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EFFECT OF FOLIAR SPRAY WITH AMINO ACIDS , CITRIC ACID, SOME CALCIUM COMPOUNDS AND MONO-POTASSIUM PHOSPHATE ON PRODUCTIVITY, STORABILITY AND CONTROLLING GRAY MOULD OF STRAWBERRY FRUITS UNDER SANDY SOIL CONDITIONS

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ABSTRACT: A filed experiment was carried out during the two successive seasons of 2016/2017 and 2017/2018 at the Experimental Farm of El-Kassasein, Hort. Res. Station, Ismailia Governorate, Egypt, to investigate the effect of foliar spray with amino acids, citric acid, some calcium compounds and mono-potassium phosphate (MKP) on vegetative growth, early and total yield, yield components, storability and gray mould disease reduction of strawberry Festival cultivar under sandy soil conditions. The obtained results showed that, spraying strawberry plants with $CaCl_2$ at 20 ml/l, amino acids at 10 ml/l, citric acid at 2 g/l, calcium amino acids chelate at 20 ml/l and calcium citric acid chelates at 20 ml/l and mono-potassium phosphate (MKP) at 20 ml/l increased yield, yield components and decreased incidence and severity of gray mould disease compared to control. Spraying with amino acids or calcium amino acids chelate increased plant height, number of leaves/ plant, shoot dry weight/ plant, average yield/plant, total yield/fad., and decreased weight loss (%) and decay (%) during cold storage periods. Spraying with MKP recorded minimum incidence (12.6 and 18.3 %) and severity (13.9 and 13.2%) of gray mould disease in fruits at the 1^{st} and 2^{nd} seasons, respectively, followed by spraying with calcium amino acids chelate. In addition, incidence and severity of gray mould disease decreased with increasing TSS and vitamin C in strawberry fruits.

Key words: Strawberry, calcium chloride, amino acids, citric acid, calcium amino acids chelate, calcium citric acid chelates, mono-potassium phosphate, gray mould, yield quality and storability.

INTRODUCTION

Strawberry (*Fragaria* x *ananassa* Duch) is considered as one of the most important vegetable crops grown in Egypt for fresh local consumption and export especially during the period from December to February. Strawberries are unique with highly desirable taste, flavor, and excellent dietary sources of ascorbic acid, potassium, fibers and simple sugar sources of energy **(Perez *et al*., 1997).** Strawberry also as highly perishable fruit was due to their soft texture, high softening rate and great sensitivity to fungal attack. The quality declines rapidly after harvest, which must be done at full maturity, and the storage life may be less than a week **(Wills 1998).**

Gray mould of strawberry or the botrytis fruit rot caused by *Botrytis cinerea* (Pers. ex Fr.) [teleomorph, *Botryotinia fuckeliana* de Bary Whetzel] is a problem wherever strawberry is grown and is probably the most serious fruit rot in strawberry worldwide **(Rosslen and Stuebler 2000).** The disease affects fruits in the field resulting in severe pre-harvest losses. It also affects fruits after harvest, since infections that begin in the field continue to develop during handling, storage and transportation even during low temperatures **(Terry *et al*., 2007).**

Mineral nutrients are generally applied to plants to ensure adequate growth and yield. Its effects are explained in terms of the function of these elements in plant metabolism. However,

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mineral nutrients may also exert secondary influences on the growth and yield of plants by causing changes in chemical composition, plant morphology and anatomy which may affect their resistance to pests and diseases. Research has been indicating that, application of certain calcium salts to fruit crops can affect disease incidence and, in particular, reduce rotting. **Saber *et al.* (2003)** reported that, proprietary nutrient sprays containing calcium increased firmness and reduced fungal decay caused by gray mould *Botrytis cinerea*.

Pre-harvest application of $CaCl_2$ reduced rooting, but was not effective as monobasic potassium phosphate **(El-Shami *et al.*, 2004).** Calcium salts may influence rotting in several different ways by direct effects on the growth and development of the fungus and, secondly, by increasing the resistance of the host crop to rotting. In this respect, pre harvest calcium sprays at 400-2000 ppm to strawberry plants reduced fruit susceptibility to rooting **(Naradison *et al.*, 2006)**.

