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Impact of Organic Fertilization and some Beneficial Elements on the Performance and Storability of Salt-Stressed Crisphead Lettuce (*Lactuca sativa L.*)

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ABSTRACT

Raising plant tolerance to environmental stress, particularly salinity is necessary. So, a pot trial was conducted to assess the impact of different compost types; normal compost (NC) and enhanced compost (EC) at a rate of 10.0 Mg ha^{-1}, with a control treatment (without soil addition) on the performance and storability of crisphead lettuce plants grown on salt-affected soil. Additionally, the exogenous application of selenium at the rate of 500 ppm (as sodium selenite, Na_2SeO_3) and silicon at the rate of 600 ppm (as potassium silicate, K_2SiO_3), was assessed. Results indicated that compared with control, the highest values for growth, yield parameters total chlorophylls, vitamin C, and edible head weight were observed in plants treated with EC, followed by those treated with NC. Conversely, plants grown without compost exhibited maximum values for total phenols, reactive oxygen species, SOD, PPO, and APX. Concerning foliar application of microelements, selenium treatment proved superior than that of silicon. Furthermore, the studied treatments prolonged crisp-head lettuce storability parameters compared to plants without compost and beneficial elements (control). Specifically, the weight loss percentage of crisp head lettuce was significantly reduced during the storage period. The combined treatment of EC and selenium fertilization demonstrated the most promising effect regarding storability. So, this combined treatment could be recommended for improving crisphead lettuce performance and quality over an extended storage period.

Keywords: lettuce; Compost; Selenium; Silicon; Salinity.

INTRODUCTION

Crisphead, or iceberg lettuce (*Lactuca sativa* L.) belongs to the family Asteraceae, and is a rounded, compact lettuce with overlapping leaves; with the interior leaves are paler and sweet, while the exterior greener leaves are more malleable and useful for lettuce wraps (Abou-El-Hassan and Desoky, 2013). The nutrients in iceberg lettuce can meet the standard daily requirements for several vitamins such as vitamin A, vitamin K, and folate and minerals such as Fe, Zn, Ca, P, Mg, Mn, and K (Kim et al., 2016). Also, it is a rich source of antioxidants, omega-3 fatty and anticarcinogenic phytochemicals (Doklega and Imryed, 2020; Farou, *et al.*, 2023).

Though soil salinity stress has an inhibitory effect on the vegetative growth of plants, the strategy of most countries is to reclaim and cultivate all degraded soils, including salt-affected soil to bridge the nutritional gap (Hamail *et al.*, 2014; Shabana *et al.*, 2020; El-Shamy *et al.*, 2022 and Ghazi *et al.*, 2022). Most common treated method is the use of compost which possesses a vital influence in improving vegetable crops' nutritional components under salinity conditions (Othman, 2021).

The handling iceberg lettuces usually at ambient temperature. especially the hot one, causes severe loss of its quality. According to Pinto and Morais (2000) and Doklega and Abd El-Hady (2023), the leafy vegetables after harvest are subject to continuous biological changes as respiration, transpiration and ethylene production, which may be desirable or undesirable. Some treatments, including low temperature storage with 1-MCP (Jiang et al., 2014), UV-C (Costa et al., 2006), hydro-cooling (Finger et al., 2018) and cold storage (Schmitz et al., 2019) were previously adopted to prevent quality decline of iceberg lettuce and other vegetables during storage.

Many investigations indicated that treatment with some anti-stress beneficial elements *e.g.*, selenium (Se) and silicon (Si) raise the plant tolerance to oxidative stress, delaying senescence and improving the growth performance of ageing seedlings (Doklega et al., 2021 and Ghazi et al., 2021). So, the objectives of the current research were to evaluate the effect of different compost sources with foliar application of selenium (Se) and silicon (Si) on performance and storability of Crisphead lettuce grown on salt-affected soil.

