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# Effect of foliar spraying of salicylic acid on growth, yield and quality of cold stored strawberry plants

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## ABSTRACT

The study was conducted to investigate the effect of foliar SA applications (1.0 or 2.0 mM) with different number of applications (once, twice or three times) as well as control on growth, chlorophyll and mineral content of leaves, some fruit-quality parameters and yield of strawberry during the two successive seasons of 2009/2010 and 2010/2011.

Results indicated that salicylic acid increased vegetative growth characteristics, i.e. plant length, number of leaves/plant, leaf area and root and vegetative growth fresh weights. Also, salicylic acid treatments increased crown carbohydrate, leaf phosphorus, soluble solid content of fruits and early and total yields/plant, while leaf chlorophyll content was decreased. There was no significant effect for the tested treatments on nitrogen and potassium contents of leaves and fruit quality characters, i.e. fruit firmness, titratable acidity, SSC/ titratable acidity and ascorbic acid. The most effective treatment in enhancing growth, fruit quality and yield of cold stored strawberry cv. Sweet Charlie was found to be salicylic acid at 2.0 mM three times.

**Key words: Strawberry, Salicylic acid, Growth, Yield, Quality.**

## INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch.) is a small fruit crop of great nutritional and medicinal value **(Maas *et al.*, 1991)** and is one of the most popular fruits worldwide. In the last two decades, strawberry has become one of the very important horticultural vegetable crops for local fresh consumption, food processing and export in Egypt. Total annual production amounted to 96,640 tons in 2010/2011 season from frigo plantations (Central Administration of Horticulture, Ministry of Agriculture and Land Reclamation, Egypt). Strawberries are unique with highly desirable taste, flavor, and excellent dietary sources of ascorbic acid, potassium, fiber and simple sugar sources of energy **(Perez *et al.*, 1997)**. Crop yield and early harvests are of primary importance to the growers, while fruit quality is the most important to the consumers.

Salicylic acid (SA; 2-hydroxybenzoic acid) is an endogenous growth regulator of phenolic nature, which is normally produced in plants in very small quantities **(Raskin, 1992)** and participates in the regulation of physiological processes in plants **(Shakirova *et al.*, 2003)**. For example, SA is postulated to play a role as a natural inductor of thermogenesis, to induce flowering in a range of plants, to control ion uptake by roots and stomatal conductivity **(Raskin, 1992)**. Exogenous application of SA may influence a range of diverse processes in plants, including stomatal closure, ion uptake and transport **(Gunes *et al.*, 2005)**, membrane permeability **(Barkosky and Einhellig, 1993)**, as well as photosynthetic and growth rates **(Khan *et al.*, 2003)**. In addition to facilitating plant growth, SA has been shown as an important signal molecule which can induce particular enzyme catalyzing biosynthetic reactions.

In recent years, application of exogenous SA at non-toxic concentrations to plants has been shown to be effective in the regulation number of processes, such as biotic and abiotic stresses **(Ananieva *et al.*, 2004; Eraslan *et al.*, 2007; Janda *et al.*, 2007; Xu and Tian, 2008)**. **Fariduddin *et al.* (2003) and Hayat *et al.* (2005)** found that SA at $10^{-5}$ M was an effective concentration to produce higher yield than higher concentrations ($10^{-4}$ and $10^{-3}$ M) and $10^{-3}$ proved to be optimal in mustard and wheat grown under non-saline conditions. While, in plants exposed to salinity stress, the favorable concentrations of SA ranged from 0.05 mM as reported by **Shakirova *et al.* (2003)** on wheat to 0.5 mM as reported by **Ananieva *et al.* (2004)** on barley and **Eraslan *et al.* (2007)** on carrot.

It also shows beneficial effects on human health and has a high oral $LD_{50(rat)}$ of 891 mg/ kg. Thus, SA use is safe with respect to human health and is likely to improve the quality and stress resistance of crops **(Peng and Jiang, 2006)**. However, the effect of the foliar applications of salicylic acid on growth and yield of strawberry has not been well studied yet. Therefore, this experiment was conducted to investigate the effect of foliar SA applications (1.0 or 2.0 mM) with different number of applications (once, twice or three times) on growth, chlorophyll and mineral content of leaves, some fruit-quality parameters and yield of strawberry.

