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Effect of Moringa and Yeast Extract on Growth and Yield of Strawberry (*Fragaria x Ananassa*) under Salinity Soil Stress

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ABSTRACT

The global productivity of strawberry cultivation is significantly impacted by soil salinity, a prominent abiotic stress factor. It is imperative to employ efficient approaches for the management of soil salinity enhance strawberry (*Fragaria x ananassa*) productivity. So, a field experiment was carried out aiming to evaluate the response of strawberry grown under salinity stress to the exogenous applications of yeast extract Y.E (0, 100, 150 ml L^{-1}) and moringa extract M.E (0,15, 20 g L^{-1}) either in single addition or combination via split-plot experimental design during two successive seasons of 2021/2022 and 2022/2023. the different rates of yeast and moringa extracts significantly affected growth performance, quantitative and qualitative yield indicators. The values of most studied parameters increased as the rate of yeast or moringa extracts increased. Except for malondialdehyde (MDA), the maximum values were observed when yeast extract was sprayed at a rate of 150 ml L^{-1} in combination with moringa extract at rate of 20 g L^{-1}. Additionally, the control treatment, which involved plants grown without yeast extract and moringa extract, exhibited the highest levels of MDA (as it is an indicator of oxidative stress). In contrast, the combined treatment of yeast extract (150 ml L^{-1}) and moringa extract (20 g L^{-1}) resulted in the lowest levels of MDA. This suggests that applying yeast and moringa extracts helped mitigate the oxidative stress and induced salinity tolerance of strawberries, thus improving the performance and yield.

Keywords: yeast extract, moringa extract, malondialdehyde

INTRODUCTION

Strawberries (*Fragaria x ananassa*) are important for their nutritional value (Abd-Elgawad, 2019), economic importance (Malhat *et al.*, 2020) and popularity among consumers (Abd-El-Kareem *et al.*, 2022). However, the presence of high salinity in the soil can negatively affect strawberry plants, resulting in decreased growth, yield, and fruit quality. Salinity stress can significantly reduce strawberry yields (Larson, 2018), as it can affect flower formation, fruit set, fruit development, leading to lower fruit quantity and quality (Shamsabad *et al.*, 2022). High levels of soil salinity can affect water uptake and disrupt nutrient balance in plants, leading to physiological and biochemical changes (El-Agrodi *et al.*, 2016; El-Hadidi *et al.*, 2020; and Ghazi *et al.*, 2021)

To overcome these challenges, it is crucial to implement effective management practices to mitigate salinity stress. One such approach involves the use of bio-stimulants, including yeast and moringa extracts. Yeast extracts contain valuable nutrients (Abdelaal *et al.*, 2019), amino acids, vitamins (Taha *et al.*, 2020), and growth-promoting substances (Abdelaal *et al.*, 2021). Yeast extracts have been used in agriculture to enhance plant growth (Rangel-Montoya *et al.*, 2022), stimulate root development, and improve stress tolerance (Babaousmail *et al.*, 2022). Yeast extracts can also promote microbial activity and nutrient cycling in the soil (Ebaid *et al.*, 2022). On the other hand, moringa is known for its nutritional value and medicinal properties. It is rich in vitamins, minerals (Awwad *et al.*, 2022), antioxidants, and bioactive compounds (Mashamaite *et al.*, 2022), which contribute to its potential health benefits and plant growth-promoting effects. Moringa extracts enhance plant growth (Ragab *et al.*, 2022), improve nutrient uptake, and mitigate abiotic stress conditions (Arif *et al.*, 2023).

The effectiveness of yeast or moringa extracts can vary depending on the environmental conditions, application methods, concentrations used and other factors. So, this research aimed to assess the impact of foliar applications of yeast extract and moringa extract either in single addition or combination on the strawberries grown under salinity stress to ensure the continued profitability and success of the strawberry crop in the Egyptian market.