Amino acids are important antioxidants which considered as precursors and constituents of proteins and important for stimulation of cell growth. Amino acids are more recognizable and easier to absorb and improving reproduction **(Hildebrandt *et al.*, 2015).** Amino acids well-known as bio-stimulant which has positive effects on plant growth, yield and significantly mitigates the injuries caused by a biotic stress. In addition, amino acids play a key role in signaling stress response and secondary metabolism in strawberry **(Mohseni *et al*., 2017).**

Citric acid was having a central role in mitochondria that creates cellular energy by phosphorylated oxidation reactions. Antioxidants such as citric acid significantly increased early, late yield and total yield compared to the untreated control. Meantime, antioxidants improved yield components of the strawberry cvs. tested reflected in a higher average fruits weight, increased marketable yield and decreased non-marketable yield by 44.9-79.8% of the untreated control onto strawberry plants grown in a field naturally infested with the gray mould fungus *Botrytis cinerea*, which significantly suppressed (19.21% - 69.16%) of disease incidence on fruits of the treated plants. Antioxidants scavengers evolved to eliminate the deleterious effects of free radicals on plants during their metabolism or by pathogen after infection which definitely was reflected in a good health in strawberry plants, higher yield potentials and better yield components **(El-Korany and Mohamed, 2008).**

Chelates as amino acids with calcium into plant tissues and their slow degradation will prevent the binding of calcium with the anionic region of plant cell membranes **(Saftner *et al*., 2003).** Calcium chelated with carboxylic acids like citric acid increased quality of strawberries. The calcium combined with citric acid was the most effect treatment on growth parameters and controlling gray mould disease **(El-Korany and Mohamed, 2008).** Recently, Ca+ amino acids chelate have been synthesized and distributed to supply different metal nutrients such as zinc and iron **(Ghasemi *et al*., 2012 and 2013)**. Amino acids can form a relatively stable complex with calcium and thus enhance its availability. It has been shown metal-amino acids chelate can easily pass through cell wall pores **(Ghasemi *et al*., 2013). Mohseni *et al*. (2017)** demonstrated that, movement of calcium from one organ to another was greater in chelated calcium form than calcium chloride in an attached strawberry plant when fed through the stolen from the mother plant. Amino acids as chelating due to the numerous benefits they provide to plants. Foliar spray of strawberry Festival cv. with chelated calcium at 100 mg/l increased vegetative growth, average number of fruits/plant, fruit volume, average fruit weight, yield/plant and total yield/ha **(Azeez *et al*., 2017).**

Mono-potassium phosphate (MKP) contains no such hazardous elements such as chlorine, sodium or heavy metals; it can be applied safely to all kinds of products. It is demonstrated that MKP application *via* leaves prevents fungi growth. The foliar spray of 1% (*W/V*) solution of mono-potassium phosphate (MKP), applied at two weeks interval starting from flowering till the end of the fruiting stage, on strawberry grown in the open field, significantly reduced both of the disease incidence and disease severity of gray mould. This was expressed by a reduction in fruits area covered with sporulating colonies and in conidia production on fruit tissues. The efficacy of MKP was compared with calcium chloride to control the disease. All treatments significantly inhibited gray mould development as compared with the non-treated control. A remarkable control of strawberry fruit gray mould was obtained when strawberry fruits were sprayed with mono-potassium phosphate. Calcium chloride was the least effective treatments. Phosphate solutions were not phytotoxic to plant tissues, and had no residual effects in fruit yield. Lower yields were recorded in non-treated control plots due to fruit infection. It is suggested that MKP may be used as an alternative practice to control gray mould on strawberry fruits at a commercial scale **(El-Shamy and El-Desouky, 2003).**

The objective of the present study was to compare the effect of foliar pre-harvest application of calcium chloride, citric acid, amino acids and Ca+amino acids chelate, Ca+ citric acid chelates and mono-potassium phosphate (MKP) on yield, storability and gray mould control of strawberry grown under sandy soil conditions.

MATERIALS AND METHODS

A filed experiment was carried out during two successive seasons of 2016/2017 and 2017/ 2018 at the Experimental Farm of El-Kassasein, Hort. Res. Station, Ismailia Governorate, Egypt. The effect of foliar spray with calcium and calcium chelated with amino acids or citric acids as well as mono-potassium phosphate (MKP) were studied, on growth parameters, yield quality, storability and gray mould control of strawberry fruits under sandy soil conditions. The soil is sandy in texture with 0.08 and 0.09% organic matter, 7.92 pH, 1.04 mmhos/cm EC. Frigo transplants of strawberry (Festival cultivar) were transplanted on 28^{th} and 30^{th} September during the 1^{st} and 2^{nd} seasons, respectively. Drip irrigation system was used. The experimental unit area was 12.6 m^2. It contains 3 ridges in 6m long. The distance between strawberry transplants was 25 cm and between ridges was 70 cm.