## MATERIALS AND METHODS

### Experimental site, cultivar and cultivation

The study was conducted in a Private Farm in Mit Kenana village, Shebin el Qanater Center, Qalubia, Egypt, during the two successive seasons of 2009/2010 and 2010/2011. Cold-stored bare rooted strawberry transplants (*Fragaria x ananassa* Duch. cv. Sweet Charlie) with one well-developed crown of diameter 8-10 mm were planted. Sweet Charlie is an important strawberry cultivar which planted widely in Egypt. The transplants were obtained from the Strawberry and Non-Traditional Crops Improvement Center of the Faculty of Agriculture, Ain Shams University.

Strawberry plants were planted on October 10$^{th}$ and 4$^{th}$ in the first and second growing seasons, respectively. The frigo transplants were cultivated in raised beds 15-20 cm height and 120 cm wide. The plants were planted 30 cm apart in a four-row system under drip irrigation system. The soil type was a loam soil with pH of 7.44 and EC of 0.41 mmhos/cm.

In both seasons, all cultural practices of cultivation (irrigation, fertilization, weeding, and pest control) were performed according to the recommendations of the Egyptian Ministry of Agriculture.

**Experimental design.**

The experiment was conducted to investigate the effect of the foliar applications of salicylic acid (1.0 and 2.0 mM) with different number of applications (once, twice or three times) on growth, chlorophyll and mineral content of leaves, some fruit-quality parameters and yield of frigo strawberry plants. Spraying of each salicylic acid concentration was done: once at 30 days, twice at 30 and 60 days, and thrice at 30, 60 and 90 days after planting.

Salicylic acid was dissolved in distilled water to make the tested concentrations and was applied during early morning using a hand-held sprayer. In order to avoid interferences with different moisture levels, the same amount of distilled water was sprayed to the control plants at a given time. The lower leaf surface was sprayed until wetted as well as upper surface since it was reported that absorption by the lower leaf surface was rapid and effective **(Hull *et al.*, 1975)**.

The experimental design was completely randomized with 7 treatments [(2 SA concentrations x 3 number of SA applications) + Control] with 3 replicates and the plot area was 3 $m^2$ included 40 plants.

**Data recorded**

**Vegetative growth**

A random sample of ten plants from the two inner rows of each experimental plot was taken at 120 days after planting for vegetative growth data. Plant length and number of leaves/plant were recorded. Leaf area was estimated using the disk method according to **Moursi *et al.* (1968)**. The plants were removed with a shovel, to prevent damage to the root system. The excess soil attached to the roots was carefully removed. In the laboratory, the plants were washed and root and vegetative growth fresh weights were recorded. They were dried in an oven at 70°C until constant weight to record the root and vegetative growth dry weights.

**Chlorophyll measurements**

A portable chlorophyll meter (SPAD–502, Konica Minolta Sensing, Inc., Japan) was used to measure leaf greenness of the plants. SPAD-502 chlorophyll meter can estimate total chlorophyll amounts in leaves of a variety of species with a high degree of accuracy, which is a non-destructive method **(Neufeld *et al.*, 2006)**. At 120 days after planting, measurements were taken at four locations on each leaf; two on each side of the midrib on the youngest fully expanded leaves of randomly selected five plants per plot and then averaged **(Khan *et al.*, 2003)**.

**Crown carbohydrate determination**

Total carbohydrate of crowns was determined at 120 days after planting using phenol sulphuric acid method **(Dubois *et al.*, 1956)**.

**Mineral analysis of leaves**

Leaf samples were taken at 120 days from planting and oven-dried at 70 C˚ until constant weight and ground to pass a 1 mm sieve then 0.1 g of the dry samples was taken and digested using a mixture of sulphuric acid ($H_2SO_4$ 98 %) and hydrogen peroxide ($H_2O_2$ 30 %) as described by **Thomas *et al.* (1967)**. All the studied elements were assayed in the digest of the concerned plant samples. Total nitrogen was determined using Kjeldahl method as described by **Piper (1950)**. Phosphorus content was measured spectrophotometrically using the ascorbic acid method **(AOAC, 2005)**. Potassium was measured by flame photometer as described by **Page *et al.* (1982)**.

