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RESPONSE OF SWEET BASIL PLANTS TO SPRAYING WITH CHITOSAN AND PROLINE GROWN IN SALINE SOIL

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ABSTRACT: A field experiment was conducted with sweet basil (*Ocimum basilicum*, L.) throughout two successive seasons of 2022 and 2023 in the Eastern Desert of Minya Governorate to evaluate the response of basil plants to spraying with chitosan and proline under saline soil conditions on its production and quality traits. Treatments consisted of three rates of chitosan (0.25, o.5 and 1 g l^{-1}) and three rates of proline (0.1, 0.2 and 0.4 g l^{-1}) compared with untreated plants in a complete randomized block design with three replications. The results revealed that chitosan treatments and proline levels affected growth characteristics, i.e., plant height, branch numbers, fresh and dry herb weight as well as essential oil content and oil constituents. Maximum herb dry weight was obtained with chitosan treatment at 1 g l^{-1} (78.80, 77.70 g), followed by proline at 0.4 g l^{-1} (77.10 and 72.60 g, respectively in the first and second seasons). Moreover, spraying plants with proline at 0.4 g l^{-1} recorded the highest content of linalool (68.0 and 66.4%, respectively for the two seasons), followed by chitosan at 1 g l^{-1} (66.3 and 64.2%). In conclusion, it is recommended to apply proline at 0.4 g l^{-1} and chitosan at 1 g l^{-1} to improve yield and quality of basil plants grown in saline soil.

Keywords: Sweet basil, saline soil, chitosan, proline

INTRODUCTION

Originally from Egypt and the Eastern Mediterranean, sweet basil (*Ocimum basilicum* L., Fam. Lamiaceae) is a therapeutic and aromatic herbaceous crop now grown worldwide for its economic value (Sadeghi *et al.*, 2009). Basil is utilized extensively for its medicinal qualities, and the herb is also consumed fresh or dried for culinary and aromatic uses. Vegetative growth extracts can be utilized as fragrant additions in foods, medicines and cosmetics (Marotti *et al.*, 1996). Furthermore, in addition to its well-known antibacterial and insecticidal properties, basil essential oil was recently discovered to exhibit antimalarial properties *in vivo* (Zheljazkov *et al.*, 2008). These species' uses in medicine, culinary, and fragrance are determined by their characteristics that cause a particular physiological response in the human body by components of bioactive phytochemicals (Krishnaiah *et al.*, 2009).

Salinity is one of the most important problems related to agriculture on newly reclaimed lands. It is considered one of the most important environmental concerns that negatively affect plant growth and development and reduce yield and quality. The negative effects of salinity stress on plants include reduced productivity (Kumar *et al.*, 2020).

Natural biopolymers like chitosan can be derived from marine crustaceans or insect exoskeletons, as known as chitin, which has the ability to transform into chitosan by removing the acetyl group and converting it to amino (Sugiyama *et al.*, 2001). According to Becker *et al.* (2000), the basic component of chitosan's formula is nitrogen. After dissolving, the chitosan-N slowly seeps into the soil and stays there for a while.

According to reports, chitosan promoted nitrogen transport in functioning leaves that boosted plant development and growth (Gornik *et al.,* 2008). Furthermore, extracellular peroxidase activity was significantly elevated by chitosan (Ortmann and Moerschbacher, 2006). (Karimi *et al.*, 2012) suggested that chitosan is an antiperspirant chemical that works well in a variety of crops. It has been utilized to shield plants from oxidative damage (Guan *et al*., 2009) and to enhance growth of plants (Farouk *et al.,* 2011).

Using chitosan as foliar spray was reported by many investigators who found enhanced productivity, quality, and vegetative growth of vegetable crops, such as cucumber (Shehata *et al.,* 2012), strawberry plants (Abdel-Mawgoud *et al.,* 2010), sweet pepper (Ghoname *et al.,* 2010).

Higher plants are known to contain substantial amounts of the proline amino acid, which typically builds up in enormous amounts in response to environmental stressors (Kavi Kishore *et al.,* 2005).

According to earlier research on proline foliar spray application, proline (30 mM) applied externally can successfully lessen the negative effects of 100 mM NaCl osmotic stress on rice (*Oryza sativa*) seed growth (Roy *et al.,* 1993). Hussein *et al.* (2021) reported that when exposed to high temperatures, foliar sprays of proline (2.5 mM) can significantly increase *Abelmoschus esculentus* L.'s water consumption efficiency and enzymatic activity. Gamal El-Din and Abd ElWahed (2005) demonstrated that applying 100 mg l^{-1} proline topically to chamomile plants improved their height, branches number, fresh and dry weights of their aerial vegetative parts, and flower head (*Matricaria chamomilla* L.).

