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RESPONSE OF YIELD AND HEAD QUALITY OF LETTUCE TO NITROGEN FERTILIZATION AND SEAWEED EXTRACT FOLIAR APPLICATION UNDER NEW VALLEY CONDITIONS

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ABSTRACT: Two field experiments were conducted at the Agricultural Research Farm of the Faculty of Agriculture, New Valley University, New Valley Governorate, Egypt, during the two successful seasons of 2022/2023 and 2023/2024 to study the effect of nitrogen fertilization at rates of 45, 60, 75, and 90 kg N/feddan in the form of urea and foliar spraying with seaweed extract (SWE) at concentrations of 2, 4, and 6 ml/l beside untreated control and their interactions between them on growth, productivity, nitrogen use efficiency (NUE), and head quality of lettuce cv. Dark Green, grown in sandy soil. The results clearly demonstrated that the interaction between fertilizing lettuce plants with 90 kg N/fed. and foliar spraying with SWE at 6 ml/l significantly enhanced plant growth parameters, leaf pigments, i.e., chlorophyll a, b, and carotenoides, head traits such as head diameter, head fresh weight, dry matter percentage in leaves, and the total yield (ton/fed.), leaves content of N, P, and K, total soluble solids, and vitamin C in both seasons. Moreover, this interaction treatment scored relative increases about 65.84% acreage of the two seasons over the interaction between fertilizing plants with 45 kg N/fed. and foliar spraying with distilled water (control plants). As for NUE and nitrate concentration in lettuce plants, fertilizing plants with 45 kg N/fed. and foliar spraying with SWE at 6 ml/l record the maximum NUE (average two seasons, 286.35 kg yield/one kg N) and the minimum nitrate concentration in leaves (average two seasons, 174.00 ppm). Despite the use of a high rate of nitrogen fertilization (90 kg/fed.) and spraying lettuce plants with SWE at 6 ml/l, which recorded the maximum yield per feddan, the percentage of nitrate (295.15 average two seasons) that was estimated in the leaves did not reach the maximum permissible limit of nitrates (2 g/kg DW).

Key words: Lettuce, nitrogen rates, seaweed extract and sandy soil.

INTRODUCTION

The most widely farmed salad vegetable in Egypt is lettuce (*Lactuca sativa* L.) **Midan and Sorial (2011)**. When ingested as a crisp green salad, lettuce is regarded as a significant source of vitamins and minerals. Furthermore, a wealth of antioxidants, vitamins A and C, and phytochemicals with anticarcinogenic properties can be found in lettuce leaves **(Masarirambi *et al*., 2012)**.

Certain physical characteristics of sandy soils include weak aggregate stability, a high rate of infiltration, and a low capacity to retain moisture. These attributes reduce the soil's biological, chemical, and physical qualities that are linked to low soil fertility, which eventually results in a small crop yield in sandy soils **(Alghamdi *et al*., 2024)**.

Nitrogen is one nutrient that is necessary for crop growth. Because nitrogen improves crop quality and increases agricultural productivity and production, large amounts of nitrogen are added to agricultural soil every year to save the world's food supply.

Nitrogen, an essential part of the plant life cycle, nitrogen increases productivity. Nitrogen

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addition has a direct impact on the components of photosynthetic pigment, photosynthesis output and transport, protein and carbohydrate accumulation, and growth and development of plants. It also has a strong correlation with productivity (**Tariq *et al*., 2023**). There are serious problems with excessive use and under uses of nitrogen fertilizers **(Feyisa *et al*., 2024)**. Under use of nitrogen is related to poorer crop production, while excessive use causes severe harm to the soil and environment as well as leads to an increase in the nitrate content of the crop tissues **(Velayudhan *et al*., 2024)**.

Many authors reported that increasing nitrogen fertilizer significantly enhanced the productivity and head quality of lettuce **(Abu-Rayyan *et al.*, 2004; Parente *et al*., 2006; Boroujerdnia and Ansari, 2007; Hosseny and Ahmed, 2009; Shahein *et al*., 2014; Awaad *et al.*, 2016; Mohamed and Zewail, 2016; Hasan *et al*., 2017; Liu *et al*., 2014; Yeshiwas *et al.*, 2018; El-Bassyouni, 2019; Aboud and Abd-Alrahman, 2021; Mohammed *et al*., 2022)**.

Plant growth regulators are known to be found in seaweed extract because it has high concentrations of cytokinins, auxins, and betaines, which may have encouraged cell division and may have aided in many stages of vegetative development and productivity (**Sani and Yong, 2021**). Furthermore, it promotes the development of flowers, which raises fruit yield overall. Additionally, it may speed up the rate of CO_2 absorption by increasing chlorophyll concentration. Moreover, it has been demonstrated that seaweed speeds up assimilation, increases nutrient uptake, reduces nitrate levels, and promotes photosynthesis, all of which enhance the amount of assimilates that are supplied to the plant (**Alloyarova *et al*., 2024**).

Spraying lettuce plants with seaweed extract improved the productivity and head quality of lettuce **(Crouch *et al.*, 1990; Faheed and Abd-El Fattah, 2008; Baslam *et al*., 2011; Menamo and Wolde, 2013** on lettuce**; Satekge *et al*., 2016** on cabbage**; Chrysargyris *et al.*, 2018; Acun, 2019; Asadi *et al*., 2022; and Rasouli *et al*., 2022** on lettuce**)**.

Therefore, the aim of this work was to determine the suitable rate of nitrogen fertilizer in the form of urea with the most appropriate concentration of seaweed extract to obtain the highest yield and the best specifications for the quality of lettuce heads under the conditions of New Valley Governorate.

MATERIALS AND METHODS

Experiment Site

Two experimental studies were conducted at Agricultural Research Farm of the Faculty of Agriculture, New Valley University, El-Kharja Oasis District (25”26’31°N, 30”33’36°E, altitude 283 m), New Valley Governorate, Egypt, during the 2022/2023 and 2023/2024 seasons, to study the response growth, yield, and head quality of lettuce plants cv. Dark Green to mineral nitrogen rates and seaweed extract (SWE) as foliar application.

Soil samples were taken at a depth of 0.0 to 30.0 cm before planting, and they were then thoroughly homogenized to study the physical and chemical and chemical features (**Jackson, 1973**). An examination of the experimental lactation's soil is illustrated in Table 1.

Experimental Design and Tested Treatments

This experiment, which includes 16 treatments, was organized in a split plot in a randomized complete block design with 3 replicates. The experimental plot area was 12 m^2, and it contained 4 rows, each 4 m in length and 0.75 m in width. A guard rows was left without cultivation to protect against border effects. These treatments were arranged as follows:

A. Main plots were fertilized with nitrogen at four rates: 45, 60, 75, and 90 kg N/fed. in the form of urea (46% N), which equals 97.83, 130.43, 163.04, and 195.65 kg urea/fed., respectively.

B. Sub-plots were sprayed with seaweed extract at concentrations 2, 4, and 6 ml/l and control treatment (untreated with seaweed extract) spraying with distilled water.

In the first and second seasons, lettuce seedlings were transplanted on 7th December and 6th December, respectively. Lettuce seedlings were transplanted manually on both sides of the rows at a distance of 25 cm between plants under a drip irrigation system.

