RESEARCH ARTICLE OPEN ACCESS

NEW VALLEY JOURNAL OF AGRICULTURAL SCIENCE
Published by Faculty of Agriculture, New Valley University, Egypt

Print ISSN 2805-2420 Online ISSN 2805-2439

10.21608/NVJAS.2024.290240.1287

Influence of Salicylic Acid and Chitosan on Quality and Productivity of Lettuce Heads Grown in Two Different Locations in Egypt

Ghada U. Radwan and Enjy A. Sultan
The Central Laboratory for Agricultural Climate, Agricultural Research Center, Egypt

* Corresponding author

Radwan, U. Ghada

Received: 16/05/2024

Revised: 28/06/2024

Accepted: 28/06/2024

Published: 30/06/2024

Abstract

Two experiments were conducted on head lettuce (*Lactuca sativa*) simultaneously grown in Bosaily (on the north coast of the Nile Delta) and Dokki, Giza, for the two successive seasons of 2020/2021 and 2021/2022. This work investigates the practical simple applications that overcome low lettuce head quality and yield under different climatic conditions. Three treatments were applied, i.e. foliar spray with salicylic acid (500 ppm), chitosan (150 ppm), and the control (tab water) five times, 10 days apart, starting from mid-December (about 3 weeks after transplanting). Each treatment was replicated three times in completely randomized plots. Lettuce heads were harvested after 105 days for chemical analyses and vegetative growth trial assessment. The chemical analysis included total sugar (g/100g D.W); nitrate (mg/kg D.W); total phosphorus and total potassium (mg/100 mg D.W). Plant growth and yield data included the total number of leaves, head diameter, head firmness, and fresh and dry weights from three heads per replicate. Total yield and total marketable yield were estimated in tons per feddan. The results indicated that head lettuce gave significantly higher vegetative growth, and higher total and marketable yield in chitosan treatment followed by salicylic acid, compared to the control. The total yield from El-Bosaily location was 23.6, 25.2, and 24.3% than Dokki for control, salicylic acid, and chitosan, respectively. Salicylic acid and chitosan gave 42.8 and 68.6% higher than control in El-Bosaily, and 41.0 & 67.7% in Dokki, respectively. Bosaily site gave significantly higher yield than Dokki.

Keywords: total sugar, nitrate, firmness, El-Bosaily; El-Dokki

Introduction

Lettuce (*Lactuca sativa*) is an important salad crop in Egypt. The cultivated area 2021 was 11776 feddans, producing about 110 thousand tons valued at about 164 million L.E. (Economic Affairs Sector, 2022). Globally cultivated area was more than 1.2 million hectares (≈2.85 million feddans), and more than 53% was in China for the same year 2021 (World Data Atlas, 2022).

Historically, lettuce has been cultivated for 4.500 years BP, as described on Egyptian tombs' walls (Lindqvist, 1960). Lettuce, as one of the most important members of the family Compositae, has several nutritional and health values due to its phenolic content, vitamins A and C, as well as carotenoids (Lin et al., 2014; Pepe et al., 2015). Lettuce plants generally contain high levels of nitrate that may exceed the permitted amount in the European Union (Colla et al. 2018). The high range of acceptable nitrate levels is reported to be 4000 mg/kg of fresh weight (European Commission, 2011). So, reducing nitrate content can add value to lettuce plants.

Salicylic acid is a phenolic compound produced by plants (Rivas-San Vicente and Plasencia, 2011). Since salicylic acid activates the plant's defense mechanisms under biotic and abiotic stress conditions and protects the plant against stress, researchers have focused on exogenous salicylic acid applications to plants, especially under stress conditions (Senaratna et al., 2000). Salicylic acid plays an important role in the regulation of many physiological events such as seed germination, plant growth and development, respiration, photosynthesis, transpiration, opening and closing of stomas, flowering, resistance to diseases, enzyme activity, senescence, and nutrient uptake (Hayat et al., 2008; Rivas-San Vicente and Plasencia, 2011). Plant growth and development are complex phenomena that are often determined by different exogenous and endogenous factors. The role of salicylic acid in the regulation of physiological processes as well as in the growth and development of plants has been reported (Cataldo et al., 1975; Krause, 1994; Janda et al., 1999; Singh & Usha, 2003; Horvath et al., 2007; Hayat et al., 2008; Khan et al., 2015; Bankole et al., 2018).

