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Effect of calcium, potassium and some antioxidants on growth, yield and storability of sweet potato:
2- Chemical composition and storability of tuber roots during storage period.

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Abstract

Two field experiments were carried out at El-Bramoon Agricultural Research farm of Mansoura Horticultural Research station, during the two successive summer seasons of 2011 and 2012 on sweet potato (*Ipomoea batatas*, L.) plants cv. Beauregard. The aim of this study was to study the effect of foliar spray of calcium at (0, 1000 and 2000 ppm), potassium fertilization at (0, 48, 72 kg K_2O/fed.), and foliar spray of antioxidants (control, ascorbic acid at 200 ppm and salicylic acid at 200 ppm) on some chemical constituents of tuber roots and quality of tuber roots during storage period. The obtained results showed that foliar spray of only 2000 ppm of calcium or with the interaction among 1000 ppm of calcium, potassium fertilization at 72 kg K_2O/fed. and foliar spray of antioxidants as ascorbic acid at 200 ppm or salicylic acid at 200 ppm recorded the highest values of the above-cited indices compared with the control. Positive interaction between foliar spray of calcium and potassium fertilization and foliar spray of antioxidants were often observed.

The best results were obtained by foliar spray of only 2000 ppm of calcium or with the interaction among 1000 ppm of calcium, potassium fertilization at 72 kg K_2O/fed. and foliar spray of antioxidants as ascorbic acid at 200 ppm or salicylic acid at 200 ppm.

Key words: sweet potato (*Ipomoea batatas*, L.), foliar spray, antioxidants, ascorbic acid**,** salicylic acid.

Introduction

Sweet potato (*Ipomoea batatas* L.) is a dicotyledonous root crop and a member of the family Convulvulaceae. Moreover, sweet potato is the seventh most important food crop in the worldwide, after wheat, rice, maize, potato, barley and cassava. The primary importance of sweet potato is cultivated in poor regions of the world. It is the fourth most important food crop in developing tropical countries and is grown in most of the tropical and subtropical regions of the earth, where the vine, as well as the roots, is consumed by humans and livestock **(Woolfe, 1992)**.

In Egypt, it is considered a very important popular vegetable crop, it has been generally cultivated for both food and starch manufactures, while the foliage parts and other refuse are utilized in feeding. Great efforts have been directed to improve sweet potato production and quality for the purpose of increasing exported yield. The applied Ca, K and antioxidants are among the major factors affecting plant growth and tuber root yields of sweet potato **(El-Sayed 1991; Abd El-Baky *et al*., 2010., Njiti *et al*., 2013)**.

Calcium is an essential macronutrient required for plant growth and has been implicated as a factor influencing tuber quality **(Lang *et al*., 1999).** Moreover, calcium is component of the middle lamella and is essential for intracellular membrane transport. Also, calcium is known to act as a signaling molecule that can regulate metabolism, controlling respiration, reducing ethylene production and mitigate the effect of heat and cold stresses on plant **(Marschner, 2013)**. Moreover, calcium deficiency has been linked to many disorders especially in storage organs, sweet potato is underground storage organs with low rates of transpiration thus, low Ca concentration often occurs and may affect on their susceptibility to bacterial pathogen **(Kleinhenz and Palta, 2002)**.

Potassium is an essential plant nutrient that plays a very important role in plant growth and development. Its role is well documented in photosynthesis, increasing enzyme activity, improving synthesis of protein, carbohydrates and fats, translocation of sugars, enabling their ability to resist pests and diseases **(Dkhil *et al*., 2011)**. Also, potassium has an established reputation as a major controlling effect on tuber production in plant and it is the most important nutrient element needed by sweet potato in terms of nutrient uptake per unit area per unit tuber production. Since sweet potato is generally grown on highly weathered and leached soils where available K status is low, management of K assumes greatest significance **(Byju and George, 2005)**.

Ascorbic acid (Vit. C) has a wide range of important functions as antioxidant defense, photoprotection, regulation of photosynthesis, affects nutritional cycle's activity in higher plants, electron transport system, as a cofactor for a large number of key enzymes in plants, also developmental senescence, programmed cell death and responses to pathogens **(Blokhina *et al*., 2003)**.

Salicylic acid (SA) naturally occurs in plants in very low amounts and participates in the regulation of physiological processes in plant such as stomatal closure, photosynthesis, transpiration, nutrient uptake, chlorophyll and protein synthesis, inhibition of ethylene biosynthesis, resistance to pathogens plant disease and increased longevity of storage period **(Hayat and Ahmad, 2007)**. Moreover, **Senaratna *et al*., (2000)** reported that salicylic acid or acetyl salicylic acid (ASA) enhanced tolerance to heat, chilling and drought stresses.

From the foregoing, the present study is very important to evaluate the effects of different rates of calcium fertilizer as foliar spray with different rates of potassium fertilizer as soil application either alone or in combination with some antioxidants; i.e., salicylic acid and ascorbic acid as foliar spray on some chemical constituents in tuber roots and storage ability of sweet potato plants cv. Beauregard.

Materials and Methods

Two field experiments were carried out at El-Bramoon farm of Mansoura Horticultural Research station, during the two successive summer seasons of 2011 and 2012. The experiments were designed to investigate the effects of some nutrients treatments namely calcium and potassium besides two antioxidants; i.e., ascorbic and salicylic acid along with their interactions, on plant growth, yield and its components, as well as some chemical constituents and tuber roots storability of sweet potato (*Ipomoea batatas*, L.) cv. Beauregard.

Experimental Soil Analysis:

Randomized samples were collected from the experimental soil at 0.0 to 50.0 cm depth, before planting to determine its physical and chemical properties in accordance to the methods of **Black (1965) and Jakson (1967)**, respectively. Data of soil analysis is presented in Table (1):

Table 1. Some physical and chemical properties of experimental soil.

Soil properties	Value	Soil properties	Value
Physical		**Soluble anions (meq/l)**	
Coarse sand	7.71 %	CL^-	3.56
Fine sand	18.14 %	HCO_3	3.20
Silt	33.65 %	CO_3^{-2}	0.00
Clay	40.50 %	SO_4^{-2}	5.16
Texture	Clay-loam	**Soluble cations (meq/l)**	
Chemical		Ca^{+2}	4.03
Organic matter (%)	1.95	Mg^{+2}	1.35
$CaCO_3$	4.55	Na^+	1.21
E.C. (dsm^{-1} at 25°C)*	1.12	K^+	5.33
PH (1:2.5 w/v)**	7.91		
Total – N (%)	0.20		
Available – P (ppm)	11.72		

***E.C: Electrical conductivity (in 1:5 soil water extract).** ****In the 1:2.5 soil/water suspension.**
The values are the average of the two growing seasons.

Experimental design and tested treatments:

The experiments were designed as split-split-plot with 3 replicates. The different rates of calcium occupied the main plots, which subsequently subdivided into 3 sub-plots; each contained one of the potassium rates, while antioxidants treatments were assigned to the sub-sub-plots.

Each sub-sub-plot area 17.5 m^2 and contained 5 rows, with 5 m in length and 0.7 m in width for each row. The experiment included 27 treatments which were 3 calcium rates (tap water, 1000 and 2000 ppm), 3 potassium rates (0, 48 and 72 kg K_2O/fed.) and 3 rates of antioxidants (tap water, ascorbic acid at 200 ppm and salicylic acid at 200 ppm).

Time and method of treatments:

- Calcium: Calcium citrate (21 %) was used as source of calcium at the rates of 0, 4.76 and 9.52 g. calcium citrate were dissolved in litter distilled water to obtain calcium at the rates of 0, 1000 and 2000 ppm, respectively and applied to plants as foliar spray at 60 and 90 days after sowing.
- Potassium: Potassium sulphate (48 %) was used as source of potassium at the rates of 0, 48 and 72 kg K_2O/fed., were obtained from 0, 100 and 150 kg potassium sulphate, respectively were equally divided and applied at planting and 30 days later.
- Antioxidants: Antioxidants were obtained from El Nasr Pharmaceutical Chemicals Co. Egypt and used at the rates of 0.2 g. ascorbic was dissolved in litter distilled water and 0.2 g. salicylic acid was dissolved in alcohol and added to litter distilled water to obtain the rates of ascorbic acid at 200 ppm and salicylic acid at 200 ppm, applied to plants as foliar spray at 15, 45, 75 days after sowing.

Cultural practices:

Sweet potato stem cuttings, about 20 cm

length, were planted on the third top of slope ridges, at 25 cm apart, on the 20, 21 of April of both growing seasons of the study. Growing plants were fertilized with 300 kg/fed. Calcium super phosphate (15.5 % P_2O_5) and 200 kg/fed. ammonium sulphate (20.5 % N). Other inter-cultural practices including weed and pest control will be followed as instructed by the Ministry of Agriculture. Harvesting of tuber roots was done on the 23, 24 of August (125 days after planting) in both seasons.

Recorded data:

1- Chemical constituents:

a- Element concentrations:

Samples of cured sweet potato tuber roots were taken to determine total nitrogen (%), phosphorus (%), potassium (%) and calcium (%), following methods described by **A.O.A.C. (1990)**, **Jhon (1970)** and **Brown and Lilleland (1946)**, respectively.

b- Organic compositions:

Samples of cured sweet potato tuber roots were picked up at random to determine total carbohydrate contents according to the method of **Michel *et al*., (1956)**, reducing and non-reducing sugar (%) according to the method of **Dubois *et al*., (1956)**, total carotene content, following the method described by **Booth (1958)** and vitamin C was determined according to **Pearson (1970)**.

2- Quality of tuber roots during storage period:

Random samples of cured roots (each was 10 kg of marketable tuber roots), were collected from each sub-sub-plot, cleaned with dry clean towels, poked in plastic boxes and stored for 120 days, at normal room conditions. The average of normal room temperature and relative humidity during storage months are shown in Table (2).

Table 2. The average of normal room temperature and relative humidity during storage months.

Month	Temperature (ºC)		Relative humidity (%)	
	2011	2012	2011	2012
September	25.4	25.1	77.6	79.2
October	22.0	23.4	69.2	79.5
November	16.6	19.7	78.5	85.9
December	13.6	14.6	86.0	83.1

Samples were picked up after 30, 60, 90 and 120 days of storage to determine weight loss percentage according to the equation:

Weight loss (%) =

$$\frac{\text{Initial weight of tuber roots} - \text{Weight of tuber roots at sampling date}}{\text{Initial weight of tuber roots}} \times 100$$

- Decay percentage was calculated at the end of storage period in relation to the total initial weight of stored tubers.

