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Effect of Foliar Spray with Calcium and some Antioxidants on Growth, Yield and Yield Quality of Potato

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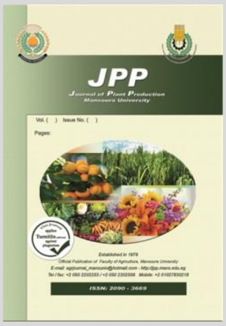

ABSTRACT

Two field trials were conducted on potato plants cv. Spunta, in the vegetable private farm at Kafr Meet Faris, Dakahlia Governorate, during two winter seasons of 2017/2018 and 2018/2019 to study the influence of foliar spray with calcium (0, 1000, 1500 and 2000 ppm) and some antioxidants (control, Ascorbic acid at 300 ppm, boric acid at 100 ppm and Salicylic acid at 50 ppm) in additions to their interaction on plant growth, yield and its components as well as chemical constituents in tuber.In general, all the studied characteristics were better in plants sprayed calcium compared with the control treatment. Plant length, number of main stems/plant, number of leaves/plant, leaf area and foliage dry weight/plant, total tubers yield, marketable tubers yield, tuber dry weight, the tuber content of N, P, K, starch and TSS were increased with increasing calcium level up to 2000 ppm.Foliar spray with antioxidants led to significant increases of the vegetative growth characteristics and enhanced total yield and its components as well as chemical constituents in tuber. Foliar spray with boric acid at 100 ppm have the highest records in all studied characteristics followed by Salicylic acid in both seasons.The positive interactions between foliar spray calcium levels and foliar spray with antioxidants were often observed.The best results were obtained by plants sprayed calcium at the level of 2000 ppm and boric acid followed by Salicylic acid.Therefore, this treatment could be recommended for raising potato yield and improving tuber quality of potato under such conditions of this study.

Keywords: Potato, calcium, antioxidants, potato growth, yield and tuber quality.

INTRODUCTION

Potato (*Solanum tuberosum*, L.) is a major world food crop. Potato is exceeded only by wheat, rice, and maize in world production for human consumption. In Egypt, it has been generally cultivated for both local consumption and export. Therefore, increasing potato yield and improving tuber quality are essential aims for both growers and consumers, but it usually depends on many factors especially that influence the plant growth throughout the growth period.

Calcium is one of the three secondary nutrients, along with magnesium and sulfur, it is required by plants for healthy growth. Calcium has many roles in plant: participates in metabolic processes of other nutrients uptake; promotes proper plant cell elongation; strengthen cell wall structure- calcium is an essential part of plant cell wall (Marschner, 1995 and Mengel and Kirkby, 2001). Also, promotes root development and growth of the plant as it is involved in root elongation and cell division, Calcium therefore increases plant tissue resistance against biotic and abiotic stress (Iiyama *et al.* 1994). It also plays an important role in tuber quality by forming part of the membrane cell wall structures (Kleinhenz and Palta 2002). Arvin *et al.*, (2005) revealed that increasing calcium in plant enhances plant tissue resistance to bacterial phytopathogens, and also enhances the structural of cell walls and membranes.

The efficiency of fertilizers used in Egypt is low, either as a result of high pH of soil or high concentration of soil calcium carbonate. This problem could be solved by addition amounts of macro-elements fertilizers to the soil or through foliar application of them (Alexander, 1986). The positive effect of foliar application of macronutrients on growth, yield and chemical constituents of different plants may be attributed to the fact that these elements which can be readily absorbed by the leaves as a result of foliar spraying application and not lost through fixation, decomposition or leaching under unfavorable soils conditions (Doeing, 1986).

Several investigators indicated that spraying plants with calcium enhanced plant growth and productivity of potato. In this respect, El-Hadidi *et al* (2017) illustrated that foliar application of Ca and Mg levels significantly increased plant growth parameters as plant fresh weight, leaf area and chlorophyll a, b and total concentrations; tubers yield and its quality as % of dry matter, starch and protein contents, and uptake of N, P, K, Ca and Mg (kg/fed) in shoots and tubers at harvest. Plant tuber yield and average tuber weight increased with increasing foliar application of Ca, whereas number of tubers/plant was decreased. Similar results reported by Chowdhury 2017, Simango and Walls 2017, Tantawy *et al.* 2017, Singh *et al.* 2018 and Mansour and Abo El-Fotoh (2019), they found that sprayed potato plants with calcium and/or boron stimulated dry matter accumulation increased tuber yield and improving quality as well as chemical composition.

Potato undergoes several adverse physiological and metabolically events and these are linked to restricted growth and tuberization during chilling stress. Exposure to drought and cold occur widely in cropping and natural ecosystems and leads to increasing reactive oxygen species (ROS) production in the chloroplast and to damaged photosynthetic function (Dat *et al*., 2000). Recently, many substances include antioxidants were exogenously applied to protect plant against adverse

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effects of environmental/oxidative stress. Antioxidants effects against the toxic and degradable effects of (ROS), e.g., O^-, OH^- and H_2O_2 which probably generated within stressed tissues were mentioned previously (Cakmank and Marschner, 1995; Bowler *et al*., 1992; Blokhina *et al*., 2003). Since, it was known that ROS induce the incidence of internal disturbances and oxidative damage, i.e., membrane breakdown, extreme permeability, solutes leakage, and depletion of carbohydrate pools within these stressed tissues (Bowler *et al*., 1992; Elstner and Osswald, 1994; Brussaard *et al*., 2007).