Chitosan is a biodegradable biopolymer, an amino polysaccharide material that is commercially produced from the exoskeleton of aquatic crustaceans (Xu and Mou, 2018). Chitosan is known to enhance plant growth regulators that protect plants from oxidative stress (Nurliana et al., 2022).

Therefore, this study aimed to study the response of lettuce plant growth and quality to foliar application of salicylic acid and chitosan in two different locations, El-Bosaily and El-Dokki.

Materials and Methods

Site Description

The experiments were conducted in two different locations belonging to the Central Laboratory for Agricultural Climate (CLAC) and the Agricultural Research Center (ARC) for the two successive winter seasons of 2020/2021 and 2021/2022. The first farm was at El-Bosaily (31°40'N; 30°40'E), protected cultivation experimental farm, at Beheira Governorate, on the Northern Coast of Egypt, while the second location was at Dokki Farm (30° 04'N; 31° 20’E).

All weather data was obtained from automatic weather stations in situ belonging to CLAC. Data in Table (1) illustrate the measured maximum, average, and minimum air temperatures (°C), as well as the maximum, average, and minimum relative humidity percentage, during the experimental period (October–February of 2021–2022) and 2022–2023, respectively. Data was collected from automated weather stations of CLAC allocated at the experimental sites. Table (1) illustrates the daily maximum, average, and minimum temperatures at El-Bosaily during the two

studied seasons of 2021/2022 and 2022/2023. As could be noticed, there are no clear differences between both sites regarding monthly average air temperature or average relative humidity.

The physical and chemical parameters of the experimental soil in both sites were determined at a depth of 0–30 cm using the methods outlined by (Page et al. 1982 and Klute 1986), and the findings are shown in Table (2). El-Bosaily soil has a loam texture and is characterized by moderate salinity, while El-Dokki soil is clay, with almost double the values of salinity, sodium, and sulfate contents.

Plant material and treatments: Lettuce seedlings "cv. Iceberg" was transplanted when they were five weeks old on the 21st and 18th of November in El-Bosaily and El-Dokki for both seasons, respectively. Six rows were used for each experiment in each location. The row dimensions were 5 m long and 70 cm wide. Lettuce transplants were placed on both sides of the ridges, with 33 cm between them. Two ridges guarded each treatment. Three foliar spray treatments were applied in each location, i.e., chitosan 150 ppm, salicylic acid 500 ppm, and tap water as a control. Two rows were used for each treatment, with about 30 plants per treatment. Five sprays were applied starting in mid-December, 10 days apart for both seasons.

The source of chitosan was the Egypt Chamita Company (Kompass). The concentration of the commercial chitosan product (Chito-Care®), with an 85% deacetylation, was 2ml/l. Aspirin® 500 tablets, with a concentration of 500 mg of salicylic acid ($C_9H_8O_4$) tablet, were used as a source of salicylic acid (ASA). Chito-care and salicylic acid (ASA) were dissolved in tap water to achieve the targeted concentrations.

Chemical Analysis of Leaves

Chemical analysis was performed in the lettuce head, such as:

1) Total sugar (g/100g D.W.) according to (Smith et al. 1956).

2) Total nitrate in heads (mg/kg D.W.) calorimetrically according to (Cataldo et al. 1975).

3) Total phosphorus of leaves (mg/100 mg D.W.) was determined as reported by (Troug and Meyer 1939).

4) Total potassium in the leaves (mg/100 mg D.W.) was determined according to (Cottenie et al. 1982).

Data were recorded on plant growth and yield at harvest on February 6 and 10 for the first and second seasons, respectively. Measurements such as head diameter, head firmness, and fresh weight were taken from three heads per replicate immediately after harvesting. Total and marketable yield was estimated from the average fresh weight of the head for each treatment and the number of plants per feddan (0.35 x 0.33 m^2/plant). Head firmness (g/cm^3) was determined according to (Opena and Lo 1980). The lettuce heads were then dried in a hot air oven for 3 days at a temperature of 50 °C, after which the dry weight measurement was recorded.