All preparations were produced by Central Lab of Organic Agriculture. The experiment included seven treatments; *i.e.*1-Control (foliar spray with tap water), 2- Mono-potassium phosphate, MKP at 20 ml/l, 3- Calcium chloride ($CaCl_2$) at 20 ml/l, 4-Amino acids at 10 ml/l ,5- Citric acid at 2 mg/ l, 6-Ca+Amino acids chelate at 20 ml/l and 7-Ca+ citric acid chelates at 20 ml/l. These treatments were arranged in a complete randomized block design (RCBD) with three replicates. Foliar application treatments were sprayed four times at 75, 90, 105 and 120 days after transplanting. The agricultural practices concerning cultivation, irrigation, fertilization and insect control were conducted according to the recommendation of the Ministry of Agriculture.

Suppressive effects of selected calcium compound solutions on *Botrytis cinerea*:

Gray Mould Assessment

Gray mould was recorded 95 till 120 days after transplanting. Disease incidence was recorded as percentage of infected fruits. Disease severity was determined according to disease index (DI) designed by **Ali (2013).** A scale was performed with 10 classes (1= 1-10%, 2= <10-20%, 3= <20-30%, 4= <30-40%, 5= <40-50%, 6= <50- 60%, 7= <60-70%, 8= <70-80%, 9= <80-90%, 10= <90-100%).

Data Recorded on the Vegetative Growth

A random sample of five plants from each plot was taken after 120 days from transplanting in the two growing seasons for measuring the vegetative growth, *i.e.*, plant height(cm), number of leaves/ plant and shoot dry weight/plant (g) was measured using dried fresh shoot/plant at 70^oC till constant weight.

Yield and its Components

The early yield was determined as weights of all harvested fruits from each plot during February and March and then early yield per fad., was calculated. Total yield was recorded from each plot all over the harvested season up to the mid of May, then, total yield per plant (g) and per fad. (ton) was calculated, also average fruit weight was determined.

Fruit Quality

Fruit quality was measured six weeks after the first harvest as follows: Firmness was determined using a Chattilon Pressure Meter Equipped with a Plunger (N4, USA) a needle 3mm diameter. Total soluble solids contents (TSS) as $brix^o$. Samples of ten ripe fruits were chosen randomly from each experimental plot at full ripe stage to measure the percentage of total soluble solids content using the hand refractometer.

Titratable acidity (TA%), samples of 100g fruits from each experimental plot at full ripe stage were randomly chosen to determine titratable acidity of juice by titration with 0.1 NaOH solution, according to the method described in **AOAC (2005)**. Ascorbic acid content was determined in juice as the method mentioned in **AOAC (2005)**.

Storability

About 500g of strawberries fruits of each experimental plot of uniform size and color were freshly harvested, divided into three lots (different cold storage periods, 5, 10, and 15 days) were stored at zero $C^{\circ} \pm 1\ C^{\circ}$ and 90 -95% relative humidity, to determine the following data:

Weight loss (%)

Weight loss (%) was measured 5, 10 and 15 days after cold storage. Fruits of each treatment were weighted after 5 days intervals and then weight loss (%) was calculated. The weight measured (Digital Electrical Balance) at zero days was taken as reference weight and calculated using the following equation:

Weight loss (%) = Initial weight of fruits - Weight of fruits at different sampling dates ÷ Initial weight of fruits × 100

Fruit decay

Three phome plats from each experimental plot were used to determine the fruit decay. Fruit decay (%) was calculated.

Different quality parameters, *i.e.*, firmness, total soluble solids, acidity and vitamin C were determined following the same methods as previously mentioned 5, 10 and 15 days after storage.

Statistical Analysis

Recorded data were subjected to the statistical analysis of variance according to **Snedecor and Cochran (1980)** and means separation was done according to **Duncan (1958)** at 0.05 levels of probability.

RESULTS AND DISCUSSION

Plant Growth

spraying strawberry plants Festival cultivar grown in sandy soil with mono-potassium phosphate (MKP), $CaCl_2$, amino acids, citric acid, Ca+ amino acids chelate and Ca+ citric acid chelates increased plant height, number of leaves/plant and dry weight of shoots/plant compared to control in both tested seasons. Spraying with amino acids or with Ca+ amino acids chelate, Ca+ citric acid chelates recorded the highest plants and gave the greatest number of leaves/plant as well as shoot dry weight/plant in both seasons. The increases in shoot dry weight/plant were about 43.03 and 59.69%, for amino acids as well as 42.13 and 57.79% for Ca+ citric acid chelates over the control in the 1st and 2nd seasons, respectively. From the foregoing results, it could be concluded that, spraying strawberry plants with amino acids or with Ca+ citric acid chelates increased plant height, number of leaves/plant and shoot dry weight/ plant in both seasons (Table 1).

