Productivity, Head Quality, and Leaf Tipburn of Lettuce Plants as Affected by Foliar Spray with Calcium Chloride Under Different Rates of Nitrogen Fertilization

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Abstract:
The present work was carried out at the private Farm to study the effect of different rates of nitrogen fertilization and foliar application with calcium chloride on dry weight, leaf pigment, mineral uptake by leaves, yield, and head quality (nitrate contents and leaf tipburn) of lettuce plants, which were grown at Al-Baalwa District, Ismailia Governorate, Egypt, during the two winter seasons of 2024/2025 and 2025/2026 under sandy soil conditions and using a drip irrigation system. This study included 12 treatments, which are combinations between 3 nitrogen rates (40, 60 and 80 kg N/fad.) and 4 levels of calcium chloride (control, $CaCl_2$ at 60, 120, and 180 mg/l). Fertilizing lettuce plants cv American grown in sandy soil during winter plantation with mineral nitrogen at 60 kg/ fed. and foliar spray with CaCl2 at 120 ppm increased total dry weight, dry matter in leaves, and total chlorophyll in leaf tissues at 75 days after planting as well as average head weight at harvesting time. Whereas, fertilizing with mineral nitrogen at 80 kg/ fed. and foliar spray with CaCl2 at 180 ppm increased head yield/ha., head diameter, and calcium contents in leaves. Fertilizing with mineral nitrogen at 60 kg/ fed. and foliar spray with $CaCl_2$ at 180 ppm increased N, P and K uptake by leaves and reduced tipburn percentage in leaves. Mineral nitrogen at 40 kg /fed. and spraying with water was the best treatment for reducing nitrate concentration in leaves. Hectare=10000 m^2=2.4 feddan.

Keywords: lettuce, nitrogen, $CaCl_2$, leaf pigments, yield and leaf tipburn.

Introduction

Lactuca sativa L. var. longifolia is a type of lettuce that produces a tall head of robust, dark green leaves with solid ribs running down the middle. Lettuce belongs to the Asteraceae family of annual plants. Grown all over the world, it is a significant green vegetable with a high market value that is mostly used as the foundation for salads. Its short vegetation period makes it easy to cultivate. In addition to being a moderate source of a number of other vitamins and nutrients, lettuce is a strong source of potassium and vitamin A (**Niari *et al.,* 2012**).

Egypt's total area under cultivation for lettuce in 2023–2024 was 9474 fad. (producing 76,149 tons at an average of 8.070 tons per fad.). according to the **Ministry of Agriculture and Land Reclamation (2024**).

Causes of Tipburn: Even when soil calcium levels are sufficient, tipburn can still occur due to calcium shortages in growing tissue. The integrity of membranes and the strength of cell walls depend on calcium. Since calcium mostly travels through the plant's transpirational flow, the outer leaves, which have higher levels of transpiration, have the highest concentration of calcium. Tipburn is more frequently caused by water stress and low evapotranspiration (ET), which results in a temporary calcium deficiency in rapidly developing leaf tissue, rather than low soil calcium. Transpiration in lettuce's inner leaves is decreased by head formation. Tipburn is more common in the inner leaves of head lettuce and leaf lettuces because they transpire less than the outer leaves. Tipburn might develop as a result of rapid growth. Weather-related low evapotranspiration (ET) lowers transpiration in leaf lettuces. Calcium delivery to the plant may also be hampered by soil water stress.

Tipburn incidence was found to be inversely connected with calcium levels in the inner head sections and positively correlated with mean monthly maximum, average, and minimum temperatures **(Yanagi *et al.,* 1983).** According to **Collier and Tibbitts (1982),** tipburn is typically discovered later in plant development, when the head is well formed and nearing maturity. The increased severity of tipburn is then linked to accelerated plant growth with young leaves, which are more sensitive because their rapid growth increases the demand for calcium.

Enzymes, nucleic acids, amino acids, chlorophyll, and other essential plant components all contain nitrogen, which is crucial for the growth and productivity of lettuce plants and plays a major part in numerous metabolic processes. Although nitrogen is also a structural component of cell walls (**Marschner, 2012)**.

