and detached leaves and fruits of tomato (**Farag and Palta, 1993a**). LPE-treated fruits displayed a longer shelf life (**Farag and Palta, 1993b**). LPE treatment has also been found to reduce senescence of leaves, fruits and cut-flowers **(Kaur and Palta, 1997; Ozgen *et al.*, 2005)** and increased marketable yield **(Ozgen *et al.*, 2015)**. Lisophos reduced activity of phospholipase D and membrane leakiness **(Hong *et al.*, 2009; Ozgen *et al.*, 2005)** and inhibited the cell wall hydrolyzing enzymes such as polygalacturonase **(Hong *et al.*, 2008)**.

Salicylic acid on the other hand, is an endogenous plant growth regulator of phenolic nature. Salicylic acid (SA) is important secondary metabolite in grape berries and plays an essential role in determining grape berry quality. SA was found in plants with roles in plant growth and development, enhanced plant vigor under biotic and abiotic stresses, photosynthesis, transpiration, reduced fruit respiration, seed germination, fruit yield, glycolysis, flowering in thermogenic plants **(Klessig and Malamy, 1994)**, interaction with other organisms, ion uptake and transport **(Hayat *et al.*, 2010)**. SA can modulate plant responses to a wide range of oxidative stresses **(Shirasu *et al.*, 1997)**. SA also induced specific changes in leaf anatomy and chloroplast structure. SA inducing phenylalanine-ammonia-lyase (PAL) in grape berries (**Wen *et al.*, 2005**) and involved in endogenous signaling, mediating in plant defense against pathogens. It plays a role in the resistance to pathogens by inducing the production of pathogenesis-related proteins. It is involved in the systemic acquired resistance (SAR) in which a pathogenic attack on one part of the plant induces resistance in other parts **(Vlot *et al.*, 2009)**. Preharvest foliar spray of 1.5 mM SA at pea stage and at veraison hastened berry maturity by 3 to 5 days and produced less compact bunches alongside larger berries in contrast to the control **(Champa *et al.*, 2015; Marzouk and Kassem, 2011)**. SA was effective in maintaining peel colour, firmness, anthocyanins, phenols and organoleptic properties during cold storage, while reducing weight loss, rachis browning and decay incidence of Flame Seedless table grapes. Thus, preharvest treatment with salicylates could be a safe, ecofriendly and new tool to improve and maintain quality attributes **(Giménez *et al.*, 2017)**.

Potassium (K) is a most important nutrient for grapes. K enhances enzyme activation (**Leigh and Wyn Jones, 1984; Walker *et al.*, 1998)**; cellular membrane transport processes and translocation of assimilates (**Salisbury and Ross, 1992; Patrick *et al.*, 2001)**; anion neutralization, which is essential in maintenance of membrane potential (**Maathuis and Sanders, 1996; Leigh, 2001)** and osmotic potential regulation, which is one of the important mechanisms in the control of plant water relations **(Davies and Zhang, 1991)**, turgor maintenance, growth and quality.

Grape growers still complain about the adverse effect of Ethrel spray on grape berries such as the negative response especially in some arid regions. In many cases, Ethrel spray resulted in dryness of cluster stem and increased berry shatter. Thompson Seedless, in particular, needs more effort and attention to improve the cluster quality and berry coloration to regain the confidence of many grape growers' that it would be profitable to cultivate such cultivar.

Therefore, this study investigated the effects of preharvest sprays of salicylic acid LPE and potassium sulphate, as an alternative to the use of Ethrel, on the clusters and berries quality at harvest of Thompson Seedless grapes. Furthermore, the study aimed to provide the grape producers with new-applicable safe, easy and cheap treatments, while potential practical application to improve berries quality at harvest and on shelf life which reflects on grower's profitability.