Proline and chitosan are affordable, naturally occurring, low-toxicity substances that are environmentally benign, biodegradable, and have a variety of uses in agriculture. Therefore, this study aimed to enhance the quality and productivity of sweet basil plants by spraying variant rates of chitosan and proline.

MATERIALS AND METHODS

This field experiment was conducted throughout two successive seasons of 2022 and 2023 on the sandy soil of Eastern Desert, Minya Governorate to determine the response of sweet basil plants to spraying with chitosan and proline on productivity and quality traits. Soil was analyzed for physical and chemical properties (Jackson, 1967) and the results are presented in Table (1).

Seeds of basil were obtained from the Experimental Farm of Sids Horticulture Research Station. Seeds were sown in the nursery on February 15th in both seasons. After 45 days from germination, uniform seedlings (10-15 cm in length) were transplanted to the experimental field. Soil preparation for the experimental field was done by adding manure and calcium superphosphate at the rate of 10 m^3 and 300 kg/feddan, respectively. Irrigation and fertilization were applied according to the technical recommendations of the cultivation and production of medicinal and aromatic plants in new lands (El-Masry *et al.,* 2022).

The study used a randomized complete blocks design with 3 replications in 3.0 × 3.5 m plots with 5 rows spaced 70 cm apart and 25 cm between plants. The following treatments were used during both trial seasons:

Table 1. Analysis of tested soil at 2022 and 2023.

Seasons	Particle size distribution			Textural class	Chemical properties					
	Clay %	Silt %	Sand %		OM %	EC, dSm^{-1} (at 25 °C)	mg kg^{-1} soil N	P	K	pH
2022	8.1	10.8	81.1	Sand	0.83	2.69	69	5.4	172	8.10
2023	8.3	11.1	80.6	Sand	0.84	2.61	71	5.6	180	8.20

T1: Untreated as control

T2: Chitosan 0.25 g l^{-1}

T3: Chitosan 0.50 g l^{-1}

T4: Chitosan 1 g l^{-1}

T5: Proline 0.1 g l^{-1}

T6: Proline 0.2 g l^{-1}

T7: Proline 0.4 g l^{-1}

After one month of planting the plants were sprayed with different concentrations of chitosan and proline according to the abovementioned treatments three times one-month intervals.

Chitosan was allowed to dissolve in 5% (v/v) 1 N hydrochloric acid (HCL) by swirling constantly while it was heated gently.

Three harvests of the plants were made throughout each growing season on the 1st of July, 15th of August and 1st of October in both seasons.

At harvest the following growth characteristics were measured: plant height (cm), number of branches/plants, leaf number, leaf area, fresh and dry weights of herb by g/plant and ton/fed and fresh and dry weights of leaves by g/plant and kg/fed.

At the flowering stage, leaf samples were collected to estimate photosynthetic pigments chlorophyll a, chlorophyll b and carotenoids mg g^{-1} F.W. according to A.O.A.C. (1984).

Fresh plants (leaves and flowers) from each treatment were collected throughout the three cuts, dried by air, and weighed (100 g of dry material/treatment) for each replicate. They were then handled by hydro-distillation, and the percentage of essential oil was calculated in accordance with Guenther (1961) and essential oil yield was calculated.

Gas chromatography–mass spectrophotometry analyses:

A Varian CP-3800 GC (Palo Alto, CA) coupled to a Varian Saturn 2000 MS/MS was used to analyze chemical standards and samples of basil oil using GC-MS. The GC was outfitted with a DB-5 fused silica capillary column (30 m × 0.25 mm, with film thickness of 0.25 μm). It was operated with the following parameters: injector temperature of 240 °C, column temperature of 60 to 240 °C at 3 °C/min and then held at 240 °C for 5 minutes; He as the carrier gas; injection volume of 1 μL (splitless); the MS mass ranged from 40 to 650 m/z, filament delay of 3 min, target total ionogram (TIC) of 20,000, a prescan ionization time of 100 μsec, an ion trap temperature of 150 °C, manifold temperature of 60 °C, and a transfer line temperature of 170 °C.

Statistical analysis:

The MSTAT-C (1985) program was used for the statistical analysis of the data, and means were compared using Duncan's multiple range test as published by Duncan (1955).

RESULTS

Vegetative growth traits:

Data in Table (2) reveal that different concentration of chitosan treatments were significantly influenced the vegetative growth i.e. plant height (cm), the number of branches, number of leaves and leaf area (cm^2) of basil plants. Spraying chitosan at 1 g l^{-1} gave high increments of 69.37, 50.00, 77.14 and 21.49% respectively, on this trait compared with control plants in the first season and by 65.88, 48.40, 74.32 and 18.40%, respectively, compared with untreated plants in the second season in the first cut. While, the increases at the second cut were 54.09, 38.46, 59.72 and 18.89% in the first season and by 50.91, 37.51, 57.76 and 20.45%, respectively in the second one compared with control plants and the same trend was in the third cut.