Table 1. Physical and chemical properties of the study location through the growing seasons

Soil characteristics	Season 2022/2023	Season 2023/2024
Silt (%)	12.77	12.53
Clay (%)	7.84	7.80
Sand (%)	79.39	79.67
Texture	Sandy	Sandy
pH	8.14	8.10
E.C dsm	1.03	1.01
Organic matter (%)	0.52	0.56
$CaCo_3$ (%)	5.02	5.06
Available N (mg/kg)	48.90	51.32
Available P (mg/kg)	5.17	5.21
Available K (mg/kg)	134.80	141.42
Soluble cations (meq/100g)		
K^+	0.23	0.26
Ca^{++}	0.98	0.95
Mg^{++}	0.66	0.40
Na^+	3.14	3.21
Soluble anions (meq/100g)		
CO_3^{--}	-	-
HCO_3^-	1.12	1.10
Cl^-	2.96	2.84
SO_4^{--}	0.93	0.88

All nitrogen rates were added in six doses through a drip irrigation system, beginning 10 days after transplanting and every 10 days intervals during the growing season until 60 days after transplanting.

Lettuce plants were sprayed four times with seaweed extract with three drops of Tween-twenty beginning 30 days after transplanting and 10 days intervals in the morning on the entire foliage according to stage of plant development. Each plot received 2.5, 3.0, 3.5, and 4.0 liter of spraying solution at the first, second, third, and forth foliar applications, respectively, using a manual pump, and control plants were sprayed with the same quantity of distilled water plus three drops of Tween-twenty at the same times. Seaweed extract was obtained from the National Research Center, Dokki, Giza., Egypt. Analysis of seaweed extract (mg/g dry weight) as shown in Table 2.

Agricultural Practices

During soil preparation, 10 m^3 of chicken manure, 150 kg of calcium super phosphate (15.5% P_2O_5), and 50 kg of sulfur per feddan were applied and fully mixed with the soil's surface layer. In addition, 50 kg of potassium sulfate (48% K_2O) per feddan was applied in four equal amounts with irrigation (the first dose with three doses of the nitrogen fertilizers).

The cultivation of lettuce was conducted using standard agricultural techniques such as irrigation, weed control, and pest control in accordance with the Egyptian Ministry of Agriculture's recommendations.

Table 2. Physico-chemical characters analysis (mg g^{-1} dry weight) of seaweed extract

	Parameter	value	Amino acid	Value
	Color	**Green**		
	pH	6.7	Aspartic acid	5.29
	Ash (%)	36.3	Glutamic acid	7.05
	Protein (%)	5.4	Serine	4.45
	Lipid (%)	1.2	Glycine	5.22
	Carbohydrate (%)	5.49	Histidine	1.36
Nutrients (mg l^{-1})	**N**	253.0	Arginine	3.82
	P	8.41	Threonine	4.65
	Ca	0.44	Proline	2.59
	Mg	0.52	Tyrosine	1.28
	K	118.81	Methionine	8.16
	Na	47.53	Leucine	5.55
	Fe	3.95	Lysine	7.35
	Zn	0.57	Phenylalanine	27.36
	Cd	0.025	Essential	54.25
	Cu	0.55	Non-essential	29.67
	Pb (mg l^{-1})	0.62	Total amino acids	83.88

Data Recorded

At harvest time

Which started on 15th Feb. 2023, and 14th Feb. 2024, in the first and second seasons, respectively, five plants from each plot were randomly taken to determine the following traits:

Vegetative growth characters

Plant height (cm), root length (cm), root fresh weight (g), number of leaves per plant, and leaves fresh weight per plant (g). In addition, leaf area per plant (cm^2) was calculated according to the formula of **Koller (1972)**.

Leaf pigments

Chlorophyll a, b, and carotenoides (mg/g FW), were measured in disc samples from the fourth upper leaf taken from five plants at harvesting time in every plot by using the technique outlined by **Saric *et al*. (1976)**.

Head traits

Head diameter (cm), average head fresh weight (g), and dry matter in leaves (%).

Total yield (ton/fed.)

Calculated by multiplying the average head weight by the number of plants per feddan. In addition, nitrogen use efficiency (NUE) was determined by dividing the head yield per feddan by the nitrogen quantity per feddan and expressed as kg head yield per kg N, according to **Clark (1982)**.

Head quality

A sample of leaves was taken for five plants from each plot at harvest time to estimate some chemical and biochemical compounds as follows:

Total nitrogen, phosphorus, and potassium content (%)

A sample of leaves was oven dried at 70°C, finely powdered, and wet digested. Semi-micro-Kjeldahl method was used to measure total nitrogen as described by **Ling (1963)**. Phosphorus was analyzed by chlorostannus reduced molybdophosphoric blue color method, in sulfuric acid system at 660 nm using a Spectro 22 spectrophotometer as described by **Jackson**

(1973). Moreover, potassium concentrations were determined using a Perkin-Elmer Flame photometer **(Page, 1982)**.

Vitamin C (mg/100g FW)

Assayed according to the method described by **Desai and Desai (2019)**.

Total soluble solids (TSS%)

Was measured by using a Galli 110 refractometer.

Nitrate content (ppm)

Was determined according to the method described by **Cheng and Tsang (1998)**.

Statistical Analysis

Recorded data in both experiments were subjected to the analysis of variance to **Snedecor and Cochran (1980**). Mean separation were done by **Duncan (1958**).

RESULTS AND DISCUSSION

Vegetative Growth Characters

Effect of nitrogen fertilization rates

Data in Table 3 showed that the growth of lettuce plants grown under New Valley conditions was significantly affected by different rates of mineral nitrogen in both seasons.

Fertilizing lettuce plants with 90 kg N/fed., equals 195.65 kg urea/fed. significantly enhanced and gave the highest values of plant height (31.75 and 33.66 cm), root length (11.91 and 12.75 cm), fresh weight of root (123.72 and 125.23 g), number of leaves per plant (29.58 and 30.91), fresh weight of leaves per plant (342.52 and 355.31 g), and leaf area per plant (8031.48 and 8511.39 cm^2) in the 1^{st} and 2^{nd} seasons, respectively, followed by fertilizing with 75 kg N/fed. equals 163.04 kg urea/fed. in both seasons. On the other hand, the plants that received the lowest rate gave the lowest values of all the above-mentioned traits in both seasons.

The relative increases in fresh weight of leaves per plant were about 45.39 and 45.82%, 32.48 and 31.42%, and 17.48 and 17.51% due to fertilizing with 90, 75, and 60 kg N/fed. over fertilizing plants with 45 kg N/fed. in the 1^{st} and 2^{nd} seasons, respectively.

This means that all plant growth parameters of lettuces significantly increased gradually with increasing N rates up to 90 kg N/fed. in both seasons.

One of the key strategies in the development production of vegetables is to assess the efficiency of different plant nutrition approaches **(Rasouli *et al*., 2022)**.

Additionally, nitrogen enhances vegetative parameters by taking part in the synthesis of tryptophan, which is the precursor of auxin IAA, which directly affects cell divisions. Protein synthesis and further compounds required for growth, such as carbohydrates **(Tariq *et al*., 2023)**. From the above results, there is a significant difference in whole treatments when treated with different rates of urea. Whereas the production of lettuce increases with a larger nitrogen fertilizer proportion **(Meskelu *et al*., 2024)**. Nitrogen is considered a necessary element for plant growth **(Halshoy *et al*., 2023)**. It is responsible for controlling crop physiological processes **(Habibi *et al*., 2024)**.