MATERIALS AND METHODS

The present study was conducted during two successive seasons of 2016 and 2017 on Thompson Seedless grapevines *(Vitis vinifera* L.*)* grown in sandy soil in a private vineyard at 2*3 m, under drip irrigation system, at Nubaria region, El-Behira governorate, Egypt on ten years old vines grown on their own roots. Forty-four uniform grapevines free from various physiological and visible pathological disorders and healthy were selected for the investigation. The selected vines for this study received the usual horticultural practices applied in the vineyard, except those dealing with the application of study treatments.

The vines received the treatments at one application time on the onset of veraison stage on 11 and 18 June during of 2016 and 2017, respectively, while the harvest followed the spray by nearly a month (12 and 20 July, respectively). The following eleven foliar spray treatments were applied with four replicates for each treatment(one vine per replicate): water only (serve as a control), salicylic acid at 1 mM, salicylic acid at 2 mM, Lisophos at 200 ppm, potassium sulphate at 0.5% (w/v), salicylic acid at 1 mM + Lisophos at 200 ppm, salicylic acid at 2 mM + Lisophos at 200 ppm, salicylic acid at 1 mM + potassium sulphate at 0.5%, salicylic acid at 2 mM + potassium sulphate at 0.5%, salicylic acid at 1 mM + Lisophos at 200 ppm + potassium sulphate at 0.5%, salicylic acid at 2 mM + Lisophos at 200 ppm + potassium sulphate at 0.5%. The spray solution was amended with Tween-20 (0.1%) as a spreading agent. A handheld spraying vines until runoff in the early morning.

At harvest time, five clusters form each replicate were randomly collected in both seasons and saved in plastic bags and immediately to the lab for the subsequent determinations: the cluster weight (g), rachis length (cm), laterals number and cluster stems weight (g). Moreover, size (cm^3), weight (g) and number of water berries in 100 berries. In the juice of berries, the percent of total soluble solids (TSS %) was measured by Carlzeiss hand refractometer, while the total acidity (TA %) was determined colorimetrically based on estimated tartaric acid (as tartaric acid per 100 ml juice) and the maturity index (TSS to Acidity ratio) was calculated by division of TSS to acidity percentage according to **A.O.A.C., (1995)**. Furthermore, Vitamin C (mg /100 ml juice) was determined as measured by **Egan *et al.*, (1987)**. Moreover, total sugars were determined colorimetrically according to the procedure of **Malik and Singh (1980)**. Also, electrolyte leakage from the tissue was measured by a standard procedure **(Farag**

and Palta, 1993a). Additionally, chlorophylls a, b and beta carotene were determined according to **Witermans and Mats (1965)**. The design of the experiment was a randomized complete block design (RCBD) with eleven treatments and four replicates for each treatment (each vine represented one replicate). Comparisons among means were made via the Least Significant Differences (LSD) at 0.05 levels according to **Senedecor and Cochran (1982)**. The values were analyzed using **SAS, program (2000)**.

RESULTS

The effect of various applied treatments before harvest on cluster weight of Thompson Seedless cultivar during the two successive seasons of 2016 and 2017 was reported in Table 1. The data revealed that there was no further significant increase by salicylic concentrations either at 1 or 2 mM when compared with the control in both seasons. Similar trend of results was obtained with the individual application of Lisophos, in the first season and with the sole application of potassium sulphate in the two seasons. However, there was a synergistic influence when the three compounds were combined, which resulted in a significant increase in cluster weight in a consistent manner in the two seasons. That was the trend whether salicylic acid was applied in these formulations at 1 or 2 mM. Meanwhile, when salicylic acid at 2 mM was combined with LPE at 200 ppm, there was still a significant influence on cluster weight by increasing it during both seasons. Similary, salicylic acid treatment at 1 mM plus Lisophos at 200 ppm tended to increase cluster weight in a significant manner only in the first season.