MATERIALS AND METHODS

Experimental site and soil sampling

A field trial was conducted over two successive seasons,of 2021/2022 and 2022/2023, at a private farm located in Seen Elbaharya Village, Badr district, Buhaira Governorate, Egypt. The physical analysis of the initial soil sample was carried out following the method described by Dane and Topp (2020), while the chemical analysis was conducted according to the procedure outlined by Sparks *et al.* (2020). The analysis of the initial soil sample revealed that the experimental soil, at a depth of 0-30 cm, had a clayey texture. The soil consisted of 29.35% silt, 20.65% sand, and 50% clay, with an organic matter content of 1.39 g per 100 grams of soil. The available nitrogen content was 48.5 mg per kg of soil, available phosphorus content was 8.94 mg per kg of soil, and available potassium content was 210.3 mg per kg of soil. The pH value of the soil was 7.85,

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and the soil electrical conductivity (EC) was recorded as 7.5 dSm^{-1}.Thus it can be said the soil of the experimental location is considered a salt affected soil. It is important to note that all the reported values of soil properties represent the average of the two seasons under study.

Studied substances

Yeast and moringa extracts were made as follows:

Yeast extract was prepared as mentioned by El-Ghamriny *et al.* (1999) as follows: Baker's yeast (soft yeast) and sugar were mixed in a 1:1 ratio. The mixture was then left at room temperature for 3 hours to undergo freezing, which caused the disruption of yeast tissue and the release of its content then the studied yeast extract rates were prepared. The yeast extract had the following composition: carbohydrates (32%), protein (47.1%), nucleic acids (9%), minerals (7.9 %) and lipids (4%).

Moringa extract was prepared as mentioned by Awwad *et al.* (2022), as it was derived from the leaves of the *Moringa oleifera* tree when they were mature but still green, as they were thoroughly washed and then cleaned to remove any dirt or impurities. Then the cleaned leaves were dried and ground into a fine powder which was subjected to extraction using a suitable solvent (alcohol), as the solvent helped to dissolve and extract the bioactive compounds present in the *Moringa oleifera* leaves. The resulting mixture was filtered to remove any solid particles then the extract was exposed to evaporation to obtain a more concentrated form. The final moringa extract was packaged then the studied moringa extract rates were prepared. The moringa extract had the following composition: calcium (2.3%), potassium (2.2%), nitrogen (2.1%), super oxide dismutase (194, IU min^{-1} mg^{-1} protein), peroxidase (22, IU min^{-1} mg^{-1} protein) and catalase (8, IU min^{-1} mg^{-1} protein).

Experimental setup

A field experiment was carried out aiming to evaluate the response of strawberry (Festival F1 hybrid) grown under salinity stress to the exogenous applications of yeast extract Y.E (0, 100, 150 ml L^{-1}) as main plot and moringa extract M.E (0,15, 20 g L^{-1}) as sub plot either in single addition or combination via split-plot experimental design with Three replicates., The foliar application treatments were done four times at 60, 75, 90 and 105 after transplanting. The soil was prepared for cultivation and all the agricultural practices recommended by the Ministry of Agriculture were implemented to produce strawberries, where fertilization and irrigation processes were done as fertigation via a drip irrigation system. Before transplantation, a careful selection process was conducted to choose the seedlings. The selection criteria included the crown diameter, with each seedling being required to have a crown diameter greater than 0.5 cm to ensure their suitability for transplantation. On the 15^{th} of October, during both seasons, the strawberry plants were transplanted.

The experimental unit area was 14.4 m^2, consisting of three beds that were 1.6 m wide and 3.0 m long. Each bed contained four rows of transplants. before planting, the fresh strawberry transplants underwent a disinfection process by immersing them in a solution called Rhizolex solution. After the disinfection process, the transplants were promptly planted, ensuring a spacing of 25 cm between each strawberry plant on both sides of the dripper lines.

Measurements

The strawberries were picked at a size that was deemed appropriate for the market, and their weight and quantity were recorded to calculate the yield in tons per hectare (both marketable and unmarketable) as well as the average weight of each fruit in grams. The harvests that took place between December and March were considered as the early yield, while the total yield was determined by measuring the weights of all harvested fruits until June 1^{st}. Additionally, measurements were taken for fruit firmness (g cm^{-2}) and fruit dry matter (%). On the other hand, Table 1 indicates the measurements of growth performance and strawberry fruit quality.