Similar findings were obtained by **Abu-Rayyan *et al*., 2004; Hosseny and Ahmed, 2009; Hasan *et al*., 2017; Liu *et al*., 2014; Yeshiwas *et al*., 2018;** and **Mohammed *et al*., 2022**. All found that increasing N fertilizer on lettuce plants enhanced plant growth parameters.

Effect of foliar spraying with seaweed extract (SWE)

There were significant differences between the plants that were sprayed with SWE at different concentrations compared to those that were sprayed with distilled water (control plants) in both seasons, as shown in Table 3.

Spraying plants with SWE at 6 ml/l significantly increased the most plant growth characteristics, with no significant differences with spraying those with 4 ml/l as for plant height, root length, and leaves fresh weight per plant in the 2^{nd} season, root fresh weight, and number of leaves per plant in both seasons.

The highest values of plant height (28.66 and 30.00 cm), root length (10.41 and 11.16 cm), fresh weight of root (108.37 and 110.38 g), number of leaves per plant (25.91 and 26.91), fresh weight of leaves per plant (310 and 314.50 g),

Table 3. Effect of nitrogen fertilization rates, foliar spraying with seaweed extract (SWE), and the interaction between them on the plant growth characters of lettuce during the 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season					2023/2024 season				
	SWE0	SWE1	SWE2	SWE3	Mean	SWE0	SWE1	SWE2	SWE3	Mean
					Plant height (cm)					
N1	22.66 f	23.33 f	23.66 ef	23.66 ef	23.33 D	23.00 g	24.00 fg	24.33 fg	24.66 fg	24.00 D
N2	24.00 ef	24.33 ef	24.33 ef	26.66 de	24.83 C	25.00 fg	25.33 fg	26.33 ef	28.00 de	26.16 C
N3	27.33 d	27.66 d	28.66 cd	30.66 bc	28.58 B	28.66 de	30.33 cd	31.33 c	32.00 bc	30.58 B
N4	30.66 bc	30.66 bc	32.00 ab	33.66 a	31.75 A	32.33 bc	32.33 bc	34.66 ab	35.33 a	33.66 A
Mean	26.16 B	26.50 B	27.16 B	28.66 A		27.25 C	28.00 BC	29.16 AB	30.00 A	
					Root length (cm)					
N1	7.33 g	7.66 g	8.00 fg	8.33 fg	7.83 D	8.00 e	8.33 e	8.66 e	8.66 e	8.41 D
N2	9.00 ef	9.00 ef	9.00 ef	9.66 e	9.16 C	9.33 de	9.33 de	10.33 cd	10.66 cd	9.91 C
N3	10.00 de	10.00 de	10.00 de	11.00 cd	10.25 B	10.66 cd	11.33 c	11.66 c	11.66 c	11.33 B
N4	11.33 bc	11.33 bc	12.33 ab	12.66 a	11.91 A	12.00 bc	12.00 bc	13.33 ab	13.66 a	12.75 A
Mean	9.41 B	9.50 B	9.83 B	10.41 A		10.00 B	10.25 B	11.00 A	11.16 A	
					Root fresh weight (g)					
N1	84.68 k	85.32 k	89.30 jk	89.88 jk	87.29 D	86.77 j	88.89 ij	92.96 hi	93.25 hi	90.47 D
N2	92.19 ij	93.20 ij	96.91 hi	99.96 gh	95.56 C	93.91 hi	94.21 hi	98.82 gh	100.98 fg	96.98 C
N3	103.78 fg	109.51 ef	112.91 de	114.06 de	110.06 B	106.25 ef	111.78 de	116.13 cd	116.36 cd	112.63 B
N4	118.34 cd	120.97 bc	126.00 ab	129.59 a	123.72 A	121.39 bc	121.88 bc	126.71 ab	130.95 a	125.23 A
Mean	99.75 B	102.25 B	106.28 A	108.37 A		102.08 B	104.19 B	108.65 A	110.38 A	
					No. of leaves/plant					
N1	20.33 f	20.66 f	21.33 ef	21.33 ef	20.91 D	20.66 j	21.00 j	21.66 ij	22.00 ij	21.33 D
N2	22.33 ef	23.00 ef	23.00 ef	24.00 de	23.08 C	23.00 hi	23.33 hi	24.00 gh	24.66 gh	23.75 C
N3	24.00 de	24.00 de	26.00 cd	26.66 cd	25.16 B	25.33 fg	26.66 ef	27.66 de	28.66 cd	27.08 B
N4	28.00 bc	28.33 bc	30.33 ab	31.66 a	29.58 A	29.33 cd	30.33 bc	31.66 ab	32.33 a	30.91 A
Mean	23.66 C	24.00 BC	25.16 AB	25.91 A		24.58 C	25.33 BC	26.25 AB	26.91 A	
					Leaves fresh weight/plant (g)					
N1	222.84 l	234.88 kl	242.29 jk	254.95 ij	238.74 D	225.96 m	238.16 lm	248.86 kl	261.61 jk	243.65 D
N2	266.48 hi	277.12 gh	285.20 gh	293.13 fg	280.48 C	271.87 ij	284.37 hi	290.82 gh	298.25 gh	286.33 C
N3	304.65 ef	310.71 ef	319.42 de	330.40 cd	316.29 B	307.00 fg	317.95 ef	325.20 de	330.69 de	320.21 B
N4	332.96 cd	341.88 bc	352.11 ab	361.54 a	347.12 A	342.52 cd	349.11 bc	362.15 ab	367.46 a	355.31 A
Mean	281.73 C	291.14 B	299.76 B	310.00 A		286.84 C	297.40 B	306.76 A	314.50 A	
					Leaf area/plant (cm^2)					
N1	4286.8 m	4608.8 lm	4794.9 kl	5168.9 jk	4714.9 D	4348.1 n	4682.8 mn	4950.9 lm	5273.0 kl	4813.7 D
N2	5441.0 ij	5614.2 ij	5927.3 hi	6257.6 gh	5810.0 C	5638.5 jk	5858.5 ij	6202.1 hi	6525.7 gh	6056.2 C
N3	6672.4 fg	6929.1 ef	7204.2 de	7517.6 d	7080.8 B	6886.5 fg	7217.8 ef	7483.3 e	7736.0 de	7330.9 B
N4	7676.2 cd	8046.3 bc	8503.1 ab	8829.9 a	8263.9 A	8031.4 cd	8279.3 bc	8778.6 ab	8956.0 a	8511.3 A
Mean	6019.1 D	6299.6 C	6607.4 B	6943.5 A		6226.1 D	6509.6 C	6853.7 B	7122.7 A	

Means have the similar letters are not significantly different at 5% by using Duncan's multiple range test.
N1 = 45 kg N/fed., N2 = 60 kg N/fed., N3 = 75 kg N/fed., N4 = 90 kg N/fed.
SWE0 = sprayed plants with distilled water (untreated with SWE), SWE1 = 2 ml/l, SWE2 = 4 ml/l, SWE3 = 6 ml/l.

and leaf area per plant (6943.54 and 7122.73 cm^2) in both seasons, respectively, were obtained when spraying plants with SWE at 6 ml/l. The relative increases in fresh weight of leaves per plant were about 10.03 and 9.64%, 6.39 and 6.94%, and 3.34 and 3.68% for spraying with 6, 4, and 2 ml/l over control treatment (spraying with distilled water) in the 1st and 2nd seasons, respectively.