The response of Thompson Seedless grapevines to applied treatments before harvest on cluster stems weight was documented in Table 1. The data showed that almost all applied treatments did not cause a significant alteration of cluster stems weight in both seasons when compared with the control. However, the formulation of salicylic acid at 2 mM plus Lisophos and potassium sulphate resulted in a significant increase in cluster stems weight as compared with the same formulation in the absence of potassium sulphate, in the first season only. In a similar way, the same formulation resulted in a greater weight of cluster stems relative to the individual application of Lisophos, in 2016 season. Thus, the cluster stems that were devoid of berries did not generally change in response to various applied treatments.

To monitor the possible changes in the length of cluster rachis, the data in Table 1 indicated that most applied treatments did not cause a significant change in that length when compared with the control. However, the formulation containing salicylic acid at either one or two mM plus Lisophos and potassium resulted in a significant incease in the rachis length only in the second season relative to control.

The influence of various applied field treatments on the number of laterals of Thompson Seedless clusters was reported in Table 1. The data indicated that there was no significant changes in such character at harvest when comparing most treatments with the control in both seasons. This character had been determined earlier, since the differentiation of the lower buds occurred in perivous summer which might explain the unchanged number of laterals in the cluster.

The influence of various applied treaments on the berry weight was reported in Table 2. The data showed that there was a significant increase in berry weight caused by some treatments relative to the control in both seasons such as Lisophos at 200 ppm whether alone or when combined with salicylic acid at 1 or 2 mM in addition to the two formulations containing either salicylic acid at 1 or 2 mM plus Lisophos 200 ppm and potassium sulphate 0.5% (w/v). However, the sole application of salicylic acid at each used concentration (1 or 2 mM) did not result in a significant change in berry weight as compared with the control. Also, the greatest increase in berry weight in the two seasons was obtained with the formulations of the three mentioned compounds including SA at 2 mM in a constant manner.

The response of size of 100 berries to preharvest applied treatments was presented in Table 2. The data showed that Lisophos alone was able to cause a significant increase in berry size in both seasons, when compared with the control where salicylic acid at both used concentrations did not change it. Moreover, potassium sulphate treatments tended to increase berry size but its effect was significant only in the 2017 season. The greatest increase in berry size was obtained by the formulation that contained salicylic acid at 2 mM plus Lisophos at 200 ppm and potassium sulphate. Anyhow, the magnitude of such increase in berry size was still nearly similar to that obtained with other formulation that included salicylic acid at 1 mM plus Lisophos at 200 ppm and potassium sulphate 0.5%. On the other hand, the combinations of salicylic acid either at 1 or 2 mM plus Lisophos at 200 ppm were still able to result in a significant increase in berry size as compared with the control in a consistent manner in both seasons.

The prcentage of water berries in 100 berries as influnced by a preharvest treatments to Thompson Seedless was shown in Table 2. The data revealed that the percentage of water berries in 100 berries did not vary among the treatments and the control in both seasons, with only one exception in the second season, since the formulation containing salicylic acid at 2 mM plus Lisophos and potassium sulphate resulted in a significant reduction in water berries in 2017 season only as compared with the control and most treatments. Thus, almost all treatments resulted in a similar number of water berriers per 100 berries.

Table 1. Effect of preharvest sprayed treatments on cluster physical characteristics of Thompson Seedless grapes at harvest during of 2016 and 2017 seasons