Statistical analysis:

All recorded data were subjected to statistical Analysis of Variance and least significance differences (Duncan's) at 0.05 leve

Results and Discussion

1- Chemical constituents:

a- Element concentrations:

Data in Table (3) clearly illustrate that calcium significantly affects the concentration on N and P concentration in tuber roots of sweet potato, in both growing seasons, and there were no significant differences between foliar spray with calcium at 2000 ppm and 1000 ppm on P concentration in tuber roots, in both growing seasons. The concentration of K was significantly increased in tuber roots in the first growing season only, and there were no significant differences between foliar spray with calcium at 2000 ppm and 1000 ppm or between calcium at 1000 ppm and 0 ppm (control), in the first growing season while in the second growing season there were no significant differences between calcium rates on the concentration of K in tuber roots of sweet potato. The concentration of Ca was significantly increased in tuber roots in both growing seasons and the highest values of N, P, K and Ca contents in tuber roots of sweet potato obtained by foliar sprayed with calcium at 2000 ppm. These increases in elemental constituents of tuber roots of sweet potato may be due to the effect of calcium which has attracted much interest in plant physiology and molecular biology because of its function as a second messenger in the signal conduction between environmental factors and plant responses in terms of growth and development **(Reddy, 2001)**. The obtained results are in accordance with those of **Palta (1996)** who said that because potato tubers are deficient in Ca, improved tuber health by increased Ca level is expected, also **Ozgen *et al*., (1999)** reported that application of calcium dramatically improved calcium, N, P, K level of potatoes tuber, and **Karlsson *et al*., (2000)** demonstrated that by the application of calcium we can dramatically improve tuber calcium level in potatoes cv. Atlantic, also **Sulaiman *et al*., (2003)** they found that contents of calcium increased significantly in (*Ipomoea batatas* L.) with the increase Ca level of calcium application, **Karlsson and Palta (2006)** reported that potato responded to the supplemental calcium treatment with significant increases in tuber calcium, starch and nitrogen concentration.

Data presented in Table (3) clarified that tuber macro-nutrients; i.e., N, P, K and Ca were significantly increased as the applied potassium increased from 0 to 72 kg K_2O/fed., the highest values of macronutrients produced from the addition of 72 kg K_2O/fed., in both growing seasons of study. Several investigators reported that K is an essential plant nutrient that plays a very important role in plant growth and development. Its role is well documented in photosynthesis, increasing enzyme activity, improving synthesis of protein, carbohydrates and fats, translocation of sugars, enabling their ability to rest pests and diseases **(Dkhil *et al*., 2011)**. Also, potassium is considered as major osmotically active cation of plant cell where it enhances water uptake and root permeability and acts as guard cell controller, beside its role in increasing water use efficiency **(Mengel and Kirkby, 1987)**. Moreover, the favorable effect of potassium on chemical constituents of roots might be due to potassium serve to balance the changes of anions and influence their uptake and transport. Potassium also, linked with carbohydrate metabolism and sugar translocation and enhanced the transport of nitrate.

The obtained results are in harmony with those of **Mukhopadhyay *et al*., (1993)** on sweet potato, they found that K application increased N concentration in tubers, and K concentration in leaf, also **Patil *et al*., (2006)** on sweet potato, reported that K application increased N content in tuber, K content in shoot and tuber, and **Habib *et al*., (2011)** showed that N, P, K, Ca, Mg, Fe, Mn, Zn and Cu uptake were found in the tissues of potato plants which spraying with potassium significantly increased N, P, K, Ca, Mg, Fe, Mn, Zn and Cu uptake during both growing season except P uptake in the first growing season only.

As for the effect of antioxidants on chemical constituents of tuber roots of sweet potato, data in Table (3) show that macronutrients; i.e., N, P, K and Ca were significantly increased by using antioxidants; i.e., salicylic acid or ascorbic acid as compared with the control, with foliar sprayed by ascorbic acid at 200 ppm being significantly the most effective, in both growing seasons of the study compared with salicylic acid except for P content in tuber roots, the highest values obtained from sprayed by salicylic acid at 200 ppm. In fact, ascorbic acid (Vit. C) has a wide range of important functions as antioxidant defense, photoprotection, regulation of photosynthesis, affects nutritional cycle's activity in higher plants, electron transport system, as a cofactor for a large number of key enzymes in plants, also developmental senescence, programmed cell death and responses to pathogens **(Blokhina *et al*., 2003)**. In addition salicylic acid as antioxidant naturally occurs in plants in very low amounts and participates in the regulation of physiological processes in plant such as stomatal closure, photosynthesis, transpiration, nutrient uptake, chlorophyll and protein synthesis, inhibition of ethylene biosynthesis, resistance to pathogens plant disease and increased longevity of storage period **(Hayat and Ahmad, 2007)**.

Table 3. Chemical constituents of sweet potato tuber roots as affected by calcium, potassium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments	Parameters							
	Tuber roots							
	N %		P %		K %		Ca %	
	2011	2012	2011	2012	2011	2012	2011	2012
Calcium								
Control	1.38 c	1.22 c	0.16 b	0.15 c	1.78 b	1.63 a	2.22 c	2.06 c
1000 ppm	1.55 b	1.37 b	0.18 a	0.17 a	1.84 ab	1.64 a	2.61 b	2.41 b
2000 ppm	1.62 a	1.45 a	0.18 a	0.17 a	1.87 a	1.67 a	2.71 a	2.50 a
Potassium								
Control	1.31 c	1.23 c	0.16 c	0.15 c	1.62 c	1.43 c	2.26 c	2.16 c
48 kg K_2O/fed.	1.53 b	1.35 b	0.17 b	0.16 b	1.77 b	1.67 b	2.55 b	2.33 b
72 kg K_2O/fed.	1.71 a	1.46 a	0.19 a	0.18 a	2.10 a	1.83 a	2.72 a	2.47 a
Antioxidants								
Control	1.38 c	1.24 c	0.15 c	0.14 c	1.72 c	1.44 c	2.33 c	2.08 c
Salicylic acid	1.51 b	1.36 b	0.19 a	0.18 a	1.84 b	1.67 b	2.53 b	2.38 b
Ascorbic acid	1.66 a	1.43 a	0.17 b	0.17 b	1.93 a	1.82 a	2.68 a	2.50 a

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

These results were similar with those of **Bardisi, (2004)** under sandy soil conditions, who found that spraying garlic plants with SA at 50 ppm recorded maximum values of N, P and K uptake by leaves and bulb and N, P and K total uptake by plant, also **El-Banna *et al*., (2006)** on potato**,** found that N, P and K contents were significantly increased by the application of ascorbic acid, **Awad and Mansour (2007)** found that (N, P and K) contents in potato tubers were significantly increased by the application of SA. **Abd El-Mageed *et al*., (2009)** on garlic plants reported that spraying garlic plants with ASA or SA as antioxidant recorded maximum values of N, P and K uptake by leaves and bulb and N, P and K total uptake by plant.

As for the effect of combination of calcium and potassium on the chemical constituents of sweet potato plants, data in Table (4) show that the interaction had a significant effect on the concentration of N, P, K and Ca in tuber roots, in both seasons of the study.

The combination of calcium as foliar spray at 1000 ppm and potassium at 72 kg K_2O/fed. was superior for enhancing N, P, and Ca in tuber roots in both growing seasons, and was superior for enhancing K in the first growing season only, and there were no significant differences between sprayed of calcium at 1000 or 2000 ppm with 72 kg K_2O/fed. on the concentration of N, P, K and Ca in tuber roots, in both growing seasons of the study. Also, there were no significant differences between sprayed of calcium at 1000 ppm plus potassium at 72 kg K_2O/fed. and sprayed of calcium at 2000 ppm plus potassium at 48 kg K_2O/fed. on the concentration of N, P and Ca in tuber roots, in the second growing season while there were no significant differences between sprayed of calcium at 1000 or 2000 ppm plus potassium at 72 kg K_2O/fed. and sprayed of calcium at 0 ppm (control) plus potassium at 72 kg K_2O/fed. on the concentration of K in tuber roots, in both growing season. Results could be explained by the fact that potassium has an established reputation as a major controlling effect on tuber production in plant and it is the most important nutrient element needed by sweet potato in terms of nutrient uptake per unit area per unit tuber production. Since sweet potato is generally grown on highly weathered and leached soils where available K status is low, management of K assumes greatest significance **(Byju and George, 2005)**. Obtained results agreed with those of **Kumar *et al*., (1991)** they said that increasing fertilizer levels of K, Ca and Mg tended to increase the starch, uptake of K, Ca and Mg content of cassava tubers, also **Pereira *et al*., (2006)** on taro, they said that increased K fertilizer rates led to increasing cormel Ca contents; on the other hand, independent of Ca application, cormel K contents increased with the increasing in K rates.

Table 4. Chemical constituents of sweet potato tuber roots as affected by the interactions between calcium and potassium at different rates during 2011 and 2012 growing seasons.

Treatments		Parameters							
		Tuber roots							
		N %		P %		K %		Ca %	
Ca.	Po.	2011	2012	2011	2012	2011	2012	2011	2012
Control	Control	1.19 f	1.12 d	0.15 d	0.14 e	1.54 e	1.40 c	2.00 f	1.96 d
	48 kg K_2O/fed.	1.41 d	1.21 c	0.16 bcd	0.15 de	1.70 cd	1.64 b	2.29 e	2.03 d
	72 kg K_2O/fed.	1.55 c	1.32 b	0.17 bc	0.17 bc	2.09 a	1.83 a	2.36 e	2.17 c
1000 ppm	Control	1.33 e	1.22 c	0.16 cd	0.15 e	1.64 de	1.43 c	2.32 e	2.21 c
	48 kg K_2O/fed.	1.54 c	1.36 b	0.17 bc	0.16 bcd	1.78 bc	1.67 b	2.61 c	2.40 b
	72 kg K_2O/fed.	1.80 a	1.54 a	0.20 a	0.19 a	2.11 a	1.81 a	2.91 a	2.62 a
2000 ppm	Control	1.42 d	1.34 b	0.16 bcd	0.15 cde	1.67 cd	1.45 c	2.47 d	2.33 b
	48 kg K_2O/fed.	1.65 b	1.48 a	0.18 b	0.17 ab	1.84 b	1.70 b	2.76 b	2.55 a
	72 kg K_2O/fed.	1.78 a	1.52 a	0.20 a	0.18 a	2.11 a	1.85 a	2.90 a	2.61 a

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Ca. = Calcium & Po. = Potassium.

Data presented in Table (5) show the effects of interaction between calcium and antioxidants on macronutrient concentration of sweet potato tubers. The above mentioned interaction shows a significant effect on N, P, K and Ca in tuber roots in both growing seasons.

In general, N, Ca contents of tuber roots of sweet potato were higher with the interaction between calcium as foliar sprayed at 2000 ppm and ascorbic acid as foliar sprayed at 200 ppm, in both growing seasons and there were no significant differences between foliar spray of calcium at 2000 ppm plus foliar spray of ascorbic acid at 200 ppm and foliar spray of calcium at 1000 ppm plus foliar spray of ascorbic acid at 200 ppm, in the first growing season, also there were no significant differences between foliar spray of calcium at 2000 ppm plus foliar spray of salicylic acid at 200 ppm and foliar spray of calcium at 2000 ppm plus foliar spray of ascorbic acid at 200 ppm on N contents of tuber roots, in the second growing season. K contents of tuber roots were higher with the interaction between calcium as foliar spray at 2000 ppm and ascorbic acid as foliar spray at 200 ppm in the first growing season only and there were no significant differences between foliar spray of calcium at 2000 ppm plus foliar spray of ascorbic acid or salicylic acid at 200 ppm and foliar spray of calcium at 0 ppm (control) or 1000 ppm plus foliar spray of ascorbic acid at 200 ppm, in both growing seasons. P content of tuber roots were higher with the interaction between calcium as foliar spray at 2000 ppm and salicylic acid as foliar spray at 200 ppm, in both growing seasons and there were no significant differences between foliar spray of calcium at 2000 ppm plus foliar spray of salicylic acid at 200 ppm and foliar spray of calcium at 1000 ppm plus foliar spray of salicylic acid at 200 ppm, in both growing seasons, also there were no significant differences between foliar spray of calcium at 1000 or 2000 ppm plus foliar spray of ascorbic acid or salicylic acid at 200 ppm and foliar spray of calcium at 0 ppm (control) plus foliar spray of salicylic acid at 200 ppm, in the second growing season. These effects could be due to the role of ascorbic acid (Vit. C) witch has a wide range of important functions as antioxidant defense, photoprotection, regulation of photosynthesis, affects nutritional cycle's activity in higher plants, electron transport system, as a cofactor for a large number of key enzymes in plants, also developmental senescence, programmed cell death and responses to pathogens **(Blokhina *et al*., 2003)**, also the role of salicylic acid as antioxidant witch participates in the regulation of physiological processes in plant such as stomatal closure, photosynthesis, transpiration, nutrient uptake, chlorophyll and protein synthesis **(Hayat and Ahmad, 2007)**. Moreover, using calcium chloride and citric acid as foliar application tended to increase the concentration of N, P, Ca and Mg of lettuce leaves. These elements are known to be closely associated with the main internal physiogical and metabolically status of plant as chlorophyll, enzymes, amino acids, sugars, ATP, nucleic acid and etc. synthesis **(El-Shabrawy and Selim, 2007)**.

