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Effect of Salicylic Acid and Mannitol on White Cabbage Plants under Saline Conditions

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ABSTRACT

An experiment was conducted in the Experimental Farm of the Desert Research Center, Ras Sudr, South Sinai Governorate to study the effects of foliar applications of salicylic acid (SA) and mannitol (M) on white cabbage Kalorama F1 cv grown under saline conditions (soil and irrigation water). White cabbage seedlings were transplanted on to soil after forty days from seed sowing. Foliar applications began 30 and 35 days after transplantation for SA and M, respectively. A total of three sprays were given at an interval of 15 days. Three different foliar applications of SA (0, 75 and 150 mg l^{-1}) and three different M treatments (0, 2000 and 4000 mg l^{-1}) were used, in factorial randomized completely block design. Stem length, head width, head weight, total yield, vitamin C, total sugars, chlorophyll a and b, dry weight and minerals content (N, P and K) were studied. All parameters were significantly influenced by applying different SA especially 75 mg l^{-1}, as well as application of higher dose of M (4000 mg l^{-1}). The highest values were observed in 75 mg SA l^{-1} + 4000 mg M l^{-1} treatment. Thus, the present results revealed that application of foliar SA and MA must be performed to overcome saline stress conditions.

Keywords: White cabbage, yield, vitamin C, dry weight, minerals contents

INTRODUCTION

White cabbage (*Brassica oleracea* var capitata) is one of the most important vegetables in the world. Cabbage contains considerable amounts of bioactive compounds such as glucosinolates, vitamin C, carotenoids, and polyphenols (Hallmann *et al*., 2017). It is rated as a moderately sensitive to salinity (Bernstein and Ayers, 1949; Osawa, 1965). The threshold salinity is 1.8 dS m^{-1} (EC_e) with a slope of 9.7% per dS m^{-1}. Cabbage heads are more solid at low salinity levels, but are less compact as salinity increases (Osawa, 1961).

Salinity stress is a widespread environmental problem; it affects about 7% of the world's total land area (Zhu, 2002) and is the major environmental factor limiting plant growth and productivity (Allakhverdiev *et al*., 2000). Major adverse effects of salinity stress include increased ion toxicity, osmotic stress, and nutrient acquisition and homeostasis/deficiency, impaired stomatal conductance, decreased reduction in leaf water potential, altered physiological biochemical processes, and elevated ROS-caused oxidative stress(Munns and Tester, 2008; Nazar *et al*., 2011; Khan *et al*., 2014).

The significance of salicylic acid (SA) has been increasingly recognized in improved various physiological and bio-chemical functions in plants and has diverse effects on the tolerance to biotic and a biotic stress (Ashraf and Foolad, 2007; Kovacik *et al*., 2009). SA is an important signal molecule for modulating plant responses to stress. Application of SA increases plant growth by improving photosynthesis, osmotic potential, stomatal conductance transpiration rate, and biochemical parameters under salt stress (Mimouni *et al*., 2016). SA can improved growth, gas exchange, yield by inhibiting the accumulation of Na^+ and Cl^- and stimulating accumulation of mineral elements including N, P and K concentrations under salinity stress conditions (Gunes *et al*., 2005 and 2007). Some studies have shown that SA played significant role at different concentration by improving plant yield and fruit quality in many crops including tomato (Yildirim and Dursun, 2009; Javanmardi and Akbari, 2016), onion (Koppad *et al*., 2017), Broccoli (Mirdad, 2014), chickpea (Hossain *et al*., 2015).

Mannitol (M) is a six carbon sugar, white and crystalline (Zidenga, 2006), which occurs widely in plants and animals (Hellebust, 1976; Yancey *et al*., 1982), it was demonstrated that M plays a pivotal role in alleviating osmotic and salinity-induced stress in plants (Tarczynski *et al*., 1993; Stoop *et al*., 1996; Tang *et al*., 2005). Sarwar *et al*. (2006) found that application of M improved plant survival and growth up to maturity under saline conditions. The highest plant growth, total soluble sugars, proline, macro and micronutrients contents were observed under salinity stress with M application (Khalid and Cai, 2011).

In this study, we investigate the effect of SA and M on growth, yield and quality of white cabbage under salinity conditions.