El-Bassyouni, (2016) showed that increasing N levels from 60 to 100 kg N/fed significantly increased the yield of lettuce; however, 80 kg N /fed. resulted in the highest lettuce productivity, and produced the minimum accumulation of nitrate. In addition, **Taha *et al*. (2017)** indicated that increasing up to 100 % of the recommended dose of nitrogen, which equals 60 kg N/fed., gave the highest values of dry weights, N, P, and K uptake by lettuce leaves cv. Balady. However, **Abd El-Ghany *et al*. (2022)** showed that increasing N fertilizer up to 90 kg N/fed. produced the highest dry weight, head yield, and nutrient contents of lettuce plants (*Lactuca sativa* L. var. longifolia Lam) . Also, **Saah *et al.* (2022)** found that the economical yield of lettuce increased with increasing N rates. Furthermore, **Hassan and El**

Nagy (2025) showed that applying 90 kg N/feddan to lettuce plants led to the highest values for dry matter, leaf pigments, head diameter, and total yield and also caused the highest nitrate accumulation.
Foliar application of $CaCl_2$ was more effective than CaO and Ca chelate in this regard. In lettuce, calcium has been regarded as a crucial nutrient. Calcium uptake has an impact on lettuce's calcium content **(Almeida *et al.,* 2016**). This has an impact on the distribution of calcium in the shoots and is linked to the roots' intake of water (**Collier and Tibbitts, 1984 and Schlagnhaufer *et al*., 1987**). Head diameter, dry head weights, total chlorophyll, and macronutrients were all considerably increased when romaine lettuce cv. Balady was foliarly treated with 20 mM calcium chloride (**Youssef *et al*., 2017**). In addition, **Attallah and Abdalla (2021)** indicated that dry leaf weight and yield parameters significantly increased with foliar spray of calcium chloride, either at 10 or 20 mM compared to control treatment. Also, foliar spray of calcium chloride resulted in a significant increase in yield and quality parameters.
El-Shabrawy and Selim (2007) reported that vegetative growth and yield of lettuce plants were affected significantly by applying the rate of 80 kg N fed-1 and foliar spray with $CaCl_2$ (2000 ppm) as compared to the control treatment.
Therefore, the aim of this study was the effect of spraying with calcium chloride under different mineral nitrogen rates to obtain the highest productivity and best head quality of lettuce plants and reduce the leaf tipburn under sandy soil conditions and using a drip irrigation system.

Materials and Methods

The present work was carried out at the private farm, Al-Baalwa District, Ismailia Governorate, Egypt, during the two winter seasons of 2024/2025 and 2025/2026 to study the effect of foliar spray with calcium chloride on dry weight, N, P, and K uptake by leaves;yield; and head quality (nitrate contents and leaf tipburn) of lettuce plants under different rates of nitrogen fertilization, which were grown in sandy soil conditions and using a drip irrigation system. This study included twelve treatments, which are combinations between three nitrogen rates (40, 60, and 80 kg N/fad.) and four concentrations of calcium chloride (60, 120, and 180 mg/l, besides control treatment).
The physical and chemical properties of the experimental soil are presented in Table 1

Table 1. The physical and chemical properties of the experimental soil in 2024/2025 and 2025/2026 seasons

Soil property	1st season	2nd season
Physical properties		
Clay (%)	5.71	6.72
Silt (%)	4.89	5.91
Sand (%)	89.4	86.37
Texture	Sandy	Sandy
Chemical properties		
E.C. (mmhos/cm)*	2.04	2.03
pH**	7.99	8.00
Organic matter (%)	0.39	0.42
Available N (ppm)	4.42	4.57
Available P_2O_5 ppm	4.41	4.54
Available K_2O ppm	11.72	12.19

Samples of the soil were obtained from 25 cm soil surface.