Plant growth regulators are known to be found in SWE because it has high concentrations of cytokinins, auxins, and betaines, which may have encouraged cell division and may have aided in many stages of vegetative development and productivity (**Sani and Yong, 2021**). Also, SWE is very rich in essential elements and amino acids, as shown in Table 2.

These results agree with those reported by **Crouch *et al.* (1990), Faheed and Abd-El Fattah (2008) and Chrysargyris *et al.* (2018)** on lettuce. They indicated that spraying plants with SWE had a significant effect on all plant characteristics as compared to control plants.

Effect of the interaction between nitrogen fertilization rates and foliar spraying with SWE

The interaction between nitrogen rates and SWE had a significant effect on different plant growth parameters of lettuce plants grown under New Valley conditions in both seasons, as shown in Table 3.

The best results for increasing plant height, root length, fresh weight of root, number of leaves per plant, fresh weight of leaves per plant, and leaf area per plant were recorded with the interaction between fertilizing plants with 90 kg N/fed. and spraying with SWE at 6 ml/l in both seasons, with no significant differences for the interaction between fertilizing plants with 90 kg N/fed. and spraying with SWE at 4 ml/l in both seasons. On the other side, there were no significant differences in the interaction between fertilizing lettuce plants with 75 kg N/fed. and spraying with SWE at 6 ml/l and the interaction between fertilizing lettuce plants with 90 kg N/fed. and spraying with distilled water for all plant growth parameters in both seasons. Whereas the lowest values of all plant growth parameters were observed for fertilizing plants with 45 kg N/fed. without seaweed (control plants) in both seasons.

The relative increases in fresh weight of leaves per plant were about 62.24 and 62.62%, and 58.01 and 60.27% for the interaction between fertilizing lettuce plants with 90 kg N/fed. and spraying with SWE at 6 ml/l, and the interaction between fertilizing lettuce plants with 90 kg N/fed. and spraying with SWE at 4 ml/l over fertilizing lettuce plants with 45 kg N/fed. and spraying with distilled water in the 1st and 2nd seasons, respectively.

The reason for increasing different vegetative growth parameters of the lettuce plant is that the combination of nitrogen fertilizers and SWE, where SW contains auxins, are vital because they promote cell division and widening, which raises the plant's vegetative parameters and increases its height, leaf area, and fresh weight **(Al-Jameel and Abd Fleih, 2023)**.

Leaf Pigments

Effect of nitrogen fertilization rates

Data in Table 4 indicated that leaf pigments in the leaves of lettuce were significantly affected by different nitrogen rates in both seasons. Fertilizing plants grown in sandy soil under New Valley conditions with 60, 75, and 90 kg N/fed. significantly increased chlorophyll a, b, and carotenoides as compared to 45 kg N/fed. in both seasons.

The maximum concentrations of chlorophyll a (3.295 and 3.378 mg/g FW), chlorophyll b (1.659 and 1.721 mg/g FW), and carotenoides (1.026 and 1.090 mg/g FW) were obtained with the plants that were fertilized with 90 kg N/fed. in the 1st and 2nd seasons, respectively.

These results are in harmony with those reported by **Abu-Rayyan *et al*. (2004), Awaad *et al*. (2016) and Mohammed *et al*. (2022)**. They showed that all leaf pigments in lettuce leaves are significantly affected by nitrogen levels.

Effect of foliar spraying with SWE

All concentrations of SWE had gradually and significantly superior chlorophyll a, b, and carotenoides as compared to control plants (sprayed with distilled water) in both seasons (Table 4).

Table 4. Effect of nitrogen fertilization rates, foliar spraying with seaweed extract (SWE), and the interaction between them on the leaf pigments of the lettuce plant during the 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season					2023/2024 season				
	SWE0	SWE1	SWE2	SWE3	Mean	SWE0	SWE1	SWE2	SWE3	Mean
	Chlorophyll a (mg/g FW)									
N1	2.673 n	2.741 mn	2.786 lm	2.829 kl	2.757 D	2.733 n	2.768 mn	2.829 lm	2.878 kl	2.802 D
N2	2.888 jk	2.940 ij	2.974 hi	3.018 gh	2.955 C	2.912 jk	2.982 ij	3.030 hi	3.072 gh	2.999 C
N3	3.053 fg	3.105 ef	3.150 de	3.186 cd	3.124 B	3.106 gh	3.144 fg	3.212 ef	3.262 de	3.181 B
N4	3.242 bc	3.262 bc	3.316 ab	3.361 a	3.295 A	3.300 cd	3.361 bc	3.401 ab	3.449 a	3.378 A
Mean	2.964 D	3.012 C	3.057 B	3.099 A		3.013 D	3.064 C	3.118 B	3.165 A	
	Chlorophyll b (mg/g FW)									
N1	1.216 m	1.250 lm	1.284 kl	1.298 kl	1.262 D	1.288 l	1.334 kl	1.377 jk	1.404 ij	1.351 D
N2	1.322 jk	1.358 ij	1.392 hi	1.434 gh	1.377 C	1.426 ij	1.458 hi	1.488 gh	1.516 fg	1.472 C
N3	1.478 fg	1.528 ef	1.553 de	1.588 cd	1.537 B	1.541 fg	1.566 ef	1.600 de	1.645 cd	1.588 B
N4	1.606 cd	1.645 bc	1.669 ab	1.714 a	1.659 A	1.681 bc	1.700 bc	1.737 ab	1.768 a	1.721 A
Mean	1.406 D	1.445 C	1.474 B	1.509 A		1.484 D	1.515 C	1.550 B	1.583 A	
	Carotenoides (mg/g FW)									
N1	0.770 k	0.786 jk	0.805 jk	0.817 ij	0.795 D	0.861 k	0.870 jk	0.890 jk	0.902 ij	0.881 D
N2	0.845 hi	0.858 h	0.873 gh	0.897 fg	0.868 C	0.929 hi	0.942 h	0.961 gh	0.982 fg	0.954 C
N3	0.913 f	0.933 ef	0.961 de	0.974 cd	0.945 B	1.001 ef	1.009 ef	1.030 de	1.049 cd	1.022 B
N4	0.997 cd	1.006 bc	1.034 ab	1.068 a	1.026 A	1.062 cd	1.074 bc	1.101 ab	1.124 a	1.090 A
Mean	0.881 C	0.896 C	0.918 B	0.939 A		0.963 C	0.974 C	0.996 B	1.014 A	

Means have the similar letters are not significantly different at 5% by using Duncan's multiple range test.
N1 = 45 kg N/fed., N2 = 60 kg N/fed., N3 = 75 kg N/fed., N4 = 90 kg N/fed.
SWE0 = sprayed plants with distilled water (untreated with SWE), SWE1 = 2 ml/l, SWE2 = 4 ml/l, SWE3 = 6 ml/l.

Spraying lettuce plants with SWE at 6 ml/l significantly enhanced chlorophyll a (3.099 and 3.165 mg/g FW), chlorophyll b (1.509 and 1.583 mg/g FW) and carotenoides (0.939 and 1.114 mg/g FW) in the 1st and 2nd seasons, respectively, followed by spraying with 4 ml/l in both seasons. On the other hand, spraying with distilled water gave the minimum concentrations of all leaf pigments in both seasons.