Ascorbic acid (AsA) is a multifunctional compound in both plants and animals (Gabriela *et al*., 2003). It plays an important role in photosynthesis as an enzymes co-factor including synthesis of abscisic acid, ethylene, gibberellins and anthocyanin and control of cell growth (Smirnoff and Wheeler, 2000). Also, it's a good scavenger of activated oxygen as O^-_2, OH^-, $^1O_2$ and reducing hydrogen peroxide (H2O2) to water via ascorbate peroxidase reaction (Bodannes and Chan, 1979 and Noctor and Foyer, 1998), as well as, enhancing the accumulation of chlorophyll and delay senescence (Mattagajasingh and Kar, 1989 and Novabour *et al*., 2003). Smirnoff (2000) found a convincing evidence of the involvement of ascorbate in cell division and the rapid growth.

Salicylic acid (SA) is an endogenous plant substance that can also be applied externally. It has an effect on physiologically process in plant at low concentration (Raskin, 1992 and Arteca, 1996). Senaratna *et al*. (2000) reported that salicylic acid or acetyl salicylic acid (ASA) enhanced tolerance to heat, chilling and drought stresses. In addition, SA participates in the plant response to adverse environmental condition (Bosch *et al*., 2007). In this respect, pretreatment of potato plants with 0.1 mM SA induced chilling tolerance (Mora-Herrera *et al*., 2005).

Boron (B) is a micronutrient necessary for plant growth. It plays an important roles in cell wall synthesis, sugar transport, cell division, cell development and synthesis of amino acids and proteins (Mengel and Kirkby, 1978). Besides, it improves calcium absorption and stabilizes calcium in cell wall. Boron reduces the oxidation of phenols and prevent discolouration of tubers (Brown *et al*., 2002).

In this respect, El-Sayed, (1991) and Arisha, (2000) found that treating potato tuber with Vit. C increased number of leaves/plant and dry weight of potato plant. Moreover, they stated that AsA had stimulatory effects on rooting and improving growth and productivity of potato. Bardisi, (2004 a) found that spraying garlic plants with Vit. C or SA recorded maximum values of plant height, number of leaves/plant, diameter of both neck and bulb and total dry weight/plant. Moreover, Awad and Mansour (2007) found that antioxidants (included SA and CA) had beneficial effects on vegetative growth characters of potato plants. In the same line, El-Morsy *et al* (2010) found that foliar application of ascorbic acid followed by citric acid significantly increased vegetative growth parameters and improved total yield and quality of garlic. Besides, El-Dissoky and Abdel-Kadar (2013) revealed that foliar spray of B-levels significantly affected potato growth parameters (i.e. plant height, No. of leaves/plant, fresh weight of plant, dry weight of plant and leaf area). Also, all of total tuber yield, dry shoot yield and average weight of tubers significantly increased. Also, foliar feeding of boron proved more effective than their soil application.

Therefore, the main objective of the present investigation is to study the influence of foliar spray with some calcium levels, as well as foliar spray with antioxidants towards better chilling tolerance and improving growth and productivity of potato crop under common local environmental condition.

MATERIALS AND METHODS

Two field experiments were carried out in vegetable private farm at Kafr Meet Faris, Dakahlia Governorate, during two winter growing seasons of 2017/2018 and 2018/2019, to study the effect of foliar spray with some calcium levels and some antioxidants on potato cv. (Spunta) growth, yield and its components, as well as tuber quality and chemical constituents in tuber. Randomized samples were obtained from the experiment soils before the application of chemical fertilization in both seasons of this study to determine the physical and chemical contents according to the standard method described by Jackson (1973). The obtained results are presented in Table (1).

Table 1. The physical and chemical analysis of the experimental soils.

Seasons	Physical properties (%)				Chemical properties					
	clay	Silt	Fine sand	Coarse sand	Soil type	O.M (%)	Total N (%)	Avail P(ppm)	Exch. K (ppm)	pH (1:2.5 w/v)
2017/2018	49.61	25.63	23.00	1.57	clay	1.90	0.13	7.75	217.00	7.90
2018/2019	49.83	25.78	22.47	1.63	clay	2.10	0.14	7.85	226.00	8.02

The experimental design was split-plots with three replicates. Tuber seeds were planted on 15th and 20th of October in the first and the second season, respectively. Foliar spray with calcium levels occupied the main plots which were subdivided to 4 sub plots each contained one of the antioxidants. The plot area was 17.5 m^2 (5 ridges each with 5 m. long and 0.75 m apart). Each experiment included 16 treatments which were 4 calcium levels and 4 antioxidants as follows:

a- Calcium levels:

1- Control treatment (untreated).
2- Foliar spray at 1000 ppm.
3- Foliar spray at 1500 ppm.
4- Foliar spray at 2000 ppm.

All calcium levels were sprayed as calcium citrate (20%Ca).

b- Antioxidants:

1- Control (untreated).
2- Ascorbic acid (300 ppm).
3- Boric acid (50 ppm).
4- Salicylic acid (100 ppm).

These treatments were supplied as a foliar application at three times 45, 60 and 75 days after planting (DAP) in the rate of 200 L/fed. The control treatment was sprayed with tap water.

All the treatments were fertilized with the recommendation rates of NPK, 150 kg N/fed (ammonium nirate, 33.5% N) was added at three equal doses after 3, 5 and 7 weeks from planting, 75 kg P_2O_5/fed (Superphosphate 15.5% P_2O_5) was added once before planting and potassium sulphate (48% K_2O) was added once at 96 kg K_2O/fed after 7 weeks from planting date. The other cultural practices were applied according to the instructions laid down by the Ministry of Agriculture, Egypt.

Data recorded:

1- Growth parameters:

A random sample of three potato plants were taken from each plot after 90 DAP to estimate the plant stem length (cm), number of main stems/plant, number of leaves/plant, leaf area/plant (m^2) and foliage dry weight/plant (gm).