The obtained results are in harmony with those **El-Banna *et al*., (2006)** on potato**,** they found that N, P and K contents were significantly increased by the application of ascorbic acid, also **Abd El-Mageed *et al*., (2009)** on garlic plants, they reported that spraying garlic plants with ASA or SA as antioxidant recorded maximum values of N, P and K uptake by leaves and bulb and N, P and K total uptake by plant.

Table 5. Chemical constituents of sweet potato tuber roots as affected by the interactions between calcium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments		Parameters – Tuber roots: N %		P %		K %		Ca %	
Ca.	An.	2011	2012	2011	2012	2011	2012	2011	2012
Control	Control	1.28 f	1.12 f	0.14 d	0.13 d	1.67 e	1.39 c	2.05 g	1.81 f
	Sa. acid	1.39 e	1.23 e	0.18 b	0.17 ab	1.79 cde	1.67 b	2.24 f	2.11 e
	As. acid	1.47 d	1.30 de	0.16 bc	0.16 bc	1.87 abc	1.82 a	2.36 e	2.25 d
1000 ppm	Control	1.38 e	1.28 de	0.15 cd	0.15 c	1.74 de	1.45 c	2.39 e	2.17 e
	Sa. acid	1.54 c	1.39 bc	0.20 a	0.18 a	1.86 bcd	1.63 b	2.66 c	2.48 c
	As. acid	1.74 a	1.45 b	0.18 b	0.17 ab	1.93 ab	1.83 a	2.79 ab	2.58 b
2000 ppm	Control	1.47 d	1.33 cd	0.16 c	0.15 c	1.77 cde	1.48 c	2.55 d	2.25 d
	Sa. acid	1.62 b	1.47 ab	0.20 a	0.18 a	1.86 abc	1.72 ab	2.70 bc	2.57 b
	As. acid	1.76 a	1.54 a	0.18 b	0.17 a	1.98 a	1.81 a	2.88 a	2.67 a

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Ca. = Calcium & An. = Antioxidants & Sa. acid = Salicylic Acid & As. acid = Ascorbic Acid.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

Concerning the interaction effect between potassium and antioxidants on mineral composition of tubers of sweet potato plants, data in Table (6), indicate that increasing potassium level from 0 to 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm caused a significant increase in the N, K and Ca content in tuber roots of sweet potato in both growing seasons, while P content in tuber roots of sweet potato significantly increased with 72 kg K_2O/fed. in the presence of foliar spray of salicylic acid at 200 ppm in both growing seasons. Also, there were no significant differences between applied potassium at 72 kg K_2O/fed. in the presence of foliar spray with salicylic acid at 200 ppm and applied potassium at 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm on N and P in tuber roots of sweet potato, in the second growing season.

These results agreed with **El-Morsy *et al*., (2010)** on garlic, they found that the interactions between PK-rates and antioxidants had a significant effect on all chemical concentrations such as N, P and K as well as TSS% and volatile oils in garlic bulbs.

Table 6. Chemical constituents of sweet potato tuber roots as affected by the interactions between potassium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments		Parameters							
		Tuber roots							
		N %		P %		K %		Ca %	
Po.	An.	2011	2012	2011	2012	2011	2012	2011	2012
Control	Control	1.23 f	1.12 f	0.14 e	0.13 g	1.48 e	1.28 g	2.11 f	1.94 f
	Sa. acid	1.32 e	1.25 e	0.17 bc	0.16 de	1.65 d	1.45 ef	2.25 e	2.21 d
	As. acid	1.40 d	1.31 de	0.16 cd	0.15 ef	1.71 cd	1.55 de	2.43 d	2.34 c
48 kg K_2O/fed.	Control	1.39 d	1.25 e	0.15 de	0.14 fg	1.71 cd	1.44 f	2.34 de	2.08 e
	Sa. acid	1.54 c	1.35 d	0.19 b	0.18 bc	1.79 c	1.73 c	2.59 c	2.40 c
	As. acid	1.66 b	1.44 bc	0.17 bc	0.17 cd	1.81 c	1.85 b	2.73 b	2.51 b
72 kg K_2O/fed.	Control	1.52 c	1.36 cd	0.16 cd	0.16 def	1.98 b	1.59 d	2.53 c	2.22 d
	Sa. acid	1.69 b	1.48 ab	0.22 a	0.20 a	2.07 b	1.84 b	2.77 b	2.54 b
	As. acid	1.91 a	1.54 a	0.19 b	0.18 ab	2.26 a	2.05 a	2.87 a	2.64 a

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Po. = Potassium & An. = Antioxidants & Sa. acid = Salicylic Acid & As. acid = Ascorbic Acid.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

Data presented in Table (7) show the interaction effect among calcium, potassium and antioxidants on macronutrients of tuber roots of sweet potato plants. Obtained results revealed significant increases in tuber N, P, K and Ca content, in both growing seasons by the above mentioned interaction, in both growing seasons.

The highest values of macronutrients obtained when plants sprayed with calcium at 1000 ppm, supplied with 72 kg K_2O/fed. and sprayed with ascorbic acid at 200 ppm in both growing seasons, except P content in tuber roots of sweet potato, the highest values obtained from sprayed with calcium at 1000 ppm, supplied with 72 kg K_2O/fed. and sprayed with salicylic acid at 200 ppm in both growing seasons. There were no significant differences between sprayed with calcium at 1000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with ascorbic acid at 200 ppm and sprayed with calcium at 2000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with ascorbic acid at 200 ppm on N, K and Ca content in tuber roots, in both growing seasons. There were no significant differences between sprayed with calcium at 2000 ppm, supplied with 48 or 72 kg K_2O/fed. plus sprayed with salicylic acid or ascorbic acid at 200 ppm and sprayed with calcium at 1000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with salicylic acid or ascorbic acid at 200 ppm on N content in tuber roots, in the second growing season, also there were no significant differences between sprayed with calcium at 1000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with salicylic acid or ascorbic acid at 200 ppm and sprayed with calcium at 0 ppm (control), supplied with 72 kg K_2O/fed. plus sprayed with salicylic acid or ascorbic acid at 200 ppm on K content in tuber roots, in the first growing season, while in the second growing season, there were no significant differences between sprayed with calcium at 0 ppm (control) or 1000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with ascorbic acid at 200 ppm and sprayed with calcium at 2000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with salicylic acid or ascorbic acid at 200 ppm on K content in tuber roots. For Ca content in tuber roots, there were no significant differences between sprayed with calcium at 1000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with salicylic acid or ascorbic acid at 200 ppm and sprayed with calcium at 2000 ppm, supplied with 48 or 72 kg K_2O/fed. plus sprayed with ascorbic acid at 200 ppm, in both growing seasons, also there were no significant differences between sprayed with calcium at 1000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with ascorbic acid at 200 ppm and sprayed with calcium at 2000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with salicylic acid at 200 ppm, in the second growing season. On the other hand, there were no significant differences between sprayed with calcium at 1000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with salicylic acid at 200 ppm and sprayed with calcium at 2000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with salicylic acid at 200 ppm on P content in tuber roots, in both growing seasons, and there were no significant differences between sprayed with calcium at 1000 or 2000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with salicylic acid or ascorbic acid at 200 ppm and sprayed with calcium at 1000 or 2000 ppm, supplied with 48 kg K_2O/fed. plus sprayed with salicylic acid at 200 ppm, also there were no significant differences between sprayed with calcium at 1000 ppm, supplied with 72 kg K_2O/fed. plus sprayed with salicylic acid at 200 ppm and sprayed with calcium at 0 ppm (control), supplied with 72 kg K_2O/fed. plus sprayed with salicylic acid at 200 ppm on P content in tuber roots, in the second growing season.