MATERIALS AND METHODS

The experiment was conducted in the Experimental Farm of the Desert Research Center in Ras Sudr, South Sinai Governorate, Egypt (30° 34′ N, 31° 34′ E) during 2015/2016 and 2016/2017 seasons. The test was carried out on white cabbage Kalorama F1 variety. Seeds were sown in the 10 and 12 September and the seedlings were planted out to field in the 20 and 22 October in the first and second seasons, respectively. The seedling were planted into soil in rows 50 cm apart, with 50 cm plant spacing. The soil was characterized by sandy loam, pH value of 7.7, highly calcareous ($CaCO_3$ 57%) and saline (EC 8.65 mS cm^{-1}). Plants were drip-irrigated by saline water pumped from a well, EC 7.03 mS cm^{-1}, pH 8.6. The experiment was arranged in a factorial randomized complete block design of three replications, 2 factors were considered SA and M. The SA (Sigma-Aldrich, (98%) 2-hydroxybenzene-carboxylic, C_6H_4 (OH) COOH, MW: 138.1, were purchased from Sigma Aldrich Co.) Foliar spray of SA at a rates of 0, 75, 150 mg l^{-1} were distributed for the experimental plots through external spray over the plant's leaves using Pressurized Spray Bottle with 0.1% Tween 20 as surface spreader. Also, mannitol (Sigma- Aldrich, $C_6H_{14}O_6$, MW: 182.17, were purchased from Sigma Aldrich Co.) was applied exogenously with sprayer using three rates 0, 2000 and 4000 mg l^{-1}. All foliar applications were carried out early in the morning, starting from 30 and 35days after transplanting for SA and M, respectively. A total of three sprays were given at an interval of 15 days. Spray was done at a rate of 1000 l ha^{-1} approximately. At harvest (after 90 days from transplanting), five plants were selected randomly for data collection in each plot. Data collected on stem length, head weight, head width and total yield. Chlorophylls (a and b) were extracted with

80% aqueous acetone (v/v) and were quantified using of Arnon (1949) method. Vitamin C content was determined according to AOAC (1990). Total sugars content was measured based on the Anthrone method (Irigoyen *et al*., 1992). Oven dried (72°C for 48 h) samples of plants were weight and determined the dry matter. Nitrogen concentration was analyzed by Kjeldhal method (Ostrowska *et al*. 1991). Potassium concentration was determined by flam photometry and phosphorus concentration was determined by Olsen *et al*. (1954) method using spectrophotometry. According to Snedecor and Cochran (1990) the averages of data from each season were statistically analyzed using 2-way analysis of variance (ANOVA). The applications of that technique were according to the COSTAT statistical software.

RESULTS AND DISCUSSION

Effect of salicylic acid and mannitol on stem length, head width, head weight and total yield

Stem length, head width, head weight and total yield were affected by changes in application of salicylic acid (SA) with or without mannitol (M) in the first and second seasons (Table 1). The characters in general were significantly increased by foliar SA application, especially at 75 mg SA l^{-1}. These finding agree with the results of (Mirdad, 2014) reported that the foliar application of SA promoted plant height, yield and its quality characters of broccoli plants irrigated with saline water. This enhance may be due to the nature of the SA which acts as a plant growth regulator. It is stated that the responses to SA are highly concentration dependent, so that moderate doses of SA improve features such as antioxidant status and induce stress resistance, while higher concentrations trigger a hypersensitive cell death pathway (Tounekti *et al*., 2013). Also, application of SA led to boost of plant yield (Aghaeifard *et al*., 2015), which may be due to promoted cell division and cell enlargement (Hayat *et al*., 2010) through its influence on plant hormones such as auxins, cytokinin and ABA balance (Shakirova, 2007) and enhanced photosynthetic rate, internal CO_2 concentration and water use efficiency (Fariduddin *et al*., 2003). Regarding M, it also enhanced stem length, head width, weight of head and total yield of white cabbage and it's described in Table 1. The increase in the characters was highly significant in both seasons. The improving of plant growth characters and yield as response to application of M under salinity stress condition (Sarwar *et al*., 2006) may be due to the increase in the chlorophyll content (Table 2) and consequently, photosynthesis efficiency. On the other hand, M increases the total carbohydrates and mineral contents (Table 3), so that the plant growth increase (Slama *et al*., 2007).The highest values at each season for stem length, head width, head weight and total yield were obtained in 75 mg SA l^{-1} + 4000 mg M l^{-1}, while the lowest values were observed in the two seasons for control treatment (Table 1).

Table 1. Effect of salicylic acid and mannitol on stem length, head width, head weight and total yield of white cabbage at harvest date during 2015/2016 and 2016/2017 seasons