Experimental design and data collection

The experiment in each location included three treatments and was replicated randomly three times, with 10 plants in each replicate planted in a double-row bed. All experiments were done in a completely randomized design. The two main independent variables were locations (El-Bosaily and El-Dokki) and spray treatments (control, chitosan and salicylic acid), while the dependent variables were all chemical analysis and vegetative growth and yield measurements on lettuce plant. The data obtained were subjected to a two-way ANOVA. Each data point was the mean average of the three replicates (10 lettuce heads per replicate). Comparisons were made with significance level at 0.05%, according to (Snedecor 1956).

Table (1): Average monthly air temperature and relative humidity of the El-Bosaily and El-Dokki during the two studied seasons of 2021/2022 and 2022/2023

Location	Month	Temperature (°C)			Humidity (%)		
		Max.	Avg.	Min.	Max.	Avg.	Min.
		First season (2021/2022)					
El-Bosaily	November	25.5	21.3	17.6	88.2	71.0	51.7
	December	19.7	15.6	12.3	86.5	73.4	56.8
	January	17.3	13.0	9.2	88.4	73.1	54.8
	February	19.0	14.0	9.2	88.5	72.2	53.3
		Second season (2022/2023)					
	November	24.5	22.5	19.9	67.4	54.6	43.9
	December	22.4	20.2	17.4	75.4	61.9	50.5
	January	20.5	17.9	15.0	79.4	64.2	49.1
	February	17.9	16.0	13.9	73.9	60.8	45.1
		First season (2021/2022)					
El-Dokki	November	24.4	21.3	18.1	87.4	70.3	53.2
	December	19.9	17.8	15.6	87.9	70.1	52.2
	January	18.6	14.7	10.8	87.5	70.7	53.8
	February	18.2	14.0	9.8	88.1	69.3	50.4
		Second season (2022/2023)					
	November	25.6	21.9	18.1	77.4	67.9	58.4
	December	20.6	17.2	13.8	82.4	69.6	56.7
	January	18.8	15.3	11.8	83.2	68.8	54.3
	February	20.9	17.0	13.1	79.2	64.5	49.8

Table (2): Soil chemical and physical characteristics of Bosaily and Dokki sites in 2021

	Chemical characteristics									
	pH	ECe dSm^{-1}	meq/l							
			Cations				Anions			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	CO_3^{--}	HCO_3^{-}	SO_4^{--}
El-Bosaily	7.6	1.3	3.1	2.9	6.7	0.9	5.6	0.0	1.8	6.2
	Physical properties									
	Soil particles (%)			Soil Texture	Field Capacity (%)		Wilting point (%)	Organic matter (%)		Bulk density
	Sand	Silt	Clay							
	39.3	43.1	17.6	Loam	16.7		7.3	0.31		1.2
	Chemical characteristics									
	pH	ECe dSm^{-1}	meq/l							
			Cations				Anions			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	CO_3^{--}	HCO_3^{-}	SO_4^{--}
El-Dokki	7.7	2.8	15.1	11.1	11.3	4.1	11.6	0.0	6.6	23.4
	Physical properties									
	Soil particles (%)			Soil Texture	Field Capacity (%)		Wilting point (%)	Organic matter (%)		Bulk density
	Sand	Silt	Clay							
	10.9	11.3	77.8	Clay	42.1		22	9.3		1.27

Results and Discussions

The results of studying the influence of salicylic acid and chitosan on the production and quality of lettuce (Lactuca sativa) heads grown in El-Bosaily and El-Dokki are illustrated in Table (3).

Vegetative growth

Table (3) shows the total leaf number, head fresh and dry weights in response to spraying lettuce plants grown in El-Bosaily and El-Dokki sites with chitosan and salicylic acid treatments for the two successive seasons of 2021/2022 and 2022/2023. Vegetative growth data of chitosan treatment were significantly higher than salicylic acid, and the latter was significantly higher than the control, regardless of location. On the other hand, lettuce plants grown in Bosaily showed significantly better performance than those grown in Dokki. As for the interaction, chitosan treatment was significantly higher than salicylic acid, and both were significantly higher than control. This could be attributed to the growth enhancement effect of chitosan (Nurliana et al., 2022), followed by salicylic acid (Bankole et al., 2018). The better performance of plants under chitosan and salicylic acid treatments was reflected in higher head fresh weight and consequently higher dry weight. This is agreed with (Sharif et al. 2018; Xu and Mou 2018 and Ibrahim et al. 2023). The low values of all treatments grown in the Dokki site compared to Bosaily ranged from 60% in head dry weight to 80.4% for head fresh weight, as the average of both seasons, could be attributed to the higher EC and warmer weather in El-Dokki (Senaratna et al. 2000).