**Yield components**

Marketable fruits were harvested at 2–3 day intervals during the growing season, counted, and weighed to record average fruit weight. The early yield/plant was determined as weights of all harvested fruit during the first four harvests. Total yield/plant was calculated.

**Fruit quality**

Thirty full mature fruits were collected randomly from each treatment in the middle of the growing season (April in both seasons) as subsamples for fruit quality. Fruit firmness was measured using Shatillon penetrometer. Soluble solid content (SSC) was determined using a hand refractomer. Titratable acidity and ascorbic acid content were determined according to **A.O.A.C. (2005)**. The SSC/titratable acidity ratio was calculated.

**Statistical analysis**

The statistical analysis was conducted using the COSTAT package program. Data were subjected to analysis of variance (ANOVA). The differences among means of data were compared by Duncan's Multiple Range Test **(Waller and Duncan, 1969)**. All statistical determinations were made at P = 0.05.

## RESULTS AND DISCUSSION

**Vegetative growth**

Data in Table 1 clearly show that all tested treatments of salicylic acid significantly increased plant length and number of leaves/ plant compared with the control treatment in both seasons. However, these increments were not significant at1.0 mM salicylic acid one time for plant length in the first season, and at 1.0 mM one or two times for number of leaves/plant in the second season. Foliar spraying of salicylic acid at 2.0 mM two or three times gave the tallest plants, and the maximum number of leaves/plant in both seasons. These results agree with those of **Mady (2009)**.

Concerning the leaf area, spraying of salicylic acid at 2.0 mM three times significantly increased leaf area compared with all other tested treatments in the first season while no significant effect was detected in the second one (Table 1). Foliar applications of salicylic acid have a pronounced enhancement of leaf area of many plant species as mentioned by **Zhou *et al.* (1999)** on sugarcane, **Mady (2009)** on tomato, **Khan *et al.* (2003)** on corn and soybean, **Stevens *et al.* (2006)** on tomato, **Amin *et al.* (2007)** on onion and **Jamali *et al.* (2011)** on strawberry. This increment in leaf area may be attributed to the promotion of cell division and cell enlargement **(Hayat *et al.*, 2005)**.

**Table 1: Effect of foliar application of salicylic acid concentrations with different number of sprays on some vegetative growth characters of cold-stored strawberry during 2009/2010 and 2010/2011 seasons.**

| Treatments | Plant length (cm) | | Number of leaves/plant | | Leaf area ($cm^2$) | |
|---|---|---|---|---|---|---|
| | 1st season | 2nd season | 1st season | 2nd season | 1st season | 2nd season |
| **0.0 mM (Control)** | 19.13 c | 17.66 b | 13.00 d | 15.60 c | 56.47 b | 57.40 a |
| **1.0 mM (once)** | 20.26 bc | 20.26 a | 16.13 c | 16.33 bc | 57.07 ab | 57.65 a |
| **1.0 mM (twice)** | 21.33 ab | 21.06 a | 15.93 c | 16.53 bc | 60.57 ab | 56.81 a |
| **1.0 mM (thrice)** | 21.66 a | 20.93 a | 16.00 c | 17.00 b | 58.33 ab | 57.49 a |
| **2.0 mM (once)** | 21.60 ab | 20.13 a | 16.26 c | 16.86 b | 60.01 ab | 57.19 a |
| **2.0 mM (twice)** | 22.20 a | 20.80 a | 17.33 b | 18.13 a | 61.28 ab | 58.25 a |
| **2.0 mM (thrice)** | 22.46 a | 21.40 a | 18.60 a | 18.53 a | 62.79 a | 60.57 a |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range test.