2- Yield and its components:

At harvest time, yield of each plot weighted in kg and converted to total yield (tons/fed), marketable tubers weight (ton/fed), average of tuber dry weight (gm) and T.S.S of tuber were recorded as well as dry weight of tuber (%) and starch content in tuber (%) were determined according to the methods which described by (AOAC, 1990) .

3- Chemical constituents in tuber:

Nitrogen, phosphour and potassium were determined after harvest in the digested dry matter of tubers according to Rangana methods (1979).

Data were subjected to the statistical analysis and means were compared using new L.S.D according to (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

1- Vegetative growth characters:

Data in Table (2) show that stem length, number of leaves/plant, leaf area/plant and foliage dry weight/plant were significantly increased in both seasons by increasing calcium foliar spray level up to 2000 ppm, while number of main stems/plant was affected by the different levels of calcium in the first season only. This result may be due to calcium role in plant such as; promotes proper plant cell elongation; strengthen cell wall structure; it forms calcium bectat compounds which give stability to cell walls and bind cells together; participates in enzymatic and hormonal processes (Marschner, 1995 and Mengel and Kirkby, 2001). These results accordance with those of El-Hadidi *et al* (2017) they illustrated that foliar application of Ca and Mg levels significantly increased plant growth parameters at 90 days as plant fresh weight and leaf area. Similar results reported by Mansour and Abu El-Fotoh (2018).

Table 2. Vegetative growth characters of potato plants as affected by calcium levels, antioxidants and their interactions during 2017/2018 (S1) and 2018/2019 (S2) winter seasons.

Characters		Plant height (cm)		No of main stems		No of leaves		Leaf area (m^2)		Foliage dry weight(gm)	
Treatments		**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Calcium foliar spray levels:											
Control		56.08	54.16	2.00	1.83	19.33	19.91	0.29	0.28	32.00	30.83
1000 ppm		58.33	57.00	2.25	2.08	21.16	20.25	0.32	0.31	31.00	30.25
1500 ppm		60.33	60.91	2.66	2.33	22.25	22.66	0.34	0.42	34.66	34.75
2000 ppm		63.00	63.33	2.91	2.75	24.83	24.00	0.38	0.35	36.41	36.58
LSd at 5 %		02.21	02.87	0.44	NS	01.53	01.30	0.01	0.01	00.54	00.46
Antioxidants:											
Control		50.58	52.58	1.75	1.50	19.25	19.33	0.25	0.30	26.00	26.41
Ascorbic acid		52.16	54.16	2.08	1.66	20.00	19.83	0.31	0.33	29.50	30.00
Boric acid		70.33	69.41	3.25	3.25	25.91	24.75	0.40	0.35	41.33	39.50
Salicylic acid		64.66	59.25	2.75	2.58	22.41	22.91	0.37	0.38	37.25	36.50
LSd at 5 %		01.96	01.57	0.63	0.66	01.02	00.74	0.01	0.01	00.61	00.44
Calcium levels X Antioxidants:											
Control	Control	50.33	49.00	1.66	1.33	18.00	18.33	0.23	0.26	24.33	25.33
	Ascorbic acid	52.33	49.66	1.66	1.33	17.66	18.66	0.24	0.26	28.33	28.00
	Boric acid	62.33	65.00	2.66	2.66	22.00	22.33	0.37	0.39	39.66	36.00
	Salicylic acid	59.33	53.00	2.00	2.00	19.66	20.33	0.33	0.30	35.66	34.00
1000 ppm	Control	50.00	50.66	1.66	1.33	19.00	19.33	0.25	0.28	24.66	25.66
	Ascorbic acid	51.66	52.66	2.33	1.66	20.00	19.00	0.30	0.29	27.33	29.00
	Boric acid	68.33	66.00	3.00	3.00	24.33	22.00	0.38	0.41	39.33	35.00
	Salicylic acid	63.33	58.66	2.33	2.33	21.33	20.66	0.36	0.34	32.66	31.33
1500 ppm	Control	51.33	56.00	1.66	1.66	19.66	19.33	0.26	0.28	26.66	26.66
	Ascorbic acid	52.33	57.00	2.33	1.66	20.33	20.66	0.33	0.31	30.00	31.00
	Boric acid	72.00	69.66	3.66	3.33	26.33	26.33	0.40	0.43	42.33	42.33
	Salicylic acid	65.66	61.00	3.00	2.66	22.66	24.33	0.37	0.36	39.66	39.00
2000 ppm	Control	50.66	54.66	2.00	1.66	20.33	20.33	0.27	0.31	28.33	28.00
	Ascorbic acid	52.33	57.33	2.33	2.00	22.00	21.00	0.36	0.37	32.33	32.00
	Boric acid	78.66	77.00	3.66	4.00	31.00	28.33	0.47	0.46	44.00	44.66
	Salicylic acid	70.33	64.00	3.66	3.33	26.00	26.33	0.41	0.40	41.00	41.66
LSd at 5 %		03.92	03.14	NS	NS	02.04	01.49	0.02	NS	01.23	00.89

Also, Data in Table (2) reveal that foliar sprays with antioxidants (ascorbic acid, boric acid and salicylic acid at in used levels) exerted significant increases on all studied parameters of vegetative growth compared with the untreated plants in both seasons. In this connection, plants sprayed with boric acid were generally stocky and healthy in appearance than the other treatments followed by salicylic acid in both seasons. These results could be attributed to the great role of such substances has a stimulatory effects on physiological process in plants (Raskin, 1992 and Arteca, 1996). These results agreement with those of El-Dissoky and Abdel-Kadar (2013) who found that foliar spray of B-levels significantly affected potato growth parameters (i.e. plant height, No. of leaves/plant, fresh weight of plant, dry weight of plant and leaf area). Similar results reported by Sharaf-Eldin *et al* (2019) on sweet potato. Also, SA and AsA increased the accumulation of chlorophyll synthesis (De Tullio *et al.*, 1999 and Maibangsa *et al.*, 2000). In this respect, El-Sayed, (1991) and Arisha, (2000) found that treating potato tuber with Vit. C increased number of leaves/plant and dry weight of potato plant. Likewise, Gad El-Hak *et al.*, (2002) stated that AsA had stimulatory effects on rooting and improving growth and productivity on potato crop. Recently, Amin *et, al.*, (2007) mentioned that SA improved most growth characters of onion plants. Furthermore, Awad and Mansour (2007) found that antioxidants (included SA and CA) had beneficial effects on vegetative growth characters of potato plants.