MATERIALS AND METHODS

Experimental site

This research work was executed during the growing season of 2022/2023 at the Farm of the Faculty of Agriculture, Mansoura University, Egypt.

Soil sampling

Saline soil was collected from El-Serw area, El-Zarqa District, Damietta Governorate, Egypt then it was analyzed before the execution of the experiment according to Dane and Topp (2020) and Sparks *et al.*, (2020) as presented in Table (1).

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Table 1. Characteristics of the experimental soil

Properties		Values
* pH		8. 00
**EC, dSm^{-1}		6.500
Total $CaCO_3$ %		2.700
OM%		2.110
Nitrogen, mg k^{-1}		55.59
Phosphorus , mg k^{-1}		9.550
Potassium , mg k^{-1}		240.9
Particles size distribution	Sand,%	15.40
	Silt,%	29.96
	Clay,%	54.64
		Texture class is clay
CEC, cmol kg^{-1}		63.80
Bulk Density, Mg m^{-3}		1.240
Total Porosity,%		58.49
Real density,Mg m^{-3})		2.600
Saturation percentage,%		89.06
Field capacity , %		44.53
Wilting point , %		22.30
Available water,%		22.30
Bulk Density, Mg m^{-3}		1.240
Total Porosity,%		58.49
Real density, Mg m^{-3})		2.600

* pH (1:5 soil suspension). **EC (soil extract 1:5).
Notes: The soil is saline because the EC exceeds 4.0 dSm^{-1}.

Preparation of the experimental materials

Compost

Normal plant residues compost (NC): 70% rice straw +30% maize residues) was prepared as follows; the plant residues were chopped into 6.0 cm long pieces, piled, moistened with water and composted in association with a chemical accelerator (7.0 kg superphosphate and 40.0 kg ammonium sulphate per ton dry matter, 100 kg fertile soil per ton dry matter and 10 % FYM). At the initial stage of composting, the effective microorganisms (EM) suspension was sprayed on the raw material at the rate of 10.0 L ton^{-1}.

Enhanced compost (EC): Agricultural by-products *i.e.*, the residues of, flax, bean, cotton and wheat straw were brought from private farms. These residues were air-dried and cut into pieces of lengths from 1.5-3.5 cm. Also, two animal manures i.e., chicken manure and farmyard manure were collected from a private farm. Moreover, mineral additives were applied (feldspar rock as a source of K was added at a rate of 100 g/10 kg, bentonite was added at a rate of 100 g/10 kg and phosphate rock as a source of P was added at a rate of 100 g/10 kg. At the initial stage of composting, the effective microorganisms (EM) suspension was sprayed on the raw material at the rate of 10.0 L ton^{-1}.

During composting (3 months), materials were manually mixed at a week intervals to provide aeration. The moisture content during the composting course was kept at a proper level (60 % by weight) throughout the irrigation for both compost types. The chemical properties of NC and EC were analyzed according to (author, year) and are presented in Table (2).

Table 2. Chemical analysis of normal plant residues compost (NC) and enhanced compost (EC).

Parameters		EC	NC
pH		6.15	6.44
EC, dSm^{-1}		3.85	3.71
Total C, %		21.7	23.4
Total N, %		1.76	1.40
C:N ratio		12.3	16.7
Available nutrients , mg kg^{-1}	Fe	88.2	59.0
	Zn	44.0	19.0
	Mn	36.0	29.0
	P	1.62	0.59
	K	1.95	0.83

Beneficial elements

Sodium selenite (Na_2SeO_3) and Potassium silicate (K_2SiO_3) were purchased from Sigma-Aldrich Chemical Company as a source for Selenium and silicon respectively. CAS no. of compounds is 10102-18-8 and 1312-76-1 respectively. The studied concentration of each element was 500 ppm for Se and 600 ppm for Si.

Lettuce seedlings

Crisp head lettuce seedlings (*Lactuca sativa* L. cv. Big Ball) were obtained from the private nursery.