Foliar application of strawberry Festival cv. with chelated calcium at 100 mg/l led to increased vegetative parameters **(Azeez *et al*., 2017)**. The stimulating effect of amino acids on plant growth may be attributed to that amino acids are well known as bio-stimulants which have positive effects on plant growth of strawberry plant besides they play a key role in secondary metabolism in plants **(Shehata *et al*., 2011 and Hildebrandt *et al*., 2015)**.

Yield and its Components

Spraying strawberry plants with $CaCl_2$, Amino acids, Citric acid, Ca+ amino acids chelate, Ca+ citric acid chelates and mono-potassium phosphate (MPK) increased average fruits weight, average yield/plant, early and total yield compared to control in both seasons (Table 2).

Foliar spray with citric acid and mono-potassium phosphate (MKP) increased average fruits weight without significant differences with Ca+ citric acid chelates in the 2nd season. General MKP and citric acid increased average fruits weight. Foliar spray with Ca+ amino acids chelates increased average yield/plant, early and total yield/fad., with no significant differences with amino acids with respect to average yield/plant and total yield/fad., in the 2nd season. The increases in total yield/fad., were about 147.8 and 103.65% , for amino acids as well as 153.1 and 100.98 % for Ca+ amino acids chelate at both tested seasons.

Table 1. Effect of foliar spray application with amino acids, citric acid, some calcium compounds and mono-potassium phosphate on plant growth parameters of strawberry fruits during 2016/2017 and 2017/2018 seasons

Treatment	Plant height (cm)		Leaf number/ plant		Shoots dry weight (g)		Relative increases in shoot DW (%)	
	1st season	2nd season	1st Season	2nd season	1st season	2nd season	1st season	2nd season
Control	23.33 d	21.33 d	14.33 c	15.00 d	25.56 c	22.53 e	00.00	00.00
Mono-potassium phosphate	25.00 d	24.33 cd	19.00 b	18.66 c	26.80 c	26.43 de	04.85	17.31
$CaCl_2$	25.33 cd	26.66 bc	16.33bc	18.00cd	27.33 c	28.51 cd	06.92	26.54
Amino acids	31.00 a	30.33 a	26.66 a	26.33 a	36.56 a	35.98 a	43.03	59.69
Citric acid	28.00 bc	27.66 ab	24.00 a	22.66 b	26.93 c	27.43d	05.36	21.74
Ca+ amino acids chelate	25.00 d	24.00 cd	26.00 a	23.66 ab	33.10 b	31.71 bc	29.49	40.74
Ca + citric acid chelates	30.33 ab	29.66 ab	25.33 a	24.00 ab	36.56 a	35.55 ab	42.13	57.79
F test	*	*	*	*	*	*	-	-

Values followed by the same letter in the same column are not statistically different

Table 2. Effect of foliar spray application with amino acids, citric acid, some calcium compounds and mono-potassium phosphate on average fruit weight, early and total yield of strawberry fruits during 2016/2017 and 2017/2018 seasons

Treatment	Average fruit weight (g)		Yield (g/plant)		Early yield (ton/fad.)		Total yield (ton/fad.)		Relative increases in total yield (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	15.51 e	17.55 b	135.47 e	165.12 e	1.022 e	0.994 e	6.322 e	7.706 e	00.0	00.00
Mono-potassium phosphate	17.55cd	19.59 a	211.14 d	250.24 d	2.222 d	2.433 c	9.853 d	11.678 d	55.8	51.54
$CaCl_2$	18.79 b	13.96 d	279.28 c	255.60 d	2.233 d	2.161 d	13.033 c	11.928d	106.1	54.78
Amino acids	18.47 b	16.07 c	335.71 b	331.88 a	3.044 b	2.744 b	15.667 b	15.694a	147.8	103.65
Citric acid	20.37 a	17.44 b	330.71 b	312.02 b	2.733 c	2.761 b	15.433 b	14.561b	144.1	88.95
Ca+ amino acids chelate	17.06 d	15.85 c	343.33 a	336.31 a	3.759 a	3.372 a	16.022 a	15.488 a	153.4	100.98
Ca + citric acid chelates	17.82 c	19.16 a	282.86 c	289.14 c	2.611 c	2.716 b	13.200 c	13.494c	108.7	75.11
F test	*	*	*	*	*	*	*	*	-	-

Values followed by the same letter in the same column are not statistically different.

* LSD at 0.05, ** LSD at 0.01 and NS = Not significant.