Table 7. Chemical constituents of sweet potato tuber roots as affected by the interactions among calcium, potassium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments			Parameters							
			Tuber roots							
			N %		P %		K %		Ca %	
Ca.	Po.	An.	2011	2012	2011	2012	2011	2012	2011	2012
Control	Control	Control	1.11 o	1.02 l	0.13 i	0.12 k	1.40 j	1.21 o	1.80 p	1.70 n
		Sa. acid	1.20 n	1.15 kl	0.16 cdefgh	0.16 efghi	1.57 hij	1.43 klmn	2.01 o	2.00 lm
		As. acid	1.27 lmn	1.19 jk	0.15 efghi	0.14 hijk	1.66 ghi	1.58 ghijk	2.18 mn	2.18 ijk
	48 kg K_2O/fed.	Control	1.33 jkl	1.11 kl	0.14 hi	0.13 k	1.66 ghi	1.39 lmn	2.14 no	1.78 n
		Sa. acid	1.40 ijk	1.20 ijk	0.18 bcd	0.16 defghi	1.74 gh	1.70 fghi	2.31 klm	2.10 kl
		As. acid	1.49 fgh	1.30 efghij	0.16 bcdefgh	0.16 efghi	1.70 gh	1.84 def	2.42 ijk	2.23 hijk
	72 kg K_2O/fed.	Control	1.41 hij	1.23 hijk	0.15 efghi	0.14 ijk	1.96 cdef	1.56 hijkl	2.20 lmn	1.96 m
		Sa. acid	1.56 ef	1.34 efghi	0.19 b	0.19 abcd	2.08 abc	1.89 bcde	2.40 ijk	2.23 hijk
		As. acid	1.67 cd	1.41 cdef	0.18 bcde	0.17 bcdef	2.25 ab	2.05 ab	2.49 ghij	2.34 fgh
1000 ppm	Control	Control	1.25 mn	1.13 kl	0.14 ghi	0.13 jk	1.48 ij	1.30 no	2.18 mn	2.02 lm
		Sa. acid	1.32 klm	1.24 ghijk	0.17 bcdef	0.17 cdefgh	1.70 gh	1.44 klmn	2.30 klmn	2.28 ghij
		As. acid	1.41 hij	1.29 fghij	0.16 cdefgh	0.15 fghij	1.75 gh	1.56 hijkl	2.48 hij	2.33 fgh
	48 kg K_2O/fed.	Control	1.34 jkl	1.30 fghij	0.16 defghi	0.15 ghijk	1.75 fgh	1.45 jklmn	2.33 jklm	2.16 jk
		Sa. acid	1.54 ef	1.36 defgh	0.19 bc	0.18 abcde	1.80 defg	1.73 efgh	2.70 def	2.46 ef
		As. acid	1.73 bc	1.42 cdef	0.17 bcdef	0.17 bcdefg	1.78 efgh	1.85 cdef	2.79 cd	2.58 cde
	72 kg K_2O/fed.	Control	1.56 ef	1.42 cdef	0.17 bcdefg	0.16 efghi	1.98 cde	1.62 ghij	2.65 defg	2.33 fgh
		Sa. acid	1.77 b	1.58 ab	0.23 a	0.20 a	2.08 abc	1.73 efgh	2.98 ab	2.70 abc
		As. acid	2.07 a	1.64 a	0.19 b	0.19 ab	2.28 a	2.08 a	3.10 a	2.82 a
2000 ppm	Control	Control	1.34 jkl	1.20 ijk	0.14 fghi	0.14 ijk	1.57 hij	1.34 mno	2.36 jkl	2.10 kl
		Sa. acid	1.43 ghi	1.38 defg	0.18 bcde	0.16 defghi	1.70 gh	1.50 jklm	2.43 ijk	2.37 fg
		As. acid	1.51 fg	1.44 bcde	0.17 bcdefgh	0.16 efghi	1.74 gh	1.53 ijkl	2.63 efgh	2.51 de
	48 kg K_2O/fed.	Control	1.49 fgh	1.35 efgh	0.16 cdefgh	0.16 efghi	1.73 gh	1.49 jklm	2.55 fghi	2.29 ghi
		Sa. acid	1.68 c	1.50 abcd	0.19 bc	0.19 abc	1.83 defg	1.76 defg	2.76 de	2.64 bcd
		As. acid	1.77 b	1.59 a	0.18 bcde	0.17 bcdef	1.96 cdef	1.86 cdef	2.98 ab	2.72 ab
	72 kg K_2O/fed.	Control	1.60 de	1.44 bcde	0.17 bcdefg	0.17 cdefgh	2.01 cd	1.60 ghijk	2.73 de	2.36 fg
		Sa. acid	1.74 bc	1.53 abc	0.23 a	0.20 a	2.07 bc	1.92 abcd	2.93 bc	2.69 abc
		As. acid	2.00 a	1.58 ab	0.19 bc	0.19 abc	2.25 ab	2.03 abc	3.03 ab	2.78 a

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Ca. = Calcium & Po. = Potassium & An. = Antioxidants & Sa. acid = Salicylic Acid & As. acid = Ascorbic Acid.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

b- Organic compositions:

Foliar spray with calcium increased total carbohydrates, reducing and non reducing sugars, total carotenoids content as well as vitamin C of fresh cured roots of sweet potato plants and the highest values obtained from foliar spray with calcium at 2000 ppm (Table 8). There were no significant differences between sprayed with calcium at 1000 and 2000 ppm on total carbohydrates content of fresh cured roots, in both growing seasons, also there were no significant differences between sprayed with calcium at 1000 and 2000 ppm on non reducing sugars of fresh cured roots, in the second growing season. On the other hand, there were no significant differences between sprayed with calcium at 1000 and 2000 ppm, also there were no significant differences between sprayed with calcium at 0 ppm (control) and 1000 ppm on total carotene of fresh cured roots, in the first growing season. The positive effect of calcium on organic composition of fresh cured roots may be due to it is involvement in one or more of important biological functions, calcium is component of the middle lamella and is essential for intracellular membrane transport. Also, calcium is known to act as a signaling molecule that can regulate metabolism, controlling respiration, reducing ethylene production **(Marschner, 2013)**. The obtained, results agreed with those of **Sulaiman *et al*., (2003)** found that contents of total sugar and starch increased significantly in (*Ipomoea batatas* L.), with the increase Ca level of calcium application and **Sulaiman *et al*., (2004)** confirmed those results in tuber roots of sweet potato increased as the Ca concentration increased.

It is clear from data in Table (8) that all organic composition including total carbohydrates, reducing and non reducing sugars, total carotenoids content as well as vitamin C in fresh cured tubers of sweet potato, significantly increased by increasing potassium from 0 to 72 kg K_2O/fed. Results may be attributed to that potassium plays a very important role in plant growth and development. Its role is well documented in photosynthesis, increasing enzyme activity, improving synthesis of protein, carbohydrates and fats, translocation of sugars, enabling their ability to rest pests and diseases **(Dkhil *et al*., 2011)**. Also, potassium is considered as major osmotically active cation of plant cell where it enhances water uptake and root permeability and acts as guard cell controller, beside its role in increasing water use efficiency **(Mengel and Kirkby, 1987)**. Moreover, the crucial importance of potassium in quality formation is related to its role in promoting synthesis of photosynthates in potato leaves and their transport to the tubers and to enhance their conversion into starch, protein and vitamins, hence overall tuber bulking and tuber composition depend on K nutrition **(Bansal and Trehan 2011)**.

Antioxidants resulted in an improvement in the chemical characteristics of sweet potato roots. Data in Table (8) show that antioxidants, including ascorbic acid or salicylic acid increased total carbohydrates, reducing and non-reducing sugars and total carotenoids content as well as vitamin C of fresh cured tuber roots, in both growing seasons of study compared with control. Plants sprayed with ascorbic acid at 200 ppm gave the highest values of all organic composition in cured roots, followed by sprayed with salicylic acid at 200 ppm. The favorable effect of ascorbic acid on organic composition of sweet potato may be due to that ascorbic acid (Vit. C) has a wide range of important functions as antioxidant defense, photoprotection, regulation of photosynthesis, affects nutritional cycle's activity in higher plants, electron transport system, as a cofactor for a large number of key enzymes in plants **(Blokhina *et al*., 2003)**. These results are in agreement with those **Bardisi, (2004)** under sandy soil conditions, who found that spraying garlic plants with Vit. C at 100 or 200 ppm gave the highest concentration of carotenoids in leaf tissues. Also, **Mandour (2011)** who showed that spraying sweet potato plants with Vit. C, Vit. B_1 and SA at 100 ppm of each gave the highest contents of sugars and carotenoids in tuber roots.

Table 8. Organic composition of sweet potato cured roots as affected by calcium, potassium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments	Total carbohydrates (%)		Reducing sugar (%)		Non-reducing sugar (%)		Total carotenoids (mg/100g. FW)		Vit. C (mg/100g. FW)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Calcium										
Control	68.04 b	63.37 b	6.39 c	6.25 c	2.25 c	2.15 b	0.99 b	1.02 c	27.65 c	28.81 c
1000 ppm	72.91 a	67.74 a	6.58 b	6.50 b	2.32 b	2.24 a	1.01 ab	1.04 b	29.18 b	30.67 b
2000 ppm	73.06 a	68.54 a	6.66 a	6.60 a	2.34 a	2.26 a	1.06 a	1.07 a	29.76 a	30.98 a
Potassium										
Control	64.69 c	59.82 c	5.78 c	5.72 c	2.08 c	1.99 c	0.91 c	0.95 c	24.24 c	24.90 c
48 kg K_2O/fed.	72.67 b	67.30 b	6.75 b	6.65 b	2.37 b	2.23 b	1.04 b	1.07 b	29.63 b	31.50 b
72 kg K_2O/fed.	76.66 a	72.53 a	7.09 a	6.98 a	2.46 a	2.42 a	1.11 a	1.11 a	32.71 a	34.05 a
Antioxidants										
Control	67.12 c	61.31 c	6.07 c	5.80 c	2.12 c	2.01 c	0.79 c	0.84 c	24.86 c	25.42 c
Salicylic acid	72.54 b	67.02 b	6.70 b	6.70 b	2.36 b	2.27 b	1.09 b	1.12 b	28.73 b	29.82 b
Ascorbic acid	74.35 a	71.32 a	6.86 a	6.84 a	2.43 a	2.37 a	1.18 a	1.18 a	32.99 a	35.21 a

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

Table (9) shows the effect of interaction between calcium and potassium on organic composition of fresh cured sweet potato roots. Data indicate that all organic composition, in fresh cured roots, significantly increased by the interaction between calcium and potassium. Significantly the highest values of vitamin C, total carbohydrates, reducing and non reducing sugars and total carotenoids content of fresh cured roots were obtained as a result of the interaction between foliar sprayed with calcium at 1000 ppm and 72 kg K_2O/fed. and there were no significant differences between sprayed with calcium at 1000 and 2000 ppm with 72 kg K_2O/fed. on organic composition of fresh cured sweet potato roots, in both growing seasons. Also, there were no significant differences between sprayed with calcium at 1000 or 2000 ppm with 48 or 72 kg K_2O/fed. and sprayed with calcium at 0 ppm (control) with 72 kg K_2O/fed. on non reducing sugars content of fresh cured roots, in the first growing season, on the other hand, there were no significant differences between sprayed with calcium at 2000 ppm with 48 or 72 kg K_2O/fed. and sprayed with calcium at 0 ppm (control) or 1000 ppm with 72 kg K_2O/fed. on total carotenoids content of fresh cured roots, in the first growing season, while in the second growing season, there were no significant differences between sprayed with calcium at 2000 ppm with 48 or 72 kg K_2O/fed. and sprayed with calcium at 1000 ppm with 72 kg K_2O/fed. These results are in agreement with those **Sulaiman *et al*., (2003)** on (*Ipomoea batatas* L.) they found that the total sugar and crude starch amounts increased with the increase of the Ca level.

Table 9. Organic composition of sweet potato plants as affected by the interactions between calcium and potassium at different rates during 2011 and 2012 growing seasons.

Treatments		Total carbohydrates (%)		Reducing sugar (%)		Non-reducing sugar (%)		Total carotenoids (mg/100g. FW)		Vit. C (mg/100g. FW)	
Ca.	Po.	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Control	Control	61.28 f	56.29 g	5.63 g	5.56 f	2.01 d	1.91 g	0.84 d	0.92 f	22.98 h	23.61 h
	48 kg K_2O/fed.	69.32 d	64.12 d	6.53 d	6.44 d	2.31 b	2.16 d	1.02 bc	1.04 d	27.75 e	29.61 e
	72 kg K_2O/fed.	73.53 c	69.72 b	7.00 b	6.74 bc	2.44 a	2.37 b	1.11 a	1.08 bc	32.21 b	33.20 b
1000 ppm	Control	66.24 e	60.91 f	5.79 f	5.73 e	2.09 cd	2.01 f	0.88 d	0.94 f	24.52 g	25.36 g
	48 kg K_2O/fed.	74.24 bc	68.12 c	6.81 c	6.68 c	2.39 ab	2.25 c	1.04 bc	1.07 cd	30.03 d	32.15 d
	72 kg K_2O/fed.	78.24 a	74.18 a	7.15 a	7.10 a	2.47 a	2.45 a	1.11 a	1.12 a	32.97 a	34.50 a
2000 ppm	Control	66.54 e	62.28 e	5.92 e	5.86 e	2.14 c	2.07 e	1.00 c	0.98 e	25.23 f	25.74 f
	48 kg K_2O/fed.	74.45 b	69.66 b	6.91 bc	6.84 b	2.41 a	2.29 c	1.06 ab	1.11 ab	31.10 c	32.74 c
	72 kg K_2O/fed.	78.20 a	73.68 a	7.13 a	7.09 a	2.46 a	2.44 a	1.11 a	1.12 a	32.94 a	34.45 a

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Ca. = Calcium & Po. = Potassium.