This study included 12 treatments, which are combinations between 3 nitrogen rates (40 , 60, and 80 kg N/fad.) and 4 levels of calcium chloride (control, $CaCl_2$ at 60, 120, and 180 mg/l). These treatments were randomly arranged in a split plot design with three replicates; nitrogen rates were randomly arranged in the main plots, while calcium chloride concentrations were randomly distributed in the subplots. Calcium chloride ($CaCl_2$) was dissolved in distilled water.
The seeds of lettuce were sown in the nursery on 10th October and transplanted in the field on 10th November in both seasons of the study. Lettuce transplants were planted at 25 cm apart on both sides of ridges. All experimental unit areas were 10.5 m², and they contained three dripper lines with 7 m in length and 50 cm in width. One dripper line was used for the samples to measure vegetative growth, and the other two lines were used for yield determination. Seeds of an American lettuce cultivar were obtained from Hort. Res. Inst., ARC, Giza. While, the source of calcium chloride was obtained from El- Gomhouria Chemicals Company, Egypt
The total amounts of nitrogen were divided into three equal amounts and applied as top dressing at 15-day intervals after 20 days from transplanting in the form of ammonium sulfate (20.5% N), while calcium chloride concentrations were added as a foliar application by hand sprayer until saturation of leaves four times after 15, 30, 45, and 60 days from transplanting after being mixed with Tween-20 as a wetting agent at a 0.02% concentration.
All plots received equal amounts of P at 150 kg/fed. Calciumsuperphosphate (15.5% $P_{2}O_{5}$), which was added at soil preparation, and K at 50 kg potassium sulfate (48% K_2O) per feddan were applied in two equal amounts, 30 and 60 days after transplanting. Routine agricultural practices were done according to the recommendation of the Ministry of Agriculture, Egypt

At 75 days from transplanting, a random sample of five plants was taken from each experimental unit for measuring total dry weight per plant (stem + leaves), which was determined after drying in an oven at 70$^{\circ C}$. In addition, the dry matter of leaves / plants was recorded. At the same time, a disc sample from the fourth outer leaf of the lettuce plant was randomly taken from every experimental unit at 75 days after planting in both growing seasons to determine chlorophyll (a+b) according to the method described by **Wettesteien (1957)**.

Chemical constituents

The uptake of N, P, and K by leaves was calculated after determination of N, P, and K in leaves. After 75 days from transplanting in both seasons according tothe methods advocated by **Bremner and Mulvaney (1982), Olsen and Sommers (1982),**and **Jackson (1970),** respectively.

Yield and its components

At harvest time (100 days after transplanting), the fresh heads of lettuce plants in each experimental plot were harvested and then weighed to determine head diameter (cm), head weight (kg), and total yield (ton/fed.).

Head quality at harvesting time

Nitrate content (mg/kg FW) **:** was determined in leaves of lettuce according to the method described by **Cheng and Tsang (1998)**.**Calcium contents in leaves** were determined according to Kalra (1998).**Tipburn percentage was** calculated immediately before harvest by dividing the heads affected by inner or outer leaf tipburn in each experimental plot by the total number of heads in the same experimental plot.

Statistical analysis

Collected data will be subjected to proper statistical analysis of variance according to **Snedecor and Cochran (1980)** and the differences among treatments were compared using **Duncans'**multiple range test (**Duncan, 1958**), where means with different letters will be statistically significant, while those means followed by the same letter were statistically insignificant.

Results and Discussion

Dry weight

Effect of N rates

Fertilizing lettuce plants with N at 60 kg/fed. gave the highest values of total dry weight/plant(30.08 and 36.20 g) and dry matter (DM) in leaves (6.94 and 7.25%) in both seasons at 75 days after transplanting (Tables2 and 3).

The stimulative effect of nitrogen on dry weight may owe much to the fact that nitrogen is an essential element for building up protoplasm, amino acids, and protein which promote cell division. Also, nitrogen plays a vital role in several biochemical processes related to dry weight (**Marschner, 1995**).

These results are in line with those of **El-Bassyouni, (2016)** , **Taha *et al* .(2017)Abd El-Ghany *et al.* (2022)** and **Hassan and El Nagy (2025)** showed that increasing the N level to 60 kg produced the best values of dry weights of lettuce leaves cv. Balady.

Effect of $CaCl_2$ as a foliar application

Spraying with $CaCl_2$ at 60, 120, and 180 ppm increased the total dry weight/plant and dry matter in leaves compared to the control (spraying with water), as shown in Tables 2 and 3 in both seasons at 75 days after transplanting.

Foliar spray with 180 ppm recorded maximum values of total dry weight/plant (32.63 and 35.50 g) in both seasons. While foliar spray with $CaCl_2$ at 120 ppm recorded maximum values of DM% in leaves (6.87 and 7.08%) in both seasons. Results are agreed with Foliar application of romaine lettuce cv. Balady with calcium chloride significantly increased dry weights of head (**Youssef *et a*l .2017**).