Treatment		Character			
Salicylic acid (SA) mg l^{-1}	Mannitol (M) mg l^{-1}	Stem length (cm)	Head width (cm)	Head weight (g)	Total yield (t ha^{-1})
1st season					
Without	Without	4.53±0.50f	11.86±0.74e	651.57±71.0e	15.27±1.32e
	2000	6.84±0.90d	12.27±0.17e	687.51±25.7de	17.90±0.81cd
	4000	7.76±0.75c	12.74±0.50d	724.59±30.5d	18.23±2.18cd
Mean		6.38±2.95	12.29±0.89	687.89±75.22	17.13±3.11
75	Without	6.77±0.70d	12.28±0.31e	712.37±66.2d	17.63±0.70cd
	2000	8.77±0.44b	13.54±0.43c	794.69±28.5c	18.71±0.60c
	4000	9.75±0.15a	14.61±0.68a	973.44±54.8a	20.84±0.59a
Mean		8.43±2.66	13.48±2.07	826.83±235.58	19.06±2.88
150	Without	5.84±0.69e	12.02±0.25e	694.89±33.4de	16.98±0.42d
	2000	9.15±0.27b	14.03±0.23b	847.62±38.6b	18.87±0.82c
	4000	8.98±0.20b	14.16±0.14b	886.68±29.4b	19.87±0.65b
Mean		7.99±3.25	13.40±2.09	809.73±178.01	18.57±2.60
Overall means of mannitol	Without	5.71±2.03	12.05±0.55	686.28±74.67	16.63±2.25
	2000	8.25±2.21	13.28±1.60	776.61±143.88	18.49±1.10
	4000	8.83±1.78	13.84±1.74	861.57±221.50	19.65±2.57
2nd season					
Without	Without	5.38±0.63f	12.10±0.51f	707.95±34.1e	16.44±0.97f
	2000	7.14±0.62e	13.05±0.68e	838.18±49.5d	18.63±0.80d
	4000	8.01±0.71cd	13.55±0.11d	885.19±29.8c	19.52±0.84c
Mean		6.84±2.39	12.90±1.34	810.44±162.54	18.20±2.85
75	Without	7.70±0.54d	12.82±0.51e	826.34±52.5d	17.96±0.59e
	2000	8.37±0.43c	14.00±0.26c	914.24±11.4c	20.16±0.75bc
	4000	9.45±0.20a	14.93±0.34a	1054.27±49.3a	21.38±0.72a
Mean		8.50±1.57	13.92±1.86	931.62±202.42	19.83±3.06
150	Without	7.06±0.24e	12.41±0.40f	802.00±23.7d	17.52±0.42e
	2000	8.90±0.29b	14.37±0.21b	966.99±58.5b	20.79±0.86ab
	4000	9.00±0.34b	14.56±0.17b	1000.94±31.5b	21.01±0.26a
Mean		8.32±1.90	13.78±2.07	923.31±187.67	19.78±3.42
Overall means of mannitol	Without	6.72±2.12	12.44±0.75	778.76±113.35	17.31±1.48
	2000	8.13±1.61	13.80±1.24	906.47±118.67	19.86±2.05
	4000	8.82±1.34	14.35±1.26	980.14±153.28	20.64±1.79
P value					
1st season	SA	0.00 (***)	0.00 (***)	0.00 (***)	0.00 (***)
	M	0.00 (***)	0.00 (***)	0.00 (***)	0.00 (***)
	SA × M	0.01 (**)	0.00 (***)	0.00 (***)	0.08 (ns)
2nd season	SA	0.00 (***)	0.00 (***)	0.00 (***)	0.00 (***)
	M	0.00 (***)	0.00 (***)	0.00 (***)	0.00 (***)
	SA × M	0.00 (***)	0.00 (***)	0.00 (**)	0.09 (ns)

Effect of SA and M on vitamin C, total sugars, chlorophyll a and b

As shown in Table 2, vitamin C, total sugars, chlorophyll a and b contents increased at all SA, M and SA + M interaction in both seasons. However, the highest values were recorded at the 75 mg SA l^{-1} + 4000 mg M l^{-1} compared with control treatment during the two seasons. ANOVA indicated that the increase in vitamin C, total sugars, chlorophyll a and b contents was significant at both seasons in all treatments, except total sugars (in both seasons), chlorophyll a and b (in first season) for SA + M treatments. The increase in vitamin C under SA treatments may be due to SA can activate ascorbate peroxidase, which is the precursor to ascorbic acid in plants and prevents vitamin C from being destroyed in cells and therefore causes the accumulation of vitamin C in the plant (Wisniewska and Chełkowski, 1999). These findings agree with the results of the experiment performed by (Javanmardi and Akbari, 2016). The stimulation effect of SA on the biosynthesis of soluble sugars was associated to an increase in photosynthetic pigments and consequently the photosynthetic system (Yildirim *et al*., 2008). Accumulation of soluble sugars in plant leaves in terms of salinity is due to reduction of the activity of glucokinase. Reduction of glucokinase activity by accumulation of soluble sugars considered as one of the important aspect of salt tolerance in SA treatment condition (Poor *et al*., 2011). (Mimouni *et al*., 2016) indicated that the treatment of plant with SA caused them to acquire higher of total sugars. The increasing pattern of chlorophyll content with SA application may be due to SA is supposed to increase the functional state of the photosynthetic machinery in plants either by the mobilization of internal tissue nitrate or chlorophyll biosynthesis (Shi *et al*., 2006). SA decreases the ACC synthase activity which causes the production of ethylene in the plant (Li *et al*., 1992) and thus reduces the loss of chlorophyll in plants (Arfan, 2007). These results corroborated those previously obtained by (Khandaker *et al*., 2011). Beneficial effect of M on vitamin C, total sugar, chlorophyll a and b contents of plant was observed in the study conducted by (Khalid and Cai (2011) who indicated that plants treated with M resulted in highest values of total sugar, chlorophyll a and b.