On the other hand, proline treatments significantly increased the vegetative growth traits. Proline at the high rate increased plant height by 57.27 and 55.81% compared with control in both seasons, respectively, and by 43.30 and 42.01% for the number of branches in the two seasons, respectively. The increment in number of leaves and leaf area

Table 2. Growth characteristics of sweet basil affected by chitosan and proline during 2022 and 2023 seasons.

Treatments	Season of 2022				Season of 2023			
	Plant height (cm)	Number of branches	Number of leaves	Leaf area (cm^2)	Plant height (cm)	Number of branches	Number of leaves	Leaf area (cm^2)
				First cut				
Control	51.33 e	10.00 e	350.0 e	15.54 e	53.00 e	10.33 d	363.3 e	15.91 c
Chitosan 0.25 g l^{-1}	72.67 bc	12.00 cd	543.3 b	17.08 bc	74.00 bc	12.00 c	553.3 b	17.17 b
Chitosan 0.50 g l^{-1}	74.33 ab	13.33 b	526.7 bc	17.29 b	77.00 ab	12.67 b	533.3 bc	17.40 b
Chitosan 1 g l^{-1}	80.00 a	15.00 a	620.0 a	18.45 a	81.33 a	15.33 a	633.3 a	18.47 a
Proline 0.1 g l^{-1}	59.00 d	10.33 e	423.3 d	15.83 de	60.00 d	10.33 d	430.0 d	15.96 c
Proline 0.2 g l^{-1}	67.00 c	11.33 d	510.0 c	16.15 de	70.00 c	12.33 bc	516.7 c	16.28 c
Proline 0.4 g l^{-1}	75.00 abc	14.33 a	610.0 a	16.38 cd	75.67 abc	14.67 a	616.7 a	16.51 c
				Second cut				
Control	53.00 d	13.00 c	463.3 e	15.67 d	55.00 c	13.33 e	473.3 e	15.40 d
Chitosan 0.25 g l^{-1}	74.67 ab	14.67 bc	663.3 b	17.31 b	75.00 abc	14.67 cd	666.7 b	17.32 b
Chitosan 0.50 g l^{-1}	75.33 ab	15.33 bc	643.3 bc	16.57 c	77.67 ab	15.67 bc	646.7 bc	16.67 c
Chitosan 1 g l^{-1}	81.67 a	18.00 a	740.0 a	18.63 a	83.00 a	18.33 a	746.7 a	18.55 a
Proline 0.1 g l^{-1}	60.33 c	13.67 c	540.0 d	16.02 cd	61.00 bc	13.67 de	543.3 d	16.03 c
Proline 0.2 g l^{-1}	68.33 b	15.33 bc	623.3 c	16.35 cd	71.67 abc	15.33 bc	626.7 c	16.39 c
Proline 0.4 g l^{-1}	77.00 a	17.33 ab	726.7 a	18.00 ab	78.67 ab	17.00 ab	726.7 a	17.83 ab
				Third cut				
Control	49.33 b	14.00 c	460.0 e	15.67 d	51.00 b	14.33 c	470.0 e	15.31 d
Chitosan 0.25 g l^{-1}	71.33 ab	16.00 abc	656.7 b	17.22 b	70.67 ab	16.00 b	663.3 b	17.32 b
Chitosan 0.50 g l^{-1}	73.00 ab	16.67 abc	633.3 bc	16.49 c	73.33 ab	16.33 b	643.3 bc	16.59 c
Chitosan 1 g l^{-1}	77.67 a	18.00 a	730.0 a	18.48 a	79.33 a	19.00 a	740.0 a	18.52 a
Proline 0.1 g l^{-1}	57,67 ab	14.33 bc	533.3 d	15.94 cd	58.00 ab	14.67 c	536.7 d	16.00 c
Proline 0.2 g l^{-1}	65.33 ab	16.33 abc	620.0 c	16.26 cd	68.33 ab	16.33 b	623.3 c	16.39 c
Proline 0.4 g l^{-1}	73.00 ab	17.00 ab	713.3 a	17.81 ab	74.67 ab	17.67 ab	723.3 a	17.63 ab

Means followed by the same letters within each column do not differ significantly according to Duncan's multiple range test at the 5% level.

were 74.29 and 16.03% in the 1st season and by 69.75 and 14.09% in the 2nd season, respectively, compared to untreated plants at the first cut. Proline treatment at 0.4 g l^{-1} was not significant with chitosan treatment at 1 g l^{-1} on the characteristic of plant height, number of branches, number of leaves per plant and leaf area (cm^2) in the three cuts at both seasons. The second cut was the best in characters of vegetative growth followed by third cut and first cut arrangement in both seasons.