Data in Table 2 show that exogenous SA applications increased fresh and dry weights of roots and vegetative growth of strawberry plants as compared to the control. The application of 2.0 mM SA three times gave the highest values for these parameters than the other treatments. The obtained results are in agreement with those reported by **Gutierrez-Coronado *et al.* (1998)** on soybean, **Hassan *et al.* (2006)** on faba bean, **Elwan and El-Hamahmy (2009)** on pepper, and **Karlidag *et al.* (2009)** and **Jamali *et al.* (2011)** on strawberry who reported increases in the growth of shoots and roots of those plants in response to salicylic acid treatment. Also, earlier studies indicated that exogenous SA treatments stimulated root formation in plants **(Khan *et al.*, 2003; Yildirim *et al.*, 2008)**. **De Klark *et al.* (1996)** reported that SA improved rooting of apple by enhancing auxin oxidation.

The stimulatory effect of salicylic acid on different estimated characteristics of strawberry growth may be attributed to the positive effect of salicylic acid upon the endogenous phytohormones specially the growth promoters i.e. auxins, gibberellins and cytokinins **(Abdel-Said *et al.*, 1996; Shehata *et al.*, 2000; Shakirova, 2007; Mady, 2009)**.

**Table 2: Effect of foliar application of salicylic acid concentrations with different number of sprays on root and vegetative growth weights of cold-stored strawberry during 2009/2010 and 2010/2011 seasons.**

| Treatments | Root fresh weight (g) | | Root dry weight (g) | | Vegetative growth fresh weight (g) | | Vegetative growth dry weight (g) | |
|---|---|---|---|---|---|---|---|---|
| | 1st season | 2nd season | 1st season | 2nd season | 1st Season | 2nd season | 1st season | 2nd season |
| **0.0 mM (Control)** | 8.30 d | 8.16 c | 1.28 d | 2.36 d | 37.79 d | 48.60 c | 9.76 d | 11.04 b |
| **1.0 mM (once)** | 10.28 bc | 8.26 c | 3.84 bc | 2.35 d | 45.75 c | 52.10 bc | 11.80 c | 11.49 ab |
| **1.0 mM (twice)** | 10.13 c | 9.00 b | 3.75 c | 2.62 c | 49.24 bc | 53.68 abc | 12.36 bc | 11.72 ab |
| **1.0 mM (thrice)** | 10.28 bc | 9.12 b | 3.80 c | 2.64 bc | 46.04 c | 55.06 ab | 11.69 c | 12.45 a |
| **2.0 mM (once)** | 10.43 bc | 9.00 b | 4.01 bc | 2.62 c | 48.94 bc | 53.31 abc | 12.54 bc | 11.96 ab |
| **2.0 mM (twice)** | 10.82 b | 9.38 b | 4.20 b | 2.75 b | 52.29 ab | 57.32 ab | 13.24 b | 12.70 a |
| **2.0 mM (thrice)** | 11.74 a | 10.24 a | 4.64 a | 2.94 a | 55.62 a | 58.51 a | 14.36 a | 12.73 a |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range test.

## Chlorophyll content

Data in Table 3 show that treatments of strawberry plants with different salicylic acid diminished the SPAD readings compared with control treatment without significant differences except for 1.0 mM twice or thrice in the first season and 1.0 mM once in the second season.

**Table 3: Effect of foliar application of salicylic acid concentrations with different number of sprays on leaf chlorophyll content and crown carbohydrates of cold-stored strawberry during 2009/2010 and 2010/2011 seasons.**

| Treatments | Chlorophyll content (SPAD Reading) | | Crown carbohydrates (mg/ g dry weight) | |
|---|---|---|---|---|
| | 1st season | 2nd season | 1st season | 2nd season |
| **0.0 mM (Control)** | 50.47 a | 48.85 a | 187.66 d | 195.66 c |
| **1.0 mM (once)** | 47.76 ab | 42.75 b | 197.00 cd | 201.33 c |
| **1.0 mM (twice)** | 44.78 b | 48.11 a | 205.33 c | 192.66 c |
| **1.0 mM (thrice)** | 42.86 b | 44.61 ab | 210.66 bc | 215.33 b |
| **2.0 mM (once)** | 45.32 ab | 46.97 ab | 225.66 ab | 238.33 a |
| **2.0 mM (twice)** | 46.06 ab | 46.03 ab | 235.66 a | 244.66 a |
| **2.0 mM (thrice)** | 45.48 ab | 46.76 ab | 237.33 a | 240.00 a |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range test.