Table (3): Effect of spraying with acetylsalicylic acid and chitosan on the total number of leaves, the fresh weight of the head (g) and the dry weight of the head (g/head) of lettuce plants growing in the El-Bosaily and El-Dokki sites during the 2021/2022 and 2022/2023 seasons

Location	El-Bosaily			El-Dokki			
Season	First	Second	Mean	First	Second	Mean	Treatment Mean
Treatments	Total Number of leaves (#)						
CONTROL	19.6	18.1	18.85c*	14.4	14.5	14.45c	16.65C
SALICYLIC A.	31.8	30.3	31.05ab	22.2	24.3	23.25b	27.15B
CHITOSAN	42.6	41.8	42.20a	32.3	33.4	32.85a	37.53A
$LSD_{0.05}$	1.7	4.1	30.37A	2.9	4.1	23.52B	
	Head fresh Weight (g)						
CONTROL	896.7	796.3	846.5c	732.2	637.1	684.7c	765.6C
SALICYLIC A.	1242.4	1175.1	1208.8b	990.4	940.1	965.3b	1087.0B
CHITOSAN	1452.7	1401.7	1427.2a	1175.2	1121.3	1148.3a	1287.7A
$LSD_{0.05}$	49.1	93.9	1160.8A	62.2	93.9	932.7B	
	Head dry weight (g/head)						
CONTROL	15.2	13.4	14.3c	8.3	6.8	7.6c	10.9C
SALICYLIC A.	29.3	33.9	31.6b	15.8	21.7	18.7b	25.2B
CHITOSAN	55.2	57.2	56.2a	37.7	32.2	35.0a	45.6A
$LSD_{0.05}$	8.2	11.1	34.0A	6.6	8.5	20.4B	

***Different small letters indicate significant differences between treatments at 0.05 level for each season. Different capital letters indicate significant differences between treatments at 0.05 level as mean of both seasons, or differences between seasons.**

Lettuce head quality

Lettuce head diameter and firmness as indicators for lettuce head quality, as shown in Table (4), significantly increased for both seasons in the two locations of study by spraying chitosan and salicylic acid, compared to the control.

Head firmness differences were 21.4, 23.8, & 25.0%, while head diameter was 6.0, 8.6, and 9.9% higher in El-Bosaily than El-Dokki for control, salicylic acid, and chitosan, respectively. This could be a consequence of higher head diameter and dry weight in El-Bosaily. Chitosan and salicylic acid treatments had 68.4 and 45.5% fruit firmness higher than the control, while they had 19.3 and 12.8% head diameters higher than the control, respectively. These results agree with (Mur et al. 1996; Hayat et al. 2008; and Bankole et al. 2018).

Table (4): Effect of spraying with acetylsalicylic acid and chitosan on head diameter (cm) and head firmness (g/cm^3) of lettuce plants growing in El-Bosaily and El-Dokki sites during 2021/2022 and 2022/2023 seasons

Location	El-Bosaily			El-Dokki			
Season	First	Second	Mean	First	Second	Mean	Treatment Mean
Treatment	Head diameter (cm)						
CONTROL	11.9	11.5	11.7c*	11.2	10.8	11.0c	11.3C
SALICYLIC A.	13.5	13.5	13.5b	12.5	12.4	12.4b	13.0B
CHITOSAN	14.3	14.6	14.4a	13	13.2	13.1a	13.8A
$LSD_{0.05}$	1.2	0.9	13.2A	0.8	0.7	12.2B	
	Head firmness (g/cm^3)						
CONTROL	3.0	2.7	2.6c	2.5	2.2	1.1c	1.8C
SALICYLIC A.	4.2	4.2	3.8b	3.4	3.4	1.7b	2.7B
CHITOSAN	4.8	5.0	4.4a	3.8	4.0	2.0a	3.2A
$LSD_{0.05}$	0.2	0.6	3.6A	0.3	0.6	1.6B	