As shown in Table (3) values of herb fresh weight, herb dry weight, leaves fresh weight and leaves dry weight were significantly affected by plants treated with chitosan and proline treatments. The maximum herb fresh weight, herb dry weight, leaves fresh weight and leaves dry weight were obtained due to plants treated with high concentration of chitosan treatment, being 460, 78.80, 113.8 and 21.28 g/plant, respectively in the first season and were 456.7, 77.70, 116.3 and 21.83 g/plant, respectively in the second one at first cut, followed by proline treatment at 0.4 g l^{-1} gave 430.0, 77.10, 111.2 and 20.11 g/plant, respectively in the first season and were 433.3, 72.60, 110.0 and 20.35 g/plant, respectively in the second growing season in the first cut compared with control plants which were 320.0, 51.87, 90.8 and 13.49 in the first one and were 313.3, 47.88, 93.0 and 14.55 g/plant, respectively, in the second growing season. The same trend was on the second and third cut.

It was observed that there were no significant differences between spraying basil plants with chitosan at 1 g l^{-1} and a high rate of proline treatment at 0.4 g l^{-1} in most characteristics.

Table 3. Yield accumulation of sweet basil affected by chitosan and proline during 2022 and 2023 seasons.

Treatments	Season of 2022				Season of 2023			
	Herb fresh weight (g/plant)	Herb dry weight (g/plant)	Leaves fresh weight (g/plant)	Leaves dry weight (g/plant)	Herb fresh weight (g/plant)	Herb dry weight (g/plant)	Leaves fresh weight (g/plant)	Leaves dry weight (g/plant)
First cut								
Control	320.0 e	51.87 d	90.8 e	13.49 e	313.3 e	47.88 d	93.0 e	14.55 f
Chitosan 0.25 g l^{-1}	380.0 d	70.00 b	101.8 c	17.62 c	396.7 c	63.22 bc	103.7 c	16.78 cd
Chitosan 0.50 g l^{-1}	410.0 c	71.60 b	106.3 b	18.56 b	410.0 c	66.10 b	105.0 c	17.25 c
Chitosan 1 g l^{-1}	460.0 a	78.80 a	113.8 a	21.28 a	456.7 a	77.70 a	116.3 a	21.83 a
Proline 0.1 g l^{-1}	360.0 d	59.90 c	97.5 d	15.75 d	370.0 d	59.00 c	99.0 d	16.03 e
Proline 0.2 g l^{-1}	366.7 d	69.47 c	99.5 cd	16.15 d	370.0 d	59.11 c	99.75 d	16.20 de
Proline 0.4 g l^{-1}	430.0 b	77.10 ab	111.2 a	20.11 ab	433.3 b	72.60 a	110.0 b	20.35 ab
Second cut								
Control	430.0 d	66.00 d	122.7 e	18.31 c	420.0 d	64.13 e	125.0 e	18.75 c
Chitosan 0.25 g l^{-1}	486.7 c	82.10 b	137.0 c	22.42 b	503.3 bc	80.60 c	139.7 c	22.88 b
Chitosan 0.50 g l^{-1}	520.0 b	84.00 b	143.3 b	23.60 b	513.3 bc	83.40 b	141.7 c	23.20 b
Chitosan 1 g l^{-1}	570.0 a	99.70 a	153.0 a	27.13 a	595.0 a	99.10 a	156.7 a	27.91 a
Proline 0.1 g l^{-1}	472.0 c	76.10 c	131.7 d	21.34 b	473.0 c	73.70 d	133.3 d	21.66 b
Proline 0.2 g l^{-1}	470.0 c	74.00 c	133.7 cd	21.66 b	473.3 c	74.60 d	134.7 d	21.84 b
Proline 0.4 g l^{-1}	536.7 b	92.70 a	149.7 a	26.29 a	541.0 b	87.90 b	148.0 b	26.08 a
Third cut								
Control	425.0 e	65.00 d	122.7 e	18.31 d	416.7 e	63.12 d	125.3 e	18.81 d
Chitosan 0.25 g l^{-1}	485.0 d	77.00 c	138.0 c	22.60 c	500.0 c	80.00 bc	140.3 c	23.06 bc
Chitosan 0.50 g l^{-1}	515.0 c	88.20 b	143.3 b	23.66 bc	515.0 c	81.20 b	142.0 c	23.40 bc
Chitosan 1 g l^{-1}	565.0 a	98.70 a	154.0 a	27.34 a	561.7 a	92.80 a	156.0 a	27.76 a
Proline 0.1 g l^{-1}	465.0 d	73.00 c	132.7 d	21.54 c	471.7 d	74.20 c	134.3 d	21.86 c
Proline 0.2 g l^{-1}	470.0 d	74.00 c	134.3 cd	21.80 c	475.0 d	76 04 bc	134.0 d	21.80 c
Proline 0.4 g l^{-1}	535.0 b	92.40 a	150.3 a	25.06 b	535.0 b	88.10 a	148.7 b	25.74 ab

Means followed by the same letters within each column do not differ significantly according to Duncan's multiple range test at the 5% level.