**Crown carbohydrate content**

It is obvious from Table 3 that all tested salicylic acid treatments increased total crown carbohydrates in both tested seasons as compared to the control treatment, although there were no significant differences between spraying of salicylic acid at 1.0 mM once and the control treatment in the first season as well as between spraying of salicylic acid at 1.0 nm (once or two times) and the control treatment in the second season. Foliar application of salicylic acid at 2.0 mM twice or three times exhibited the highest significant values in the two tested seasons. Our results are similar to those obtained by **Mady (2009)**. This increment in total carbohydrates in crowns may be attributed to the increment of vegetative growth characteristics, i.e. plant length, number of leaves/plant, leaf area and root and vegetative growth fresh and dry weights as found in Tables 1 and 2.

**Mineral analysis of leaves**

That there was no significant effect for the tested treatments on nitrogen and potassium contents of leaf tissues in both seasons (Table 4). On the other hand, all tested salicylic acid treatments increased phosphorus content of leaf tissues than control treatment in both seasons. However, this increment was not significant among the foliar applications with 1mM salicylic acid once, twice or three times in both seasons. Foliar spraying of salicylic acid at 2.0 mM two times gave the highest values of phosphorus content in both seasons. Our results coincide with those reported by **Karlidag *et al.* (2009)** on strawberry and **Mady (2009)** on tomato who stated that foliar spraying of salicylic acid increased phosphorus leaf content.

**Table 4: Effect of foliar application of salicylic acid concentrations with different number of sprays on mineral analysis of cold-stored strawberry leaves during 2009/2010 and 2010/2011 seasons.**

| Treatments | Nitrogen (%) | | Phosphorus (%) | | Potassium (%) | |
|---|---|---|---|---|---|---|
| | 1st season | 2nd season | 1st season | 2nd season | 1st season | 2nd season |
| **0.0 mM (Control)** | 3.12 a | 3.64 a | 0.10 c | 0.12 d | 1.06 a | 1.00 a |
| **1.0 mM (once)** | 3.03 a | 3.02 a | 0.21 ab | 0.20 bc | 1.20 a | 1.03 a |
| **1.0 mM (twice)** | 3.45 a | 3.44 a | 0.18 b | 0.19 cd | 1.07 a | 0.96 a |
| **1.0 mM (thrice)** | 3.12 a | 3.30 a | 0.18 b | 0.18 cd | 1.06 a | 0.83 a |
| **2.0 mM (once)** | 3.12 a | 3.00 a | 0.22 ab | 0.26 ab | 1.12 a | 0.71 a |
| **2.0 mM (twice)** | 3.04 a | 3.00 a | 0.25 a | 0.31 a | 1.30 a | 0.69 a |
| **2.0 mM (thrice)** | 3.40 a | 3.40 a | 0.23 ab | 0.25 ab | 1.06 a | 0.67 a |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range test.

**Yield components**

Average fruit weight response to the tested salicylic acid treatments had an oscillating trend, as all tested treatments of salicylic acid significantly increased average fruit weight in comparison with control treatment in the first season and spraying of salicylic acid at 2.0 mM one time was the best treatment. While spraying of salicylic acid at 2.0 mM three times gave the highest average fruit weight in the second season (Table 5).

**Table 5: Effect of foliar application of salicylic acid concentrations with different number of sprays on average fruit weight and fruit yield of cold-stored strawberry during 2009/2010 and 2010/2011 seasons.**

| Treatments | Average fruit weight (g) | | Early yield / plant (g) | | Total yield / plant (g) | |
|---|---|---|---|---|---|---|
| | 1st season | 2nd season | 1st season | 2nd season | 1st season | 2nd season |
| **0.0 mM (Control)** | 10.37 c | 9.19 b | 174.72 b | 140.58 c | 349.38 c | 375.93 b |
| **1.0 mM (once)** | 13.12 b | 9.16 b | 180.72 b | 170.60 bc | 401.38 bc | 413.35 ab |
| **1.0 mM (twice)** | 12.84 b | 10.46 ab | 188.06 ab | 188.23 ab | 391.44 bc | 435.86 a |
| **1.0 mM (thrice)** | 12.52 b | 10.00 ab | 193.03 ab | 202.80 ab | 409.05 abc | 457.67 a |
| **2.0 mM (once)** | 15.09 a | 9.25 b | 195.21 ab | 211.09 a | 429.55 abc | 455.11 a |
| **2.0 mM (twice)** | 12.21 b | 10.08 ab | 200.42 ab | 218.31 a | 448.72 ab | 461.80 a |
| **2.0 mM (thrice)** | 12.51 b | 11.02 a | 218.00 a | 220.60 a | 485.94 a | 454.27 a |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range test.