Treatments	Cluster Weight(g)		Cluster Stems Weight (g)		Length of Cluster Rachis (cm)		Number of Laterals	
	2016	2017	2016	2017	2016	2017	2016	2017
Control	417.15* e	382.87 b	8.60 abc	8.65 a	19.45 a	18.55 cd	17.50 a	16.50 bc
Salicylic acid (SA) at 1 Mm	422.12 e	411.71 ab	8.46 abc	8.53 a	18.08 a	18.80 cd	19.25 a	17.00 abc
Salicylic acid (SA) at 2 mM	451.73 de	451.75 ab	7.82 abc	8.43 a	17.43 a	19.00 bc	18.25 a	16.00 bc
Lisophos (LPE) at 200 ppm	435.54 de	513.03 a	8.68 c	8.23 a	17.50 a	18.95 bc	17.25 a	17.50 abc
Potassium Sulphate (PS) at 0.5%	443.02 de	493.05 ab	8.59 abc	8.75 a	17.90 a	18.93 bc	16.75 a	19.25 abc
SA at 1 mM + LPE at 200 ppm	516.85 bc	410.71 ab	8.96 abc	8.73 a	18.83 a	18.40 cd	17.75 a	17.00 abc
SA at 2 mM + LPE at 200 ppm	554.19 ab	520.81 a	8.25 bc	9.23 a	20.90 a	20.65 ab	17.25 a	19.25 abc
SA at 1 mM + PS at 0.5%	445.45 cd	470.96 ab	8.99 abc	9.49 a	18.78 a	17.00 de	17.75 a	15.75 c
SA at 2 mM + PS at 0.5%	479.39 cd	485.21 ab	8.72 abc	9.45 a	19.00 a	16.50 e	18.50 a	18.00 abc
SA at 1 mM + LPE at 200 ppm + PS at 0.5%	545.78 ab	500.59 ab	9.50 ab	8.71 a	20.43 a	21.33 a	19.50 a	19.50 ab
SA at 2 mM + LPE at 200 ppm + PS at 0.5%	575.70 a	513.72 a	9.72 a	9.50 a	20.20 a	21.53 a	19.75 a	20.25 a

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

Table 2. Effect of preharvest sprayed treatments on berry physical characteristics of Thompson Seedless grapes at harvest during of 2016 and 2017 seasons

Treatments	Weight of 100 berries (g)		Size of 100 berries (cm^3)		Number of water berries / 100 berries	
	2016	2017	2016	2017	2016	2017
Control	201.30* e	148.20 c	201.30 e	148.20 c	4.00 a	6.75 a
Salicylic acid (SA) at 1 mM	204.89 de	193.80 bc	204.89 de	193.80 bc	4.25 a	6.75 a
Salicylic acid (SA) at 2 mM	214.42 bcde	197.94 bc	214.42 bcde	197.94 bc	4.50 a	5.75 ab
Lisophos (LPE) at 200 ppm	226.51 abcd	290.74 a	226.51 abcd	290.74 a	5.50 a	4.75 ab
Potassium Sulphate (PS) at 0.5%	219.61 bcde	233.07 ab	219.61 bcde	233.07 ab	4.75 a	6.75 a
SA at 1 mM + LPE at 200 ppm	224.62 abcd	250.87 ab	224.62 abcd	250.87 ab	3.75 a	6.50 a
SA at 2 mM + LPE at 200 ppm	235.94 ab	265.71 ab	235.94 ab	265.71 ab	5.50 a	6.75 a
SA at 1 mM + PS at 0.5%	206.88 de	200.52 bc	206.88 de	200.52 bc	5.25 a	6.75 a
SA at 2 mM + PS at 0.5%	212.32 cde	231.90 ab	212.32 cde	231.90 ab	4.25 a	7.00 a
SA at 1 mM + LPE at 200 ppm + PS at 0.5%	233.61 abc	248.30 ab	233.61 abc	248.30 ab	2.50 a	4.50 ab
SA at 2 mM + LPE at 200 ppm + PS at .5%	242.81 a	308.27 a	242.81 a	308.27 a	4.25 a	2.75 b

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

With regard to the effect of various applied treatments before harvest on the percentage of total soluble solids (TSS%) in Thompson Seedless grapes after harvest, the obtained data were reported in Table 3. It was evident that the individual application of Lisophos was consistently able to cause a singnificant increase in TSS, while salicylic acid at either used concentratins was not ingeneral able to significaltly increase TSS in the berry juice singnificantly comparing with the control. However, the combination of both compounds wether salicylic acid at 1 or 2 mM plus Lisophos resulted in a significantly increase in TSS relative to the control or to the sole application of salicylic acid at 1 or 2 mM. The greatest magnitude of TSS increase was found with the treatment that contained salicylic acid at 2 mM plus Lisophos and potassium sulphate.