Pots used

Plastic pots have a 25.0 cm diameter and 30.0 cm depth were filled by air-dry saline soil equaled to 10 kg oven dry soil.

Experimental set up

A pots trial was carried out aiming at evaluating the effect of different compost types as the main factor *i.e.*, normal plant residues compost (NC) and enhanced compost (EC) in addition to the control treatment (without soil addition) as well as the exogenous application of some beneficial elements as a sub main factor [control (without), selenium (as sodium selenite, Na_2SeO_3) and silicon (as potassium silicate, K_2SiO_3)] on the performance and storability of crisphead lettuce plants grown on salt-affected soil.

This research work was performed in a split-plot design with three replicates. Consequently, total number of pots was 27 as follows; 3 "compost treatments" ×3 "beneficial element treatments" × 3 "replicates". Both NC and EC were added to pots in a single addition two weeks before transplanting at the rate of g Kg^{-1} soil for all of them.

Seedlings of crisphead lettuce were transplanted on 2^{nd} of November in pots at rate of one plant per pot. Foliar application of Se and Si solutions was sprayed after 15, 30 and 45 days from transplanting. Irrigation process was with 500 ml of water volume per pot. Mineral fertilization (N, P and K) were added according to the recommendations of the Ministry of Agriculture. Three plants were selected randomly for estimation of yield parameters i.e. total yield (g/plant).

Harvesting

Crisphead lettuces were harvested at optimal maturity after reaching a marketable size (after three months from planting; 20^{th} January) then transported directly to the laboratory in the Department of Postharvest and Handling Vegetables, Horticultural Research Station, Mansoura, Dakahlia Governorate, Egypt. Crisphead lettuces were packed with polyethylene film, (37cm× 15cm) and stored at controlled storage conditions (0ºC and 95% relative humidity for two weeks).

Measurements

Parameters which measured after two months from transplanting were total chlorophylls, carotenoids, vitamin C, Na, Cl, edible head weight, total phenols, total flavonoids, proline, reactive oxygen species, and the activity of SOD, PPO and APX. In addition, total chlorophylls, vitamin C, the activity of PPO and APX, total flavonoids, and reactive oxygen species as well as WLP%, PDP%, respiration rate and ethylene were determined after storage for two weeks. Methods for assessing the studied parameters are shown in Table (3).

Table 3. Methods used for chemical analyses of crisphead lettuce leaves.

Parameters	Methods	References
Chlorophyll and carotene content	Using organic solvent (methanol 100%).	Sadasivam and Manickam, (1996).
Na percentage	Flame photometer	Bauserman and Cerney, (1953).
Cl percentage	Plasma-mass spectrometry	Tagami *et al.,* (2006).
T. Phenol	Folin Ciocalteu reagent	McDonald *et al.,* (2001).
Vitamin C	Via titration with 2.6 diclorophenol indophenol blue dye	AOAC, (1980).
T. Flavonoid	Aluminum chloride colorimetric method	Chang *et al.,* (2002).
Proline	Colourimetric measurement	Ábrahám *et al.,*(2010).
Reactive oxygen species	Using the stable 1,1-diphenyl-2-picryl hydroxyl radical	Koleva *et al.,* (2002)
Super oxide dismutase enzyme, SOD Peroxidase enzyme, POD Ascorbate peroxidase, APX	Spectrophotometrically	Elavarthi and Martin, (2010).
Respiration rate	With a portable gas exchange system (Li-6400, Li-COR Inc., Lincoln, NE, USA)	Van Iersel, (2003).
Polyphenol oxidase enzyme, PPO	Specrophotometrically	Maria *et al.,* (1981).
Ethylene	Gas chromatogram	Wang et al., (2020).
Weight loss percentage (WLP%)	(Initial – final weight) /initial weight)] × 100	A.O.A.C (2007)
Post-harvest decay percentage (PDP %)	Number of crisp head lettuces showing decay symptoms / Number of total crisp head lettuces) ×100.	EL-Mougy et al., (2012)