The simulative effect of amino acids on total yield may be due to that amino acids increased plant height, number of leaves/plant and shoot dry weight/plant (Table 1). From the obtained results, it could be concluded that, spraying strawberry plants with Ca+ amino acids chelate, followed by amino acids increased average yield/plant, early and total yield, whereas MKP and citric acid increased average fruits weight. Foliar spray of strawberry Festival cv., with chelated calcium at 100 mg/l led to increased average number of fruits/plant, fruit volume, average fruit weight, yield/plant and total yield/ ha **(Azeez *et al*., 2017)**. The general positive effects of amino acids observed in this study on yield and fruit characteristics of strawberry may be the result of applying amino acids that contributed to synthesis of polyamines, which affected floral development and consequently fruit yield on strawberry **(Mohseni *et al*., 2017)**.

Incidence and Severity (%) of Gray Mould Disease

Spraying strawberry plants grown in sandy soil with $CaCl_2$, amino acids, citric acid, Ca+ amino acids chelate, Ca+ citric acid chelates and mono-potassium phosphate (MKP) significantly decreased incidence (DI%) and severity (DS%) of gray mould disease (*Botrytis cinerea*) compared to the control in both tested seasons (Table 3). Spraying with MKP gave the lowest DI (%) and DS (%) which valued 16.2 and 18.3% for DI which valued 13.9 and 13.2% for DS in the 1st and 2nd seasons, respectively followed by spraying with Ca+ amino acids chelate (21.6 and 23.8%) for DI and (13.4 and 12.8%) for DS in the 1st and 2nd seasons, respectively.

From the results, it could be concluded that, spraying plants with MKP decreased incidence and severity percentages of gray mould disease followed by spraying with Ca+ amino acids chelate. MKP used for controlling gray mould disease gives the highest control to *Botrytis cinerea*. **Deliopoulos *et al*. (2010)** described phosphates as ideal candidates for fungal disease management as they are fast absorbed by the plant, they have high mobility within tissues and have low cost nutrient source. Furthermore, phosphates exhibit antifungal activity through the induction of systemic acquired resistance.

This result can be explained in the light of fact that natural chelators as mid molecular weight compounds like amino acids that have long organic chains diffuse easily to cell cytoplasm according to their chemical structure. These chelators are not phytotoxic to plants and limited direct action on the pathogen. Its particular chelated chemical structure may have allowed accumulation on the strawberry surface sufficient to enhance its natural resistance against gray mould disease **(Machado *et al*., 2008).**

Firmness and Fruit Chemical Constituents at Harvest

Spraying strawberry plants with $CaCl_2$ amino acids, citric acid, Ca+ amino acids chelate, Ca+ citric acid chelates and mono-potassium phosphate (MKP) increased fruit firmness, TSS and vitamin C. compared to the control (Table 4). In general, MKP, Ca+ amino acids chelate and Ca+ citric acid chelates increased fruit firmness and TSS in fruits, whereas MKP and Ca+ citric acid chelates increased vitamin C in fruits. There was correlation between gray mould disease (Table 3) and chemical constituents of fruits (Tale 4). Incidence and severity of gray mould disease decreased with increasing TSS and vitamin C in fruits. Also, incidence and severity of gray mould disease decreased with increasing fruit firmness.

Storability

Weight loss and decay (%)

Spraying strawberry plants with $CaCl_2$, amino acids, citric acid, Ca+ amino acids chelate, Ca+ citric acid chelates and mono-potassium phosphate (MKP) gave the lowest values of weight loss and decay percentages compared to the control during cold storage periods (5, 10 and 15 days) in both seasons. Weight loss and decay (%) increased with prolonging cold storage periods. Spraying with Ca+ amino acids chelate, followed by spraying with amino acids decreased weight loss (%) and decay (%) during cold storage period compared with to other treatments (Tables 5 and 6). Moreover, spray with calcium preparations increase soluble solids concentration and decreased titratable acidity of improve quality and shelf life of strawberry fruits **(Wojcik and Lewandowski, 2003).**

Table 3. Effect of foliar spray application with amino acids, citric acid, some calcium compounds and mono-potassium phosphate on development of strawberry gray mould in 2016/2017 and 2017/2018 seasons

Treatment	Disease incidence (%)		Disease severity (%)	
	2016	2017	2016	2017
Control	60.0 a	65.0 a	31.0 a	28.6 a
Mono-potassium phosphate	16.2 f	18.3 f	13.9 e	13.2 e
$CaCl_2$	30.0 c	33.2 c	17.5 c	17.2 cd
Amino acids	28.8 c	30.3 d	18.6 c	16.7 d
Citric acid	35.2 b	38.2 b	23.7 b	18.5 bc
Ca+ amino acids chelate	21.6 e	23.8 e	13.4 e	12.8 ef
Ca + citric acid chelates	27 d	30.0 d	15.3 de	17.3 cd
F test	*	*	*	*

Values followed by the same letter in the same column are not statistically different.