Table 2. Effect of salicylic acid and mannitol on vitamin C, total sugar, chlorophyll a and b of white cabbage at harvest date during 2015/2016 and 2016/2017 seasons

Treatment		Character			
Salicylic acid (SA) mg l^{-1}	Mannitol (M) mg l^{-1}	Vitamin C (mg $100g^{-1}$fw)	Total sugar (% fw)	Chlorophyll a (mg g-1 fw)	Chlorophyll b (mg g-1 fw)
		1st season			
	Without	28.59±2.60f	3.53±0.50b	0.006±0.002f	0.005±0.002c
Without	2000	36.26±2.03e	3.88±0.31ab	0.010±0.002de	0.008±0.001ab
	4000	39.19±1.71d	4.02±0.39a	0.012±0.002d	0.009±0.002a
Mean		34.68±9.66	3.81±0.56	0.009±.006	0.007±0.004
	Without	34.80±3.72e	3.60±0.48b	0.010±0.002de	0.007±0.002b
75	2000	45.39±3.67c	4.21±0.10a	0.014±0.002c	0.009±0.001a
	4000	52.40±1.74a	4.25±0.13a	0.018±0.003a	0.010±0.001a
Mean		44.20±15.59	4.02±0.68	0.014±.008	0.009±0.003
	Without	34.61±2.14e	3.59±0.34b	0.008±0.002e	0.007±0.001b
150	2000	48.82±5.20b	4.23±0.11a	0.015±0.001bc	0.009±0.002a
	4000	51.20±1.64ab	4.19±0.07a	0.016±0.001b	0.010±0.001a
Mean		44.87±15.81	4.00±0.65	0.013±.008	0.008±0.003
Overall means of mannitol	Without	32.67±6.61	3.57±0.39	0.008±0.004	0.006±0.002
	2000	43.49±11.73	4.11±0.39	0.013±0.005	0.009±0.002
	4000	47.60±12.74	4.15±0.29	0.016±0.006	0.009±0.001
		2nd season			
	Without	20.40±3.38f	3.92±0.17c	0.005±0.002e	0.004±0.001d
Without	2000	33.26±3.76d	4.28±0.10ab	0.008±0.002cd	0.005±0.001cd
	4000	36.72±1.64c	4.19±0.33b	0.010±0.001c	0.006±0.001cd
Mean		30.13±15.13	4.13±0.38	0.008±0.004	0.005±0.002
	Without	29.02±3.09e	4.14±0.11b	0.008±0.001d	0.005±0.001d
75	2000	39.36±1.70b	4.38±0.03a	0.013±0.002b	0.007±0.001bc
	4000	44.20±1.72a	4.42±0.07a	0.015±0.002a	0.009±0.001a
Mean		37.53±13.58	4.31±0.27	0.012±0.006	0.007±0.003
	Without	27.13±2.86e	3.93±0.17c	0.007±0.001d	0.005±0.002cd
150	2000	41.65±2.91ab	4.37±0.04a	0.014±0.001ab	0.008±0.002ab
	4000	41.37±2.62ab	4.39±0.06a	0.013±0.001b	0.007±0.001ab
Mean		36.72±14.59	4.23±0.46	0.011±0.006	0.007±0.003
Overall means of mannitol	Without	25.52±8.30	4.00±0.25	0.007±0.003	0.005±0.002
	2000	38.09±7.93	4.34±0.11	0.012±0.006	0.007±0.003
	4000	40.77±6.78	4.33±0.28	0.013±0.005	0.007±0.003
		P value			
	SA	0.00 (***)	0.02 (*)	0.00 (***)	0.00 (**)
1st season	M	0.00 (***)	0.00 (***)	0.00 (***)	0.00 (***)
	SA × M	0.00 (**)	0.48 (ns)	0.05 (ns)	0.68 (ns)
	SA	0.00 (***)	0.00 (***)	0.00 (***)	0.00 (***)
2nd season	M	0.00 (***)	0.00 (***)	0.00 (***)	0.00 (***)
	SA × M	0.04 (*)	0.12 (ns)	0.01 (*)	0.02 (*)

Effect of SA and M on dry matter, N, P and K contents

The dry matter and minerals nutrients (N, P, K) contents in white cabbage plants as a function of the foliar SA and M application are displayed in Table 3. Dry matter, N, P, and K contents during both seasons were significantly influenced by applying various levels of SA. Foliar spraying of plants with SA by rate 75 mg l^{-1} was the most effective, while spraying with SA by rate 150 mg l^{-1} was the least effective. These results corroborated those previously obtained in strawberry (Karlidag *et al*., 2009) and broccoli plants (Mirdad, 2014). Increases in dry matter of salt stressed plants in response to SA might be related to the induction of antioxidant response and protective role of membranes that increase the tolerance of plant to damage (Gunes *et al*., 2007) or may be attributed to the increased mineral uptake by stressed plant with SA treatment (Yildirim *et al*., 2008). The effect of SA on nutrient uptake might be ascribed to its ability in regulating enzymic activities in secondary metabolic pathway and the biosynthesis of phenolic compounds (Dong *et al*., 2010), which involves in the lignification of cell wall and alleviates the osmoregulatory stress (Sinha *et al*., 2006; Hayat *et al*., 2010).