Statistical Analysis

Statistical analysis of the obtained data was done according to Gomez and Gomez, (1984)

RESULTS AND DISCUSSION

Results

Growth criteria and yield

Data in Table (4) show the individual and interaction effects of different treatments on the performance of crisphead lettuce plants grown on salt-affected soil expressed in total chlorophylls (mg g^{-1}), total carotenoids (mg g^{-1}), vitamin C (mg $100g^{-1}$), Na, Cl and edible head weight (g $plant^{-1}$) after 90 days from transplanting. Results show that the maximum values of all aforementioned traits were recorded when the plants were treated with the enhanced compost followed by that were treated with normal plant residues compost. Regarding the foliar of the studied beneficial elements, the superior treatment was the Se application and then the Si treatment compared to the control treatment. Concerning the interaction effect, the enhanced compost and Se fertilization as combined treatment had the most positive effects, improving the crisphead lettuce performance under saline conditions.

Table 4. Effect of soil addition of different compost sources with foliar application of beneficial elements on total chlorophylls, total carotenoids (mg g^{-1}) , vitamin C, Na, Cl and total yield of crisphead lettuce during both seasons 2021/2022 (??? growing season of 2022/2023 according to M&M).

Treatments		Total Chlorophyll	Carotene	Vitamin C	Na	Cl	Yield
		(mg g^{-1})		(mg $100g^{-1}$)	(%)		(g $plant^{-1}$)
Soil additions							
Control (without soil addition)		1.234c	0.305c	2.93b	0.77c	0.22c	196.61b
Enhanced Compost		1.339a	0.368a	3.64a	1.05a	0.46a	233.56a
Normal plant Compost		1.302b	0.347b	3.43a	0.97b	0.38b	171.84c
LSD at 5%		0.002	0.001	0.24	0.02	0.04	11.96
Foliar applications							
Control (without foliar application)		1.258c	0.321c	3.14b	0.85c	0.27c	158.56c
Selenium		1.320a	0.355a	3.49a	1.00a	0.42a	186.82b
Silicon		1.296b	0.344b	3.37a	0.94b	0.38b	256.63a
LSD at 5%		0.001	0.001	0.12	0.03	0.02	12.38
Interaction							
Control	Control	1.214i	0.295i	2.83e	0.70g	0.15i	142.70f
	Selenium	1.252g	0.317g	3.05d	0.85e	0.28g	209.47c
	Silicon	1.234h	0.304h	2.92de	0.77f	0.24h	237.67b
Enhanced Compost	Control	1.289e	0.340e	3.27c	0.94cd	0.35e	155.73f
	Selenium	1.379a	0.388a	3.88a	1.13a	0.54a	158.13ef
	Silicon	1.347b	0.376b	3.77a	1.08ab	0.50b	386.80a
Normal plant Compost	Control	1.271f	0.329f	3.33c	0.90d	0.31f	177.23de
	Selenium	1.328c	0.360c	3.55b	1.04b	0.45c	192.87cd
	Silicon	1.307d	0.353d	3.42bc	0.98c	0.39d	145.43f
LSD at 5%		0.001	0.002	0.21	0.05	0.03	21.44

Enzymatic and non-enzymatic antioxidants

As shown in Table (5), the maximum values of parameters which expressed the tolerance of crisphead lettuce plants to salinity conditions *i.e.,* total phenols, total flavonoids, proline, reactive oxygen species, and the activity of SOD, PPO and APX were realized with plants grown without compost, while the normal plant residues compost came in the second order then the enhanced compost. Regarding the foliar application of the studied beneficial elements, the plants grown without both Se and Si, either received compost treatments or not, possessed the highest values of all the above-mentioned traits. While the exogenous application of both Se and Si and the combinations with both enhanced and normal compost decreased the aforementioned characters.