The presence of cytokines in SWE has been shown to have a good impact on many physiological processes and to raise the concentration of chlorophyll, which is vital for photosynthesis and the production of synthetic materials **(Al-Jameel and Abd Fleih, 2023)**.

Similar results were obtained by **Rover *et al*. (2023)** on lettuce. They found that spraying plants with SWE extract recorded the best leaf pigments compared to unsprayed plants.

Effect of the interaction between nitrogen fertilization rates and foliar spraying with SWE

All the interaction treatments had a significant effect on leaf pigments in lettuce as compared to the interaction between fertilizing with 45 kg N/fed. and spraying with distilled water in both seasons (Table 4).

The interaction between fertilizing with 90 kg N/fed., and spraying with SWE at 6 ml/l gave the best results for increasing chlorophyll a (3.361 and 3.449 mg/g FW), chlorophyll b (1.714 and 1.768 mg/g FW), and carotenoides (1.068 and 1.124 mg/g FW) in the 1st and 2nd seasons, respectively, with no significant differences between the interaction between fertilizing with 90 kg N/fed. and sprayed with SWE at 4 ml/l in both seasons.

In this regard, there were no significant differences between the interaction between fertilizing plants with 75 kg N/fed. and spraying with SWE at 6 ml/l and the interaction between 90 kg N/fed. and spraying with distilled water for all leaf pigments in both seasons.

Integration between N and SWE positively develops photosynthetic efficacy by promoting the translocation of different nutrients and metabolism. Moreover, proteins accumulation and phytohormones biosynthesis delay the aging process and increase the fresh and dry weight of plants **(Shukla *et al*., 2019)**.

Head Traits

Effect of nitrogen fertilization rates

Tabulated data in Table 5 clear that fertilization with nitrogen rates had significant effects on all prior traits, such as head diameter, head fresh weight, and dry matter percentage in leaves in both seasons. The current results show that increasing mineral nitrogen rates from 45 to 90 kg N/fed., led to a gradual increase in all the abovementioned parameters compared with 45 kg N/fed.

The highest values of head diameter (25.36 and 25.62 cm), head fresh weight (422.60 and 425.05 g), and dry matter in leaves (5.77 and 5.81%) were scored with fertilizing with 90 kg N/fed. in the 1st and 2nd seasons, respectively, followed by fertilizing plants with 75 kg N/fed. in both seasons.

The relative increases in fresh weight of head were about 48.78 and 47.14%, 34.70 and 33.39%, and 17.96 and 17.11% for fertilizing with 90, 75, and 60 kg N/fed., over fertilizing plants with 45 kg N/fed., in the 1st and 2nd seasons, respectively.

Plants need nitrogen as a certain mineral nutrient to grow and to produce a high yield, being required in the largest quantities and generally becoming deficient first in the soil, especially in sandy soil. The availability of nutrient has been reported to be directly related to yield (**Roberts, 2001**).

Our findings coincide with some earlier findings by **Awaad *et al*., 2016; Mohamed and Zewail, 2016; Hasan *et al*., 2017; El-Bassyouni, 2019; Aboud and Abd-Alrahman, 2021; and Mohammed *et al*., 2022**. All found that increasing nitrogen fertilizer significantly enhanced all head traits of lettuce.

Effect of foliar spraying with SWE

The foliar spraying with SWE has a positive effect on plants and significantly improves all parameters in treated plants compared to untreated plants in the two growing seasons (Table 5). Spraying SWE at a concentration of 6 ml/l resulted in increasing head diameter (23.19 and 23.70 cm), head fresh weight (372.80 and 375.89 g), and dry matter of leaves (5.22 and 5.30%) in the 1st and 2nd seasons, respectively, with no significant differences with spraying with 4 ml/l in both seasons for head diameter and dry matter in leaves in the 1st season.

The relative increases in fresh weight of leaves per plant were about 10.24 and 10.17%, 7.03 and 7.32%, and 3.81 and 3.86% for spraying with 6, 4, and 2 ml/l over control treatment (spraying with distilled water) in the 1st and 2nd seasons, respectively.

These results are similar to those of **Menamo and Wolde (2013) and Rasouli *et al.* (2022)** on lettuce; also, **Satekge *et al*. (2016)** came up with similar results on cabbage.

Effect of the interaction between nitrogen fertilization rates and foliar spraying with SWE

The interaction between nitrogen rates and spraying with different concentrations of SWE had a significant effect on head diameter, head fresh weight, and dry matter in leaves in both seasons (Table 5).

The interaction between the plants that were fertilized with 90 kg N/fed. and sprayed with SWE at 6 ml/l recorded the maximum values of head diameter (26.14 and 26.50 cm), head fresh weight (437.13 and 440.41 g), and dry matter in leaves (6.04 and 6.05%) in the 1st and 2nd seasons, respectively, with no significant differences between the same interaction and the

Table 5. Effect of nitrogen fertilization rates, foliar spraying with seaweed extract (SWE), and the interaction between them on the head traits of the lettuce plant during the 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season					2023/2024 season				
	SWE0	SWE1	SWE2	SWE3	Mean	SWE0	SWE1	SWE2	SWE3	Mean
					Head diameter (cm)					
N1	18.87 k	18.98 k	19.51 jk	20.23 ij	19.40 D	18.96 i	19.70 hi	20.16 gh	20.81 g	19.91 D
N2	20.61 hi	21.56 gh	22.35 fg	22.37 fg	21.72 C	21.04 g	22.15 f	23.04 ef	23.08 ef	22.32 C
N3	23.14 ef	23.57 de	23.58 de	24.03 de	23.58 B	23.51 de	23.72 de	24.34 cd	24.42 cd	24.00 B
N4	24.58 cd	25.08 bc	25.64 ab	26.14 a	25.36 A	24.82 bc	25.38 bc	25.78 ab	26.50 a	25.62 A
Mean	21.80 C	22.30 BC	22.77 AB	23.19 A		22.08 C	22.74 B	23.33 A	23.70 A	
					Head fresh weight (g)					
N1	262.52 m	279.20 lm	290.60 kl	303.83 jk	284.03 D	266.73 m	282.06 lm	296.82 kl	309.87 jk	288.87 D
N2	317.67 ij	329.32 hi	341.12 gh	352.10 fg	335.05 C	320.79 ij	333.59 hi	344.64 gh	354.24 fg	338.31 C
N3	367.43 ef	379.22 de	385.34 de	398.46 cd	382.61 B	368.25 ef	384.73 de	389.33 d	399.05 cd	385.34 B
N4	405.30 c	416.85 bc	431.11 ab	437.13 a	422.60 A	408.91 c	417.00 bc	433.86 ab	440.41 a	425.05 A
Mean	338.23 D	351.15 C	362.04 B	372.88 A		341.17 D	354.34 C	366.16 B	375.89 A	
					Dry matter in leaves (%)					
N1	4.34 i	4.35 i	4.36 i	4.55 hi	4.40 D	4.38 l	4.49 kl	4.49 kl	4.63 jk	4.50 D
N2	4.68 gh	4.79 gh	4.90 fg	4.95 fg	4.83 C	4.77 ij	4.88 hi	5.00 gh	5.10 fg	4.93 C
N3	5.11 ef	5.19 ef	5.29 de	5.35 de	5.23 B	5.16 fg	5.29 ef	5.32 ef	5.43 de	5.30 B
N4	5.52 cd	5.66 bc	5.86 ab	6.04 a	5.77 A	5.58 cd	5.71 bc	5.89 ab	6.05 a	5.81 A
Mean	4.91 C	5.00 BC	5.10 AB	5.22 A		4.97 C	5.09 B	5.18 B	5.30 A	

Means have the similar letters are not significantly different at 5% by using Duncan's multiple range test.
N1 = 45 kg N/fed., N2 = 60 kg N/fed., N3 = 75 kg N/fed., N4 = 90 kg N/fed.
SWE0 = sprayed plants with distilled water (untreated with SWE), SWE1 = 2 ml/l, SWE2 = 4 ml/l, SWE3 = 6 ml/l.

interaction between 90 kg N/fed. and spraying with 4 ml/l for all abovementioned traits in both seasons.