Table 1. Parameters, methods and references of measurements

Parameters	Methods	References
Growth parameters and photosynthetic pigments at a period of 125 days from transplanting		
1.Plant height (cm) 2.Foliage fresh weight (g $plant^{-1}$) 3.Secondary crown number $plant^{-1}$ 4.Number of leaves $plant^{-1}$ 5.Leaf area (cm^2 $plant^{-1}$) 6.Leaf dry matter (%)	Manually and visually	----------------
Chlorophyll content, SPAD reading value	SPAD reading(SPAD-502, Soil-Plant Analysis Development (SPAD) Section, Minolta Camera, Osaka, Japan)	Castelli *et al.* (1996)
Carotene content (mg g^{-1})	Spectrophotometrically	Picazo *et al.* (2013)
Quality traits of fruits in the first week of April		
Total dissolved solids,%	Hand refractometer	A.O.A.C (2000)
Total sugars (%)	In dry matter	A.O.A.C (2000)
Acidity (%)	As grams of citric acid per 100g of juice	A.O.A.C (2000)
Vitamin C (VC, mg $100g^{-1}$)	Dichloro phenol dye solution	A.O.A.C (2000)
Anthocyanin (mg $100g^{-1}$)	----------------	Crecente-Campo *et al.* (2012)
Malondialdehyde (MDA, µmol.g^{-1} F.W)	Spectrophotometric method	Mendes *et al.* (2009)
superoxide dismutase (SOD, unit.g^{-1}.min^{-1})	Spectrophotometric method	Alici and Arabaci (2016)

Statistical analysis

It was carried out via CoStat version 6.303 (1998 - 2004), as reported by Gomez and Gomez (1984) at a significance level of 0.05.

RESULTS AND DISCUSSION

Results

- Growth performance and photosynthetic pigments

Table 2 illustrates the effects of foliar application of various rates of yeast and moringa extracts on vegetative, reproductive growth criteria as well as photosynthetic pigments of strawberry plants at 125 days from transplanting. Regarding the individual effect of yeast extract, the rate of 150 ml L^{-1} led to obtain the maximum values of plant height, foliage fresh weight, secondary crown No. $plant^{-1}$, No. of leaves $plant^{-1}$, leaf area, leaf dry matter, chlorophyll and carotene content followed by the rate of 150 ml L^{-1}, while the plants grown without yeast extract had the lowest values. Concerning the individual effect of moringa extract, the highest values for plant height, foliage fresh weight, secondary crown No. $plant^{-1}$, No. of leaves $plant^{-1}$, leaf area, leaf dry matter, chlorophyll and carotene content were achieved with a rate of 20 g L^{-1}. The second-highest values were obtained with a rate of 15 g L^{-1}, while the plants grown without moringa extract had the lowest values for these traits. Notably, when yeast extract was sprayed at a rate of 150 ml L^{-1} in combination with moringa extract at 20 g L^{-1}, the maximum values for all the mentioned traits were achieved, as shown in Table 2. This indicates that the combined application of yeast and moringa extracts resulted in the most favorable growth and photosynthetic pigment outcomes for strawberry plants.