***Different small letters indicate significant differences between treatments at 0.05 level for each season. Different capital letters indicate significant differences between treatments at 0.05 level as mean of both seasons, or differences between seasons.**

Head lettuce chemical characteristics

The effect of foliar applications of salicylic acid and chitosan during the two growing seasons in two locations on chemical parameters such as total sugar, total nitrate, phosphorus, and potassium are illustrated in Table (5). There were insignificant differences between both locations regarding total sugar, while El-Dokki showed significantly higher concentrations than El-Bosaily regarding nitrate, phosphorous and potassium. There were insignificant differences between salicylic acid and chitosan treatments regarding total sugar, phosphorus, or potassium, while both were significantly higher than control, regardless of location.

Regarding the interaction, total sugar was significantly lower in salicylic acid and chitosan treatments by 11.4 and 13.1 in El-Bosaily; 7.0 and 13.7% in El-Dokki, than control, respectively. These results agree with (Helaly et al., 2021). Similarly, total nitrate was significantly lower in salicylic acid and chitosan treatments by 22.5 and 27.7 in El-Bosaily; and 16.2 and 23.4% in El-Dokki, than in control, respectively. Regarding phosphorus and potassium content in lettuce heads, results show that El-Bosaily gave lower P content of– 12.0, -9.0, and -13.4% for control, salicylic acid, and chitosan treatments, respectively. Salicylic acid and chitosan treatment were -9.0

and -11.8% compared to control, respectively. Similarly, phosphorus was significantly lower by–15.0, -17.7 and -14.8% in El-Bosaily location for control, salicylic acid, and chitosan treatments. There were insignificant differences between all treatments compared to control. These results could be attributed to differences in climatic conditions as shown in Table (1), and nutrient availability in the soil as shown in Table (2). Similar results were concluded by (Bankole et al., 2018; Colla et al., 2018; Hayat et al., 2008; Khan et al., 2015; Nurliana et al., 2022; and Senaratna et al. 2000).

Table (5): Effect of spraying with acetylsalicylic acid and chitosan on total sugars (mg/100g D.W)., total nitrates (mg/ kg D.W)., phosphorus (mg/kg D.W) and potassium (mg/100g D.W) of lettuce plants grown in Al-Bosaily and El-Dokki locations during 2021/2022 and 2022/2023 seasons

Location	El-Bosaily			El-Dokki			
Season	First	Second	Mean	First	Second	Mean	Treatment Mean
Total sugar (g/100g D.W)							
CONTROL	2.9	3.2	3.1a	3.1	2.9	3.0a	3.0A
SALICYLIC A.	2.7	2.7	2.7b	2.8	2.7	2.8b	2.7B
CHITOSAN	2.6	2.7	2.7b	2.5	2.7	2.6c	2.6B
$LSD_{0.05}$	0.1	0.2	2.8A	0.2	0.1	2.8A	
Total nitrate (mg/ kg D.W)							
CONTROL	195.2	187.4	191.3a	187.4	201.1	194.a	192.8A
SALICYLIC A.	144.4	152.3	148.4b	152.3	173.3	162.8b	155.6B
CHITOSAN	135.7	140.8	138.3c	140.8	156.6	148.7c	143.5C
$LSD_{0.05}$	22.3	19.5	159.3B	19.5	22.4	168.6A	
Phosphorus (mg/kg D.W)							
CONTROL	0.27	0.28	0.28a	0.32	0.31	0.32a	0.30A
SALICYLIC A.	0.27	0.26	0.26ab	0.29	0.29	0.29b	0.28AB
CHITOSAN	0.25	0.24	0.24b	0.28	0.27	0.28b	0.26B
$LSD_{0.05}$	N.S.	N.S.	0.26B	N.S.	N.S.	0.29A	
Potassium (mg/100g D.W)							
CONTROL	2.42	2.63	2.53a	3.12	2.82	2.97a	2.75A
SALICYLIC A.	2.12	2.4	2.26b	2.87	2.62	2.75b	2.50B
CHITOSAN	1.95	2.32	2.14b	2.54	2.47	2.51c	2.32B
$LSD_{0.05}$	0.11	0.12	2.31B	0.21	0.14	2.74A	