* LSD at 0.05, ** LSD at 0.01 and NS = Not significant.

Table 4. Effect of foliar spray application with amino acids, citric acid, some calcium compounds and mono-potassium phosphate on firmness and some chemical constituents of strawberry fruits at harvest time during 2016/2017 and 2017/2018 seasons

Treatment	Firmness (g/cm^2)		TSS ($brix^o$)		Total acidity (mg/100 ml juice)		Vitamin C (mg/100 ml juice)	
	1st season	2nd season	1st season	2nd season	2nd season	2nd season	2nd season	1st season
Control	306.6 d	316.6 e	8.35 c	8.66 c	0.38a	0.40 a	30.38 c	28.40 d
Mono-potassium phosphate	460.0 a	533.3 b	11.20 a	12.00 a	0.37a	0.36 a	39.42 a	34.80 ab
$CaCl_2$	406.6 c	433.3 d	9.14 bc	9.00 c	0.36a	0.38 a	37.29 b	33.20 c
Amino acids	400.0 c	433.3d	9.83 b	10.33 b	0.34a	0.38 a	37.34 b	33.20 c
Citric acid	416.6 bc	516.6 bc	9.78 b	9.33 b	0.37a	0.38 a	38.76 ab	34.00 bc
Ca+ amino acids chelate	486.6 a	616.6 a	11.48 a	11.66 a	0.32a	0.35 ab	39.28 a	33.20 c
Ca + citric acid chelates	453.3 ab	500.0 bc	9.53 b	9.83 b	0.36a	0.30 b	40.22 a	35.73 a
F test	*	*	*	*	NS	*	*	*

Values followed by the same letter in the same column are not statistically different.

* LSD at 0.05, ** LSD at 0.01 and NS = Not significant.

Table 5. Effect of foliar spray application with amino acids, citric acid, some calcium compounds and mono-potassium phosphate on fruit of strawberry weight loss (%) during cold storage periods in 2016/2017 and 2017/2018 seasons

Treatment	Weight loss (%)					
	Storage time (day)					
	5		10		15	
	1st season	2nd season	1st season	2nd season	1st Season	2nd season
Control	5.08 a	4.37 a	7.64 a	7.03 a	9.87 a	9.02 a
Mono-potassium phosphate	3.56 b	3.08 b	5.05 b	4.55 b	7.62 b	7.01 b
$CaCl_2$	2.53 c	2.33 c	4.30 bc	3.93 bc	6.41c	5.90 c
Amino acids	1.58 e	1.45 d	2.69 de	2.47 de	4.38 e	4.03 e
Citric acid	1.79 de	1.65 d	3.04 d	2.80 d	4.83 d	4.44 d
Ca+ amino acids chelate	1.22 e	1.12 e	2.07 e	1.90 e	3.61 f	3.32 f
Ca + citric acid chelates	2.35 cd	2.16 c	4.00 c	3.48 c	5.03 d	4.63 d
F test	*	*	*	*	*	*

Values followed by the same letter in the same column are not statistically different.

* LSD at 0.05, ** LSD at 0.01 and NS = Not significant.

Table 6. Effect of foliar spray application with amino acids, citric acid, some calcium compounds and mono- potassium phosphate on fruit of strawberry decay (%) during cold storage periods in 2016/2017 and 2017/2018 seasons

Treatment	Decay (%)					
	Storage time (day)					
	5		10		15	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	8.72 a	7.42 a	15.25 a	16.25 a	22.28 a	24.07 a
Mono-potassium phosphate	0.00 c	0.00 d	6.33 e	4.22 f	11.05 e	12.05 cd
$CaCl_2$	7.09 b	4.09 c	8.96 d	9.72 c	11.56 d	11.79 cd
Amino acids	0.00 d	0.00 d	11.81 c	5.22 e	15.72 c	12.72 cd
Citric acid	7.69 ab	4.69 b	12.67 b	11.43 b	16.67 b	14.67 b
Ca+ amino acids chelate	0.00 c	0.00 d	6.70 e	5.18 ef	10.79 e	11.56 d
Ca + citric acid chelates	0.00 c	0.00 d	6.36 e	7.61 d	11.91 d	12.91 c
F test	*	*	*	*	*	*

Values followed by the same letter in the same column are not statistically different.