Yield components:

Results shown in Table (4) noticed significant differences in herb dry weight ton/fed and leaves dry weight kg/fed resulting from spraying chitosan and proline treatments at different concentrations compared with untreated plants. The highest values of herb and leaves dry weights were obtained from chitosan at 1 g l^{-1} which recorded 1.604 and 485.1 in the first season and 1.585 and 497.6 in the second one, respectively at the first cut compared with untreated plants, 1.145 and 307.7 in the first one and 1.076 and 331.7 in order, followed by proline treatment at 0.4 g l^{-1} which increased herb dry weight and leaves dry weight by 37.53 and 51.84% in the first season and by 39.22 and 33.01% in the second season, respectively, compared with untreated plants. The results were very similar in both two cuts.

Also, the data shown in Table (4), indicates that spraying chitosan and proline treatments at different concentrations has a positive and significant impact in improving and increasing the percentage and yield of oil. Chitosan at 1 g l^{-1} gave the highest percentage of oil being 1.03% and 0.97% compared to control plants (0.67 and 0.63%, respectively in both seasons) at first cut. The difference between chitosan at 1 g l^{-1} and proline treatment at 0.4 g l^{-1} was not significant regarding oil percentage at the first and last cut.

Furthermore, the highest oil yield kg/fed resulted from plants treated with chitosan at 1 g l^{-1} which was 16.52 and 15.37 kg/fed, respectively in both seasons, followed by proline treatment at 0.4 g l^{-1} which gave 15.28 and 13.93 kg/fed compared with untreated control (7.67 and 7.78 kg/fed at first cut)

Table 4. Dry yield and essential oil yield of sweet basil affected by chitosan and proline during 2022 and 2023 seasons.

Treatments	Season of 2022				Season of 2023			
	Herb dry weight (ton/fed)	Leaves dry weight (kg/fed)	Oil (%)	Oil yield (kg/fed)	Herb dry weight (ton/fed)	Leaves dry weight (kg/fed)	Oil (%)	Oil yield (kg/fed)
First cut								
Control	1.145 d	307.7 e	0.67 d	7.67 d	1.076 d	331.7 d	0.63 e	6.78 f
Chitosan 0.25 g l^{-1}	1.454 b	401.6 c	0.93 b	14.10 b	1.337 b	382.5 c	0.87 bc	11.63 c
Chitosan 0.50 g l^{-1}	1.481 b	423.2 bc	0.83 c	12.29 b	1.387 b	393.3 c	0.83 cd	11.51 cd
Chitosan 1 g l^{-1}	1.604 a	485.1 a	1.03 a	16.52 a	1.585 a	497.6 a	0.97 a	15.37 a
Proline 0.1 g l^{-1}	1.280 c	359.1 d	0.77 c	9.86 c	1.265 c	365.4 c	0.77 d	9.74 e
Proline 0.2 g l^{-1}	1.237 c	368.3 d	0.83 c	10.26 c	1.268 c	369.4 c	0.80 cd	10.14 de
Proline 0.4 g l^{-1}	1.575 ab	467.2 ab	0.97 ab	15.28 ab	1.498 a	441.2 b	0.93 ab	13.93 ab
Second cut								
Control	1.505 e	417.5 d	0.71 e	10.68 e	1.462 e	427.5 e	0.70 d	10.23 d
Chitosan 0.25 g l^{-1}	1.872 c	511.2 c	0.93 bc	17.41 b	1.838 c	521.7 c	0.97 a	17.82 b
Chitosan 0.50 g l^{-1}	1.915 c	538.1 b	0.87 c	16.66 bc	1.902 c	529.0 c	0.90 b	17.11 b
Chitosan 1 g l^{-1}	2.273 a	618.6 a	1.00 a	22.72 a	2.259 a	636.3 a	0.97 a	21.90 a
Proline 0.1 g l^{-1}	1.734 d	486.6 c	0.79 d	13.66 d	1.680 d	493.8 d	0.80 c	13.44 c
Proline 0.2 g l^{-1}	1.687 d	493.8 c	0.83 cd	14.00 d	1.701 d	498.0 cd	0.87 b	14.80 c
Proline 0.4 g l^{-1}	2.114 b	599.4 a	0.97 ab	20.51 a	2.004 b	594.6 b	0.93 ab	18.63 ab
Third cut								
Control	1.482 d	417.5 d	0.71 d	10.52 e	1.439 e	428.9 d	0.71 d	10.22 e
Chitosan 0.25 g l^{-1}	1.756 c	515.3 bc	1.03 ab	18.08 c	1.824 c	525.8 bc	1.03 a	18.77 bc
Chitosan 0.50 g l^{-1}	2.011 b	539.4 b	0.97 b	19.50 bc	1.851 c	533.5 b	0.93 b	17.20 c
Chitosan 1 g l^{-1}	2.250 a	623.4 a	1.07 a	24.07 a	2.116 a	632.9 a	1.03 a	21.79 a
Proline 0.1 g l^{-1}	1.664 c	491.1 c	0.80 c	13.31 d	1.692 d	498.4 c	0.80 c	13.53 d
Proline 0.2 g l^{-1}	1.687 c	497.0 c	0.87 c	14.67 d	1.734 d	497.0 c	0.87 b	15.08 d
Proline 0.4 g l^{-1}	2.107 b	571.4 b	1.02 ab	21.49 ab	2.009 b	564.1 b	1.00 a	20.09 ab