Table 5. Effect of soil addition of different compost sources with foliar application of beneficial elements on crisp head lettuce self-production of antioxidants expressed in T.phenols (µg g^{-1} F.W) , T. flavonoids (µg g^{-1} F.W), proline (µg g^{-1} F.W), reactive oxygen species (µmol g^{-1} F.W), SOD (unit mg^{-1} $protein^{-1}$), PPO (unit mg^{-1} $protein^{-1}$) and APX(unit mg^{-1} $protein^{-1}$) during both seasons 2021/2022.

Treatments		Phenol	Flavonoid	Proline	Reactive oxygen species O2	H2O2	SOD	PPO	APX
		(µg g^{-1} F.W)			(µmol g^{-1} F.W)		(unit mg^{-1} $protein^{-1}$)		
Soil additions									
Control (without soil addition)		64.50a	33.83a	19.26a	1.705a	1.623a	55.03a	55.01a	3.17a
Enhanced Compost		54.23c	29.17c	15.40c	0.866c	0.823c	35.81c	48.41c	1.97c
Normal plant Compost		58.67b	30.35b	16.70b	1.180b	1.149b	42.80b	51.03b	2.37b
LSD at 5%		0.14	0.48	0.05	0.013	0.011	0.19	0.52	0.12
Foliar applications									
Control (without foliar application)		62.32a	32.60a	18.28a	1.517a	1.449a	50.68a	53.49a	2.90a
Selenium		55.88c	29.89c	16.13c	1.001c	0.955c	39.10c	49.48c	2.16c
Silicon		59.21b	30.86b	16.95b	1.233b	1.190b	43.86b	51.48b	2.44b
LSD at 5%		0.99	0.56	0.08	0.003	0.017	0.72	0.88	0.03
Interaction									
Control	Control	65.93a	34.55a	20.57a	1.850a	1.746a	58.20a	56.01a	3.40a
	Selenium	63.05bc	33.17b	18.15c	1.557c	1.497c	51.85c	53.92bc	2.95c
	Silicon	64.52ab	33.78ab	19.06b	1.708b	1.625b	55.03b	55.09ab	3.15b
Enhanced Compost	Control	59.60d	31.22cd	16.64e	1.283e	1.235e	45.42e	51.65de	2.54e
	Selenium	48.11g	27.83e	14.04b	0.461i	0.403i	27.18i	44.92h	1.45i
	Silicon	54.98f	28.45e	15.51g	0.854h	0.831h	34.84h	48.64g	1.93h
Normal plant Compost	Control	61.42c	32.04c	17.63d	1.418d	1.368d	48.41d	52.81cd	2.77d
	Selenium	56.49ef	28.66e	16.18f	0.985g	0.966g	38.28g	49.59fg	2.08g
	Silicon	58.12de	30.36d	16.27f	1.138f	1.113f	41.71f	50.70ef	2.26f
LSd at 5%		1.73	0.96	0.14	0.007	0.028	1.25	1.52	0.05

Storability

Data in Table (6) show the individual and interaction effects of tested treatments on the storability of crisphead lettuce plants grown on salt-affected soil as revealed from the levels of total chlorophylls, vitamin C, the activity of SOD, PPO and APX, total flavonoids , reactive oxygen species, respiration rate and Ethylene after two weeks in storage.

Table 6. Effect of soil addition of different compost sources with foliar application of beneficial elements on crisp head lettuce performance after two weeks from harvest for evaluating the storability during both seasons 2022/2023.