Table 3. Effect of salicylic acid and mannitol on dry matter, N, P and K contents of white cabbage at harvest date during 2015/2016 and 2016/2017 seasons

Treatment		Character			
Salicylic acid (SA) mg l^{-1}	Mannitol (M) mg l^{-1}	Dry matter (%)	N (%)	P (%)	K (%)
		1st season			
	Without	7.62±0.82e	1.02±0.04e	0.286±0.017e	2.50±0.31f
Without	2000	8.35±0.13cd	1.27±0.08cd	0.294±0.014de	3.04±0.15cd
	4000	8.46±0.16bcd	1.30±0.05bcd	0.310±0.006abc	3.11±0.10bc
Mean		8.14±0.89	1.20±0.28	0.297±0.024	2.89±0.60
	Without	8.46±0.32bcd	1.28±0.15cd	0.305±0.011bcd	2.94±0.13de
75	2000	8.68±0.21abc	1.38±0.06bc	0.310±0.013abc	3.20±0.02ab
	4000	9.02±0.33a	1.50±0.17a	0.322±0.008a	3.31±0.06a
Mean		8.72±0.55	1.39±0.23	0.312±0.018	3.15±0.34
	Without	8.15±0.32d	1.23±0.08d	0.298±0.004cd	2.83±0.14e
150	2000	8.70±0.07abc	1.41±0.07b	0.313±.006ab	3.22±0.05ab
	4000	8.85±0.17ab	1.39±0.05b	0.318±0.004ab	3.27±0.05ab
Mean		8.56±0.67	1.34±0.19	0.310±0.018	3.11±0.42
	Without	8.08±0.87	1.17±0.25	0.296±0.020	2.76±0.43
Overall means of mannitol	2000	8.57±0.36	1.35±0.14	0.305±0.020	3.15±0.19
	4000	8.75±0.53	1.40±0.19	0.316±0.012	3.23±0.19
		2nd season			
	Without	7.96±0.37g	1.10±0.04e	0.299±0.014f	2.61±0.13f
Without	2000	8.55±0.07f	1.40±0.03c	0.307±0.013e	3.12±0.10d
	4000	9.00±0.24d	1.42±0.08c	0.317±0.005cd	3.20±0.07cd
Mean		8.50±0.93	1.31±0.31	0.308±0.019	2.98±0.57
	Without	8.80±0.19e	1.37±0.06cd	0.312±0.011de	3.00±0.08e
75	2000	9.22±0.15c	1.48±0.03b	0.322±0.008bc	3.28±0.04bc
	4000	9.64±0.15a	1.55±0.04a	0.334±0.008a	3.40±0.02a
Mean		9.22±0.75	1.47±0.17	0.323±0.021	3.23±0.36
	Without	8.44±0.19f	1.32±0.07d	0.308±0.005e	2.92±0.14e
150	2000	9.36±0.16bc	1.52±0.05ab	0.328±0.005ab	3.31±0.04ab
	4000	9.45±0.10b	1.52±0.05ab	0.328±0.009ab	3.33±0.11ab
Mean		9.08±0.98	1.45±0.20	0.321±0.021	3.19±0.41
	Without	8.40±0.76	1.27±0.25	0.306±0.015	2.84±0.38
Overall means of mannitol	2000	9.04±0.76	1.47±0.11	0.319±0.020	3.24±0.18
	4000	9.37±0.56	1.50±0.13	0.326±0.016	3.31±0.19
		P value			
	SA	0.00 (***)	0.00 (***)	0.00 (***)	0.00 (***)
1st season	M	0.00 (***)	0.00 (***)	0.00 (***)	0.00 (***)
	SA × M	0.18 (ns)	0.06 (ns)	0.41 (ns)	0.03 (*)
	SA	0.00 (***)	0.00 (***)	0.00 (***)	0.00 (***)
2nd season	M	0.00 (***)	0.00 (***)	0.00 (***)	0.00 (***)
	SA × M	0.00 (**)	0.00 (***)	0.03 (*)	0.00 (**)

According to ANOVA results (Table 3), dry matter and minerals nutrients (N, P, K) contents were significantly affected by foliar M application in the first and second seasons, the increase in the application of M leads to an increase in plant dry matter, N, P and K contents; Khalid and Cai (2011) also reported that M caused an increase in the dry mass and accumulation of nutrients in plants. M is often recommended for use on plants that are under stress conditions, because it is contribute towards better root survival, it is protected the roots against lipid peroxidation under stress conditions and increase mineral absorption and translocation (Will *et al.* 2011). Significant interaction between SA and M was observed on K content in both seasons and dry weight, N and P in the second season. The best results were obtained when plants treated with SA (75 mg l^{-1}) and M (4000 mg l^{-1}) treatment compared with other treatments for the two growing seasons (Table 3).