In the same table (2), the interaction results indicated that the vegetative growth characters i.e., stem length, number of leaves/plant and foliage dry weight/plant were significantly affected by spraying calcium levels with all antioxidants in both seasons. Whereas, number of main stems/plant was not affected with different treatments. Also, leaf area/plant was affected in the first season only. The highest records were obtained from the interaction between spray with calcium at 2000 ppm and boric acid followed salicylic acid in both seasons. These results may be related to the important role of boron to improves calcium absorption and stabilizes calcium in cell wall. Boron plays an important roles in cell wall synthesis, sugar transport, cell division, cell development and synthesis of amino acids and proteins (Mengel and Kirkby, 1978). These results are agreement with those of El- Dissoky and Abdel-Kadar (2013), Chowdhury (2017), Simango and Walls (2017), Tantawy *et al*, (2017) and Mansour and Abu El-Fotoh (2018) they found that spraying potato plants with calcium or boron singly or in combination gave the higher values of plant height , number of leaves/plant , both fresh and dry weight of potato plant than that of plants which sprayed with calcium or boron singly.

2- Yield and its components:

Data in Tables (3 and 4) indicated that the total yield, marketable yield number of tubers/plant and average tuber weight were significantly affected by application of calcium levels in both seasons. Spraying calcium at the level of (2000 ppm) had an increases of total yield, marketable yield, number of tubers/plant and average tuber weight in both seasons. Moreover, the percentage of tuber dry weight, T.S.S% and starch% in tuber were increased with increasing calcium level up to 2000 ppm in both seasons, also. These results may be related to stocky and healthy of plant growth with increasing calcium foliar spray (Table 2) which had positive reflecte on yield. These results are in accordance with those obtained by Hamdi *et al.,* (2015) they found that applying additional calcium nitrate levels (0, 20, 40, 60, 80, 100 and 120 kg ha-1) increased tubers yield, tuber weight, dry matter and tuber size.

Table 3. Total yield and its components of potato plants as affected by calcium levels, antioxidants and their interactions during 2017/2018 (S1) and 2018/2019 (S2) winter seasons.

Characters		Total yield (ton/fed)		Marketable yield (ton/fed)		Number of tubers /plant		Tuber weight average (gm)	
Treatments		**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Calcium Foliar spray levels:									
Control		13.25	13.75	12.74	13.27	3.9	4.2	105.62	110.38
1000 ppm		13.90	14.28	13.41	13.85	4.3	4.4	116.69	119.59
1500 ppm		14.65	14.63	14.22	14.17	4.5	4.5	121.18	123.95
2000 ppm		15.13	15.61	14.69	15.18	4.6	4.7	122.30	127.07
LSd at 5 %		00.05	00.03	00.04	00.04	0.1	0.1	000.86	000.18
Antioxidants:									
Control		13.12	13.67	12.54	13.10	3.8	3.8	103.11	106.25
Ascorbic acid		14.12	14.48	13.62	14.02	4.2	4.3	114.20	117.54
Boric acid		15.20	15.27	14.84	14.91	4.8	4.9	126.85	131.27
Salicylic acid		14.50	14.84	14.07	14.43	4.6	4.8	121.64	125.93
LSd at 5 %		00.04	00.02	00.05	00.03	0.1	0.1	001.32	000.35
Calcium levels X Antioxidants:									
Control	Control	12.36	13.01	11.71	12.38	3.6	3.5	90.88	99.25
	Ascorbic acid	13.31	13.48	12.78	13.01	3.8	4.0	105.01	107.42
	Boric acid	13.94	14.36	13.53	13.96	4.2	4.7	116.60	119.74
	Salicylic acid	13.41	14.15	12.93	13.72	4.1	4.7	110.00	115.12
1000 ppm	Control	12.85	13.35	12.23	12.76	3.7	3.8	104.51	106.29
	Ascorbic acid	13.96	14.25	13.44	13.81	4.1	4.3	114.21	118.81
	Boric acid	14.59	14.95	14.21	14.63	4.8	4.9	127.85	129.14
	Salicylic acid	14.21	14.59	13.78	14.20	4.6	4.7	120.19	124.11
1500 ppm	Control	13.35	13.65	12.81	13.08	3.9	4.0	107.11	109.00
	Ascorbic acid	14.60	14.78	14.15	14.28	4.3	4.3	120.00	121.75
	Boric acid	15.94	15.27	15.62	14.91	4.2	5.0	130.75	136.21
	Salicylic acid	14.72	14.83	14.29	14.40	4.6	4.8	126.85	128.85
2000 ppm	Control	13.92	14.69	13.41	14.16	4.1	4.0	109.92	110.44
	Ascorbic acid	14.62	15.42	14.11	15.00	4.4	4.6	117.56	122.19
	Boric acid	16.34	16.51	15.98	16.15	5.1	5.1	132.20	140.00
	Salicylic acid	15.67	15.82	15.27	15.41	4.9	5.0	129.52	135.65
LSd at 5 %		00.09	00.05	00.10	00.06	0.1	0.1	001.64	003.70

In the same line, El-Hadidi *et al*, (2017) they found that plant tuber yield and average tuber weight increased with increasing foliar application of Ca, whereas number of tubers plant-1 was decreased.