***Different small letters indicate significant differences between treatments at 0.05 level for each season. Different capital letters indicate significant differences between treatments at 0.05 level as mean of both seasons, or differences between seasons.**

Total and marketable yield

The effect of foliar application of salicylic acid and chitosan in El-Bosaily and El-Dokki for the two successive seasons 2020/2021, and 2021/2022 on yield and marketable yield of lettuce are shown in Table (6). Yield and marketable yield were significantly increased in chitosan followed by salicylic acid regardless of location. Total and marketable yield were significantly higher in El-Bosaily than El-Dokki.

Regarding the interaction, the total yield from El-Bosaily location was 23.6, 25.2 and 24.3% than El-Dokki for control, salicylic acid, and chitosan, respectively. Salicylic acid and chitosan gave 42.8 and 68.6% higher than control in El-Bosaily, and 41.0 & 67.7% in El-

Dokki, respectively. Consequently, the total marketable yield was significantly more than 22% higher in El-Boaily than in El-Dokki. Chitosan gave 63.1 and 64.3% than control, while salicylic acid gave 42.8 and 40.9% than control, in Bosaily and Dokki, respectively. Those results agreed with the results obtained by other research work on head lettuce and other vegetable crops (Mur *et al*, 1996.; Senaratna et al. 2000; Hayat et al., 2008; Khan et al., 2015; Bankole et al., 2018; and Nurliana et al., 2022).

Table (6): Effect of spraying with acetylsalicylic acid and chitosan on total yield (ton/feddan) and total marketable yield (ton/feddan) of lettuce plants growing in the El-Bosaily and El-Dokki sites during 2021/2022 and 2022/2023 seasons

Location	El-Bosaily			El-Dokki			
Season	First	Second	Mean	First	Second	Mean	Treatment Mean
Treatments	Total yield (ton/feddan)						
CONTROL	32.3	28.7	30.5c	26.4	22.9	24.6c	27.6C
SALICYLIC A.	44.7	42.3	43.5b	35.7	33.8	34.8b	39.1B
CHITOSAN	52.3	50.5	51.4a	42.3	40.4	41.3a	46.4A
$LSD_{0.05}$	7.0	6.4	41.8A	7.4	5.6	33.6B	
	Total marketable yield (ton/feddan)						
CONTROL	25.2	22.1	21.3c	20.6	17.7	8.8c	15.1C
SALICYLIC A.	34.9	32.6	30.2b	27.8	26.1	13.0b	21.6B
CHITOSAN	39.7	37.3	34.5a	31.7	31.1	15.5a	25.0A
$LSD_{0.05}$	3.0	2.6	28.7A	3.4	3.2	12.5B	

CONCLUSION

The use of foliar spray with chitosan (150 ppm) and salicylic acid (500ppm) five times, 10 days apart, starting from mid-December (about 3 weeks after transplanting) on head lettuce grown in El-Bosaily and El-Dokki for the two successive seasons of 2020/2021 and 2021/2022 gave significantly higher head quality, higher total, and marketable yield.

REFERENCES

Bankole, A. E., Umebese, C. E., Feyisola, R. T., & Bamise, T. O. (2018). Influence of salicylic acid on the growth of lettuce (*Lactuca sativa* var longifolia) during reduced leaf water potential. *Journal of Applied Sciences and Environmental Management*, *22*(4), 543-540.

Cataldo, D. A., Maroon, M., Schrader, L. E., & Youngs, V. L. (1975). Rapid colorimetric determination of nitrate in plant tissue by nitration of salicylic acid. *Communications in soil science and plant analysis*, *6*(1), 71-80.

Colla, G., Kim, H. J., Kyriacou, M. C., & Rouphael, Y. (2018). Nitrate in fruits and vegetables. *Scientia Horticulturae*, *237*, 221-238.