CONCLUSION

This study showed that (1) Stem length, head width, head weight, total yield, vitamin C, total sugars, chlorophyll a and b, dry weight and minerals content (N, P, K) were significantly increased by foliar SA, especially 75 mg l^{-1}; (2) the M treatment led to a significant increase of all values in white cabbage; (3) the highest values of growth, yield, vitamin C, total sugars, chlorophyll a and b, dry weight and minerals contents were recorded at the 75 mg SA l^{-1} + 4000 mg M l^{-1} treatments. It may be concluded that SA and M reduces the harmful effects of saline stress on white cabbage plants.

REFERENCES

Aghaeifard F., M. Babalar, E. Fallahi and A. Ahmadi (2015) Influence of humic acid and salicylic acid on yield, fruit quality, and leaf mineral elements of strawberry (*Fragaria ananassa* duch.) cv. Camarosa. J. Plant Nutr., 39(13):1821-1829.

Allakhverdiev, S.I., A. Sakamoto, Y. Nishiyama, M. Inaba, N. Murata (2000) Ionic and osmotic effects of NaCl-induced inactivation of photosystems I and II in *Synechococcus* sp. Plant Physiol., 123(3):1047–1056.

AOAC (1990) Official Methods of Analysis of the Association of Official Agriculture Chemists. Published by Association of Official Agriculture Chemists, 13 Ed. Washington, DC

Arfan M., H.R. Athar and M. Ashraf (2007) Does exogenous application of salicylic acid through the rooting medium modulate growth and photosynthetic capacity in two differently adapted spring wheat cultivars under salt stress? Journal of Plant Physiology, 164(6): 685-694.

Arnon, D.I. (1949) Copper enzymes in isolated chloroplasts polyphenol oxidase in Beta vulgaris. Plant Physiol. 24, 1–15.

Ashraf, M. and M.R. Foolad (2007) Roles of glycine betaine and proline in improving plant a biotic stress resistance. Environ. Exp. Bot., 59(2):206–216.

Bernstein, L. and A.D. Ayers (1949) Salt tolerance of cabbage and broccoli. United States Salinity Laboratory Report to Collaborators. Riverside, CA, 39 pp.

Dong, J., G. Wan and Z. Liang (2010) Accumulation of salicylic acid-induced phenolic compounds and raised activities of secondary metabolic and antioxidative enzymes in Salvia miltiorrhiza cell culture. J. Biotechnol., 148(2-3): 99–104.

Fariduddin Q., S. Hayat and A. Ahmad (2003) Salicylic acid influences net photosynthetic rate, carboxylation efficiency, nitrate reductase activity, and seed yield in *Brassica juncea*. Photosynthetica, 41(2):281-284.

Gunes, A., A. Inal, M. Alpaslan, F. Eraslan, E.G. Bagci and N. Cicek (2007) Salicylic acid induced changes on some physiological parameters symptomatic for oxidative stress and mineral nutrition in maize (*Zea mays* L.) grown under salinity. J. Plant Physiol., 164:728–736.

Gunes, A., A. Inal, M. Alpaslan, N. Cicek, E. Guneria and F. Eraslana (2005) Effects of exogenously applied salicylic acid on the induction of multiple stress tolerance and mineral nutrition in maize (*Zea mays* L.). Arch. Agron. Soil Sci., 51:687–695.

Hallmann, E., R. Kazimierczak, K. Marszalek, N. Drela, E. Kiernozek, P. Toomik, D. Matt, A. Luik and E. Rembialkowska (2017) The Nutritive Value of Organic and Conventional White Cabbage (*Brassica Oleracea* L. Var. Capitata) and Anti-Apoptotic Activity in Gastric Adenocarcinoma Cells of Sauerkraut Juice Produced Therof. J. Agric. Food Chem., 65:8171-8183.

Hayat Q., S. Hayat, M. Irfan and A. Ahmad (2010) Effect of exogenous salicylic acid under changing environment: A review. Environ. Exp. Bot., 68(1):14-25.

Hellebust, J.A. 1976. Annu. Rev. Plant Physio., 27:485

Hossain, M.I., M.A. Mannan and M.A. Karim (2015) Salicylic acid and gibberelic acid ameliorates the adverse effects of salinity on chickpea. Bangaladesh agron. J., 18(1):81-88.

Irigoyen J.J., D.W. Emerich and M. Sanchez-Diaz (1992) Water stress induced changes in concentrations of proline and total soluble sugars in nodulated alfalfa (*Medicago sativa*) plants. Physiol. Plant, 84(1):55-60.

Javanmardi, J. and N. Akbari (2016) Salicylic acid at different plant growth stages affects secondary metabolites and phisico-chemical parameters of greenhouse tomato. Adv. Hort. Sci., 30(3):151-157.