Concerning the effect of foliar spray by antioxidants on the yield and its components, data in Tables (3 and 4) also revealed that the maximum total yield, marketable yield, number of tubers/plant, average tuber weight, tuber dry weight %, T.S.S% and starch % in tuber were obtained by foliar spray with boric acid followed by salicylic acid in both seasons. In this respect, Bardisi, (2004 b) on garlic, stated that foliar spray with AsA at 100, 200 ppm and SA at 50 ppm gave the highest yield. Amin *et al*., (2007) reported that SA improved yield and yield components of onion plants. Also, Abd El-Mageed *et al*., (2009) recorded that low concentration (100 ppm) of ASA enhanced fresh yield of garlic compared with high concentration. Besides, El-Dissoky and Abdel-Kadar (2013) found that foliar spray of B-levels significantly increased total tuber yield, and average weight of tubers significantly increased. Also, Sharaf-Eldin *et al*. (2019) found that similar results on sweet potato.

Regarding the interaction effects, it is clear from data in Tables (3 and 4) that the interactions between foliar spray of calcium levels and antioxidants had a significant effect on total tubers yield, number of tubers/plant, average tuber weight, dry weight of tuber, T.S.S. % and starch of tuber %. In general, plants sprayed with 2000 ppm calcium level and boric acid produced the highest values. These results may be related to the important roles of boron in improves calcium absorption and stabilizes calcium in cell wall, sugar transport, cell division, cell development and synthesis of amino acids and proteins (Mengel and Kirkby, 1978). These results coincide with those of Chowdhury (2017), Simango and Walls (2017), Tantawy *et al.* (2017) and Mansour and Abu El-Fotoh (2019) they found that spraying potato plants with calcium or boron singly or in combination gave the higher yield as well as yield components than that of plants which sprayed with calcium or boron singly.

Table 4. Dry weight of tuber %, TSS% and Starch% as affected by calcium levels, antioxidants and their interactions during 2017/2018 (S1) and 2018/2019 (S2) winter seasons.

Character		Dry weight of tubers %		TSS %		Starch %	
Treatments		S1	S2	S1	S2	S1	S2
Calcium Foliar spray levels:							
Control		19.08	19.83	5.41	5.41	13.60	13.91
1000 ppm		19.83	20.33	5.62	5.54	14.22	13.83
1500 ppm		20.75	21.25	5.62	5.83	14.29	14.56
2000 ppm		22.00	22.08	5.87	5.70	15.20	15.59
LSd at 5 %		00.54	0.59	NS	0.23	00.05	00.01
Antioxidants:							
Control		19.41	19.41	5.16	5.25	13.35	13.69
Ascorbic acid		20.33	20.91	5.58	5.62	13.86	14.39
Boric acid		21.50	21.91	6.00	5.91	15.48	15.28
Salicylic acid		20.41	21.25	5.79	5.70	14.62	14.53
LSd at 5 %		00.40	00.42	0.32	0.30	00.03	00.01
Calcium levels X Antioxidants:							
Control	Control	18.00	18.33	5.00	5.00	13.14	13.91
	Ascorbic acid	19.00	20.00	5.33	5.16	13.07	13.63
	Boric acid	20.00	20.66	5.66	5.83	14.45	14.29
	Salicylic acid	19.33	20.33	5.66	5.66	13.75	13.80
1000 ppm	Control	19.00	19.00	5.00	5.00	13.19	12.94
	Ascorbic acid	20.00	20.33	5.66	5.66	13.73	13.82
	Boric acid	20.66	21.33	6.00	5.83	15.29	14.64
	Salicylic acid	19.66	20.66	5.83	5.66	14.68	13.93
1500 ppm	Control	20.00	19.66	5.16	5.66	13.45	13.34
	Ascorbic acid	20.66	21.33	5.66	5.83	13.70	14.51
	Boric acid	21.66	22.33	6.00	6.00	15.76	15.84
	Salicylic acid	20.66	21.66	5.66	5.83	14.26	14.57
2000 ppm	Control	20.66	20.66	5.50	5.33	13.61	14.57
	Ascorbic acid	21.66	22.00	5.66	5.83	14.96	15.61
	Boric acid	23.66	23.33	6.33	6.00	16.43	16.35
	Salicylic acid	22.00	22.33	6.00	5.66	15.81	15.84
LSd at 5 %		NS	NS	NS	NS	00.07	00.02

Chemical constituents in tuber:

Data in Table (5) indicated that the contents of N, P and K (%) in tuber increased significantly by increasing foliar spray of calcium level up to 2000 ppm in both seasons. The highest concentrations of N, P and K in tuber were obtained when plants sprayed by calcium at the level of 2000 ppm in both seasons. These results are in harmony with those of El-Hadidi *et al*, (2017) they found that at harvest, tubers content of N, P, K, Ca and Mg increased significantly with foliar application of Ca up to Ca2 (0.8 % Ca) and spraying with Mg up to level Mg1 (0.2 % Mg). Similarly, reported by Mansour and Abu El-Fotoh (2019).

With respect to effect of antioxidants, results in Table (5) showed that the contents of N, P and K in tubers increased significantly by spraying all antioxidants used compared with the control treatment. The highest records resulted in spray with boric acid followed by salicylic acid in both seasons. Similar results were reported by El-Dissoky and Abdel-Kadar (2013).