Change in juice acidity of Thompson Seedless grapes berries as influenced by various preharvest treatment during the two seasons were shown in Table 3. The data indicated that there was a significant reduction of juice acidity by many treatments relative to the control. These treatmnts included Lisophos at 200 ppm alone or in combination with salicylic acid either at 1 or 2 mM in addition to the formulations that contained salicylic acid at 1 or 2 mM plus both of Lisophos at 200 ppm and potassium sulphate in a consistent manner in both seasons. Meanwhile, some treatments were effective on reducing juice acidity but only during the first season such as potassium sulphate or only during the second season as obtained with the application of salicylic acid at 1 mM plus potassium sulphate. Furthermore, the highest values of berry acidity was found with the control as well as in salicylic acid treated berries.

With regard to the ratio of TSS/acidity ratio in treated clusters in 2016 and 2017 seasons, data in Table 3 revealed that there was a significant increse in such ratio caused by Lisophos and potassium sulphate individual application as compared with control in two seasons except potassium sulphate in the second season. On the other hand, salicylic acid at both concentrations did not vary than the control in the two years in such ratio of TSS/acidity. Both SA 1 mM and SA 2 mM with Lisophos incresed that ratio. In addition, salicylic acid at both concentrations with potassium sulphate increased such ratio in the first season, only. Similarly, the addition of potassium sulphate plus salicylic acid at 1 mM to Lisophos at 200 ppm increased TSS/acidity ratio than that found in the control clusters in both seasons. In pirfe, the highest increase in the ratio of TSS to acidity was obtained with spraying Lisophos 200 ppm in a formulation with potassium sulphate and SA at 2 mM.

The influence of various treatments on vitamin C content in the berry juice was reported in Table 3. The data indicated that Thompson Seedless grapes had a significant increase in vitamin C in response to most applied treatments as compare with the control except SA at 1 mM alone during the two seasons and SA at 2 mM during the second season only. However, the sole application of LPE at 200 ppm was able to cause a significant increase in vitamin C in the berry juice as well as its combination with SA at either used concentrations. Meanwhile, the highest magnitude of increase in vitamin C at harvest time was attained with the formulation containing SA at 2 mM plus LPE at 200 ppm and potassium sulphate in both seasons. Furthermore, individual application of potassium sulphate also resulted in a consistent increase in vitamin C content over the control in both seasons. However, the most efficient formulation mentioned above on vitamin C both did not significantly vary from the same formulation but with the lower concentration of SA at 1 mM.

The effect of preharvest application of treatments shown in Table 3 on total sugars of Thompson Seedless grapes revealed that SA 2 mM plus LPE at 200 ppm was consistently able to increase total sugars in berry juice. However, other treatments resulted in increaseing total sugars in the second season such as LPE at 200 ppm, potassium sulphate at 0.5% and the combinations of SA (at 1 or 2 mM) plus LPE at 200 ppm. Meanwhile, the formulation of SA at 2 mM plus LPE and potassium sulphate tended to increase total sugars, but only in a signicant manner in the second season.

The change in electrolyte leakage percentage of laterals in Thompson Seedless grape in response to various applications before harvest was reported in Table 3. The data revealed that many treatments caused a significant reduction in electrolyte leakage percentage of the cluster laterals such as the individual treatments of salicylic acid at 1 or 2 mM, the sole application of Lisophos at 200 ppm, in addition to the application of potassium sulphate, relative to the control. Meanwhile, the highest reduction of such leakage was obtained with the formulation containing salicylic acid at either one or two mM plus Lisophos and potassium sulphate. Moreover, the combination of salicylic acid at both concentrations plus potassium sulphate were still able to cause a significant reduction in electrolyte leakage, relative to the control in both seasons.