Karlidag, H., E. Yildirim and M. Turan (2009) Salicylic acid ameliorates the adverse effect of salt stress on strawberry. Sci. Agric. (Piracicaba, Braz.), 66(2):180-187.

Khalid, A.K. and W. Cai (2011) The effects of mannitol and salinity stresses on growth and biochemical accumulations in lemon balm. Acta Ecologica Sinica, 31(2):112-120.

Khandaker, L., A.S.M.G. Masum Akond and O.B.A. Shinya (2011) Foliar application of salicylic acid improved the growth, yield and leaf's bioactive compounds in red amaranth (*Amaranthus tricolor* l.). Vegetable Crops Research Bulletin, 74: 77-86.

Khan, M.I.R., M. Asgher and N.A. Khan (2014) Alleviation of salt-induced photosynthesis and growth inhibition by salicylic acid involves glycinebetaine and ethylene in mungbean (*Vigna radiata* L.). Plant Physiol. Biochem., 80: 67–74.

Koppad, S.R., S.B. Babaleshwar, P.R. Dharmatti and K.K. Math (2017) Influence of salicylic acid on growth and bulb yield of onion (*Allium cepa* L.). Int. J. Curr. Microbiol. App. Sci., 6(9):1732-1737.

Kovacik, J., B. Klejdus, J. Hedbavny and M. Backor (2009) Salicylic acid alleviates NaCl induced changes in the metabolism of *Matricaria chamomilla* plants. Ecotoxicology 18(5):544–554.

Li N., B.L. Parsons, D,R. Liu and A.K. Mattoo (1992) Accumulation of woundinducible ACC synthase transcript in tomato fruit is inhibited by salicylic acid and polyamines. Plant Molecular Biology, 18(3): 477-487.

Mimouni, H., S. Wasti, A. Manaa, E. Gharbi, A. Chalh, B. Vandoone, S. Lutts and H.B. Ahmed (2016) Does salicylic acid (SA) improve tolerance to salt stress in plants? A study of SA effects on tomato plant growth, water dynamics, photosynthesis, and biochemical parameters. OMICS A Journal of Integrative Biology, 20(3):1-11.

Mirdad, Z.M (2014) Effect of k^+ and salicylic acid on broccoli (*Brassica oleraceae* var. italica) plants grown under saline water irrigation. Journal of Agricultural Science. 6(10):57-66.

Munns, R. and M. Tester (2008) Mechanism of salinity tolerance. *Annu. Rev.* Plant Biol., 59: 651–681.

Nazar, R., N. Iqbal, S. Syeed and N.A. Khan (2011) Salicylic acid alleviates decreases in photosynthesis under salt stress by enhancing nitrogen and sulphur assimilation and antioxidant metabolism differentially in two mungbean cultivars. J. Plant Physiol., 168: 807–815.

Olsen, S.R., C.V. Cole, F.S. Watanabe, L.A. Dean (1954) Estimation of Available phosphorous in Soil by Extraction with Sodium Bicarbonate. USDA Circ. 939. U.S. Government Printing Office, Washington, DC, USA

Osawa, T. (1961) Studies on the salt tolerance of vegetable crops in sand cultures. II. Leafy vegetables. J. Jpn. Soc. Hort. Sci., 30: 48-56

Osawa, T. (1965) Studies on the salt tolerance of vegetable crops with special reference to mineral nutrition. Bull. Univ. Osaka Pref., Ser. B, 16:13-57

Ostrowska, A., S. Gawlinski and Z. Szczubialka (1991) Methods of analysis and evaluation of soil and plants. IOŚ, Warszawa (in Polish)

Poor P., K. Gemes, F. Horvath, A. Szepesi, L. Simon L. and I. Tari (2011) Salicylic acid treatment via the rooting medium interferes with stomatal response, CO2 fixation rate and carbohydrate metabolism in tomato, and decreases harmful effects of subsequent salt stress. Plant Biology, 13(1): 105-114.

Sarwar, N., S. Yousaf and F.F. Jamil (2006) Induction of salt tolerance in chickpea by using simple and safe chemicals. Pak. J. Bot., 38(2):325-329

Shakirova F. (2007) Role of hormonal system in the manifestation of growth promoting and antistress action of salicylic acid. Salicylic Acid: A plant Hormone, pp 69-89.

Shi, Q., Z. Bao, Z. Zhu, Q. Ying and Q. Qian (2006) Effects of different treatments of salicylic acid on heat tolerance, chlorophyll fluorescence and antioxidant enzyme activity in seedlings of *Cucumis sativa* L. Plant Growth Regulation, 48(2):127-135.

Sinha, P., B.K. Dube, P. Srivastava and C. Chatterjee (2006) Alteration in uptake and translocation of essential nutrients in cabbage by excess lead. Chemosphere, 65(4): 651–656.

Slama, I., T. Ghnaya, K. Hessini, D. Messedi, A. Savoure, C. Abdelly (2007) Comparative study of the effects of Mannitol and PEG osmotic stress on growth and solute accumulation in *Sesuvium portulacastrum*, Environ. Exp. Bot., 61(1):10–17.