Concerning the interaction between foliar spray of calcium levels and antioxidants, the data in Table (5) indicated that the concentrations of N, P and K were affected by the interaction in both seasons. The highest values of N, P and K were obtained by spraying calcium at level of 2000 ppm with spraying boric acid compared with the other treatments. These results are in accordance with those obtained by Mansour and Abu El-Fotoh (2019).

Table 5. Chemical constituents in potato tuber as affected by calcium levels, antioxidants and their interactions during 2017/2018 (S1) and 2018/2019 (S2) winter seasons.

Characters		Chemical constituents					
		N %		P %		K %	
Treatments		S1	S2	S1	S2	S1	S2
Calcium Foliar spray levels:							
Control		2.75	2.99	0.29	0.27	2.57	2.80
1000 ppm		3.00	3.21	0.32	0.30	2.61	2.56
1500 ppm		3.21	3.39	0.38	0.38	2.75	2.45
2000 ppm		3.47	3.54	0.37	0.40	2.58	2.43
LSd at 5 %		0.004	0.005	0.04	0.04	0.005	0.008
Antioxidants:							
Control		2.53	2.51	0.29	0.31	2.51	2.51
Ascorbic acid		3.03	3.40	0.33	0.31	2.49	2.64
Boric acid		3.76	3.81	0.36	0.36	2.71	2.73
Salicylic acid		3.11	3.42	0.37	0.35	2.79	2.35
LSd at 5 %		0.005	0.009	0.034	NS	0.009	0.007
Calcium levels X Antioxidants:							
Control	Control	2.48	2.20	0.22	0.24	2.25	2.73
	Ascorbic acid	2.69	3.16	0.28	0.26	2.88	2.83
	Boric acid	3.30	3.43	0.34	0.32	2.18	2.98
	Salicylic acid	2.54	3.18	0.32	0.27	2.95	2.67
1000 ppm	Control	2.42	2.50	0.30	0.26	2.11	2.90
	Ascorbic acid	2.80	3.29	0.32	0.28	2.42	2.84
	Boric acid	3.90	3.69	0.34	0.33	2.94	2.34
	Salicylic acid	2.88	3.39	0.32	0.32	2.98	2.15
1500 ppm	Control	2.68	2.49	0.32	0.33	2.97	2.11
	Ascorbic acid	3.02	3.47	0.35	0.35	2.43	2.64
	Boric acid	3.82	3.92	0.38	0.39	2.94	2.78
	Salicylic acid	3.33	3.69	0.46	0.43	2.66	2.26
2000 ppm	Control	2.54	2.85	0.33	0.43	2.72	2.31
	Ascorbic acid	3.63	3.68	0.37	0.37	2.24	2.25
	Boric acid	4.02	4.21	0.40	0.41	2.76	2.83
	Salicylic acid	3.70	3.42	0.38	0.39	2.58	2.34
LSd at 5 %		0.01	0.01	NS	NS	0.01	0.01

REFFERENCES

A.O.A.C. (1990). Association of Official Agricultural Chemists.Official Methods of Analysis. 10th. Ed. A.O.A.C., wash., D.c

Abd El-Mageed, I. Y. T.; N. S. Youssef, and Shereen M. Youssef (2009). Effect of some anti oxidant sources on growth, yield and storability of garlic. Egypt J. Agric. Res., 87 (1): 245-264.

Alexander, A. (1986). Foliar fertilization. ed. By Alexander. Schering Agroche-mical Division, Special fertilizer group, Berlin (FRG), P. 17-60.

Amin, A. A., Sh. M. Rashad and H. M. H. El-Abagy (2007). Physiological effect of indol3-butyric acid and salicylic acid on growth, yield and chemical constituents of onion plants. Journal of Applied Sciences Research, 3(11): 1554-1563.

Arisha, H.M. (2000). Effect of vitamin C on growth, yield and tuber quality of some potato cultivars under sandy soil conditions. Zagazig J. Agric. Res. 27 (1): 91-104.

Arteca, R. N. (1996). Plant Growth Substances. Principles and Application. Chapman and Hall. ISS fifth Avenue, New York, 332 pp.

Arvin, M.; A. Habib and J. Donnelly (2005). Effect of calcium concentrations in medium on microtuberization of potato (*Solanum tuberosum* L.). Iranian J. Biotech., 3: 3.

Awad, E. M. M. and Safa, A. A. Mansour (2007). Growth and quality of potato as affected by some antioxidants. J. Agric. Mansoura Univ., 32 (8): 6661-6669.

Bardisi, A. (2004 a). Influence of vitamin C and Salicylic acid foliar application on garlic plants under sandy soil condition. 1. Growth and plant chemical composition. Zagazig J. Agric. Res., Vol. 31 No (4A): 1337-1348.

Bardisi, A. (2004 b). Influence of vitamin C and Salicylic acid foliar application on garlic plants under sandy soil condition. 2. Yield and its Storability. Zagazig J. Agric. Res., Vol. 31 No (4A): 1349-1360.

Blokhina, O.; E. Virolainen, and K. V. Fagersted (2003). Antioxidants, oxidative damage and oxygen deprivation stress. A review. Ann Bot. (lond.), 91: 179-194.

Bodannes, R. S. and P. C. Chan (1979). Ascorbic acid as a scavenger of singlet oxygen. FEBS Lett, 105: 195-196.

Bosch, S. M.; J. Penuelas and J. Llusia (2007). A deficiency in salicylic acid alters isoprenoid accumulation in water-stressed NahG transgenic Arabidopsis plants. Plant Science, 172 (4): 125-127.

Bowler, C.; M. V. Montogu and D. Inze (1992). Superoxide dismutase and stress tolerance. Ann. Rev. Plant Physiol. Plant Mol. Biol., 48: 233-250.