The response of cluster pedicels electrolyte leakage to preharvest application of various treatments during of 2017 and 2018 seasons, was shown in Table 3. The data indicated that there was a significant reduction in pedicels electrolyte leakage caused by individual application of used treatments such as salicylic acid 1 or 2 mM, Lisophos 200 ppm in addition to potassium suphate at 0.5% (w/v), when compared with the control in both seasons. The magnitude of such reduction was even higher with the application of the formulations containing salicylic acid (at 1 or 2 mM) plus Lisophos and potassium sulphate. The greatest electrolyte leakage was found with the control pedicels. When Lisophos was combined with salicylic acid, it was able to cause a further reduction in electrolyte leakage in a greater magnitude than the addition of potassium sulphate to salicylic acid at both used concentrations.

The content of chlorophylls a and b in the treated berries at harvest of Thompson Seedless as affected by preharvest treatments revealed that chlorophyll a of the control berries was similar to that found with various used treatments except with the application of the combination of SA at 1 or 2 mM plus LPE at 200 ppm in the second season that resulted in higher chlorophyll a in the berry skin as compared with the control. However, chlorophyll b content did not vary between all applied treatments and the control at harvest time in the two seasons. In other words, all treatments were equally effective on the content of chlorophyll b in both seasons including the control (Table 4).

The response of berry carotenes to various preharvest treatments was shown in Table 4. There was non significant changes in carotene content at harvest even though, carotenes tended to show greater values relative to the control in both seasons whether treated with the formulation that incorporated SA at 1 or 2 mM plus LPE at 200 ppm and potassium sulphate at 0.5%.

Table 3. Effect of preharvest sprayed treatments on some berry chemical characteristics of Thompson Seedless grapes at harvest as affected with preharvest sprayed treatments during of 2016 and 2017 seasons

Treatments	TSS (%)	Acidity (%)	TSS/acid ratio	Vitamin C (mg /100ml juice)	Total Sugars (%)	Electrolyte Leakage(%)	
						EC Laterals	EC pedicels
Season 2016							
Control	17.23*c	0.893a	19.30e	2.30e	18.03b	38.05a	46.93a
Salicylic acid (SA) at 1 mM	17.58c	0.883a	20.01de	2.45de	17.88b	35.05b	44.58b
Salicylic acid (SA) at 2 mM	17.55c	0.825ab	21.41cde	2.98abc	18.30ab	33.10bc	41.55de
Lisophos (LPE) at 200 ppm	20.90b	0.758bc	27.67b	3.00abc	18.78ab	26.70d	40.88e
Potassium Sulphate (PS) at 0.5%	18.30c	0.785bc	23.34c	2.75cd	18.05b	35.30b	44.55b
SA at 1 mM + LPE at 200 ppm	20.45b	0.750bc	27.52b	3.08abc	19.03ab	27.08d	41.40de
SA at 2 mM + LPE at 200 ppm	21.30ab	0.748bc	28.58ab	3.23ab	19.80a	27.13d	40.73e
SA at 1 mM + PS at 0.5%	18.00c	0.810abc	22.41cd	2.93bc	18.63ab	25.83d	43.38bc
SA at 2 mM + PS at 0.5%	18.13c	0.813abc	22.37cd	3.08abc	19.03ab	32.25c	42.50cd
SA at 1 mM + LPE at 200 ppm + PS at 0.5%	21.88ab	0.743bc	29.59ab	3.10ab	19.03ab	26.05d	39.05f
SA at 2 mM + LPE at 200 ppm + PS at 0.5%	22.58a	0.723c	31.25a	3.30a	19.60ab	25.93d	38.53f
Season 2017							
Control	17.40e	0.825a	21.09e	2.375e	17.80de	37.25a	46.40a
Salicylic acid (SA) at 1 mM	17.75de	0.826a	21.53e	2.68de	17.58de	33.85b	44.75b
Salicylic acid (SA) at 2 mM	18.73cd	0.805ab	23.37de	2.63de	17.45e	30.90d	43.68c
Lisophos (LPE) at 200 ppm	19.73bc	0.751b	26.29cd	3.30ab	18.98bc	27.2e	40.73d
Potassium Sulphate (PS) at 0.5%	18.35de	0.793ab	23.19e	3.23ab	19.11b	35.25b	43.68c
SA at 1 mM + LPE at 200 ppm	19.55bc	0.679c	29.04bc	3.28ab	18.83bc	27.10e	39.03ef
SA at 2 mM + LPE at 200 ppm	19.68bc	0.682c	28.94bc	3.33ab	19.00bc	26.75e	39.13ef
SA at 1 mM + PS at 0.5%	17.70de	0.755b	23.62de	2.88cd	18.13b-e	32.15cd	44.88b
SA at 2 mM + PS at 0.5%	18.08de	0.771ab	23.51de	3.10bc	18.08cde	32.80cd	44.63b
SA at 1 mM + LPE at 200 ppm + PS at 0.5%	20.65ab	0.680c	30.39ab	3.15abc	18.56bcd	25.98e	39.63e
SA at 2 mM + LPE at 200 ppm + PS at 0.5%	21.20a	0.639c	33.23a	3.45a	20.85a	25.80e	38.70f