Data in Table (10) represent the combined effect between calcium and antioxidants on organic composition of fresh cured roots. Vitamin C, total carbohydrates, reducing and non reducing sugars and total carotenoids content of fresh cured roots significantly affected by the interaction, in both growing seasons. The highest and significant increase in vitamin C, reducing and non reducing sugars and total carotenoids content resulted from the interaction between foliar sprayed with calcium at 2000 ppm and foliar sprayed with ascorbic acid at 200 ppm, in both growing seasons. However, the highest and significant increase in total carbohydrates content resulted from the interaction between foliar sprayed with calcium at 1000 ppm and foliar sprayed with ascorbic acid at 200 ppm, in both growing seasons. There were no significant differences between foliar sprayed with calcium at 1000 ppm plus foliar sprayed with ascorbic acid at 200 ppm and foliar sprayed with calcium at 2000 ppm plus foliar sprayed with ascorbic acid at 200 ppm on total carbohydrates content of fresh cured roots, in the second growing season, also there were no significant differences between foliar sprayed with calcium at 2000 ppm plus foliar sprayed with salicylic acid or ascorbic acid at 200 ppm and foliar sprayed with calcium at 1000 ppm plus foliar sprayed with ascorbic acid at 200 ppm on reducing sugar content of fresh cured roots, in the second growing season. On the other hand, there were no significant differences between foliar sprayed with calcium at 2000 ppm plus foliar sprayed with ascorbic acid at 200 ppm and foliar sprayed with calcium at 1000 ppm plus foliar sprayed with ascorbic acid at 200 ppm on non reducing sugar content of fresh cured roots, in both growing seasons, while in the first growing season, there were no significant differences between foliar sprayed with calcium at 2000 ppm plus foliar sprayed with ascorbic acid at 200 ppm and foliar sprayed with calcium at 1000 ppm plus foliar sprayed with salicylic acid or ascorbic acid at 200 ppm. Also, there were no significant differences between foliar sprayed with calcium at 2000 ppm plus foliar sprayed with salicylic acid or ascorbic acid at 200 ppm and foliar sprayed with calcium at 0 ppm (control) or 1000 ppm plus foliar sprayed with ascorbic acid at 200 ppm on total carotene content of fresh cured roots, in the second growing season.

Table 10. Organic composition of sweet potato plants as affected by the interactions between calcium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments		Parameters									
		Total carbohydrates (%)		Reducing sugar (%)		Non-reducing sugar (%)		Total carotenoids (mg/100g. FW)		Vit. C (mg/100g. FW)	
Ca.	**An.**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Contro	Control	62.89 h	56.25 f	5.97 g	5.46 f	2.09 d	1.96 e	0.76 d	0.80 e	23.51 i	23.51 i
	Sa. acid	69.42 f	64.49 d	6.50 e	6.58 c	2.30 c	2.19 c	1.07 c	1.07 c	27.44 f	28.58 f
	As. acid	71.82 d	69.38 b	6.69 d	6.70 bc	2.37 bc	2.29 b	1.14 b	1.17 a	31.99 c	34.33 c
1000 ppm	Control	67.98 g	63.00 e	6.10 f	5.88 e	2.12 d	2.01 de	0.78 d	0.84 d	25.20 h	26.24 h
	Sa. acid	74.52 b	67.78 c	6.76 cd	6.74 bc	2.39 abc	2.31 b	1.10 bc	1.12 b	29.20 e	30.31 e
	As. acid	76.23 a	72.44 a	6.89 b	6.90 a	2.45 ab	2.39 a	1.15 b	1.17 a	33.13 b	35.45 b
2000 ppm	Control	70.48 e	64.68 d	6.14 f	6.07 d	2.16 d	2.06 d	0.81 d	0.86 d	25.88 g	26.51 g
	Sa. acid	73.70 c	68.79 bc	6.83 bc	6.79 ab	2.38 bc	2.32 b	1.11 bc	1.16 a	29.54 d	30.57 d
	As. acid	75.02 b	72.15 a	7.00 a	6.94 a	2.47 a	2.42 a	1.24 a	1.19 a	33.85 a	35.85 a

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Ca. = Calcium & An. = Antioxidants & Sa. acid = Salicylic Acid & As. acid = Ascorbic Acid.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

Concerning the interaction effect between potassium and antioxidants on organic composition of sweet potato fresh cured tuber roots, data in Table(11) indicate that increasing the applied potassium from 0 to 72 kg K_2O/fed. in the presence of foliar sprayed with ascorbic acid at 200 ppm, caused significant increases in vitamin C, total carbohydrates, reducing and non reducing sugars and total carotenoids content of fresh cured roots. The described results were consistent through the two seasons of the experiment. Data also show that the highest values of tested parameters in fresh cured roots obtained as a results of interaction of 72 kg K_2O/fed. with foliar sprayed with ascorbic acid at 200 ppm, in both growing seasons. There were no significant differences between applied potassium at 72 kg K_2O/fed. in the presence of foliar sprayed with ascorbic acid at 200 ppm and applied potassium at 48 kg K_2O/fed. in the presence of foliar sprayed with ascorbic acid at 200 ppm on non reducing sugar content of fresh cured roots, in the first growing season, also there were no significant differences between applied potassium at 72 kg K_2O/fed.

Table 11. Organic composition of sweet potato plants as affected by the interactions between potassium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments		Parameters									
		Total carbohydrates (%)		Reducing sugar (%)		Non-reducing sugar (%)		Total carotenoids (mg/100g. FW)		Vit. C (mg/100g. FW)	
Po.	**An.**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Contro	Control	60.92 h	54.99 g	5.43 i	5.24 g	1.97 e	1.87 h	0.71 f	0.75 g	21.03 i	21.70 i
	Sa. acid	65.28 g	60.13 f	5.88 h	5.90 ef	2.12 d	2.01 g	0.94 d	1.02 e	24.14 h	24.71 h
	As. acid	67.85 f	64.36 d	6.03 g	6.01 e	2.16 cd	2.10 f	1.07 c	1.08 d	27.57 f	28.31 f
48 kg K_2O/fed	Control	68.17 f	61.96 e	6.28 f	5.79 f	2.15 d	2.00 g	0.80 e	0.87 f	25.48 g	25.95 g
	Sa. acid	74.06 d	67.15 c	6.89 d	7.00 c	2.43 b	2.30 d	1.14 b	1.14 c	29.56 d	31.19 d
	As. acid	75.79 c	72.80 b	7.08 c	7.16 b	2.52 ab	2.40 c	1.18 b	1.22 ab	33.85 b	37.36 b
72 kg K_2O/fed	Control	72.26 e	66.99 c	6.50 e	6.37 d	2.25 c	2.16 e	0.85 e	0.89 f	28.08 e	28.61 e
	Sa. acid	78.29 b	73.78 b	7.32 b	7.20 b	2.52 b	2.51 b	1.20 b	1.20 b	32.49 c	33.57 c
	As. acid	79.42 a	76.81 a	7.47 a	7.36 a	2.61 a	2.60 a	1.29 a	1.23 a	37.56 a	39.98 a

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Po. = Potassium & An. = Antioxidants & Sa. acid = Salicylic Acid & As. acid = Ascorbic Acid.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

in the presence of foliar sprayed with ascorbic acid at 200 ppm and applied potassium at 48 kg K_2O/fed. in the presence of foliar sprayed with ascorbic acid at 200 ppm on total carotenoids content of fresh cured roots, in the second growing season. The obtained results are in harmony with those of **WuZhong *et al*., (1997)** on taro, they found that K application improved the quality of the produce by increasing vitamin C levels also; **Imas (1999)** showed that applying K to potato significantly increased the vitamin C contents and, **Dzida *et al*., (2011)** on *Beta vulgaris* L., reported that potassium had a positive effect on the content of vitamin C in the leaves.

Data presented in Table (12) show the interaction effect among calcium, potassium and antioxidants on organic composition of sweet potato fresh cured roots. There were significant effects for the interaction on vitamin C, total carbohydrates, reducing and non reducing sugars and total carotenoids content of fresh cured roots, in both growing seasons.

In general, foliar spray with calcium at 1000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm had the highest values of vitamin C, total carbohydrates, reducing and non reducing sugars and total carotenoids content of fresh cured roots of sweet potato, in both growing seasons of study. There were no significant differences between foliar spray with calcium at 1000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with salicylic acid or ascorbic acid at 200 ppm and foliar spray with calcium at 2000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with salicylic acid or ascorbic acid at 200 ppm on total carbohydrates and non reducing sugars of sweet potato fresh cured roots, in the first growing season. Moreover there were no significant differences between foliar spray with calcium at 1000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 2000 ppm and 48 kg K_2O/fed. in the presence of foliar spray with salicylic acid or ascorbic acid at 200 ppm on non reducing sugars of sweet potato fresh cured roots, in the first growing season, while in the second growing season, there were no significant differences between foliar spray with calcium at 1000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 0 ppm (control) or 2000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm. Also there were no significant differences between foliar spray with calcium at 1000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with salicylic acid or ascorbic acid at 200 ppm and foliar spray with calcium at 2000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with salicylic acid or ascorbic acid at 200 ppm on reducing sugars and total carotenoids content of fresh cured roots of sweet potato, in both growing seasons. Moreover, there were no significant differences between foliar spray with calcium at 1000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 2000 ppm, without K_2O and foliar spray with ascorbic acid at 200 ppm or foliar spray with calcium at 0 ppm (control) and 72 kg K_2O/fed. in the presence of foliar spray with salicylic acid at 200 ppm on total carotene content of fresh cured roots of sweet potato, in the first growing season, while in the second growing season, there were no significant differences between foliar spray with calcium at 1000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 2000 ppm and 48 kg K_2O/fed. in the presence of foliar spray with salicylic acid at 200 ppm or foliar spray with calcium at 0 ppm (control) and 48 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm. On the other hand, there were no significant differences between foliar spray with calcium at 1000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 0 ppm (control) or 2000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with acid ascorbic acid at 200 ppm on vitamin C content of fresh cured roots, in the second growing season. Also, there were no significant differences between foliar spray with calcium at 1000 or 2000 ppm and 48 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 0 ppm (control) and 72 kg K_2O/fed. in the presence of foliar spray with acid ascorbic acid at 200 ppm on total carotene content of fresh cured roots of sweet potato, in both growing seasons. For reducing sugars content of fresh cured roots of sweet potato, there were no significant differences between foliar spray with calcium at 1000 ppm and 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 2000 ppm and 48 kg K_2O/fed. in the presence of foliar spray with acid ascorbic acid at 200 ppm, in the second growing season.