Brown, P.H., N. Bellaloui, M.A. Wimmer, E.S. Bassil, J. Ruiz, H. Hu and V. Römheld (2002). Boron in plant biology, 205-223

Brussaard, L., C. Peter de Ruiter, and G. G. Brown (2007). “Soil biodiversity for agricultural sustainability.” Agriculture, Ecosystems and Environment 121: 233–244.

Cakmank, T. and H. Marschner (1995). Magnesium deficiency and high light intensity enhance activities of super oxide dismutase, ascorbite peroxidase and glutathione reductase in bean leaves. Plant Physiol., 98: 1222-1227.

Chowdhury R.S. (2017). Effect of calcium, magnesium, sulphur, zinc and boron on growth and yield of potato (cv. KufriJyoti). M.Sc Thesis, Fac. Hort. Uttar BangaKrishiViswavidyalaya.

Dat, J.; S. Vandenabeele, E. Vranova, M. Van Montagu, D. Inze, and V. F. Breusegem (2000). Dual action of the active oxygen species during plant stress responses. Cell Mol Life Sci 57, 779-795.

De Tullio M. C.; F. Dalla Vecchia, N. Rascio, S. D. Emerico, L. DeGara, R. Liso, and O. Arrigoni (1999). Change in onion root development induced by the inhibition of peptide-ppropyl hydroxylase and ifluence of the ascorbate system on cell division and elongation. Planta 209: 424-434.

Doeing, H.W. (1986). Foliar fertilization. An effect method for controlling micronutrients deficiencies on calcareous and saline soil in arid lands. In: Proc. Symp. Application of Special Fertilizers. Alex. 21-23 Feb., Egypt (Ed.).

El-Dissoky R.A. and A.E.S. Abdel-Kadar (2013). Effect of Boron as a Foliar Application on Some Potatoes Cultivars Under Egyptian Alluvial Soil Conditions. Research Journal of Agriculture and Biological Sciences, 9(5): 232-240, 2013 ISSN 1816-1561.

El-Hadidi, E. M. 1; R.A. El-Dissoky and Amal A. H. Abd Elhafez (2017). Foliar Calcium and Magnesium Application Effect on Potato Crop Grown in Clay Loam Soils. J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 8(1): 1- 8, 2017

El-Morsy, A. H. A; A. S. Ezzat and U. M. Saif El-Deen (2010). Effect of some phosphorus and potassium rates and foliar spray with antioxidants on growth, yield and yield quality of garlic (*Allium sativum* L.). Annals Of Agric. Sc., Moshtohor, Vol, 48(3): 27-40, (2010

El-Sayed, H.A. (1991). Growth and yield of potato as affected by CCC, GA and vitamin C. J. Agric. Sci., Mansoura Univ.16 (3):648-652.

Elstner E. F. and W. Osswald. (1994). Mechanism of oxygen activation during plant stress. PROC. R. Soc. Edin., 102B: 131-154.

Gabriela, M. Pastori, K. Guy, A. John, B. Stephanie, V. P. Sonja, J. V. G. Noctor, and H. Ch. Foyer (2003). Leaf vitamin C contents modulate plant defense transcripts and regulate genes that control development through hormone signaling. The Plant Cell, 15, 939-951.

Gad El-Hak, S. H.; I. Y. T. Abd El-Mageed, A. A. Galal, N. S.Youssef and A. Z. Osman (2002). Influence of antioxidants and calcium chloride on potato growth and yield. Proc. Minia 1st Conf. For Agric. & Environ. Sci., Minia, Egypt, Marc. 1. 25-28.

Gommez, K. A. and A. A. Gommez (1984). “Statistical Procedure for agric. Res.” 2 nd. Ed. John-Wiley and Sons. Inc. New Yourk, 680 pages.

Gupta U.C., (1993). Boron and its role in crop production. Boca Raton, FL: CRC Press, USA pp. 53–85.

Hamdi, W.; L. Helali; R. Beji; K. Zhani; S. Ouertatani and A. Gharbi (2015). Effect of levels calcium nitrate addition on potatoes fertilizer. Int. Res. J. of Eng. and Tech. (IRJET), 2(3): 2006-2013.

Iiyama K.; T.B.T Lam and B.A. Stone (1994). Covalent cross-links in the cell wall. Plant Physiology 104: 315-320.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice-Hall of India Private Limited, New Delhi.

Kleinhenz, M. D. and J. P. Palta (2002). Root zone calcium modulates the response of potato plants to heat stress. Physiologia Plantarum, 115: 111–118.

Maibangsa, S.; M. Thangaras and R. Stephen (2000). Effect of brassinnosteroid and salicylic acid on rice (*Oryza sativa* L.) growth under low irradiance condition. Indian J. Agric. Research. 34: 258-260.

Mansour and Hanan M. Abu El-Fotoh (2018). Effect of planting date, irrigation level and foliar spraying with calcium and boron treatments on potato. 1. Plant growth, plant water relationship and plant chemical constituents. J. Product. & Dev., 23(3): 755 – 788 (2018).

Mansour and Hanan M. Abu El-Fotoh (2019). Effect of planting date, irrigation level and foliar spraying with calcium and/or boron treatments on potato crop formation. 2. Yield and its components. Cracking phenomenon and tuber quality. J. Product. & Dev., 24(1): 37 – 61(2019)

Marschner H. (1995). Mineral nutrition of higher plants. 2nd ed. Academic Press London 285-299.

Mattagajasingh, S. N. and M. Kar (1989). Changes in the oxidant system during the preening of etiolated wheat leaves. J. Plant Physiol., 134: 656-660.

Mengel, K. and E.A. Kirkby (1978). "Principles of Plant Nutrition", International Potash Institute, Bern, Switzerland.

Mengel, K. and E.A. Kirkby (2001). "Principles of Plant Nutrition", International Potash Institute, Bern, Switzerland.