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

Table 4. Qualitative analysis of berry pigments (Chl. a, Chl. b and Carotene) of Thompson Seedless grapes at harvest as affected with preharvest sprayed treatments during of 2016 and 2017 seasons

Treatments	Chlorophyll a (mg/l)		Chlorophyll b (mg/l)		Carotene (mg/l)	
	2016	2017	2016	2017	2016	2017
Control	2.14* ab	1.73 cde	0.720 a	0.770 a	0.933 abc	0.958 a
Salicylic acid (SA) at 1 mM	1.82 b	1.89 abcd	0.695 a	0.788 a	0.828 cd	0.786 a
Salicylic acid (SA) at 2 mM	1.79 b	1.87 cde	0.720 a	0.820 a	0.718 d	0.823 a
Lisophos (LPE) at 200 ppm	1.78 b	1.59 e	0.659 a	0.768 a	0.938 abc	1.013 a
Potassium Sulphate (PS) at 0.5%	1.83 b	1.99 abc	0.72 a	0.695 a	0.871 c	0.888 a
SA at 1 mM + LPE at 200 ppm	1.77 b	2.16 a	0.634 a	0.805 a	0.891 bc	0.983 a
SA at 2 mM + LPE at 200 ppm	3.22 a	2.15 ab	0.617 a	0.755 a	0.965 abc	0.963 a
SA at 1 mM + PS at 0.5%	1.81 b	1.73 cde	0.639 a	0.688 a	0.889 c	0.895 a
SA at 2 mM + PS at 0.5%	1.76 b	1.77 cde	0.654 a	0.713 a	0.935 abc	0.933 a
SA at 1 mM + LPE at 200 ppm + PS at 0.5%	1.72 b	1.88 bcd	0.617 a	0.743 a	1.04 ab	1.005 a
SA at 2 mM + LPE at 200 ppm + PS at 0.5%	1.72 b	1.64 de	0.587 a	0.713 a	1.045 a	1.075 a