The reasons behind the observed effects of yeast and moringa extracts on the growth, development, and photosynthetic pigments of strawberry plants under salinity stress conditions can be attributed to their bioactive compounds and their impact on various physiological processes. Yeast extract contains a range of bioactive compounds (Abdelaal *et al.,* 2019), such as amino acids, vitamins, enzymes (Taha *et al.*, 2020) and growth-promoting substances (Abdelaal *et al.*, 2021). These compounds can enhance nutrient uptake (Rangel-Montoya *et al.,* 2022), stimulate metabolic activities, and promote plant growth (Ebaid *et al*,. 2022). The application of yeast extract at a rate of 150 ml L^{-1} resulted in the maximum values for plant height, foliage fresh weight, secondary crown number per plant, number of leaves per plant, leaf area, leaf dry matter, chlorophyll content, and carotene content. This indicates that the bioactive compounds present in yeast extract positively influenced the vegetative and reproductive growth of strawberry plants. Similarly, moringa extract contains various bioactive compounds (Awwad *et al.,* 2022), including phenolic compounds, flavonoids, and antioxidants. These compounds have been reported to have plant growth-promoting properties, enhance photosynthesis (Mashamaite *et al.*, 2022), and improve plant tolerance to abiotic stresses (Ragab *et al*., 2022). The highest values for growth criteria and photosynthetic pigments were observed when moringa extract was applied at a rate of 20 g L-1, followed by a rate of 15 g L^{-1}. This suggests that the bioactive compounds in moringa extract contributed to improved growth and photosynthetic efficiency in strawberry plants. When yeast extract was combined with moringa extract at the specific rates mentioned, it led to the highest values for all the studied parameters. The combined application likely resulted in synergistic effects, where the bioactive compounds from both extracts complemented each other and acted together to enhance strawberry plant growth, development, and photosynthetic pigment synthesis.

Table 2. Effects of foliar application of various rates of yeast and moringa extracts on vegetative, reproductive growth criteria as well as photosynthetic pigments of strawberry plants at 125 days from transplanting.

Treatments		Plant height, cm		Foliage fresh weight g $plant^{-1}$		Secondary crown No $plant^{-1}$		Leaves number $plant^{-1}$		Leaves area cm^2 $plant^{-1}$		Leaves dry matter, %		Chlorophyll, SPAD reading		Carotene mg.g^{-1}	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Yeast extract (Y.E) levels																	
Control (0 ml L^{-1})		18.38b	19.13b	53.68c	54.72c	5.78b	7.44b	30.11b	30.89b	370.89c	375.44c	25.87b	26.67b	42.14b	42.83b	0.233b	0.236b
Yeast. E (100 ml L^{-1})		19.02a	19.82a	55.99b	57.11b	6.56a	8.22ab	32.78a	33.89a	420.56b	426.33b	26.41a	27.18a	43.05a	43.75a	0.250a	0.255a
Yeast. E (150 ml L^{-1})		19.30a	20.13a	57.09a	58.25a	7.00a	8.67a	33.67a	35.22a	442.78a	448.22a	26.62a	27.47a	43.44a	44.10a	0.257a	0.260a
LSD at 5%		0.61	0.63	0.12	0.99	0.62	0.98	2.46	1.51	15.49	2.79	0.31	0.32	0.53	0.54	0.007	0.007
Moringa extract (M.E) levels																	
Control (0 g L^{-1})		18.26b	19.02b	53.06c	54.16c	5.44b	7.11b	29.44c	30.11c	357.33c	361.67c	25.76b	26.54b	41.94b	42.55c	0.229c	0.232c
Moringa. E (15 g L^{-1})		19.03a	19.84a	56.01b	57.13b	6.67a	8.33a	32.56b	33.67b	422.22b	427.67b	26.41a	27.24a	43.06a	43.74b	0.250b	0.254b
Moringa. E (20 g L^{-1})		19.42a	20.23a	57.69a	58.79a	7.22a	8.89a	34.56a	36.22a	454.67a	460.67a	26.72a	27.54a	43.63a	44.39a	0.260a	0.265a
LSD at 5%		0.63	0.66	0.89	0.70	0.92	0.61	1.63	1.57	13.83	13.95	0.42	0.45	0.59	0.26	0.002	0.002
Interaction																	
Control	Control	17.82	18.52	51.65	52.84	5.00	6.33	28.00	29.00	324.00	327.67	25.40	26.09	41.37	42.00	0.216	0.220
	M.E (15 g L^{-1})	18.44	19.22	54.00	55.00	5.67	7.67	30.00	30.33	376.33	382.00	25.90	26.85	42.18	42.78	0.234	0.236
	M.E (20 g L^{-1})	18.89	19.65	55.40	56.32	6.67	8.33	32.33	33.33	412.33	416.67	26.31	27.08	42.86	43.71	0.248	0.253
Y. E(100 ml L^{-1})	Control	18.25	18.98	52.96	54.06	5.33	7.00	29.33	29.67	355.00	360.67	25.75	26.46	41.92	42.51	0.228	0.233
	M.E (15 g L^{-1})	19.24	20.05	56.61	57.76	7.00	8.67	33.67	34.67	438.67	444.00	26.59	27.36	43.36	44.15	0.257	0.262
	M.E (20 g L^{-1})	19.58	20.44	58.40	59.50	7.33	9.00	35.33	37.33	468.00	474.33	26.88	27.71	43.86	44.60	0.265	0.270
Y.E(150 ml L^{-1})	Control	18.70	19.56	54.57	55.58	6.00	8.00	31.00	31.67	393.00	396.67	26.13	27.07	42.53	43.13	0.242	0.244
	M.E (15 g L^{-1})	19.41	20.24	57.42	58.63	7.33	8.67	34.00	36.00	451.67	457.00	26.74	27.50	43.65	44.30	0.260	0.264
	M.E (20 g L^{-1})	19.78	20.59	59.28	60.53	7.67	9.33	36.00	38.00	483.67	491.00	26.98	27.82	44.15	44.86	0.269	0.274
LSD at 5%		1.09	1.14	1.54	1.21	1.58	1.06	2.82	2.72	23.95	24.16	0.72	0.79	1.03	0.44	0.004	0.004