Mora-Herrera M. E, H.; Lopez-Delgado, M. Castillo and C. H. Foyer (2005). Salicylic acid and H2O2 function by independent pathways in the induction of freezing tolerance in potato. Physiol. Plant 125:430–440

Noctor, G. and C. H. Foyer (1998). Ascorbate and glutathione: keeping active oxygen under control. Ann. Rev. Plant Physiol. And Plant Mol. Biol.49: 249-279.

Novabpour, S.; K. Morris; R. Allen; E. Harrison; A. H. M. Soheila and V. Buchanan-Wollaston (2003). Expression of senescence enhanced genes in response to oxidative stress. Journal of Experimental Botany, 54: 2285-2292.

Rangana, S. (1979). Manual of analysis of fruit and vegetable productes. Tata McGraw Hill Pub.Co.Ltd.New Delhi ;363 pp.

Raskin, I. (1992). Role of salicylic acid in plants. Ann Rev. Plant Physiol. Plant Mol. Biol., 43: 439-463.

Senaratna, T.; D. Touchell; E. Bunn and K. Dixon (2000). Acetyl salicylic acid (Aspirin) and salicylic acid induce multiple stress tolerance in bean and tomato plants. Plant Growth Regulation, 30 (2): 157-161.

Sharaf-Eldin, M. A.; M. A. AbdAlla; S. A. Mostafa and W. E. Montaser (2019). Boron Foliar Application in Relation to Sweet Potato Productivity. J. Plant Production, Mansoura Univ., Vol. 10 (3): 327 - 333, 2019

Simango. K., and J.E.V. Walls (2017). Effects of Different Soil Treatments on the Development of *Spongospora subterranean*. sp. subterranea in Potato Roots and Tubers in the Greenhouse. European Association for Potato Research. 60:47–60.

Singh S.K., M. Sharma , K.R. Reddy and T. Venkatesh (2018). Integrated application of boron and sulphur to improve quality and marketable yield in potato. J. Environ. Bio. (39): 204-210.

Smirnoff, N. (2000). Ascorbic acid: metabolism and functions of a multifaceted molecule. Current Opinion in Plant Biology, 3 (3): 229-235.

Smirnoff, N. and G. L. Wheeler (2000). Ascorbic acid in plants: Biosynthesis and function. Critical Rev. Plant Sci., 19 (4): 267-290.

Tantawy, A. S.; Y.A. Salama; Saleh S. A.; and A. A. Ghoname (2017). Enhancing yield and quality of two potato cultivars by using boron foliar Application. Middle East J. Appl. Sci. 7 (3): 510-518. Univ., Egypt, P 55.

تأثير الرش ببعض مستويات الكالسيوم ومضادات الأكسدة على نمو وإنتاج وجودة البطاطس

عبدالله حلمي على المرسى ، حمادة ماهر بدير المتولى* و السعيد محمود السعيد
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نُفذت تجربتان حقليتان على محصول البطاطس (صنف اسبونتا) فى مزرعة خضر خاصة بكفر ميت فارس ـ المنصورة ـ دقهلية خلال موسمى الزراعة الشتويين (2018/2017 و 2019/2018 م) لدراسة تأثير الرش الورقى بمستويات مختلفة من الكالسيوم (صفر ،1000 ،1500 ، 2000 جزء فى المليون) كل منها منفردٌ أو مع الرش ببعض مضادات الأكسدة (بدون، حمض الأسكوربيك عند تركيز 300 جزء فى المليون، حمض البوريك عند تركيز 50 جزء فى المليون و حمض الساليسيلك عند تركيز 100 جزء فى المليون) وكذلك التفاعل بينهما على نمو النباتات والمحصول ومكوناته وكذلك ايضاً المحتويات الكيماوية فى الدرنات. وقد وزعت المعاملات فى قطع منشقة مرة واحدة فى ثلاث مكررات. ويمكن تلخيص النتائج المتحصل عليها فيما يلى : أدى الرش بالكالسيوم إلى زيادة فى كل الصفات المدروسة مقارنة بالكنترول، كما أدت زيادة مستوى الرش بالكالسيوم حتى 2000 جزء فى المليون إلى حدوث زيادات معنوية فى معظم الصفات المدروسة (طول النبات، عدد السيقان الرئيسية، عدد الأوراق، المساحة الورقية، الوزن الجاف لعرش النبات، المحصول الكلى، المحصول القتصادى، الوزن الجاف للدرنات ومحتوى الدرنات من النتروجين والفوسفور والبوتاسيوم)، وكذا محتواها من المادة الصلبة الكلية والنشا. أدى الرش الورقى بمضادات الأكسدة إلى حدوث زيادات معنوية فى معظم صفات النمو الخضرى للنباتات والمحصول الكلى ومكوناته ، وكذلك أيضاً المحتويات الكيماوية للدرنات. وقد أدى الرش بحمض البوريك إلى الحصول على أعلى النتائج للصفات المدروسة متبوعاً بالرش بحمض الساليسيلك فى كلا موسمى الدراسة.التفاعلات بين مستويات الرش بالكالسيوم والرش بمضادات الأكسدة لوحظت فى حالات كثيرة، ولقد كانت معظم القيم المتحصل عليها بصفة عامة أفضل من تلك الناتجة باستخدام كل منها منفرداً. ولقد أدى الرش بالكالسيوم عند مستوى 2000 جزء فى المليون مع الرش بحمض البوريك إلى الحصول على أفضل النتائج. وبناءً على ماتقدم ، يمكن يمكن التوصية باستخدام هذه المعاملة لرفع إنتاجية البطاطس وتحسين صفات الجودة للدرنات تحت الظروف المشابهة لظروف هذه الدراسة.