* LSD at 0.05, ** LSD at 0.01 and NS = Not significant.

Firmness and Fruit Chemical Constituents during Cold Storage Periods

Results in Tables 7, 8, 9 and 10 shows that fruit firmness, TSS and vitamin C. decreased with prolonging cold storage periods, whereas total acidity increased. There were significant differences among all tested treatments with respect to total acidity in fruits during cold storage periods. Spraying $CaCl_2$ increased fruit firmness during cold storage periods followed by spraying with amino acids. Calcium ions in fruit are associated with firmness and are attributed to increase cell wall strengthens and mainly the middle lamella by holding the cells altogether thus, reduced ripening. Calcium may enhance fruit firmness and, consequently, delay gray mould development if calcium penetrates the fruit **(Vicente *et al.*, 2007)**.

In general, spraying with Ca+ amino acids chelate increased TSS and vitamin C in fruits during cold storage periods without significant differences with spraying with citric acid chelate to vitamin C. Pre harvest foliar sprays of $CaCl_2$ at 0.4% appeared to only have a significant effect on TSS at harvest of strawberry **(Toivonen and Stan, 2001)**. Also, calcium pre-harvest treatment of strawberry fruits has higher TSS and ascorbic acid content with lower acidity than control **(Kazemi, 2014).** Higher concentrations of calcium delayed the rapid oxidation of ascorbic acid in the samples.

Table 7. Effect of foliar spray application with amino acids, citric acid, some calcium compounds and mono-potassium phosphate on fruit of strawberry firmness during cold storage periods in 2016/ 2017 and 2017/2018 seasons

Treatment	Fruit firmness (g/cm^2)					
	Storage time (day)					
	5		10		15	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	166.6 e	218.2 e	143.3 d	143.2 c	126.0 e	107.4 e
Mono-potassium phosphate	433.3 b	433.6 c	283.3 c	372.6 ab	233.3 d	279.4 b
$CaCl_2$	466.6 a	499.2 a	433.3 a	401.2 a	373.3 a	300.9 a
Amino acids	433.3 b	463.6 b	316.6 b	372.6 ab	273.3 b	279.4 b
Citric acid	316.6 d	338.7 d	316.6 b	272.2 ab	260.0 bc	204.2 d
Ca+ amino acids chelate	316.6 d	418.7 c	283.3 c	372.2 b	250.0 cd	264.2 c
Ca + citric acid chelates	403.3 c	431.5 c	266.6 c	346.8 b	246.6 cd	260.1 c
F test	*	*	*	*	*	*

Values followed by the same letter in the same column are not statistically different.

* LSD at 0.05, ** LSD at 0.01 and NS = Not significant.

Table 8. Effect of foliar spray application with amino acids, citric acid, some calcium compounds and mono-potassium phosphate on fruit of strawberry TSS during cold storage periods in 2016/2017 and 2017/2018 seasons

Treatment	TSS (brix^0)					
	Storage time (day)					
	5		10		15	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	8.16 ef	9.33 b	8.00 e	9.00 c	7.00 b	5.33 d
Mono-potassium phosphate	9.00 cd	8.66 bc	9.50 c	9.00 c	7.50 a	6.83 bc
$CaCl_2$	7.50 f	7.00 d	9.00 d	9.00 c	6.00 d	6.16 cd
Amino acids	9.50 c	9.33 b	10.50 b	10.33 b	6.50 c	5.66 d
Citric acid	8.50 de	8.00 c	9.50 c	9.33 c	6.00 d	6.00 cd
Ca+ amino acids chelate	12.00 a	12.66 a	11.42 a	11.66 a	7.51 a	8.16 a
Ca + citric acid chelates	11.00 b	12.66 a	10.50 b	10.33 b	7.50 a	6.33 cd
F test	*	*	*	*	*	*

Values followed by the same letter in the same column are not statistically different.

* LSD at 0.05, ** LSD at 0.01 and NS = Not significant.

Table 9. Effect of foliar spray application with amino acids, citric acid, some calcium compounds and mono-potassium phosphate on strawberry fruit total acidity during cold storage periods in 2016/ 2017 and 2017/2018 seasons

Treatment	Total acidity (mg/100ml)					
	Storage time (day)					
	5		10		15	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	0.39a	0.46 a	0.42a	0.53 a	0.58 a	0.54 a
Mono-potassium phosphate	0.38a	0.41 a	0.37a	0.44 a	0.49 a	0.51 a
$CaCl_2$	0.37a	0.40 a	0.42a	0.44 a	0.57 a	0.48 a
Amino acids	0.37a	0.40 a	0.39a	0.48 a	0.55 a	0.52 a
Citric acid	0.38a	0.43 a	0.38a	0.46 a	0.54 a	0.51 a
Ca+ amino acids chelate	0.35a	0.37 e	0.34a	0.39 a	0.46 a	0.48 a
Ca + citric acid chelates	0.36a	0.40 a	0.37a	0.45 a	0.47 a	0.52 a
	NS	NS	NS	NS	NS	NS

Values followed by the same letter in the same column are not statistically different.