Table 12. Organic composition of sweet potato plants as affected by the interactions among calcium, potassium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments			Parameters									
			Total carbohydrates (%)		Reducing sugar (%)		Non-reducing sugar (%)		Total carotenoids (mg/100g. FW)		Vit. C (mg/100g. FW)	
Ca.	Po.	An.	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Control	Control	Control	56.34 s	50.14 p	5.29 o	4.89 l	2.09 m	2.10 m	0.66 l	0.73 k	19.48 v	20.07 u
		Sa. acid	61.75 r	57.15 no	5.69 m	5.83 hi	2.22 lm	2.24 lm	0.89 efgh	0.98 g	23.18 r	23.07 r
		As. acid	65.75 op	61.58 klm	5.90 l	5.95 h	2.33 l	2.31 jklm	0.96 ef	1.07 def	26.28 o	27.70 l
	48 kg K_2O/fed.	Control	63.60 q	57.64 no	6.04 kl	5.47 j	2.38 kl	2.40 ijkl	0.78 ijk	0.82 ij	22.83 s	23.48 q
		Sa. acid	71.31 ij	63.72 ij	6.68 g	6.87 f	2.69 ghi	2.59 ghi	1.12 d	1.09 cde	27.52 m	30.00 i
		As. acid	73.05 gh	71.01 ef	6.87 f	7.00 def	2.90 efg	2.68 efgh	1.18 bcd	1.22 a	32.89 fg	35.35 d
	72 kg K_2O/fed.	Control	68.73 lm	60.99 lm	6.58 gh	6.03 h	2.72 fghi	2.65 fgh	0.86 fghi	0.86 hi	28.21 l	26.97 n
		Sa. acid	75.19 de	72.60 de	7.13 cd	7.05 cdef	3.07 cde	2.88 cde	1.19 abcd	1.15 bc	31.63 h	32.68 f
		As. acid	76.66 bc	75.56 bc	7.30 bc	7.14 bcde	3.14 bcd	3.17 ab	1.28 ab	1.23 a	36.80 c	39.95 a
1000 ppm	Control	Control	61.14 r	56.41 o	5.47 no	5.19 k	2.29 lm	2.10 m	0.73 kl	0.75 k	21.50 u	22.32 t
		Sa. acid	67.38 n	60.54 m	5.93 l	5.94 h	2.43 jkl	2.25 klm	0.94 efg	1.02 fg	24.37 q	25.28 p
		As. acid	70.21 jk	65.78 h	5.97 l	6.06 h	2.56 ijk	2.29 jklm	0.98 e	1.05 ef	27.71 m	28.48 k
	48 kg K_2O/fed.	Control	68.98 kl	62.94 jk	6.38 ij	5.91 hi	2.61 ij	2.50 hij	0.79 hijk	0.88 hi	26.39 o	26.97 n
		Sa. acid	76.21 cd	68.37 g	6.93 ef	6.98 ef	2.87 efgh	2.65 fgh	1.14 d	1.13 c	30.10 j	31.62 h
		As. acid	77.53 b	73.06 d	7.13 cd	7.14 bcdef	2.98 de	2.85 cdef	1.18 abcd	1.21 ab	33.62 e	37.86 c
	72 kg K_2O/fed.	Control	73.83 fg	69.64 fg	6.45 hi	6.53 g	2.94 def	2.75 defg	0.84 ghij	0.90 h	27.71 m	29.42 j
		Sa. acid	79.96 a	74.44 cd	7.43 ab	7.29 abc	3.26 abc	2.93 cd	1.20 abcd	1.22 a	33.13 f	34.04 e
		As. acid	80.94 a	78.48 a	7.58 a	7.49 a	3.39 a	3.27 a	1.29 a	1.24 a	38.07 a	40.03 a
2000 ppm	Control	Control	65.29 p	58.41 n	5.52 mn	5.65 ij	2.34 kl	2.27 klm	0.74 jkl	0.77 jk	22.13 t	22.70 s
		Sa. acid	66.73 no	62.71 jkl	6.03 kl	5.94 h	2.64 ij	2.36 jkl	0.99 e	1.06 def	24.87 p	25.78 o
		As. acid	67.60 mn	65.72 h	6.21 jk	6.01 h	2.72 fghi	2.47 hijk	1.26 abc	1.11 cd	28.71 k	28.74 k
	48 kg K_2O/fed.	Control	71.92 hi	65.29 hi	6.43 hi	5.99 h	2.67 hi	2.59 ghi	0.85 ghij	0.92 h	27.22 n	27.40 m
		Sa. acid	74.65 ef	69.36 fg	7.07 de	7.17 bcde	3.23 abc	2.89 cde	1.16 cd	1.19 ab	31.05 i	31.94 g
		As. acid	76.79 bc	74.33 cd	7.25 bcd	7.36 ab	3.35 ab	2.99 bc	1.18 abcd	1.22 a	35.04 d	38.87 b
	72 kg K_2O/fed.	Control	74.23 efg	70.35 f	6.48 hi	6.56 g	2.92 defg	2.75 defg	0.84 ghij	0.90 h	28.31 l	29.43 j
		Sa. acid	79.72 a	74.30 cd	7.40 ab	7.27 abcd	3.26 abc	2.91cd	1.20 abcd	1.22 a	32.70 g	33.98 e
		As. acid	80.66 a	76.40 b	7.53 a	7.44 a	3.34 ab	3.26 a	1.29 a	1.23 a	37.80 b	39.95 a

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Ca. = Calcium & Po. = Potassium & An. = Antioxidants & Sa. acid = Salicylic Acid & As. acid = Ascorbic Acid.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

2- Quality of tuber roots during storage period:

Data in Table (13) show clearly that the keeping quality parameters of stored roots; i.e., weight loss and decay percentage was influenced by calcium treatments. It is also clear from the same data that the application of calcium to sweet potato plants significantly decreased weight loss percentage during storage period (four months) under room temperature in both growing seasons. There were no significant differences between foliar spray with calcium at 1000 ppm and 2000 ppm on weight loss percentage at 60 and 120 days during the storage period under normal room conditions, in the first growing season. Also there were no significant differences between foliar spray with calcium at 1000 ppm and 2000 ppm on weight loss percentage at 30 days during the storage period under normal room conditions, in the second growing season. Calcium may be reduce weight loss by developing storage root with bitter skin and develop flesh with more compound water which restricts water loss during the early storage periods. In addition, respiratorical, and physiological changes might be lower with calcium. Also, the graduall increase in weight loss may be due to that calcium deficiency has been linked to many disorders especially in storage organs, sweet potato is underground storage organs with low rates of transpiration thus, low Ca concentration often occurs and may affect on their susceptibility to bacterial pathogen **(Kleinhenz and Palta, 2002)**. Data on decay percent (Table 13) show also, that, in general, treating sweet potato plants with calcium significantly decreased the values of decay of 120 day storage roots, compared with control treatments under room conditions and the differences reach the level of significance.

Presented data in Table (13) show the effect of potassium on keeping quality of studied parameters; i.e., weight loss and decay percentage of storage roots under room temperature. It is clear that the values of weight loss and decay percentages were negatively correlated with potassium application. This means that increasing potassium significantly decreased the percentages of the above mentioned parameters during storage. It could be concluded that potassium at 72 kg K_2O/fed. had beneficial effect in reducing studying parameters. The favorable effects of K-fertilizer could be explained through the great role of potassium, which is an essential plant nutrient that plays a very important role in plant growth and development. Its role is well documented in photosynthesis, increasing enzyme activity, improving synthesis of protein, carbohydrates and fats, translocation of sugars, enabling their ability to rest pests and diseases **(Dkhil *et al*., 2011)**. Also, potassium is considered as major osmotically active cation of plant cell where it enhances water uptake and root permeability and acts as guard cell controller, beside its role in increasing water use efficiency **(Mengel and Kirkby, 1987)**. These results are agreeable with those reported by **Okwuowulu and Asiegbu (2000)** on sweet potato, who found that tuber losses significantly decreased as a result of K fertilizer application, **Al-Easily (2002)** found that increasing potassium fertilizer level resulted in significantly decreased weight loss and decay in storage roots of sweet potato during storage period, **Trehan *et al*., (2009)** they reported that potassium fertilization promotes a lustrous appearance on the surface of the potato tubers and potassium application has a significant role in enhancing tuber keeping quality under storage and **Bansal and Trehan (2011)** indicated that there was less weight loss and rottage of potato tubers with potassium application.

Data in Table (13) show that antioxidants including salicylic acid or ascorbic acid had significant effect on weight loss and decay percentage of stored sweet potato roots in both growing seasons. Treatment of sweet potato plants with foliar sprayed with ascorbic acid at 200 ppm recorded the lowest values of all parameters except the weight loss percentage at 30 and 60 days during the storage period under normal room conditions, in both growing seasons, and there were no significant differences between foliar sprayed with salicylic acid and ascorbic acid at 200 ppm on weight loss percentage at 30 and 60 days during the storage period under normal room conditions, in the second growing season.

Ascorbic acid as antioxidants has a wide range of important functions as antioxidant defense, photoprotection, regulation of photosynthesis, affects nutritional cycle's activity in higher plants, electron transport system, as a cofactor for a large number of key enzymes in plants, also developmental senescence, programmed cell death and responses to pathogens **(Blokhina *et al*., 2003)**. Also, salicylic acid as antioxidants naturally occurs in plants in very low amounts and participates in the regulation of physiological processes in plant such as stomatal closure, photosynthesis, transpiration, nutrient uptake, chlorophyll and protein synthesis, inhibition of ethylene biosynthesis, resistance to pathogens plant disease and increased longevity of storage period **(Hayat and Ahmad, 2007)**. These results agree with this reported by **El-Morsy *et al*., (2010)** who mentioned that bulb storability of garlic plants sprayed with some antioxidants; i.e., salicylic acid, citric acid and ascorbic acid at the rate of 100 ppm, 300 ppm and 150 ppm, respectively was better than that of the untreated plants (control). Moreover, application of ascorbic acid was more beneficial than the application ones.

Respecting the interaction effect between calcium and potassium on storability of sweet potato roots under room conditions, data in Table (14) show that weight loss percentage was significantly reduced during storage periods; i.e., 30, 60, 90 and 120 days under normal temperature, in the two growing seasons of study.

Decay percentage was significantly reduced, in both growing seasons. Plants supplied with K_2O at 72 kg/fed. and sprayed with calcium at 1000 ppm, gave lower values of weight loss and decay percentage of stored sweet potato roots during storage period, in both growing seasons, and there were no significant differences between values of weight loss and decay percentage by supplied plants with K_2O at 72 kg/fed. and sprayed with calcium at 1000 and supplied plants with K_2O at 72 kg/fed. and sprayed with calcium at 2000 ppm, in both growing seasons, except for weight loss percentage at 90 days during the storage period under normal room conditions, in the second growing season. Also there were no significant differences between supplied plants with K_2O at 72 kg/fed. and sprayed with calcium at 1000 and supplied plants with K_2O at 48 kg/fed. and sprayed with calcium at 2000 ppm on weight loss percentage at 30 days during the storage period under normal room conditions, in the first growing season. Meanwhile, there were no significant differences between supplied plants with K_2O at 72 kg/fed. and sprayed with calcium at 1000 and supplied plants with K_2O at 72 kg/fed. and sprayed with calcium at 0 ppm (control) on weight loss percentage at 60 days during the storage period under normal room conditions, in the second growing season.