Treatments (storage)		T. Chlorophyll	V. C	SOD	PPO	APX	Flavonoid	Reactive oxygen species O2	H2O2	Respiration rate, ml $CO_2 \cdot kg^{-1} \cdot h^{-1}$	Ethylene, µl L^{-1}	WLP	PDP
		(mg g^{-1})	(mg 100 g^{-1})	(unit mg^{-1} $protein^{-1}$)			(µg g^{-1} F.W)	(µmol g^{-1} F.W)				(%)	
Soil additions													
Control (without)		1.069c	2.62c	57.78a	57.71a	3.33a	34.50a	1.742a	1.649a	8.16a	3.92a	12.91b	50.00a
Enhanced compost		1.173a	2.94a	37.64c	50.97c	2.07c	29.72c	0.881c	0.834c	6.90c	2.85c	24.00a	22.22a
Normal plant compost		1.142b	2.85b	44.99b	53.66b	2.49b	30.95b	1.200b	1.163b	7.24b	3.22b	12.71b	62.96a
LSD at 5%		0.027	0.01	0.49	0.14	0.03	0.33	0.017	0.036	0.24	0.02	6.57	N.S
Foliar applications													
Control (without foliar application)		1.097c	2.71b	53.26a	56.29a	3.04a	33.23a	1.548a	1.471a	7.93a	3.69a	16.13b	62.96a
Selenium		1.153a	2.87a	40.99c	52.04c	2.27c	30.53c	1.019c	0.970c	7.06c	3.04c	9.76c	38.87a
Silicon		1.133b	2.83a	46.17b	54.02b	2.58b	31.41b	1.256b	1.206b	7.31b	3.25b	23.72a	33.33a
LSD at 5%		0.013	0.05	0.81	0.06	0.05	0.54	0.008	0.010	0.21	0.01	3.75	N.S
Interaction													
Control	Control	1.044g	2.55h	61.09a	58.85a	3.55a	35.24ab	1.893a	1.771a	8.37a	4.10a	9.65c	83.33a
	Selenium	1.091ef	2.68fg	54.43c	56.59c	3.12c	33.74b	1.589c	1.522c	7.95bc	3.74c	7.49c	33.3ab
	Silicon	1.071f	2.64g	57.83b	57.70b	3.32b	34.52ab	1.745b	1.655b	8.16ab	3.93b	21.58b	33.3ab
Enhanced Compost	Control	1.134cd	2.81de	47.59e	54.60e	2.65e	31.83c	1.306e	1.251e	7.75c	3.38e	29.86a	66.7ab
	Selenium	1.199a	3.02a	28.45i	47.37i	1.52i	28.27f	0.468i	0.408i	6.31f	2.47i	12.12c	0b
	Silicon	1.185ab	2.98ab	36.89h	50.96h	2.03h	29.06ef	0.869h	0.842h	6.64ef	2.69h	3004a	0b
Normal plant Compost	Control	1.113de	2.76ef	51.10d	55.42d	2.92d	32.61c	1.446d	1.390d	7.66c	3.58d	8.88c	38.9ab
	Selenium	1.169b	2.92bc	40.09g	52.16g	2.19g	29.59e	1.001g	0.980g	6.92de	2.93g	9.68c	83.33a
	Silicon	1.143c	2.88cd	43.79f	53.39f	2.38f	30.64d	1.153f	1.120f	7.14d	3.15f	19.56b	66.7ab
LSd at 5%		0.023	0.08	1.41	0.11	0.08	0.93	0.014	0.017	0.35	0.01	6.49	N.S

Results show that the maximum values of total chlorophylls and vitamin C were recorded when the plants were treated with the enhanced compost followed by that treated with normal plant residues compost compared with control. On the contrary, the maximum values of parameters such as SOD, PPO, APX and flavonoid were recorded in stored plants that were not treated with compost pre-storage, with stored plants that treated with normal plant residues compost came second in this respect. The lowest values for there parameters were recorded in stored plants that were treated with enhanced compost. Regarding the foliar of the studied beneficial elements, the superior treatment was the Se application then the Si treatment compared to the control treatment. Generally, the studied treatments enhanced crisp head lettuce storability, evidently through significant reduction of weight loss percentage during the storage period. The enhanced compost and Se fertilization as combined treatment was the most efficient treatment for augmenting storability.