Fruit yield and quality

Table 3 presents the effects of foliar application of various rates of yeast and moringa extracts on the yield characteristics of strawberries grown on salt affected soil *i.e.*, average fruit weight, fruit firmness, fruit dry matter, early and total yield. While, Table 4 demonstrates the effects of the same treatments on quality traits *i.e.*, TDS, total sugars, acidity, VC, anthocyanin, MDA and SOD during seasons of 2021/2022-2022/2023.

Regarding antioxidants which is represented by the SOD enzyme, it can be noticed that the different rates of yeast and moringa extracts significantly affected SOD values which increased as the rate of yeast or moringa extracts increased under salinity conditions. Additionally, it is noteworthy that the combined application of yeast extract (150 ml L^{-1}) and moringa extract (20 g L^{-1}) led to increased antioxidant production in strawberry fruits, as evidenced by higher levels of SOD activity. This indicates that the combined treatment (Y.E + M.E at the high rate for each one) enhanced the antioxidant defense system of the strawberry plants under salinity conditions, potentially reducing oxidative stress and promoting fruit quality. This trend can be attributed to the bioactive compounds present in both yeast and moringa extracts. These compounds likely stimulated the production of SOD, an antioxidant enzyme, in strawberry plants.

Table 3. Effects of foliar application of various rates of yeast and moringa extracts on yield traits of strawberry plants