Data in Table 5 clearly show that all tested treatments of salicylic acid increased early and total yields/plant compared with the control treatment in both seasons. However, these increments were not significant among salicylic acid at 1.0 mM with different number of applications, 2.0 mM one or two times and control in the first season, and between salicylic acid at 1.0 mM once and control in the second season. The most effective treatments were found to be salicylic acid at 2.0 mM three times for early yield and 2.0 mM two or three times for total yield in both tested seasons. Foliar application of salicylic acid have a pronounced enhancement of yields of many plant species as mentioned by **Yildirim *et al.* (2006)** on cucumber, **Elwan and El-Hamahmy (2009)** on pepper, **Karlidag *et al.* (2009)** on strawberry, and **Mady (2009)** and **Javaheri *et al.* (2012)** on tomato. These increases in yields may be closely linked to the increase in vegetative growth characteristics, i.e. plant length, number of leaves/plant, leaf area, and fresh and dry weights of root and vegetative growth (Tables 1and 2), and may be also linked to the increase in the crown carbohydrate content (Table 3). According to **Shakirova *et al.* (2003)**, the positive effect of salicylic acid on yield can be due to its influence on other plant hormones. Salicylic acid altered the auxin, cytokinin and ABA balances in wheat and increased the growth and yield under both normal and saline conditions. Increasing of yield under foliar application of salicylic acid could be ascribed to the well-known roles of salicylic acid on photosynthetic parameters and plant water relations. **Fariduddin *et al.* (2003)** reported that exogenous application of salicylic acid enhanced the net photosynthetic rate, internal $CO_2$ concentration and water use efficiency in *Brassica juncea*.

**Fruit quality**

There was no significant effect for the tested treatments on fruit firmness, titratable acidity, SSC/ titratable acidity and ascorbic acid of the fruits in both seasons (Table 6). This result is in agreement with that of **Shafiee *et al.* (2010)** who reported that strawberry fruit quality characteristics, i.e. fruit firmness, titratable acidity and vitamin C content, did not show changes in response to addition of SA to nutrient solution as preharvest treatment while these characteristics showed significant differences when the fruits were dipped in salicylic acid as postharvest treatment, since the single application strategy postharvest treatment of strawberry fruits was more effective than treatment at fruit development stage and it was more effective than treatment at vegetative stage **(Babalar *et al.*, 2007)**.

On the other hand, all tested treatments of salicylic acid increased soluble solids content than control in both seasons. However, this increment was not significant among the foliar application with 1.0 mM salicylic acid three times, 2.0 mM once and thrice and the control, in the first season.

**Table 6 Effect of foliar application of salicylic acid concentrations with different number of sprays on fruit quality of strawberry during 2009/2010 and 2010/2011 seasons.**