Table 13. Weight loss and decay percentage of sweet potato tuber roots as affected by calcium, potassium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments	Parameters									
	Weight Loss (%)								Decay (%)	
	30 days		60 days		90 days		120 days			
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Calcium										
Control	10.94 a	10.56 a	18.87 a	18.19 a	24.09 a	23.65 a	28.94 a	27.75 a	22.35 a	20.88 a
1000 ppm	9.92 b	10.07 b	18.23 b	17.63 b	23.83 b	23.09 b	28.73 b	27.40 b	20.02 b	19.23 b
2000 ppm	9.23 c	9.96 b	17.98 b	17.29 c	23.69 c	22.90 c	28.70 b	27.30 c	19.72 c	19.00 c
Potassium										
Control	11.08 a	11.14 a	20.04 a	19.11 a	26.01 a	25.11 a	30.99 a	29.34 a	23.18 a	22.03 a
48 kg K_2O/fed.	10.03 b	10.21 b	18.10 b	17.58 b	24.54 b	23.61 b	28.82 b	27.61 b	20.61 b	19.45 b
72 kg K_2O/fed.	8.97 c	9.23 c	16.94 c	16.41 c	21.05 c	20.91 c	26.56 c	25.48 c	18.28 c	17.62 c
Antioxidants										
Control	11.81 a	11.80 a	20.68 a	19.73 a	26.39 a	25.48 a	31.93 a	29.08 a	22.47 a	21.27 a
Salicylic acid	8.93 c	9.26 b	16.86 c	16.50 b	22.72 b	22.21 b	27.36 b	26.94 b	19.98 b	19.13 b
Ascorbic acid	9.34 b	9.52 b	17.54 b	16.87 b	22.49 c	21.95 c	27.08 c	26.42 c	19.63 c	18.69 c

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

Table 14. Weight loss and decay percentage of sweet potato tuber roots as affected by the interactions between calcium and potassium at different rates during 2011 and 2012 growing seasons.

Treatments		Parameters									
		Weight Loss (%)								Decay (%)	
		30 days		60 days		90 days		120 days			
Ca.	Po.	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Control	Control	11.76 a	11.49 a	21.02 a	20.08 a	26.25 a	25.87 a	31.11 a	29.62 a	25.59 a	24.00 a
	48 kg K_2O/fed.	10.99 bc	10.32 cd	18.24 c	17.79 cd	24.79 d	23.93 d	28.89 b	27.83 c	21.86 c	20.66 c
	72 kg K_2O/fed.	10.06 d	9.86 d	17.35 de	16.69 e	21.22 g	21.13 g	26.83 c	25.78 e	19.59 f	17.97 e
1000 ppm	Control	11.12 ab	11.10 ab	19.86 b	19.12 b	25.99 b	25.02 b	30.99 a	29.31 b	22.36 b	21.27 b
	48 kg K_2O/fed.	10.22 d	10.20 d	18.14 c	17.55 cd	24.54 e	23.55 e	28.79 b	27.54 d	20.10 e	18.98 d
	72 kg K_2O/fed.	8.41 e	8.90 e	16.68 f	16.21 e	20.95 h	20.71 i	26.42 d	25.34 f	17.59 g	17.43 f
2000 ppm	Control	10.35 cd	10.83 bc	19.24 b	18.13 c	25.79 c	24.45 c	30.87 a	29.09 b	21.60 d	20.82 c
	48 kg K_2O/fed.	8.88 e	10.11 d	17.93 cd	17.41 d	24.31 f	23.35 f	28.78 b	27.45 d	19.89 e	18.71 d
	72 kg K_2O/fed.	8.45 e	8.93 e	16.78 ef	16.33 e	20.98 h	20.90 h	26.43 d	25.34 f	17.66 g	17.46 f

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Ca. = Calcium & Po. = Potassium.

As for the effect of interaction between calcium and antioxidants on storage parameters of tuber roots, data in Table (15) indicated that calcium treatments generally gave the lowest values in weight loss and decay, compared with the control. Moreover, application of antioxidants with calcium produced the lowest values for four months of storage under room temperature. Weight loss during the storage months, decay after 120 days, were significantly affected by treating plants with both antioxidants and calcium.

Foliar sprayed with calcium at 2000 ppm with salicylic acid at 200 ppm resulted in the lowest values of weight loss percentage at 30 and 60 days during the storage period under normal room conditions, in both growing seasons, and there were no significant differences between foliar sprayed with calcium at 2000 ppm with salicylic acid or ascorbic acid at 200 ppm and foliar sprayed with calcium at 1000 ppm with salicylic acid at 200 ppm on weight loss percentage at 30 and 60 days during the storage period, in both growing seasons. Moreover, there were no significant differences between foliar sprayed with calcium at 2000 ppm with salicylic acid at 200 ppm and foliar sprayed with calcium at 1000 ppm with ascorbic acid at 200 ppm on weight loss percentage at 30 and 60 days during the storage period, in the second growing season. On the other hand, foliar sprayed with calcium at 2000 ppm with ascorbic acid at 200 ppm resulted in the lowest values of weight loss percentage at 90, 120 days during the storage period and total decay percentage after storage period, in both growing seasons, and there were no significant differences between foliar sprayed with calcium at 2000 ppm with ascorbic acid at 200 ppm and foliar sprayed with calcium at 1000 ppm with ascorbic acid at 200 ppm on weight loss percentage at 90 days during the storage period, in the first growing season, while there were no significant differences between foliar sprayed with calcium at 2000 ppm with ascorbic acid at 200 ppm and foliar sprayed with calcium at 1000 ppm with ascorbic acid at 200 ppm on decay percentage after storage period, in the second growing season. For the weight loss percentage at 120 days during the storage period. There were no significant differences between foliar sprayed with calcium at 1000 or 2000 ppm with ascorbic acid at 200 ppm and foliar sprayed with calcium at 0 ppm (control) with ascorbic acid at 200 ppm, in both seasons. Also there were no significant differences between foliar sprayed with calcium at 2000 ppm with ascorbic acid at 200 ppm and foliar sprayed with calcium at 1000 ppm with salicylic acid or ascorbic acid at 200 ppm, in the first growing season.

Table 15. Weight loss and decay percentage of sweet potato tuber roots as affected by the interactions between calcium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments		Parameters									
		Weight Loss (%)								Decay (%)	
		30 days		60 days		90 days		120 days			
Ca.	An.	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Control	Control	12.68 a	12.01 a	20.98 a	20.09 a	26.68 a	25.91 a	32.17 a	29.45 a	24.26 a	22.52 a
	Sa. acid	9.81 cd	9.71 bc	17.46 c	17.02 cd	22.93 d	22.64 d	27.47 c	27.24 c	21.58 bc	20.25 c
	As. acid	10.32 c	9.95 b	18.18 b	17.44 c	22.65 e	22.39 e	27.20 cde	26.55 de	21.20 d	19.85 d
1000 ppm	Control	11.65 b	11.68 a	20.54 a	19.78 ab	26.38 b	25.41 b	31.88 ab	28.99 b	21.71 b	20.86 b
	Sa. acid	8.79 ef	9.14 cd	16.68 d	16.43 de	22.67 e	22.04 f	27.26 cde	26.81 d	19.32 e	18.66 e
	As. acid	9.32 de	9.39 bcd	17.47 c	16.67 de	22.42 f	21.83 g	27.05 de	26.38 e	19.01 f	18.16 f
2000 ppm	Control	11.09 b	11.71 a	20.53 a	19.33 b	26.11c	25.11 c	31.74 b	28.79 b	21.45 c	20.43 c
	Sa. acid	8.21 f	8.94 d	16.45 d	16.04 e	22.57 e	21.96 f	27.35 cd	26.77 d	19.03 f	18.48 e
	As. acid	8.38 f	9.23 cd	16.97 cd	16.50 de	22.41 f	21.63 h	26.99 e	26.32 e	18.67 g	18.07 f

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Ca. = Calcium & An. = Antioxidants & Sa. acid = Salicylic Acid & As. acid = Ascorbic Acid.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

Results in Table (16) showed a significant interaction between potassium and antioxidants for loss in weight percent after 30, 60, 90 and 120 days, in both growing seasons, decay percentage, in both growing seasons were significantly reduced during storage period under the condition of room temperature. Results generally, showed that lowest values of weight loss percentage at 30 and 60 days during the storage period under normal room conditions were recorded by supplying plants with potassium at 72 kg K_2O/fed. in the presence of foliar spray with salicylic acid at 200 ppm, in both growing seasons and there were no significant differences between supplying plants with potassium at 72 kg K_2O/fed. in the presence of foliar spray with salicylic acid at 200 ppm and supplying plants with potassium at 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm on weight loss percentage at 30 days, in both growing seasons. Also there were no significant differences between supplying plants with potassium at 72 kg K_2O/fed. in the presence of foliar spray with salicylic acid at 200 ppm and supplying plants with potassium at 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm on weight loss percentage at 60 days, in the second growing season. On the other hand, the lowest values of weight loss percentage at 90 and 120 days during the storage period under normal room conditions and decay percentage were recorded by supplying plants with potassium at 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm, in both growing seasons, and there were no significant differences between supplying plants with potassium at 72 kg K_2O/fed. in the presence of foliar spray with ascorbic acid at 200 ppm and supplying plants with potassium at 72 kg K_2O/fed. in the presence of foliar spray with salicylic acid at 200 ppm on weight loss percentage at 120 days, in the first growing season. These results are concerted with those of **Imas (1999)** who showed that applying K to potato significantly increased the vitamin C contents and decreased weight losses from the tubers after harvest and **El-Morsy *et al.*, (2010)** on garlic, they showed that the interactions between PK-rates and antioxidants had positive effect on storability of bulbs and gave the lowest total weight loss percentage during storage period.

Table 16. Weight loss and decay percentage of sweet potato tuber roots as affected by the interactions between potassium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments		Parameters									
		Weight Loss (%)								Decay (%)	
		30 days		60 days		90 days		120 days			
Po.	An.	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Control	Control	12.83 a	12.67 a	22.24 a	20.91 a	28.90 a	27.36 a	33.73 a	30.96 a	25.12 a	23.48 a
	Sa. acid	9.97 de	10.29 c	18.60 d	18.09 c	24.71 c	24.09 c	29.74 cd	28.73 c	22.34 b	21.55 b
	As. acid	10.43 cd	10.45 c	19.28 c	18.33 c	24.42 d	23.88 d	29.51 d	28.34 d	22.09 c	21.06 c
48 kg K_2O/fed	Control	11.77 b	11.58 b	20.24 b	19.89 b	26.94 b	25.83 b	32.21 b	29.52 b	22.21 bc	20.96 c
	Sa. acid	8.94 f	9.38 d	16.72 e	16.21 de	23.44 e	22.65 f	27.28 e	26.95 e	19.98 d	18.84 e
	As. acid	9.38 ef	9.68 d	17.35 e	16.65 d	23.25 f	22.35 g	26.97 f	26.36 f	19.66 e	18.55 e
72 kg K_2O/fed	Control	10.83 c	11.14 b	19.55 c	18.40 c	23.33 ef	23.24 e	29.85 c	26.76 e	20.10 d	19.39 d
	Sa. acid	7.90 g	8.11 e	15.27 g	15.20 f	20.01 g	19.90 h	25.06 g	25.14 g	17.61 f	17.00 f
	As. acid	8.19 g	8.43 e	16.00 f	15.63 ef	19.81 h	19.60 i	24.76 g	24.56 h	17.14 g	16.47 g

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Po. = Potassium & An. = Antioxidants & Sa. acid = Salicylic Acid & As. acid = Ascorbic Acid.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