Discussion

Salinity may lead to a decrease in the plant's absorption of water, causing an increase in the concentration of salts in the symplast and apoplast, and thus a decrease in all trophic transformation activities in the plant cells (Parihar et al., 2015). Increasing salts in the soil may cause a significant decrease in cell division and elongation (Safdar et al., 2019). Increasing the content of Cl & Na ions in chloroplasts affects the synthesis and activity of enzymes associated with photosynthesis (Othman, 2021; El-Shamy *et al*., 2022 and Ghazi *et al*., 2022).

In the present study, salinity stress raised enzymatic and non-enzymatic antioxidants production in crisphead lettuce plants to hinder the hazard impact of salinity-induced ROS, which have a devastating effect on nuclear DNA, proteins and sugars (Parihar et al., 2015). On the other hand, studied treatments led to a decline of the crisphead lettuce plant's self-production from enzymatic and non-enzymatic antioxidants (Table 5). Likewise, temperature as abiotic stress induced lipid peroxidation and increased senescence in spinach and Lamb's lettuce (Ferrante et al., 2009; Antonacci et al., 2011).

Ethylene biosynthesis is considered a senescence marker and increases in tissues under stress conditions.The gas caused russet spotting and yellowing under cold storage conditions. These results are in harmony with those recorded by (Spinardi and Ferrante, 2012). Chlorophyll retention of vegetables during postharvest depends mainly on species, preserving treatments and storage temperature. Chlorophyll losses occur after 5 days, but wide variations can be observed. The present results showed that the crisphead lettuce stored at 4 °C had a decrease in chlorophyll and carotenoids after 8 days of storage. These results are in harmony with those recorded by (Ferrante *et al.,* 2008; Agüero *et al.,* 2008) on swiss chard and lettuce. The sucrose content present in leaves serves as an energy reserve and is directly linked to the rate of respiration. This study observed that lower temperatures contribute to a deceleration in sugar reduction, resulting in a reduction of tissue respiration. This phenomenon is reflected in the weight loss percentage and postharvest decay percentage. The findings align with the observations made by Spinardi and Ferrante (2012) concerning crisp head lettuce. Additionally, the ascorbic acid content, known for its instability, experiences a rapid decline during the postharvest stage. These results are consistent with the findings reported by Myojin *et al.*, (2008) for green pepper and Ferrante *et al.*, (2009) for lettuce plants.

Generally, it can be said that all different compost sources (*i.e.*, normal plant residues compost and enhanced compost) had a vital role in improvement the performance of crisp head lettuce grown on saline soil because of supplying nutrients to crisp head lettuce under salinity stress conditions. Also, it can increase soil aggregates and thereby raising the leaching of salts away from the root zone. The superiority of enhanced compost compared to plant residues compost may be attributed to that enhanced compost had lower C/N ratio compared with plant residues compost as well as its high content from nutrients (Abd El-Hady *et al*., 2021; Ghazi *et al.,* 2021; Seadh *et al.,* 2021 and Omar *et al.,* 2022).

The superiority of selenium more than silicon may be attributed to its involvement in the action of the enzymes which protect the internal structure of cells against the oxidation process. Selenium appears to be effective in delaying plant senescence, thus decreasing postharvest losses due to its antioxidant properties, and as a component of different enzymes such as glutathione peroxidase, super oxidase dismutase, peroxidase, Polyphenol oxidase and catalase (Malagoli et al., 2016). Selenium is considered a powerful antioxidant that preserves cell membranes, enzymes and cell contents from oxidation by free radicals

Recent studies have shown that the application of exogenous selenium also affects the concentration of phenolic compounds, ascorbic acid and other antioxidants in plants (Wrobel et al., 2020).

Silicon is absorbed in the form of salicylic acid or silicate ions into plant cells. Treatment with silica compounds lead to the entry of silica into the structure of cell walls and the formation of polymers containing silicon that make cell walls more rigid and thus resistant to any environmental stress. There are many reports indicating that the treatment of plants with silica compounds leads to morphological changes that increase the thickness of the leaves (Frasetya et al., 2021). Silicate can improve the physiological response of plant cells as increased the photosynthetic pigments, compatible solutes, and enzyme activity, thereby improving their ability to resist storage diseases (Khalifa et al., 2019).