Effect of the interaction

The interaction between N rates at 60 kg/fed. and foliar spray with $CaCl_2$ at 120 ppm in the 1st season and the interaction between N at 60 kg/fed. and foliar spray with $CaCl_2$ at 180 ppm in the 2nd season was the best interaction treatment for enhancing total dry weight per plant and DM% in leaves at 75 days after transplanting (Tables 2 and 3). Fertilizing with mineral N at 60 and 80 kg/fed. increased total dry weight/plant and dry matter in leaves of lettuce compared to 40 kg N / fed. and 60 kg N/fed. was the best treatment in both seasons. Also, foliar spray with $CaCl_2$ at 60, 120, and 180 ppm increased total dry weight / plant and dry matter in leaves compared to the control (spraying with water), and 120 ppm was the best treatment.

From the foregoing results, it could be concluded that, in general, fertilizing lettuce plants with N at 60 kg/fed. and foliar spray with $CaCl_2$ at 120 ppm increased total dry weight/plant and dry matter in leaves, whereas N at 60 kg/fed. and $CaCl_2$ at 180 ppm increased plant height in both seasons.

Table (2). Effect of nitrogen rates, calcium concentrations, and their interaction on total dry weight /plant (g) of lettuce at 75 days after planting during 2024/2025 and 2025/2026 seasons

Treatments	0 (control)	60 ppm	120 ppm	180 ppm	Mean (N)

	2024/2025 season				
40 kg N/fed.	19.75 j	22.54 i	26.23 h	27.72 g	**24.06 C**
60 kg N/fed.	29.37 f	33.29 d	37.54 a	36.13 b	**34.08 A**
80 kg N/fed.	29.35 f	32.11 e	33.19 d	34.06 c	**32.17 B**
Mean ($CaCl_2$)	**26.15 C**	**29.31 B**	**32.32 A**	**32.63 A**	
LSD at 0.05level	**N= 0.33**	**$CaCl_2$=0.32**		**N x $CaCl_2$=0.57**	
	2025/2026 season				
40 kg N/fed.	17.45 j	24.58 i	27.21 h	29.27 g	**24.62 C**
60 kg N/fed.	31.05 ef	34.78 d	37.85 b	41.13 a	**36.20 A**
80 kg N/fed.	30.71 f	31.93 e	36.53 c	36.12 c	**33.82 B**
Mean ($CaCl_2$)	**26.40 D**	**30.43 C**	**33.86 B**	**35.50 A**	
LSD at 0.05level	**N=0.80**	**$CaCl_2$= 0.70**		**N x $CaCl_2$=1.21**	

Table (3). Effect of nitrogen rates, calcium concentrations, and their interaction on dry matter in leaves (%) of lettuce at 75 days after planting during 2024/2025 and 2025/2026 seasons

Treatments	**0 (control)**	**60 ppm**	**120 ppm**	**180 ppm**	**Mean (N)**
	2024/2025 season				
40 kg N/fed.	6.26 g	6.48 f	6.71 de	6.76 cd	**6.55 C**
60 kg N/fed.	6.86 bc	6.94 ab	7.00 a	6.98 ab	**6.94 A**
80 kg N/fed.	6.61 ef	6.90 ab	6.90 ab	7.02 a	**6.85 B**
Mean ($CaCl_2$)	**6.57 C**	**6.77 B**	**6.87 A**	**6.92 A**	
LSD at 0.05level	**N= 0.08**	**$CaCl_2$=0.07**	**N x $CaCl_2$=0.12**		
	2025/2026 season				
40 kg N/fed.	6.41 f	6.52 e	6.61 e	6.81 d	**6.58 C**
60 kg N/fed.	6.98 c	7.19 b	7.43 a	7.43 a	**7.25 A**
80 kg N/fed.	6.88 cd	6.98 c	7.20 b	7.15 b	**7.05 B**
Mean ($CaCl_2$)	**6.75 C**	**6.89 B**	**7.08 A**	**7.13 A**	
LSD at 0.05level	**N=0.06**	**$CaCl_2$=0.05**		**N x $CaCl_2$=0.09**	

Leaf pigments

Effect of N rates

The highest concentrations of total chlorophyll (a+b) in leaf tissues were obtained with the N rate at 80 kg N/fed. (4.53 and 4.61 mg/g FW) in both seasons, with no significant differences with N at 60 kg in the 2nd season (Table 4). These results are in harmony with those obtained by Inkham ***et al.*** **(2021)** showed that the highest dry weight of lettuce leaves and total chlorophyll in leaf tissues were obtained with N at 15 mM/L as compared to7.5 or 22.5 mM/L.