In this respect, there were no significant differences between the interaction between fertilizing plants with 75 kg N/fed. and spraying with SWE at 6 ml/l and the interaction between 90 kg N/fed. and spraying with distilled water as for head diameter, head fresh weight, and dry matter in leaves in both seasons.

Total Yield and Nitrogen Use Efficiency

Effect of nitrogen fertilization rates

Fertilizing lettuce plants with mineral nitrogen had a significant effect on total yield and nitrogen use efficiency (NUE) in both seasons (Table 6). Total yield per feddan increased with increasing nitrogen rates, up to 90 kg N/fed. The highest total yield per feddan (17.74 and 17.85 ton/fed.) was recorded with 90 kg N/fed. in the 1st and 2nd seasons, respectively, followed by the plants that were fertilized with 75 kg N/fed. The increases in total yield per feddan were about 48.83 and 47.16% for 90 kg N/fed. over fertilizing with 45 kg N/fed. in the 1st and 2nd seasons, respectively.

As for NUE, the values of nitrogen use efficiency decreased gradually with increasing N fertilizer rates in both seasons. Fertilizing lettuce plants with the lowest rate (45 kg N/fed.) recorded the highest NUE (265.1 and 269.6 kg yield/one kg N) in the 1st and 2nd seasons, respectively.

Table 6. Effect of nitrogen fertilization rates, foliar spraying with seaweed extract (SWE), and the interaction between them on the total yield and nitrogen use efficiency of the lettuce plant during the 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season					2023/2024 season				
	SWE0	SWE1	SWE2	SWE3	Mean	SWE0	SWE1	SWE2	SWE3	Mean
	Total yield (ton/fed.)									
N1	11.02 m	11.72 lm	12.20 kl	12.76 jk	11.92 D	11.20 m	11.84 lm	12.46 kl	13.01 jk	12.13 D
N2	13.34 ij	13.83 hi	14.32 gh	14.79 fg	14.07 C	13.47 ij	14.01 hi	14.47 gh	14.88 fg	14.20 C
N3	15.43 ef	15.93 de	16.18 de	16.73 cd	16.07 B	15.46 ef	16.15 de	16.35 d	16.76 cd	16.18 B
N4	17.02 c	17.50 bc	18.10 ab	18.36 a	17.74 A	17.17 c	17.51 bc	18.22 ab	18.49 a	17.85 A
Mean	14.20 D	14.74 C	15.20 B	15.66 A		14.32 D	14.88 C	15.37 B	15.78 A	
	Nitrogen use efficiency (kg yield/one kg N)									
N1	245.0 c	260.5 b	271.2 ab	283.5 a	265.1 A	248.9 c	263.2 b	277.0 a	289.2 a	269.6 A
N2	222.3 ef	230.5 de	238.7 cd	246.4 c	234.5 B	224.5 ef	233.5 de	241.2 cd	247.9 c	236.8 B
N3	205.7 g-i	212.3 f-h	215.7 fg	223.1 ef	214.2 C	206.2 gh	215.4 fg	218.0 fg	223.4 ef	215.7 C
N4	189.1 j	194.5 ij	201.1 h-j	204.0 g-i	197.2 D	190.8 i	194.6 hi	202.4 hi	205.5 gh	198.3 D
Mean	215.5 D	224.5 C	231.7 B	239.3 A		217.6 D	226.7 C	234.7 B	241.5 A	

Means have the similar letters are not significantly different at 5% by using Duncan's multiple range test.
N1 = 45 kg N/fed., N2 = 60 kg N/fed., N3 = 75 kg N/fed., N4 = 90 kg N/fed.
SWE0 = sprayed plants with distilled water (untreated with SWE), SWE1 = 2 ml/l, SWE2 = 4 ml/l, SWE3 = 6 ml/l.

The increase in total yield was clearly achieved owing to the increases in leaf pigments (Table 4), head diameter, and head fresh weight (Table 5). In addition, the results obtained with yield and its components reflected a similar trend to that obtained with plant growth.

These results are in harmony with those reported by **Boroujerdnia and Ansari, 2007; Awaad *et al*., 2016; Mohamed and Zewail, 2016; Aboud and Abd-Alrahman, 2021; and Mohammed *et al*., 2022**.

Effect of foliar spraying with SWE

The foliar spraying with SWE has a positive effect on total yield and nitrogen use efficiency compared to sprayed with distilled water in both seasons (Table 6). Spraying with SWE at 6 ml/l significantly increased both total yield per feddan (15.66 and 15.78 ton/fed.) and NUE (293.3 and 241.5 kg yield/one kg N) in the 1st and 2nd seasons, respectively. The increases in total yield per feddan were about 10.28 and 10.19%, and NUE were about 11.04 and 10.98 for spraying with SWE at 6 ml/l over control treatment in the 1st and 2nd seasons, respectively.

The superiority of total yield in response to foliar application of SWE extract can be attributed to its content of various nutrients, such as P, K, Mg, Ca, Fe, Ba, Mn, and Zn, higher values of free amino acids, and vitamins (Table 2), all of which may play a role in improving growth and then enhancing total yield **(Bevilacqua *et al*., 2008)**.

These findings are in agreement with **Acun (2019), Asadi *et al*. (2022) and Rasouli *et al*. (2022)**, on lettuce. They showed that spraying with seaweed extract improved the productivity of lettuce heads compared to unsprayed plants.

Effect of the interaction between nitrogen fertilization rates and foliar spraying with SWE

The interaction between fertilization with mineral nitrogen rates and spraying with different concentrations of SWE had a significant effect on the total yield per feddan and NUE of lettuce plants in both seasons (Table 6).

As for total yield per feddan, fertilizing plants with 90 kg N/fed., and spraying with SWE at 6 ml/l gave the maximum total yield (18.36 and 18.49 ton/fed.), with no significant differences for 90 kg N/fed., and spraying with SWE at 4 ml/l in both seasons, respectively.

The interaction between fertilizing plants with 75 kg N/fed. and spraying SWE at 6 ml/l and the interaction between 90 kg N/fed. and distilled water spraying as for both seasons did not differ significantly in this regard.

As for NUE, the same data in Table 6 showed that the interaction between fertilizing lettuce plants with a low rate of 45 kg N/fed., and spraying with SWE at 6 ml/l gave the best results for increasing NUE (283.5 and 289.2 kg yield/one kg N) in both seasons, respectively, with no significant differences with the same rate of nitrogen fertilizer and spraying with SWE at 4 ml/l in both seasons, respectively.