Snedecor, G.W. and W.G. Cochran (1990) Statistical Methods, 11th ed., Iowa State Univ, Press. Ames, Iowa, USA

Stoop, J.M.H., J.D. Williamson and D. Pharr (1996) Mannitol metabolism in plants: a method for coping with stress. Trends in Plant Science, 1(5):139-144.

Tang, W., X. Peng and R.J. Newton (2005) Enhanced tolerance to salt stress in transgenic loblolly pine simultaneously expressing two genes encoding mannitol-1-phosphate dehydrogenase and glucitol-6-phosphate dehydrogenase, Plant Physiol. Biochem., 43(2):139–146.

Tarczynski, M.C., R.G. Jensen and H.J. Bohnert (1993) Stress protection of transgenic tobacco by production of the osmolyte mannitol. Science.259:508-510.

Tounekti T., I. Hernandez and S. Munne-Bosch (2013) Salicylic acid biosynthesis and role in modulating terpenoid and flavonoid metabolism in plant responses to abiotic stress. In Salicylic acid, chapter 8, Springer Netherlands, pp. 141-162.

Will, S., T. Eichert, V. Fernandez, J. Mohring, T. Muller and V. Romheld (2011) Absorption and mobility of foliar-applied boron in soybean as affected by plant boron status and application as a polyol complex. Plant Soil, 344(1-2): 283-293.

Wisniewska H., J. Chełkowski (1999) Influence of exogenic salicylic acid on Fusarium seedling blight reduction in barley. Acta Physiologiae Plantarum, 21(1): 63-66.

Yancey, P.H., M.E. Clark, S.C. Hand, R.D. Bowlus and G.N. Somero (1982) Science. 217:1214

Yıldırım, E. and A. Dursun (2009) Effect of foliar salicylic acid applications on plant growth and yield of tomato under greenhouse conditions. Acta Hortic., 807:395-400.

Yildirim, E., M. Turan and I. Guvenc (2008) Effect of foliar salicylic acid applications on growth, chlorophyll, and mineral content of cucumber grown under salt stress. Journal of Plant Nutrition, 31:593-612.

Zidenga, T. (2006) Progress in Molecular Approaches to Drought Tolerance in Crop Plants, ISB News Reported,http://www.isb.vt.edu/news/2006/ news 06. mar.htm

Zhu, J.K. (2002) Salt and drought stress signal transduction in plants. Annu. Rev. Plant Biol., 53: 247-273

تأثير حامض السالسيلك والمانيتول على نباتات الكرنب الأبيض تحت الظروف الملحية

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أجريت هذه التجربة فى محطة التجارب الزراعية بمركز بحوث الصحراء، رأس سدر، محافظة جنوب سيناء لدراسة تأثير الرش الورقى بحامض السالسيلك والمانيتول على نباتات الكرنب الأبيض صنف Kalorama F1 النامية تحت الظروف الملحية (ملوحة التربة ومياه الرى). تمت زراعة شتلات الكرنب فى الحقل بعد ٤٠ يوم من زراعة البذرة فى المشتل. بدأ تطبيق معاملات الرش بعد ٣٠ و٣٥ يوم من عملية الشتل بالنسبة لحامض السالسيلك والمانيتول على التوالى. وكان إجمالى عدد الرشات ثلاثة رشات بين كل رشة والأخرى ١٥ يوم. أستخدمت ثلاثة مستويات من حامض السالسيلك وهى صفر، ٧٥ و ١٥٠ مليجرام لتر$^{-1}$. أيضا تم الرش بثلاث مستويات من المانيتول وهى صفر، ٢٠٠٠ و ٤٠٠٠ مليجرام لتر$^{-1}$ ، وذلك فى تصميم تجارب عاملية فى قطاعات كاملة العشوائية. تم دراسة طول الساق، عرض الرأس، وزن الرأس، المحصول الكلى، و محتوى النبات من فيتامين C، السكريات الكلية، كلوروفيل أ و ب، النيتروجين، الفوسفور والبوتاسيوم. أوضحت النتائج أن هناك زيادة معنوية فى جميع الصفات المدروسة نتيجة المعاملة بحامض السالسيلك خاصة عند تركيز ٧٥ مليجرام لتر$^{-1}$، كذلك بالمعاملة بالمانيتول عند التركيز الأعلى (٤٠٠٠ مليجرام لتر$^{-1}$). كانت أفضل معاملة لجميع الصفات المدروسة هي معاملة الرش بمستوي ٧٥ مليجرام لتر$^{-1}$ من حامض السالسيلك + ٤٠٠٠ مليجرام لتر$^{-1}$من المانيتول. وتوصي الدراسة الحالية بإمكانية أستخدام الرش الورقى بكل من حامض السالسيلك والمانيتول للتغلب على ظروف الإجهاد الملحى وتحسين الحالة التغذوية للنبات.