Effect of $CaCl_2$ as a foliar application

The concentrations of total chlorophyll (a+b) in leaf tissues significantly increased with increasing $CaCl_2$ up to 120 ppm (4.39 and 4.49 mg/g FW), with no significant differences with $CaCl_2$ at 180 ppm in both seasons(Table 4). In this concern, total chlorophyll in lettuce leaves increased when romaine lettuce cv. Balady was treated with 20 mM calcium chloride (**Youssef *et al.*, 2017**). In addition , **Inkham *et al.* (2021)** showed that treated lettuce plants with 7.5 mM/L produced the highest values of total chlorophyll in leaf tissues of lettuce compared to 2.5 and 5 mM/l

Effect of the interaction

The interaction between N at 60 kg/fed. and $CaCl_2$ at 120 ppm was the best treatment for enhancing the concentrations of total chlorophyll (a+b), in leaf tissues (4.69 and 4.82 mg/g FW) in both seasons (Table, 4).

Table (4). Effect of nitrogen rates, calcium concentrations, and their interaction on chlorophyll a+b (mg /g FW) in leaf tissues of lettuce at 75 days after planting during 2024/2025 and 2025/2026 seasons

Treatments	**0 (control)**	**60 ppm**	**120 ppm**	**180 ppm**	**Mean (N)**
	2024/2025 season				
40 kg N/fed.	3.30 g	3.55 f	3.78 e	3.83 e	**3.61 C**
60 kg N/fed.	4.04 d	4.16 d	4.69 a	4.52 bc	**4.35 B**
80 kg N/fed.	4.44 c	4.36 c	4.69 a	4.66 ab	**4.53 A**
Mean ($CaCl_2$)	**3.93 C**	**4.02 B**	**4.39 A**	**4.33 A**	
LSD at 0.05level	**N=0.10**	**$CaCl_2$=0.08**		**N x $CaCl_2$=0.15**	

	2025/2026 season				
40 kg N/fed.	3.41 f	3.67 e	3.87 e	3.86 e	**3.70 B**
60 kg N/fed.	4.24 d	4.38 cd	4.82 a	4.65 ab	**4.52 A**
80 kg N/fed.	4.44 bcd	4.50 bc	4.78 a	4.71 a	**4.61 A**
Mean ($CaCl_2$)	**4.03 C**	**4.19 B**	**4.49 A**	**4.41 A**	
LSD at 0.05level	**N=0.13**	**$CaCl_2$=0.11**		**N x $CaCl_2$= 0.20**	

N, P, and K uptake by leaves

Effect of N rates

Fertilizing lettuce plants with mineral N at 80 kg/fed. had a significant effect on N, P, and K uptake by leaves with no significant differences with N at 60 kg/fed. with respect to N and P in the 1^{st} season and K in both at 75 days after transplanting (Tables 5 to 7). Results are in harmony with those obtained by **Awaad *et al.* (2016**), and **Taha *et al.* (2017)** reported increasing N levels up to 60 kg N/fed. which equals 100% of the recommended dose, gave the highest N, P and K uptake by lettuce leaves cv. Balady.

Effect of $CaCl_2$ as a foliar application

Foliar application with $CaCl_2$ solution at 180 ppm increased N, P, and K contents and their uptake by leaves, followed by $CaCl_2$ at 120 in both seasons at 75 days after transplanting (Tables 5 to 7).In this regard**, El-Shabrawy and Selim (2007)** reported that spraying lettuce plants with $CaCl_2$ 2000 ppm gave the highest values of N, P and K uptake as compared to the other treatments.

Effect of the interaction

Data in Tables 5 to 7 indicate that the interaction between N at 60kg/fed. and spraying with $CaCl_2$ at 180 ppm significantly increased N, P, and K uptake by leaves, with no significant differences with the interaction between N at 60 kg /fed. and $CaCl_2$ at 120 ppm regarding N, P, and K uptake in the 1^{st} season at 75 days after transplanting in both seasons.