* LSD at 0.05, ** LSD at 0.01 and NS = Not significant.

Table 10. Effect of foliar spray application with amino acids, citric acid, some calcium compounds and mono-potassium phosphate on strawberry fruit vitamin C during cold storage periods in 2016/ 2017 and 2017/2018 seasons

Treatment	Vitamin C (mg/100 ml)					
	Storage time (days)					
	5		10		15	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	21.52 d	24.40 e	16.44 e	16.80 f	16.00 e	13.80 f
Mono-potassium phosphate	35.60 a	32.00 c	27.81 a	32.26 b	22.80 c	21.22 bc
$CaCl_2$	29.84 bc	34.80 b	19.84 d	24.80 e	20.40 d	17.32 e
Amino acids	31.21 b	30.26 d	24.64 b	30.80 c	22.80 c	20.24 cd
Citric acid	29.49 c	31.86 c	22.40 c	28.00 d	24.40 b	19.52 d
Ca+ amino acids chelate	36.80 a	36.00 a	26.56 a	33.20 ab	27.20 a	22.76 ab
Ca + citric acid chelates	36.58 a	35.73 a	27.20 a	34.00 a	27.06 a	23.65 a
F test	*	*	*	*	*	*

Values followed by the same letter in the same column are not statistically different.

* LSD at 0.05, ** LSD at 0.01 and NS = Not significant.

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تأثير الرش الورقي بالأحماض الأمينية وحامض ألستريك وبعض مركبات الكالسيوم وأحادي فوسفات البوتاسيوم على الإنتاجية والقدرة التخزينية ومقاومة مرض العفن الرمادي لثمار الفراولة تحت ظروف التربة الرملية

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أجريت هذه التجربة خلال موسمي ٢٠١٧/٢٠١٦ ، ٢٠١٨/٢٠١٧ بمزرعة محطة بحوث البساتين بالقصاصين، محافظة الإسماعيلية – مصر، وذلك بهدف دراسة تأثير الرش الورقي بالأحماض الأمينية و حمض ألستريك وبعض مركبات الكالسيوم وأحادي فوسفات البوتاسيوم بجانب معاملة المقارنة على النمو و المحصول المبكر والكلى والقدرة التخزينية للفراولة ومقاومة مرض العفن الرمادي للصنف فيستيفال النامي تحت ظروف التربة الرملية، وقد أظهرت النتائج ان رش نباتات الفراولة ، بالأحماض الأمينية بمعدل ١٠ مل/لتر، حمض ألستريك بمعدل ٢ جرام/لتر، كالسيوم مخلبي مع أحماض أمينيه بمعدل ٢٠ مل/لتر ، وكالسيوم مخلبي مع حمض ألستريك بمعدل ٢٠ مل/لتر، كلوريد الكالسيوم بمعدل ٢٠ مل/لتر وأحادي فوسفات البوتاسيوم بمعدل ٢٠ مل/لترادي إلى زيادة المحصول ومكوناته ونقص معدل وشدة الإصابة بمرض عفن ثمار الفراولة بالمقارنة بالنباتات غير المعاملة، كما أدى الرش، بالأحماض ألأمينية وكالسيوم مخلبي مع أحماض أمينية إلى زيادة ارتفاع النبات، عدد الأوراق/ النبات، الوزن الجاف للمجموع الخضري، متوسط محصول النبات، المحصول المبكر، والمحصول الكلى للفدان ، وكذلك أدى ذلك إلى نقص في نسبه الفقد في الوزن والتلف في الثمار أثناء فترات التخزين المبرد.وقد سجل الرش بأحادي فوسفات البوتاسيوم أقل معدل لنسبة الإصابة (١٢.٦، ١٨%) وشدة الإصابة (١٣.٩، ١٣.٢%) في الموسم الأول والثاني على التوالي، يليه الرش بكالسيوم مخلبي مع أحماض أمينية. كما قل معدل وشده الإصابة بعفن الثمار الرمادي مع زيادة نسبة المواد الصلبة الذائبة الكلية وفيتامين ج في الثمار.

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