Treatments	Average fruit weight, g		Fruit firmness, g cm^{-2}		Fruit dry matter, %		Early yield, ton ha^{-1} Marketable		Early yield, ton ha^{-1} unmarketable		Total yield, ton ha^{-1} Marketable		Total yield, ton ha^{-1} unmarketable	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Yeast extract (Y.E) levels														
Control (0 ml L^{-1})	18.92c	19.68c	283.56c	286.56b	7.92b	8.04a	14.62a	11.70c	0.86b	1.15a	57.03a	51.39c	1.46a	1.52a
Yeast. E (100 ml L^{-1})	19.85b	20.65b	296.67b	300.89a	8.05a	8.18	12.51b	13.52b	1.09a	1.05a	53.06b	54.65b	1.57a	1.55a
Yeast. E (150 ml L^{-1})	20.23a	21.08a	302.67a	306.44a	8.11a	8.25a	10.47c	14.29a	1.16a	1.05a	49.06c	56.52a	1.44a	1.46a
LSD at 5%	0.24	0.23	0.80	5.91	0.08	N.S	0.14	0.09	0.22	N.S	0.61	0.02	N.S	N.S
Moringa extract (M.E) levels														
Control (0 g L^{-1})	18.67c	19.44c	280.22b	282.89b	7.90b	8.02a	13.22a	11.20c	1.00a	1.24a	54.47a	50.48c	1.41a	1.50a
Moringa. E (15 g L^{-1})	19.87b	20.69b	298.33a	302.33a	8.04a	8.16a	12.56b	13.51b	1.01a	1.03b	52.98b	54.85b	1.59a	1.39a
Moringa. E (20 g L^{-1})	20.45a	21.29a	304.33a	308.67a	8.14a	8.27a	11.83c	14.79a	1.09a	0.98b	51.69c	57.22a	1.48a	1.65a
LSD at 5%	0.25	0.33	11.05	8.81	0.10	N.S	0.21	0.05	N.S	0.11	0.65	0.26	N.S	N.S
Interaction														
Control – Control	18.07	18.83	271.67	273.33	7.81	7.92a	15.17	10.26	0.87	1.23	58.25	48.58	1.43	1.39
Control – M. E (15 g L^{-1})	18.95	19.72	286.00	289.67	7.91	8.01a	14.65	11.73	0.86	1.14	56.99	51.64	1.61	1.31
Control – M. E (20 g L^{-1})	19.74	20.48	293.00	296.67	8.02	8.18a	14.05	13.10	0.84	1.06	55.86	53.94	1.35	1.86
Y. E (100 ml) – Control	18.61	19.37	279.33	282.67	7.90	8.00	13.39	11.13	0.97	1.17	54.64	50.03	1.41	1.60
Y. E (100 ml) – M. E (15 g L^{-1})	20.24	21.06	302.00	306.33	8.09	8.23a	12.45	14.09	1.07	0.97	52.89	55.64	1.64	1.69
Y. E (100 ml) – M. E (20 g L^{-1})	20.70	21.54	308.67	313.67	8.17	8.29a	11.69	15.34	1.22	1.02	51.65	58.28	1.66	1.38
Y.E (150 ml) – Control	19.35	20.11	289.67	292.67	7.98	8.15a	11.09	12.22	1.17	1.31	50.53	52.82	1.39	1.51
Y.E (150 ml) – M. E (15 g L^{-1})	20.43	21.28	307.00	311.00	8.12	8.24a	10.58	14.70	1.10	0.98	49.07	57.28	1.50	1.17
Y.E (150 ml) – M. E (20 g L^{-1})	20.91	21.85	311.33	315.67	8.22	8.34a	9.74	15.94	1.21	0.86	47.57	59.45	1.44	1.71
LSD at 5%	0.43	0.56	19.13	15.25	0.17	N.S	0.36	0.09	N.S	0.19	1.12	0.45	N.S	N.S

Table 4. Effects of foliar application of various rates of yeast and moringa extracts on fruit quality traits of strawberry plants