The stimulative effect of the interaction between mineral N and spraying with SWE may be due to their vital role in enhancing plant growth (Table 3) and leaf pigments (Table 4) and hence the photosynthetic rate, which may reflect a favorable effect on total yield.

In this regard, it is possible to provide 15 kg of nitrogen per feddan by spraying with SWE at a concentration of 6 ml/l without any reduction in total yield.

Head Quality

Effect of nitrogen fertilization rates

Results represented in Table 7 pointed out that fertilization with nitrogen rates had significant effects on the head quality of lettuce, such as N, P, and K, vitamin C concentration, total soluble solids (TSS), and nitrate content in both seasons.

Nitrogen, P, and K, vitamin C concentration, TSS, and nitrate content significantly increased with increasing N rates up to 90 kg N/fed. in both seasons. The lowest values of all head quality parameters, especially nitrate concentration (185.18 ppm, average of two seasons), were recorded with 45 kg N/fed., while the highest concentrations of nitrate (282.99 ppm, average of two seasons) were obtained with the highest rate (90 kg N/fed.).

Despite the use of the high rate of nitrogen (90 kg/fed.), which recorded the maximum yield per fed., the percentage of nitrates that was estimated in the leaves did not reach the maximum permissible limit of nitrates. In this regard, **Socaciu and Stanila (2007)** pointed out that the maximum level of nitrate permitted in lettuce in Romania is 2 g/kg DW.

Similar results were reported by **Mohamed and Zewail, 2016; Hasan *et al.*, 2017; Liu *et al*., 2014; Yeshiwas *et al*., 2018; El-Bassyouni, 2019; Aboud and Abd-Alrahman, 2021; and Mohammed *et al*., 2022**, on lettuce.

Effect of foliar spraying with SWE

The same data in Table 7 showed that spraying with SWE at different concentrations significantly enhanced all head quality characteristics of lettuce, except nitrate concentration, as compared to control treatment in both seasons.

Spraying plants with seaweed extract at 6 ml/l led to a great increase in N, P, and K, vitamin C concentration, and total soluble solids, while the concentration of nitrate decreased, followed by using 4 ml/l of SWE in both seasons.

The lowest concentration of nitrate (219.62 and 224.08 ppm) was obtained by spraying plants with SWE at 6 ml/l in the 1^{st} and 2^{nd} seasons, respectively, while the highest concentration of nitrate (243.83 and 248.21 ppm) was recorded with control treatment in the 1^{st} and 2^{nd} seasons, respectively.

The higher vitamin C concentrations can be attributed to the enhancements in chlorophyll content due to the stimulatory effects of SWE. Similarly **(Tiruvaimozhi *et al*., 2018)**, on spinach plants.

Notably, SWE increased antioxidant compounds, which increased antioxidant activity, and decreased the accumulation of nitrate content in the lettuce plant, thus improving its nutritional quality **(Atero-Calvo *et al*., 2024)**. Also, SWE application had a positive effect on the ascorbic acid content of lettuce plants.

Utilizing SWE increases the potential for photosynthetic processes, increases the absorption of nitrogen and phosphorus, and finally results

Table 7. Effect of nitrogen fertilization rates, foliar spraying with seaweed extract (SWE), and the interaction between them on the head quality of the lettuce plant during the 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season					2023/2024 season				
	SWE0	SWE1	SWE2	SWE3	Mean	SWE0	SWE1	SWE2	SWE3	Mean
					Nitrogen (%)					
N1	1.85 l	1.98 kl	2.06 k	2.15 jk	2.01 D	1.95 k	2.11 jk	2.23 ij	2.30 i	2.15 D
N2	2.29 ij	2.41 hi	2.52 gh	2.60 gh	2.45 C	2.40 hi	2.49 gh	2.63 fg	2.69 f	2.55 C
N3	2.70 fg	2.80 ef	2.92 de	3.02 cd	2.86 B	2.81 ef	2.90 e	2.97 de	3.09 cd	2.94 B
N4	3.15 bc	3.23 b	3.31 ab	3.44 a	3.28 A	3.17 c	3.26 bc	3.39 ab	3.52 a	3.33 A
Mean	2.50 D	2.60 C	2.70 B	2.80 A		2.58 D	2.69 C	2.80 B	2.90 A	
					Phosphorus (%)					
N1	0.241 k	0.248 jk	0.253 jk	0.261 ij	0.251 D	0.257 k	0.262 k	0.270 jk	0.278 j	0.267 D
N2	0.269 i	0.276 hi	0.288 gh	0.297 fg	0.282 C	0.284 ij	0.291 hi	0.298 gh	0.302 gh	0.294 C
N3	0.302 fg	0.307 ef	0.319 de	0.324 cd	0.313 B	0.310 fg	0.321 ef	0.327 de	0.337 cd	0.324 B
N4	0.330 cd	0.338 bc	0.346 ab	0.354 a	0.342 A	0.345 c	0.350 bc	0.359 ab	0.366 a	0.355 A
Mean	0.286 C	0.292 C	0.301 B	0.309 A		0.299 D	0.306 C	0.314 B	0.321 A	
					Potassium (%)					
N1	2.18 n	2.32 mn	2.45 lm	2.55 kl	2.38 D	2.28 m	2.42 l	2.54 kl	2.63 jk	2.47 D
N2	2.62 jk	2.71 j	2.77 ij	2.88 hi	2.74 C	2.70 ij	2.79 hi	2.90 gh	2.98 fg	2.84 C
N3	2.96 gh	3.03 fg	3.12 ef	3.19 de	3.07 B	3.04 ef	3.06 ef	3.14 e	3.33 d	3.14 B
N4	3.27 cd	3.40 bc	3.47 ab	3.55 a	3.42 A	3.43 cd	3.52 bc	3.62 ab	3.71 a	3.57 A
Mean	2.76 D	2.87 C	2.95 B	3.04 A		2.86 D	2.95 C	3.05 B	3.16 A	
					Vitamin C (mg/100g F.W)					
N1	2.33 n	2.53 m	2.70 lm	2.79 kl	2.58 D	2.47 m	2.57 lm	2.73 kl	2.88 jk	2.66 D
N2	2.91 jk	3.04 ij	3.23 hi	3.32 h	3.12 C	3.01 j	3.11 ij	3.27 hi	3.41 gh	3.20 C
N3	3.42 gh	3.55 fg	3.64 ef	3.77 de	3.59 B	3.52 fg	3.68 ef	3.83 de	3.93 d	3.74 B
N4	3.90 cd	4.00 bc	4.16 ab	4.31 a	4.09 A	4.05 cd	4.23 bc	4.36 ab	4.52 a	4.29 A
Mean	3.14 D	3.28 C	3.43 B	3.54 A		3.26 D	3.40 C	3.55 B	3.68 A	
					Total soluble solids (brix)					
N1	3.23 l	3.45 kl	3.63 jk	3.85 ij	3.54 D	3.39 l	3.57 l	3.75 kl	3.98 jk	3.67 D
N2	4.04 i	4.22 hi	4.46 gh	4.63 fg	4.34 C	4.15 j	4.36 ij	4.58 hi	4.77 gh	4.46 C
N3	4.79 fg	5.00 ef	5.19 de	5.41 cd	5.10 B	5.00 fg	5.18 ef	5.39 de	5.57 cd	5.28 B
N4	5.59 c	5.76 bc	5.98 ab	6.17 a	5.88 A	5.80 bc	5.97 b	6.16 ab	6.39 a	6.08 A
Mean	4.41 D	4.61 C	4.81 B	5.01 A		4.58 D	4.77 C	4.97 B	5.18 A	
					Nitrate (ppm)					
N1	195.03 kl	188.03 lm	179.05 mn	170.82 n	183.23 D	198.72 jk	189.64 kl	183.03 kl	177.19 l	187.14 D
N2	227.98 gh	220.30 hi	211.01 ij	203.37 jk	215.66 C	231.56 g	223.16 gh	215.30 hi	206.27 ij	219.07 C
N3	259.58 de	252.21 e	245.09 ef	235.84 fg	248.18 B	264.99 cd	257.75 de	248.17 ef	238.91 fg	252.45 B
N4	292.73 a	283.86 ab	277.21 bc	268.44 cd	280.56 A	297.57 a	289.70 ab	280.47 bc	273.96 bc	285.43 A
Mean	243.83 A	236.10 B	228.09 C	219.62 D		248.21 A	240.06 B	231.74 C	224.08 D	