The interaction among all factors under investigation; i.e., calcium, potassium and antioxidants had a significant effect on weight loss during storage periods; i.e., 30, 60, 90 and 120 days, under normal temperature in both growing seasons as shown in Table (17). Decay percentage was significantly decreased, in the both growing seasons during storage period. Results generally, showed that lowest values of weight loss percentage at 30 and 60 days during the storage period under normal room conditions were recorded by foliar spray with calcium at 1000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with salicylic acid at 200 ppm, in both growing seasons, while lowest values of weight loss percentage at 90 and 120 days during the storage period under normal room conditions, in both growing seasons, and lowest value of decay percentage, in the second growing season were recorded by foliar spray with calcium at 1000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with ascorbic acid at 200 ppm. There were no significant differences between foliar spray with calcium at 1000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with salicylic acid or ascorbic acid at 200 ppm and foliar spray with calcium at 2000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with salicylic acid or ascorbic acid at 200 ppm on weight loss percentage at 30 and 60 days, in both growing seasons. Also, there were no significant differences between foliar spray with calcium at 1000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with salicylic acid or ascorbic acid at 200 ppm and foliar spray with calcium at 2000 ppm plus applied potassium at 48 kg K_2O/fed. and foliar spray with salicylic acid or ascorbic acid at 200 ppm on weight loss percentage at 30 days, in the first growing season. Moreover, there were no significant differences between foliar spray with calcium at 0 ppm (control) or 1000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with salicylic acid or ascorbic acid at 200 ppm and foliar spray with calcium at 2000 ppm plus applied potassium at 48 kg K_2O/fed. and foliar spray with salicylic acid at 200 ppm on weight loss percentage at 60 days, in the second growing season. On the other hand, there were no significant differences between foliar spray with calcium at 1000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 2000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with ascorbic acid at 200 ppm on weight loss percentage at 90 and 120 days, in both growing seasons. Also there were no significant differences between spray with calcium at 1000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 1000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with salicylic acid at 200 ppm on weight loss percentage at 90 days, in the first growing season. Moreover, there were no significant differences between foliar spray with calcium at 0 ppm (control) or 1000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 2000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with ascorbic acid at 200 ppm on weight loss percentage at 120 days, in both growing seasons. Also there were no significant differences between foliar spray with calcium at 1000 or 2000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with salicylic acid or ascorbic acid at 200 ppm and foliar spray with calcium at 0 ppm (control) plus applied potassium at 72 kg K_2O/fed. and foliar spray with ascorbic acid at 200 ppm on weight loss percentage at 120 days, in the first growing season. For decay percentage, there were no significant differences between foliar spray with calcium at 2000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 1000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with ascorbic acid at 200 ppm, in the first growing season, while there were no significant differences between foliar spray with calcium at 1000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with ascorbic acid at 200 ppm and foliar spray with calcium at 0 ppm (control) or 2000 ppm plus applied potassium at 72 kg K_2O/fed. and foliar spray with ascorbic acid at 200 ppm, in the second growing season.

Table 17. Weight loss and decay percentage of sweet potato tuber roots as affected by the interactions among calcium, potassium and some antioxidants; i.e., salicylic acid and ascorbic acid, separately at different rates during 2011 and 2012 growing seasons.

Treatments			Parameters									
			Weight Loss (%)								Decay (%)	
			30 days		60 days		90 days		120 days			
Ca.	Po.	An.	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Control	Control	Control	13.52 a	13.07 a	23.18 a	21.85 a	29.11 a	28.38 a	33.97 a	31.36 a	27.38 a	24.99 a
		Sa. acid	10.55 def	10.63 efghi	19.59 cd	19.05 cdef	25.00 f	24.69 f	29.80 cd	28.97 de	24.97 b	23.60 b
		As. acid	11.22 cd	10.78 efgh	20.28 c	19.34 cde	24.66 g	24.54 f	29.57 d	28.55 efg	24.41 c	23.41 b
	48 kg K_2O/fed.	Control	12.60 ab	11.50 cde	20.26 c	20.03 bc	27.77 c	26.00 d	32.26 b	29.72 c	23.69 d	22.30 c
		Sa. acid	9.91 efghi	9.52 jk	16.83 ghi	16.38 ijkl	23.44 ij	23.04 j	27.40 e	27.38 h	21.00 hij	20.09 efg
		As. acid	10.46 defg	9.94 hijk	17.65 fg	16.95 ij	23.15 k	22.76 k	27.01 e	26.41 i	20.89 ijk	19.60 g
	72 kg K_2O/fed.	Control	11.93 bc	11.45 cde	19.48 cd	18.40 efg	23.16 k	23.37 i	30.28 c	27.27 h	21.72 e	20.29 def
		Sa. acid	8.98 ijk	8.98 klm	15.97 hijk	15.65 klm	20.37 l	20.18 n	25.20 f	25.38 j	18.76 n	17.06 k
		As. acid	9.27 hi	9.14 k	16.61 ghij	16.03 jklm	20.14 m	19.86 o	25.02 fg	24.69 kl	18.30 o	16.55 klm
1000 ppm	Control	Control	12.76 ab	12.68 ab	21.81 b	20.98 ab	28.96 a	27.37 b	33.59 a	30.89 ab	24.37 c	23.19 b
		Sa. acid	9.98 efghi	10.26 ghij	18.52 def	18.13 fgh	24.70 g	24.00 g	29.74 d	28.69 ef	21.40 efg	20.68 d
		As. acid	10.62 de	10.36 fghij	19.26 cde	18.25 efgh	24.31 h	23.71 h	29.65 d	28.34 fg	21.32 fgh	19.93 efg
	48 kg K_2O/fed.	Control	11.93 bc	11.37 cdef	20.30 c	20.02 bc	26.77 d	25.84 d	32.35 b	29.54 c	21.68 ef	20.39 de
		Sa. acid	9.05 ij	9.51 jk	16.71 ghij	16.23 ijkl	23.50 i	22.48 l	27.08 e	26.75 i	19.57 l	18.37 ij
		As. acid	9.69 efghi	9.74 ijk	17.41 fg	16.41 ijkl	23.35 ijk	22.31 l	26.95 e	26.35 i	19.05 mn	18.18 j
	72 kg K_2O/fed.	Control	10.27 defgh	10.98 defg	19.50 cd	18.35 efg	23.43 ij	23.02 j	29.72 d	26.56 i	19.08 mn	18.99 h
		Sa. acid	7.34 l	7.66 n	14.81 l	14.94 m	19.81 no	19.65 p	24.97 fg	25.00 jk	17.00 pq	16.94 kl
		As. acid	7.64 l	8.06 mn	15.75 ijkl	15.34 lm	19.61 o	19.46 q	24.57 g	24.45 l	16.68 qr	16.37 m
2000 ppm	Control	Control	12.21 bc	12.27 abc	21.73 b	19.91 bc	28.64 b	26.35 c	33.64 a	30.62 b	23.60 d	22.25 c
		Sa. acid	9.38 ghi	10.00 ghijk	17.69 fg	17.09 hij	24.44 h	23.59 h	29.69 d	28.54 efg	20.67 jk	20.36 def
		As. acid	9.46 fghi	10.21 ghij	18.30 ef	17.39 ghi	24.29 h	23.41 i	29.30 d	28.13 g	20.53 k	19.85 fg
	48 kg K_2O/fed.	Control	10.78 de	11.86 bcd	20.17 c	19.62 cd	26.29 e	25.65 e	32.03 b	29.31 cd	21.26 ghi	20.18 def
		Sa. acid	7.87 kl	9.12 kl	16.63 ghij	16.01 jklm	23.40 ij	22.43 l	27.37 e	26.73 i	19.36 lm	18.07 j
		As. acid	8.00 jkl	9.37 jk	16.98 gh	16.60 ijk	23.25 jk	21.98 m	26.96 e	26.32 i	19.04 mn	17.87 j
	72 kg K_2O/fed.	Control	10.29 defgh	11.00 defg	19.68 c	18.46 defg	23.41 ij	23.34 i	29.57 d	26.45 i	19.50 l	18.88 hi
		Sa. acid	7.39 l	7.69 n	15.04 kl	15.01 m	19.86 n	19.87 o	25.00 fg	25.05 jk	17.07 p	17.02 kl
		As. acid	7.67 l	8.10 lmn	15.64 jkl	15.53 klm	19.68 no	19.50 pq	24.71 fg	24.52 l	16.43 r	16.49 lm

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.
Ca. = Calcium & Po. = Potassium & An. = Antioxidants & Sa. acid = Salicylic Acid & As. acid = Ascorbic Acid.
Salicylic acid and Ascorbic acid were applied at 200 ppm.

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تأثير الكالسيوم والبوتاسيوم وبعض مضادات الأكسدة على النمو والمحصول والقدرة التخزينية فى البطاطا:

2- المكونات الكيماوية والقدرة التخزينية للجذور الدرنية خلال فترة التخزين.

سمير كامل الصيفى[1] ، محمود عبد المحسن حسن[1] ، سوسن محمد حسن سرج[1] ، أسامة محمد سيف الدين[2] ومحمد احمد محمد على.[1]

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أجريت تجريتان حقليتان فى مزرعة البرامون للبحث الزراعى التابعة لمحطة بحوث البساتين بالمنصورة خلال موسمى الزراعة الصيفى (2011 ، 2012) على نباتات البطاطا صنف بيوريجارد بهدف دراسة تأثير الرش الورقى بالكالسيوم بمعدل (صفر ، 1000 ، 2000 جزء فى المليون) على صورة سترات كالسيوم 21 ٪ ، التسميد الأرضى البوتاسى بمعدل (صفر ، 48 ، 72 كجم أكسيد بوتاسيوم/فدان) على صورة سلفات بوتاسيوم 48 ٪ ، بالأضافة إلى الرش الورقى بمضادات الأكسدة بمعدل (صفر ، حامض الأسكوربيك بمعدل 200 جزء فى المليون ، حامض السالسيليك بمعدل 200 جزء فى المليون) على بعض المكونات الكيماوية والقدرة التخزينية للجذور الدرنية خلال فترة التخزين. أوضحت النتائج المتحصل عليها أن الرش الورقى بالكالسيوم بمعدل 2000 جزء فى المليون منفرداً أو 1000 جزء فى المليون عند إضافته مع التسميد الأرضى البوتاسى بمعدل 72 كجم أكسيد بوتاسيوم/فدان مع الرش الورقى بحامض الأسكوربيك أو حامض السالسيليك كلٍ بمعدل 200 جزء فى المليون كمضادات أكسدة أدى إلى زيادة معنوية فى بعض المكونات الكيماوية والقدرة التخزينية للجذور الدرنية خلال فترة التخزين مقارنة بالكنترول. لوحظت التفاعلات الموجبة بين الرش الورقى بالكالسيوم ومستويات التسميد الأرضى البوتاسى والرش الورقى بمضادات الأكسدة.

وجد أن أفضل نتيجة تم الحصول عليها هى الرش الورقى للبطاطا بالكالسيوم بمعدل 2000 جزء فى المليون منفرداً أو 1000 جزء فى المليون عند إضافته مع التسميد الأرضى البوتاسى بمعدل 72 كجم أكسيد بوتاسيوم/فدان مع الرش الورقى بحامض الأسكوربيك أو حامض السالسيليك كلٍ بمعدل 200 جزء فى المليون كمضادات أكسدة.