Treatments	TDS %		Total sugar %		Acidity %		Vitamin C mg.100g^{-1}		Anthocyanin mg.100g^{-1}		MDA (μmol.g^{-1} F.W)		SOD (unit.g^{-1}.min^{-1})	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Yeast extract (Y.E) levels														
Control (0 ml L^{-1})	6.64c	6.74c	5.07c	5.17c	0.768a	0.782a	50.13c	51.02c	51.83c	52.76b	9.65a	9.93a	69.29c	72.11b
Yeast. E (100 ml L^{-1})	7.20b	7.31b	5.54b	5.64b	0.731b	0.743b	51.36b	52.31b	53.06b	53.97a	8.90b	9.19b	70.44b	73.25ab
Yeast. E (150 ml L^{-1})	7.48a	7.59a	5.72a	5.81a	0.709b	0.720b	52.05a	53.08a	53.32a	54.26a	8.50c	8.56	71.02a	73.91a
LSD at 5%	0.12	0.08	0.07	0.06	0.022	0.023	0.57	0.67	0.05	0.58	0.11	0.51c	0.49	1.25
Moringa extract (M.E) levels														
Control (0 g L^{-1})	6.49c	6.57c	5.09c	5.18c	0.778a	0.793a	49.75c	50.67c	51.88c	52.75b	9.84a	9.94a	68.93c	71.85c
Moringa. E (15 g L^{-1})	7.22b	7.35b	5.53b	5.63b	0.732b	0.741b	51.38b	52.38b	52.69b	53.69a	8.96b	9.24b	70.51b	73.22b
Moringa. E (20 g L^{-1})	7.60a	7.72a	5.71a	5.81a	0.697c	0.711c	52.41a	53.35a	53.64a	54.55a	8.25c	8.50c	71.32a	74.20a
LSD at 5%	0.09	0.12	0.08	0.09	0.007	0.007	0.81	0.73	0.26	0.91	0.13	0.48	0.26	0.90
Interaction														
Control – Control	6.14	6.23	4.92	5.00	0.795	0.811	48.99	49.78	51.49	52.30	10.17	10.46	68.18	71.24
Control – M.E (15 g L^{-1})	6.68	6.79	5.16	5.26	0.769	0.782	50.10	51.15	51.56	52.59	9.71	10.01	69.39	72.06
Control – M.E (20 g L^{-1})	7.09	7.19	5.14	5.24	0.739	0.754	51.31	52.11	52.44	53.39	9.08	9.33	70.31	73.04
Y. E (100 ml) – Control	6.45	6.52	5.02	5.11	0.784	0.799	49.62	50.57	52.13	53.04	9.92	10.24	68.78	71.66
Y. E (100 ml) – M.E (15 g L^{-1})	7.37	7.52	5.66	5.75	0.722	0.729	51.74	52.72	53.01	54.04	8.73	9.00	70.90	73.53
Y. E (100 ml) – M.E (20 g L^{-1})	7.77	7.90	5.93	6.04	0.687	0.700	52.72	53.64	54.05	54.84	8.06	8.33	71.65	74.56
Y.E (150 ml) – Control	6.87	6.97	5.33	5.43	0.755	0.770	50.65	51.66	52.02	52.91	9.44	9.12	69.82	72.64
Y.E (150 ml) – M.E (15 g L^{-1})	7.62	7.75	5.78	5.87	0.706	0.712	52.29	53.27	53.49	54.44	8.45	8.72	71.25	74.08
Y.E (150 ml) – M.E (20 g L^{-1})	7.94	8.05	6.05	6.14	0.664	0.678	53.21	54.31	54.44	55.42	7.62	7.84	71.99	75.01
LSD at 5%	0.15	0.21	0.14	0.16	0.011	0.011	1.41	1.26	0.44	1.56	0.22	0.83	0.46	1.56

In terms of acidity, the data show that the control treatment, where plants were grown without yeast extract and moringa extract, exhibited the highest values for acidity, which is an important quality parameter in strawberries.

Conversely, the combined treatment of yeast extract (150 ml L^{-1}) and moringa extract (20 g L^{-1}) resulted in the lowest values for acidity. This implies that the addition of yeast and moringa extracts had a positive impact on reducing acidity levels in strawberry fruits. This can be attributed to the bioactive compounds present in the studied extracts, which may have influenced the enzymatic activity and metabolic processes related to acidity regulation in strawberries.

Similarly, as for malondialdehyde (MDA) values, the control treatment achieved the highest levels of MDA, which serves as an indicator of oxidative stress. On the other hand, the combined treatment of yeast extract (150 ml L^{-1}) and moringa extract (20 g L^{-1}) exhibited the lowest levels of MDA. This suggests that the spraying yeast and moringa extracts effectively mitigated oxidative stress in strawberries, resulting in reduced MDA levels. The bioactive compounds in both yeast and moringa extracts likely contributed to the enhancement of antioxidant mechanisms, resulting in lower oxidative stress levels in strawberry plants.

As for the other yield and quality traits, the data indicate that the values of average fruit weight, fruit firmness, fruit dry matter, early and total yield, TDS, total sugars, VC and anthocyanin significantly increased as the rate of yeas extract rate increased. Also, the values pronouncedly increased as the moringa extract rate increased. Generally, the highest values were recorded when plants were sprayed with yeast extract at a rate of 150 ml L^{-1} and simultaneously with moringa extract at 20 g L^{-1}. The effects observed on the yield and quality traits can be explained by the physiological and biochemical responses of strawberry plants grown under salinity stress conditions to the foliar application of yeast and moringa extracts under salinity conditions.The bioactive compounds in both yeast and moringa extracts likely enhanced nutrient uptake, improved plant metabolism, and increased fruit quality. The highest values for these traits were observed with the combined treatment of yeast extract (150 ml L^{-1}) and moringa extract (20 g L^{-1}), indicating the synergistic effects of the two extracts. These results are in agreement with those of Neamah *et al.* (2022); and Arif *et al.* (2023).