Means have the similar letters are not significantly different at 5% by using Duncan's multiple range test.
N1 = 45 kg N/fed., N2 = 60 kg N/fed., N3 = 75 kg N/fed., N4 = 90 kg N/fed.
SWE0 = sprayed plants with distilled water (untreated with SWE), SWE1 = 2 ml/l, SWE2 = 4 ml/l, SWE3 = 6 ml/l.

in an increase in ascorbic acid content. Also, the higher vitamin C concentrations can be attributed to the enhancements in chlorophyll content due to the stimulatory effects of SWE. Similarly **(Tiruvaimozhi *et al*., 2018)** on spinach plants.

These findings are in agreement with the results of **Chrysargyris *et al.*, 2018; Acun, 2019; Asadi *et al*., 2022; and Rasouli *et al*., 2022**, on lettuce. They indicated that spraying lettuce plants with SWE gave the highest values of N, P, and K, total soluble solids, and vitamin C than untreated plants.

Effect of the interaction between nitrogen fertilization rates and foliar spraying with SWE

All head quality traits were significantly affected by the interaction between mineral nitrogen rates and spraying plants with different concentrations of SWE in both seasons (Table 7).

The interaction between nitrogen at 90 kg N/fed. and spraying plants with SWE at 6 ml/l gave maximum values of nitrogen, phosphorous, and potassium contents, vitamin C, and TSS with no significant differences with the same rate of nitrogen fertilizer and spraying with SWE at 4 ml/l in both seasons.

As for nitrate concentration in lettuce plants, the same data in Table (7) indicate that the interaction between 90 kg N/fed. and spraying with distilled water (without SWE) gave the maximum values (292.73 and 297.57 ppm) in the 1st and 2nd seasons, respectively, against the interaction between 90 kg N/fed. and spraying with SWE at 6 ml/l (268.44 and 273.96 ppm) in the 1st and 2nd seasons, respectively.

The above results exhibited that the co-use of SWE and N has absolutely improved chemical constituents. Via SWE, the availability of different growth hormones, numerous amino acids, macro- and microelements increased **(Choi *et al*., 2018)**. Results following the previous study **(Dudaš *et al*., 2016)** in lettuce and **(Rouphael *et al*., 2017)** in squash.

This implies that the use of mineral fertilizers in the production of lettuce may have increased the levels of some hazardous chemicals, such as nitrate, in plants. On the other hand, employing SWE aids in the production of the healthiest and safest food, with the least amount of harmful substances, such as nitrate, found in lettuce leaves. The European Commission's Scientific Committee on Food (SCF) decided to stick with the nitrate ion's previous Acceptable Daily Intake (ADI) of 3.7 mg/kg body weight, according to **Lidder and Webb (2013)**.

Conclusion

Under New Valley conditions, it could be concluded that fertilizing lettuce plants grown in sandy soil with 90 kg nitrogen per feddan in the form of urea equals 195.65 kg per feddan, and spraying with seaweed extract at 6 ml/l was the best interaction treatment for increasing productivity and head quality. Feddan = 4200 m^2 = 0.42 hectar.

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استجابة محصول وجودة رؤوس الخس للتسميد النيتروجيني والرش الورقي بمستخلص الطحالب البحرية تحت ظروف الوادي الجديد

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أجريت تجربتين حقليتين بمزرعة البحوث الزراعية التابعة لكلية الزراعة جامعة الوادي الجديد بمحافظة الوادي الجديد بمصر خلال الموسمين المتتاليين 2023/2022، 2024/2023م لدراسة تأثير التسميد النيتروجيني عند معدلات 45، 60، 75، 90 كجم نيتروجين/ فدان في صورة يوريا والرش الورقي بمستخلص الطحالب البحرية عند تركيزات 2، 4، 6 مل/لتر بجانب الكنترول غير المعامل، والتفاعل بينهما على النمو والمحصول وكفاءة استخدام النيتروجين وجودة رؤوس الخس (صنف دارك جرين) المنزرع في أرض رملية. أظهرت النتائج بوضوح أن التفاعل بين تسميد نباتات الخس بـ 90 كجم نيتروجين/فدان ورشها بمستخلص الطحالب البحرية بمعدل 6 مل/لتر أدت إلى تحسن معنوي لمؤشرات نمو النبات وصبغات الأوراق مثل كلوروفيل أ و ب والكاروتينات، صفات الرأس مثل قطر الرأس وزن الرأس الطازج ونسبة المادة الجافة في الأوراق، المحصول الكلي (طن/فدان)، محتوى الأوراق من النيتروجين والفوسفور والبوتاسيوم والمواد الصلبة الذائبة الكلية وفيتامين ج في كلا الموسمين. كما سجلت معاملة التفاعل هذه زيادات نسبية بلغت حوالي 65.84% كمتوسط للموسمين عن معاملة التفاعل بين تسميد النباتات بـ 45 كجم نيتروجين/فدان ورشها بالماء المقطر (نباتات المقارنة). أما بالنسبة لكفاءة استخدام النيتروجين وتركيز النترات في نباتات الخس، فإن تسميد النباتات بـ 45 كجم نيتروجين/فدان ورشها بمستخلص الطحالب البحرية بمعدل 6 مل/لتر سجل أعلى القيم لكفاءة استخدام النيتروجين (286.35 كجم محصول/1 كجم نيتروجين كمتوسط للموسمين)، وأقل تركيز للنترات في الأوراق (174.00 جزء في المليون كمتوسط للموسمين). على الرغم من استخدام معدل مرتفع من التسميد النيتروجيني (90 كجم/فدان) ورش نباتات الخس بمستخلص الطحالب البحرية بمعدل 6 مل/لتر والتي سجلت أعلى إنتاجية للفدان، إلا أن نسبة النترات التي قُدرت في الأوراق (295.15 جزء في المليون كمتوسط للموسمين) لم تصل إلى الحد الأقصى المسموح به من النترات (2 جم/كجم وزن جاف).

الكلمات الإسترشادية: الخس ، معدلات النيتروجين ، مستخلص الطحالب البحرية، الأراضي الرملية.

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