Means followed by the same letters within each column do not differ significantly according to Duncan's multiple range test at the 5% level.

without significant difference between them. The same trend was noticed on the second and third cut.

Photosynthetic pigments:

Results illustrated in Table (5) indicated that all the tested chitosan and proline treatments showed significant effects on the chlorophyll content of sweet basil plants. The highest chlorophyll a (2.297 and 2.410 mg g^{-1}), chlorophyll b (0.505 and 0.544 mg g^{-1}) and carotenoids content (0.695 and 0.688 mg g^{-1}) was recorded with chitosan 1 g l^{-1} followed by proline at 0.4 g l^{-1} without significant difference between both. The corresponding mean values of chlorophyll a were 2.290 and 2.2334 mg g^{-1}, chlorophyll b being 0.480 and 0.542 mg g^{-1} and 0.685 and 0.676 mg g^{-1} for carotenoids content, respectively for the first cut in two seasons. The same trend was obtained for the second and third cuts.

Essential oil constituents:

The quality of volatile oil depends on the relative concentration of different components. Data in Table (6) cleared that the chemical composition of basil essential oil was affected by different chitosan and proline treatments compared to the untreated control.

Gas chromatographic analysis of the essential oil from basil essential oil herb revealed the existence of 10 components from the identified oil composition. The main components in basil herb oil were linalool (62.71- 68.0%), β-eudesmol (4.62-5.94%), 1.8-cineol (4.26-6.21%), trans-a-bergamotene (4.32-5.70%) and myrcene (4.03-4.56%).

A comparison between the composition of basil oil shows that plants which were sprayed with proline at 0.4 g l^{-1} gave the highest content of linalool (68.0-66.4%)

Table 5. Photosynthetic pigments of sweet basil affected by chitosan and proline during 2022 and 2023 seasons.

Treatments	Season of 2022			Season of 2023		
	Chlorophyll a (mg g^{-1} F.W.)	Chlorophyll b (mg g^{-1} F.W.)	Carotenoids (mg g^{-1} F.W.)	Chlorophyll a (mg g^{-1} F.W.)	Chlorophyll b (mg g^{-1} F.W.)	Carotenoids (mg g^{-1} F.W.)
			First cut			
Control	2.151 c	0.411 c	0.629 b	2.142 d	0.386 c	0.611 b
Chitosan 0.25 g l^{-1}	2.270 a	0.460 a-c	0.676 ab	2.270 b	0.512 a	0.666 a
Chitosan 0.50 g l^{-1}	2.277 a	0.469 a-c	0.682 ab	2.272 b	0.522 a	0.672 a
Chitosan 1 g l^{-1}	2.297 a	0.505 a	0.695 a	2.410 a	0.544 a	0.688 a
Proline 0.1 g l^{-1}	2.210 b	0.438 bc	0.648 ab	2.202 c	0.446 b	0.651 a
Proline 0.2 g l^{-1}	2.250 ab	0.448 a-c	0.665 ab	2.264 b	0.452 b	0.655 a
Proline 0.4 g l^{-1}	2.290 a	0.480 ab	0.685 ab	2.334 a	0.542 a	0.676 a
			Second cut			
Control	2.320 d	0.441 c	0.714 c	2.258 d	0.423 c	0.650 c
Chitosan 0.25 g l^{-1}	2.400 b	0.476 ab	0.772 a-c	2.330 b	0.478 a	0.745 a
Chitosan 0.50 g l^{-1}	2.405 b	0.482 ab	0.790 ab	2.461 b	0.489 a	0.766 a
Chitosan 1 g l^{-1}	2.562 a	0.520 a	0.822 a	2.543 a	0.502 a	0.791 a
Proline 0.1 g l^{-1}	2.360 c	0.464 ab	0.750 bc	2.303 c	0.465 b	0.702 b
Proline 0.2 g l^{-1}	2.400 b	0.477 ab	0.752 bc	2.310 c	0.471 b	0.733 b
Proline 0.4 g l^{-1}	2.550 a	0.507 ab	0.803 ab	2.501 a	0.495 a	0.780 a
			Third cut			
Control	2.300 e	0.424 c	0.690 d	2.240 d	0.418 d	0.645 d
Chitosan 0.25 g l^{-1}	2.388 bc	0.498 a	0.750 b	2.323 c	0.472 bc	0.700 bc
Chitosan 0.50 g l^{-1}	2.396 bc	0.500 a	0.782 a	2.366 b	0.485 ab	0.730 b
Chitosan 1 g l^{-1}	2.450 a	0.510 a	0.811 a	2.423 a	0.502 a	0.803 a
Proline 0.1 g l^{-1}	2.353 d	0.461 b	0.720 c	2.284 c	0.450 c	0.686 c
Proline 0.2 g l^{-1}	2.375 cd	0.492 a	0.741 bc	2.300 c	0.461 c	0.692 bc
Proline 0.4 g l^{-1}	2.411 ab	0.508 a	0.807 a	2.411 a	0.492 ab	0.771 a