CONCLUSION

In conclusion, the field experiment highlighted the significant impact of soil salinity on strawberry cultivation and the importance of managing this abiotic stress factor. The application of yeast extract (Y.E) and moringa extract (M.E) demonstrated positive effects on the growth performance, quantitative and qualitative yield indicators of strawberries under salinity stress. Increasing the rates of yeast and moringa extracts generally improved the studied parameters, except for malondialdehyde (MDA), an indicator of oxidative stress. The combination of yeast extract (150 ml L^{-1}) and moringa extract (20 g L^{-1}) showed the highest effectiveness in mitigating oxidative stress and enhancing salinity tolerance in strawberries. This combined treatment resulted in the lowest levels of MDA, indicating reduced oxidative damage. Consequently, the application of yeast and moringa extracts can be recommended as a strategy to alleviate the negative impact of soil salinity, improve strawberry performance, and enhance overall yield. Therefore, future strawberry cultivation practices should consider the use of yeast and moringa extracts as management approaches to enhance productivity in salinity-stressed environments. Further research could focus on optimizing the application rates and investigating the underlying mechanisms through which these extracts improve salinity tolerance in strawberries.

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تأثير مستخلص المورينجا والخميرة علي نمو ومحصول الفراولة تحت إجهاد الملوحة التربة

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الملخص

الإنتاج العالمي للفراولة يتأثر بشكل كبير بملوحة التربة، فالملوحة أحد عوامل الإجهاد الغير حيوي البارزة. فمن الضروري توظيف أساليب فعالة لإدارة ملوحة التربة من أجل زيادة إنتاجية الفراولة. لذا تم إجراء تجربة حقلية بهدف تقييم استجابة الفراولة النامية تحت ظروف اجهاد الملوحة للرش الورقي بمستخلص الخميرة بمعدلات (0، 100، 150 مل / لتر) ومستخلص المورينجا بمعدل(0، 15، 20 جم / لتر) وكانت الإضافات اما فردية او بشكل مدمج معًا من خلال تصميم تجريبي القطع المنشقة خلال موسمين متعاقبين (2022/2021 و2023/2022). أظهرت النتائج المتحصل عليها أن المعدلات المختلفة من مستخلصات الخميرة والمورينجا أثرت بشكل كبير على النمو ومؤشرات الإنتاج الكمي والنوعي. اذ زادت قيم معظم الصفات المدروسة مع زيادة المعدلات من مستخلصات الخميرة أو المورينجا. باستثناء مادة المالونديالدهيد(MDA) ، حيث تم ملاحظة القيم القصوى عند رش مستخلص الخميرة بمعدل 150 مل / لتر بالاشتراك مع مستخلص المورينجا بمعدل 20 جم / لتر. بالإضافة إلى ذلك، أظهرت معاملة الكنترول، التي تضمنت النباتات التي نمت بدون مستخلص الخميرة ومستخلص المورينجا، أعلى مستويات MDA (كمؤشر للإجهاد التأكسدي). على النقيض، أسفرت المعاملة المشتركة لمستخلص الخميرة (150 مل / لتر) ومستخلص المورينجا (20 جم / لتر) عن أدنى مستويات من المالونديالدهيد (MDA) وهذا يشير إلى أن رش مستخلصات الخميرة والمورينجا ساهم في التخفيف من الإجهاد اللاتأكسدي وزيادة تحمل الفراولة للملوحة، مما يحسن الأداء والإنتاجية.

الكلمات الدالة: الفراولة ، مستخلص الخميرة، مستخلص المورينجا ، المالونديالدهيد