Generally, it can be concluded that both compost sources with applied Se and Si as sprayed treatment have a beneficial impact on reducing oxidative stress imposed on crisphead lettuce plants in response to salinity pre-harvest and ageing during storage post-harvest due to their role in scavenging ROS through increasing the antioxidant enzymes SOD and APX activities as revealed by lower levels of O^-_2 and $H_2O_2^-$ in plants receiving Si and Se sprays.

CONCLUSIONS

The results revealed that enhanced compost, particularly when combined with selenium fertilization, significantly improved the growth and yield parameters of the lettuce. Additionally, plants treated with enhanced compost and selenium exhibited enhanced storability, as indicated by a reduced weight loss percentage during the storage period. Further research could explore different types of compost and their optimal ratios to maximize the benefits for plant growth and stress tolerance. Foliar application methods and dosages should be fine-tuned through additional research to ensure optimal results and minimize any potential adverse effects.

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تأثير التسميد العضوي وبعض العناصر المفيدة في الأداء والقدرة التخزينية لنبات الخس الكابوتشا النامي بتربة ملحية

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الملخص

من الضروري زيادة قدرة النبات على تحمل الإجهاد البيئي، وخاصة الملوحة. لذلك، تم إجراء تجربة أصص لتقييم تأثير أنواع سماد المكمورة المختلفة؛ سماد المكمورة العادية (NC) وسماد المكمورة المحسن (EC) بمعدل ١٠,٠ طن للهكتار، مع معاملة الكنترول (بدون إضافة سماد المكمورة) على أداء والقدرة التخزينية لنبات الخس الكابوتشا النامي بتربة ملحية. بالإضافة إلى ذلك، تم تقييم الرش الورقي للعناصر المفيدة، مثل السيلينيوم بمعدل ٥٠٠ جزء في المليون (كسيلينيت الصوديوم، Na_2SeO_3) والسيليكون بمعدل ٦٠٠ جزء في المليون (سيليكات البوتاسيوم، K_2SiO_3). أشارت النتائج إلى أن أعلى القيم لمدلولات النمو والإنتاجية، مثل الكلوروفيل الكلي، وفيتامين سي، ووزن الرأس الصالح للأكل، لوحظت مع النباتات التي تم تسميدها بسماد المكمورة المحسن (EC)، تليها تلك المعاملة بسماد المكمورة العادية (NC) ، وأخيراً معاملة الكنترول (بدون سماد). على العكس من ذلك، أظهرت النباتات النامية بدون سماد اعلي القيم للمدلولات التي تشير إلى تحمل ظروف الملوحة، مثل الفينول، والشوارد الحرة، وSOD، وPPO، وAPX. أما من حيث الرش الورقي فقد أثبتت معاملة السيلينيوم تفوقها تليها معاملة السيليكون مقارنة بمعاملة الكنترول بالنسبة لمدلولات النمو والانتاجية. علاوة على ذلك، عززت المعاملات المدروسة والقدرة التخزينية لنبات الخس مقارنة بالنباتات النامية بدون سماد المكمورة والعناصر مفيدة (الكنترول). كما أن نسبة الفقد في الوزن للخس انخفضت بشكل ملحوظ خلال فترة التخزين. ومن الجدير بالذكر أن المعاملة المشتركة لسماد المكمورة المحسن ورش السيلينيوم أظهرت نتائج واعدة، مما أدى إلى تعزيز القدرة التخزينية بشكل كبير. يشير هذا إلى أنه يمكن التوصية بهذه المعاملة المشتركة لتحسين أداء ونوعية خس الكابوتشا على مدى فترة طويلة في ظل ظروف صعبة مماثلة.