Cottenie, A., Verloo, M., Kiekens, L., Velghe, G., & Camerlynck, R. (1982). Chemical analysis of plants and soils. *Lab. Agroch. State Univ. Gent, Belgium*, *63*.

Economic Affairs Sector (2022). Farm Income Estimates for 2021, Ministry of Agriculture and Land Reclamation.

(https://www.agri.gov.eg/uploads/topics/16870811114739.pdf).

European Commission (2011). Regulation no. 1258/2011 of 2 Dec. 2011 amending regulation no. 1881/2006 as regards maximum levels for nitrates in foodstuffs. OJ. L. 320, 15–17. https://www.fsai.ie/uploadedfiles/reg1258-2011.pdf.

Hayat, S., Hasan, S. A., Fariduddin, Q., & Ahmad, A. (2008). Growth of tomato (*Lycopersicon esculentum*) in response to salicylic acid under water stress. *Journal of plant interactions*, *3*(4), 297-304.

Helaly, A. A., Ashmawi, A. E., Mohammed, A. A., El-Abd, M. T., & Nofal, A. S. (2021). Effect of soil application of nano NPK fertilizers on growth, productivity and quality of Lettuce (*Lactuca sativa*). *Al-Azhar Journal of Agricultural Research*, 46(1), 91-100.

Horvath, E., Pál, M., Szalai, G., Páldi, E., & Janda, T. (2007). Exogenous 4-hydroxybenzoic acid and salicylic acid modulate the effect of short-term drought and freezing stress on wheat plants. *Biologia plantarum*, *51*, 480-487.

Ibrahim, E. A., Ebrahim, N. E., & Mohamed, G. Z. (2023). Effect of water stress and foliar application of chitosan and glycine betaine on lettuce. *Scientific Reports*, *13*(1), 17274.

Janda, T., Szalai, G., Tari, I., & Paldi, E. (1999). Hydroponic treatment with salicylic acid decreases the effects of chilling injury in maize (*Zea mays* L.) plants. *Planta*, *208*, 175-180.

Khan, M. I. R., Fatma, M., Per, T. S., Anjum, N. A., & Khan, N. A. (2015). Salicylic acid induced abiotic stress tolerance and underlying mechanisms in plants. *Frontiers in plant science*, *6*, 462.

Klute, A., & Page, A. L. (1986). *Methods of soil analysis. Part 1. Physical and mineralogical methods; Part 2. Chemical and microbiological properties*. American Society of Agronomy, Inc..

Krause, G. H. (1994). The role of oxygen in photoinhibition of photosynthesis. *Causes of photooxidative stress and amelioration of defense systems in plants*, 43-76.

Lin, Y., Yngve, A., Lagergren, J., & Lu, Y. (2014). A dietary pattern rich in lignans, quercetin and resveratrol decreases the risk of oesophageal cancer. *British journal of nutrition*, *112*(12), 2002-2009.

Lindqvist, K. (1960). On the origin of cultivated lettuce. *Hereditas*, *46*(3-4), 319-350.

Mur, L. A., Naylor, G., Warner, S. A., Sugars, J. M., White, R. F., & Draper, J. (1996). Salicylic acid potentiates defence gene expression in tissue exhibiting acquired resistance to pathogen attack. *The Plant Journal*, *9*(4), 559-571.

Nurliana, S., Fachriza, S., Hemelda, N. M., & Yuniati, R. (2022, February). Chitosan application for maintaining the growth of lettuce (*Lactuca sativa*) under drought condition. In *IOP Conference Series: Earth and Environmental Science* (Vol. 980, No. 1, p. 012013). IOP Publishing.

Opena, R. T., & Lo, S. H. (1980). Procedures for chinese cabbage evaluation trials. *International Cooperator's Guide*, (144).

Page, A. L., Miller, R. H., & Keeney, D. R. (1982). Methods of soil analysis, part 2. *Chemical and microbiological properties*, *2*, 643-698.

Pepe, G. (2015). Evaluation of anti-infammatory activity and fast UHPLC-DAD-IT-TOF profling of polyphenolic compounds extracted from green lettuce (*Lactuca sativa* L.; var. Maravilla de Verano). Food Chem. 167, 153 161.

Rivas-San Vicente, M., & Plasencia, J. (2011). Salicylic acid beyond defence: its role in plant growth and development. *Journal of experimental botany*, *62*(10), 3321-3338.