Means followed by the same letters within each column do not differ significantly according to Duncan's multiple range test at the 5% level.

Table 6. Effect of chitosan and proline on main components of sweet basil for the second cut during 2022 and 2023 seasons.

Main compounds	Control		Chitosan 0.25 g l^{-1}		Chitosan 0.50 g l^{-1}		Chitosan 1 g l^{-1}		Proline 0.1 g l^{-1}		Proline 0.2 g l^{-1}		Proline 0.4 g l^{-1}	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
β-pinene	0.48	0.42	0.43	0.54	0.41	0.49	0.53	0.51	0.43	0.49	0.52	0.48	0.48	0.56
Myrcene	4.06	4.12	4.16	4.33	4.23	4.56	4.02	4.36	4.17	4.03	4.23	4.19	4.12	4.28
1.8-cineol	4.73	4.61	4.32	5.02	4.68	5.11	5.21	4.36	4.82	4.96	5.01	4.83	4.96	4.26
β-ocimene	3.82	3.62	3.92	3.42	3.49	4.02	3.92	3.42	3.86	3.94	3.16	3.61	4.11	3.89
Linalool	62.71	63.1	63.8	64.9	65.9	65.2	66.3	64.2	63.8	64.2	64.8	67.2	68.0	66.4
Methyl chavicol	2.14	2.26	2.04	2.08	1.93	1.31	1.89	2.32	2.02	1.83	2.26	1.39	1.41	2.39
Eugenol	3.81	3.67	4.11	3.82	3.62	4.16	3.99	3.82	3.94	3.84	3.94	4.04	3.62	3.60
α-selinene	1.81	1.92	1.72	1.86	2.01	2.14	2.04	1.89	1.79	1.83	1.62	1.93	1.98	2.01
β-eudesmol	5.41	5.49	5.62	5.92	5.83	5.72	5.62	5.62	5.69	5.92	5.62	4.92	4.62	5.94
Trans-a-bergamotene	4.72	4.91	5.08	4.93	5.17	4.82	4.93	5.13	4.32	5.02	4.61	5.04	4.82	5.70
Unknown compounds	6.31	5.88	4.80	3.18	2.73	2.47	1.55	4.37	5.16	3.94	4.23	2.37	1.88	0.97

respectively for the two seasons, followed by chitosan at 1 g l^{-1} (66.3-64.2%). The maximum values of β-eudesmol (5.83-5.72%) and myrcene (4.23-4.45%) resulted from plants treated with chitosan at 0.5 g l^{-1}, while 1.8-cineol (5.21-4.36%) in both seasons resulted from chitosan at 1 g l^{-1}.

DISCUSSION

Soil salinity poses a major threat to the agricultural crops productivity, especially for plants that cannot tolerate salt. Salinity is a main contributing factor to a serious global problem, especially in arid and semi-arid countries (Rady *et al.*, 2011). In addition, salinity also causes "osmotic stress" that leads to water imbalance, a decrease in growth stimulators (IAA and GA_3), an increase in growth inhibitors (ABA), stomatal closure, ionic imbalance, loss of photosynthesis, and accumulation of toxic ions. Thus inhibiting plant growth and productivity (Sadak and Dawood, 2023). Therefore, the current study aimed to evaluate the balance between the impact of salt stress and existing climate changes. Our results showed that chitosan and proline treatments significantly improved the growth of sweet basil under salinity stress by improving various physiological parameters.

In addition, the nature of chitosan is hydrophilic. It may mitigate the effects of stress by reducing water content in the cell and accelerating many biological process activities of macromolecules (Chakraborty *et al.,* 2020). Furthermore, the current results showed that chitosan treatment with different concentrations on sweet basil plants fulfils pronounced improvements in growth, under salinity stress conditions.