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

DISCUSSION

This investigation provided evidences about the possibility of enhancing the quality on Thompson Seedless grapes at harvest by salicylic acid (SA), Lisophos (Lisophosphatidylethanolamine, LPE) and potassium sulphate sprayed at the veraison stage, the influence of the natural compound LPE on fruit quality characteristics of grape berries and clusters were supported by the findings of **Farag and Palta (1993a,b)** by inhibiting the enzyme phospholipase D **(Ryu *et al.*, 1997)**. Moreover, LPE was able to inhibit cell wall hydrolyzing enzymes in fruits such as β-galactosidase and polygalactourenase, which reflected on maintaining the structure of the cell wall, retarding the loss of firmness and increasing marketable yield **(Hong *et al.*, 2006)**. Furthermore, **Hong (2006)** reported that the influence of LPE on fruit tissue was dependent on the stage of ripening. Thus, in a mature fruit (ready to ripen), LPE stimulated ripening, while in a ripened fruit; it inhibited ethylene production and maintained fruit firmness and prolonged the shelf life.

In general, the results of the present study on grapes were also supported by the findings of **Farag and Palta (1992a,b, 1993a)**. The positive effect of Lisophos on physical and chemical characteristics might be due to their effects on maintaining membrane integrity and retarding leaves senescence, which reflects on photosynthesis and partitions carbohydrates to the plant parts, especially fruit such as cluster weight.

Salicylic acid is well known to regulate several biological processes during plant and fruit development. Thus, SA spray is being used to increase berry weight and size of seedless grape cultivars **(Srivastava and Dwivedi, 2000)**. Similar results for the positive effects of SA on cluster and berry characteristics have been reported on Thompson Seedless **(Marzouk and Kassem, 2011)** and on Flame Seedless grapes **(Champa *et al.*, 2015)**, where SA decreased pectinmethylesterase of Flame Seedless grapes at harvest. In other fruit, SA has been reported to inhibit ethylene biosynthesis and hydrolytic enzymes (cellulase, polygalactourenase and xylanase) and delay fruit softening **(Srivastava and Dwivedi, 2000; Zhang *et al.*, 2003)**.

In addition, SA treatment increased photosynthetic pigments and total carbohydrates **(Mady, 2009)** and promotes translocation of sugars from leaves to fruit **(Elwan and El-Hamahmy 2009)**, which can be postulated that it hastens maturity. Early yields when treated with SA have been reported that significant increase in cluster weight, length, breadth and yield were observed in both seasons, when vines were sprayed with SA as compared to control**.** Berry weight, length and breadth were prominently higher in clusters treated with the higher concentration of SA on the contrary to control and the lowest dose. Evidently, grapes treated with either 1 or 2 mM SA produced less compact bunches (as indicated by higher cluster length and breadth) alongside larger berries in contrast to control. SA enhances bioproductivity of crops by increasing leaf area, photosynthetic pigments and subsequently rate of photosynthesis **(Hayat *et al.*, 2010)**.

Potassium plays an important role in plant physiological activities including the activation of enzymes and plant protein synthesis, photosynthesis and osmotic adjustment. In plants with potassium deficiency, soluble nitrogen compounds and sugars will be accumulated and also starch will be reduced **(Marschner, 1995)**. Potassium is necessary for basic physiological functions, such as the formation of sugars and starch, the synthesis of proteins, cell division and growth, fruit formation and could improve fruit size, flavour, and colour **(Abbas and Fares, 2008)**. Potassium recorded highest fruit length, in this study. The significant increase in fruit length has also been reported by **Jazduk *et al.*, (1998); Robinson and Stiles (2000); Fallahi *et al.*, (2010)**. This increase in fruit length may be due to the role of potassium in protein and carbohydrate synthesis and their translocation, water relations in the plant and transpiration **(Parr and Laughman, 1983)**.

The combinations treatment of SA plus LPE and potassium sulphate resulted in maximum fruit length, which can be attributed to the roles played by SA and potassium in increasing cell and cell elongation thus, increasing the fruit length. Potassium registered maximum fruit size, weight and length is probably due to increase in translocation of sugars to sink tissues, promoting their growth. These are in agreement with the findings of **Jadczuk *et al.*, (1998); Anjum *et al.*, (2008); David and Cahoon (1987)**.

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