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

Sharif, R., Mujtaba, M., Ur Rahman, M., Shalmani, A., Ahmad, H., Anwar, T.,... & Wang, X. (2018). The multifunctional role of chitosan in horticultural crops; a review. *Molecules*, *23*(4), 872.

Singh, B., & Usha, K. (2003). Salicylic acid induced physiological and biochemical changes in wheat seedlings under water stress. *Plant growth regulation*, *39*, 137-141.

Smith, F.M.A., Hamilton G.D.K., & Geeds P.A. (1956). Colorimetric method for determination of sugars and related substance. *Anal. Chem*. 28: 550.

Snedecor, G. W. (1956). Statistical methods: applied to experiments in agriculture and biology. The Iowa state college press. https://117.239.25.194:7000/jspui/bitstream/123456789/907/1/PRILIMINERY%20AND%20CONTENTS.pdf

Troug, E., & Meyer, A.H. (1939). Improvement in denies colorimetric method for phosphorus and arsenic Ind. Eng. Chem. Anal. Ed., 1: 136- 139.

World Data Atlas (2022). The production of lettuce in the World. (https://knoema.com/data/agriculture-indicators).

Xu, C., & Mou, B. (2018). Chitosan as soil amendment affects lettuce growth, photochemical efficiency, and gas exchange. *Hort. Technology*, *28*(4), 476-480.

تأثير حمض الساليسيليك والشيتوزان على جودة وإنتاجية رؤوس الخس النامية في موقعين مختلفين في مصر

غادة رضوان وإنجي سلطان

المعمل المركزي للمناخ الزراعي، مركز البحوث الزراعية، جمهورية مصر العربية

الملخص العربي

تم زراعة تجربتين من خس الرؤوس (*Lactuca sativa*) بالتزامن بمنطقتي البوصيلي (على الساحل الشمالي لدلتا النيل) والدقي بالجيزة للموسمين المتتاليين 2021/2020 و2022/2021. تم إجراء ثلاث معاملات بكل منطقة: الرش الورقي خمس مرات بحمض الإيثايل سالسيلك (500 جزء في المليون)، أو الشيتوزان (150 جزء في المليون) أو المقارنة (ماء صنبور)، بفاصل 10 أيام، بدءاً من منتصف ديسمبر (حوالي 3 أسابيع بعد الزراعة). تم تكرار كل معاملة ثلاث مرات في قطع كاملة العشوائية. تم حصاد رؤوس الخس بعد حوالي 105 يوم من الشتل حيث تم إجراء التحليل الكيميائي للأوراق وقراءات النمو الخضري بعد الحصاد مباشرة. اشتمل التحليل الكيميائي على السكريات الكلية (جم/100 جم وزن جاف)؛ نترات (ملجم/كجم وزن جاف)؛ فوسفور كلي وبوتاسيوم كلي (مجم/100 مجم وزن جاف). تضمنت البيانات المتعلقة بنمو النبات والإنتاجية على عدد الأوراق، قطر الرأس، صلابة الرأس، والوزن الطازج والجاف من ثلاثة رؤوس لكل مكررة. تم تقدير المحصول الكلي و القابل للتسويق بالطن لكل فدان. أشارت النتائج إلى أن زراعة خس الرؤوس أعطت نمواً خضرياً أعلى معنوياً، وأعلى محصولاً كلياً ومحصولاً قابلاً للتسويق في معاملة الشيتوزان، يليها المعاملة بحمض الساليسيليك، مقارنة بالكنترول. وكان المحصول الكلي من موقع البوصيلي 23.6، 25.2 و 24.3% أعلى من موقع الدقي بحمض الإيثايل سالسيلك، والكيتوزان، والكنترول، على التوالي. وأعطى الرش بحمض الإيثايل سالسيلك والشيتوزان أعلى من الكنترول 42.8 و68.6% في البوصيلي و41.0 و67.7% في الدقي على، التوالي. كان المحصول الكلي بالبوصيلي أعلى معنوياً من الدقي.

الكلمات الدالة: السكر الكلي، النترات، الصلابة، البوصيلي؛ الدقي