Furthermore, chitosan treatments improved the photosynthetic pigments of sweet basil plants underneath Salinity stress. These rises could be explained by chitosan's ability to enhance cytokinin ingredients that promote the production of chlorophylls and/or make amino compounds more readily available, which came out of chitosan (Chibu and Shibayama, 2001). Chitosan's improved ability to raise the IAA content of sweet basil plants cultivated under salt stress may enhance enzyme activity and raise growth indices in treated plants. Additionally, these rises might result from chitosan's enhanced effect on bound auxin gene expression, which decreases IAA oxidase activities and speeds up IAA production (Li *et al.,* 2018). The foliar application of chitosan may improve the output of essential oils by increasing cycle growth, enhancing nutrient uptake, or altering the population of leaf oil glands and the manufacture of monoterpenes (Ghasemi Pirbalouti *et al.*, 2014).

Higher plants are known to contain substantial amounts of the amino acid proline, which typically builds up in enormous amounts in response to environmental stressors (Kavi Kishore *et al.,* 2005). Proline supports osmotic adjustment by acting as an osmolyte. It also helps stabilize subcellular structures (such proteins and membranes), scavenge free radicals, and buffer cellular redox potential in stressful situations. It might also act as a hydrotrope that is compatible with proteins (Srinivas and Balasubramanian, 1995). Rapid breakdown of proline upon stress relief may also provide sufficient reducing agents to support mitochondrial oxidative phosphorylation and ATP generation for stress recovery and repair of stress-induced damage (Hare *et al.,* 1998). In response to drought stress in plants, proline accumulation typically occurs in the cytosol where it contributes significantly to cytoplasmic osmotic adjustment. Furthermore, It was determined that in response to water deficiency and salinity, the increase in proline concentration in the apical meristem of maize roots was paralleled by the increase in abscisic acid concentration (Ober and Sharp, 1994).

In plant cells, proline regulates the activity and function of the enzymes catalase, peroxidase, and polyphenol oxidase as well as their involvement in the formation of metabolic reactions to environmental stimuli (Öztürk and Demir, 2002). Increase in vegetative developmental traits because the application of proline can regulate the osmotic regulation of cells and enhance its ability to capture and absorb water (Morgan *et al.,* 1986). The improvement in the photosynthetic pigment efficiency may be due to the stimulation of chlorophyll biosynthesis and/or suppression of its breakdown, in addition to more effective scavenging of reactive oxygen species and regulation of photosynthetic processes by proline (Abdelhamid *et al*., 2013).

CONCLUSION

In this study, it was observed that the highest values of the growth characters, yield and volatile oil percentage and yield of oil of Sweet basil (*Ocimum basilicum,* L.) plants, resulted from plants treated with the highest concentration of chitosan treatment at 1 g l^{-1} or proline treatment at 0.4 g l^{-1}.

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استجابة نباتات الريحان الحلو للرش بالشيتوزان والبرولين المنزرعة في الأراضي الملحية

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أجريت تجربة حقلية علي نباتات الريحان الحلو خلال موسمين متتاليين ٢٠٢٢ و ٢٠٢٣ بالصحراء الشرقية بمحافظة المنيا لتقييم استجابة نباتات الريحان للرش بالشيتوزان والبرولين تحت ظروف التربة المالحة وتأثيرها علي الإنتاجية والجودة. تكونت المعاملات من ثلاثة معدلات من الشيتوزان (٠,٢٥ ، ٠,٥ و ١ جرام/ لتر) وثلاثة معدلات من البرولين (٠,١ ، ٠,٢ و٠,٤ جرام/لتر) مقارنة بالنباتات غير المعاملة في تصميم القطاعات الكاملة العشوائية بثلاث مكررات. أظهرت النتائج أن معاملات الشيتوزان ومستويات البرولين أثرت على خصائص النمو، مثل ارتفاع النبات وعدد الفروع ووزن الأعشاب الطازجة والجافة وكذلك محتوى الزيت العطري ومكونات الزيت. تم الحصول على أعلى وزن جاف للأعشاب بمعاملة الشيتوزان عند ١ جرام/لتر (٧٨,٨٠ و ٧٧,٧٠ جم)، تليها البرولين عند ٠,٤ جرام/لتر (٧٧,١٠ و ٧٢,٦٠ جم)، على التوالي في كلا الموسمين. علاوة على ذلك أعطت معاملة الرش بالبرولين بمعدل ٠,٤ جرام/لتر أعلى محتوى من اللينالول (٦٨,٠ و ٦٦,٤٪) للموسمين على التوالي، يليه الشيتوزان بمعدل ١ جرام/لتر (٦٦,٣ و ٦٤,٢٪). لذلك نوصى باستخدام البرولين بمعدل ٠,٤ جرام/لتر والشيتوزان بمعدل ١ جرام/لتر لتحسين إنتاجية وجودة نباتات الريحان المزروعة في التربة المالحة.