| Treatments | Fruit firmness ($g/cm^2$) | | SSC (°Brix) | | Titratable acidity (%) | | SSC/ Titratable acidity ratio | | Ascorbic acid content (mg /100 g fw) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st season | 2nd season | 1st season | 2nd season | 1st season | 2nd season | 1st season | 2nd season | 1st season | 2nd season |
| **0.0 mM (Control)** | 220.33 a | 229.25 b | 8.80 bc | 8.34 b | 0.27 a | 0.28 a | 32.21 a | 29.82 a | 62.91 a | 69.63 a |
| **1.0 mM (once)** | 249.66 a | 261.66 a | 9.28 a | 9.32 a | 0.29 a | 0.28 a | 32.06 a | 33.35 a | 77.76 a | 66.00 a |
| **1.0 mM (twice)** | 210.53 a | 240.50 ab | 9.28 a | 9.66 a | 0.28 a | 0.30 a | 33.60 a | 32.21 a | 64.15 a | 66.79 a |
| **1.0 mM (thrice)** | 232.13 a | 248.66 ab | 8.76 c | 9.59 a | 0.28 a | 0.28 a | 31.56 a | 34.36 a | 71.94 a | 65.09 a |
| **2.0 mM (once)** | 247.33 a | 251.16 ab | 8.98 abc | 9.44 a | 0.28 a | 0.29 a | 31.81 a | 32.40 a | 71.00 a | 67.96 a |
| **2.0 mM (twice)** | 225.33 a | 252.83 ab | 9.28 a | 9.54 a | 0.28 a | 0.27 a | 32.74 a | 34.55 a | 72.21 a | 71.13 a |
| **2.0 mM (thrice)** | 248.00 a | 237.00 ab | 9.24 ab | 9.44 a | 0.29 a | 0.28 a | 32.32 a | 33.35 a | 75.25 a | 77.43 a |

Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan᾽s multiple range test.

Data obtained from the present study agree with other studies which indicated that salicylic acid maintained higher concentrations of total soluble solids of cowpea **(Chandra *et al.*, 2007)**, tomato **(Mady, 2009; Javaheri *et al.*, 2012)**, pepper **(Elwan and El-Hamahmy, 2009)**, strawberry **(Karlidag *et al.*, 2009)** and kiwifruits **(Bal and Celik, 2010)** than the control. This enhancement of fruit soluble solids content can be attributed to the role of salicylic acid in improving membrane permeability, absorption and utilization of mineral nutrients. Some researches indicated that salicylic acid increased membrane permeability which would facilitate absorption and utilization of mineral nutrients and transport of assimilates **(Barkosky and Einhellig, 1993, Gunes *et al.*, 2005)**. This would also contribute towards enhancing the capacity of the treated plants for biomass production as is reflected in the observed increase in fresh and dry weights of plants (Table 2).

## CONCLUSION

In conclusion, this study demonstrated that foliar spraying of salicylic acid induced positive effects on the plant growth, fruit yield, and quality of cold-stored strawberry plants cv. Sweet Charlie. The most effective treatment was found to be salicylic acid at 2.0 mM three times. Further studies are required in order to determine the effect of salicylic acid on the net photosynthetic rate, water relations, antioxidant compounds, enzyme activity and endogenous phytohormones.

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## الملخص العربى

## تأثير الرش الورقي بحمض السالسيليك على نمو وجودة ومحصول نباتات الفراولة المبردة

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أجريت هذه الدراسة خلال موسمى 2010/2009 ، 2011/2010 بمزرعة خاصة بقرية ميت كنانة بمركز شبين القناطر بالقليوبية لبحث تأثير الرش بحمض السالسيليك (1، 2 ملليمولر) بعدد من الرشات (مرة، مرتان وثلاث مرات) بالإضافة للكنترول على النمو ومحتوى الأوراق من الكلوروفيل وبعض العناصر الكبرى وبعض مواصفات الجودة ومحصول الفراولة المبردة.

أوضحت النتائج أن رش حمض السالسيليك أدى إلى زيادة وتحسين صفات النمو الخضري كطول النبات وعدد الأوراق/نبات ومساحة سطح الورقة والوزن الطازج والجاف للنمو الخضري والجذور. كذلك فإن معاملات حمض السالسيليك أدت إلى زيادة محتوى التاج من الكربوهيدرات ومحتوى الأوراق من الفوسفور بينما قل محتوى كلوروفيل الأوراق. لم يوجد تأثير معنوي للمعاملات تحت الدراسة على محتوى الأوراق من النيتروجين والبوتاسيوم وصفات جودة الثمار كصلابة الثمار والحموضة المعايرة ونسبة المواد الصلبة الذائبة الكلية/الحموضة المعايرة وحمض الأسكوربيك. كانت المعاملة الأكثر تأثيراً لتحسين نمو وجودة ومحصول الفراولة صنف سويت شارلي هي رش النباتات بحمض السالسيليك 2 ملليمولر ثلاث مرات خلال موسم النمو.