Fertilizing lettuce plants with N at 40, 60, and 80 kg/fed and $CaCl_2$ at 60, 120, and 180 ppm as a foliar application increased N, P, and K uptake by leaves compared to N at 40, 60, and 80 kg/fed and without $CaCl_2$ (spraying with water).Results are in accordance with **El-Shabrawy and Selim (2007)** reported that applying lettuce plants with nitrogen at 80 kg / fed. and foliar spray with $CaCl_2$ (2000 ppm gave the highest values of N, P and K uptake as compared to the other treatments

Table (5). Effect of nitrogen rates, calcium concentrations, and their interaction on N uptake by leaves (mg) of lettuce at 75 days after planting during 2024/2025 and 2025/2026 seasons

Treatments	**0 (control)**	**60 ppm**	**120 ppm**	**180 ppm**	**Mean (N)**
	2024/2025 season				
40 kg N/fed.	166.27 h	209.73 g	256.36 f	268.27 ef	**225.16 B**
60 kg N/fed.	285.63 e	337.57 cd	375.54 ab	392.27 a	**347.75 A**
80 kg N/fed.	319.66 d	348.76 c	369.19 b	385.04 ab	**355.66 A**
Mean ($CaCl_2$)	**257.19 D**	**298.69 C**	**333.70 B**	**348.53 A**	
LSD at 0.05level	**N=12.10**	**$CaCl_2$= 10.57**		**N x $CaCl_2$=18.32**	
	2025/2026 season				
40 kg N/fed.	148.99 i	223.62 h	261.06 g	286.23 f	**229.97 C**
60 kg N/fed.	294.09 f	338.72 de	393.05 c	444.64 a	**367.62 B**
80 kg N/fed.	331.42 e	354.53 d	418.50 b	417.32 b	**380.44 A**
Mean ($CaCl_2$)	**258.17 D**	**305.62 C**	**357.54 B**	**382.73 A**	
LSD at 0.05level	**N=10.14**	**$CaCl_2$=8.86**	**N x $CaCl_2$=15.35**		

Table (6). Effect of nitrogen rates, calcium concentrations, and their interaction on P uptake by leaves (mg) of lettuce at 75 days after planting during 2024/2025 and 2025/2026 seasons

Treatments	**0 (control)**	**60 ppm**	**120 ppm**	**180 ppm**	**Mean (N)**
	2024/2025 season				
40 kg N/fed.	23.58 h	28.18 g	34.11 f	36.99 e	**30.71 B**
60 kg N/fed.	38.15 e	46.76 c	52.60 a	53.25 a	**47.69 A**
80 kg N/fed.	42.93 d	48.66 b	49.81 b	51.84 a	**48.31 A**
Mean ($CaCl_2$)	**34.88 D**	**41.20 C**	**45.50 B**	**47.36 A**	
LSD at 0.05level	**N=1.04**	**$CaCl_2$=0.90**		**N x $CaCl_2$=1.57**	

	2025/2026 season				
40 kg N/fed.	20.65 i	30.84 h	36.14 g	40.25 f	**31.97 C**
60 kg N/fed.	39.90 f	48.28 d	56.28 b	61.37 a	**51.45 B**
80 kg N/fed.	43.66 e	50.29 c	60.96 a	61.53 a	**54.11 A**
Mean ($CaCl_2$)	**34.73 D**	**43.13 C**	**51.12 B**	**54.38 A**	
LSD at 0.05level	**N=0.38**	**$CaCl_2$=0.34**	**N x $CaCl_2$=0.58**		

Table (7). Effect of nitrogen rates, calcium concentrations, and their interaction on K uptake by leaves (mg) of lettuce at 75 days after planting during 2024/2025 and 2025/2026 seasons

Treatments	**0 (control)**	**60 ppm**	**120 ppm**	**180 ppm**	**Mean (N)**
	2024/2025 season				
40 kg N/fed.	214.94 h	256.58 g	299.65 f	327.70 e	**274.72 B**
60 kg N/fed.	371.69 d	416.69 c	461.05 a	476.19 a	**431.41 A**
80 kg N/fed.	389.36 d	423.36 bc	439.28 b	462.41 a	**428.60 A**
Mean ($CaCl_2$)	**325.33 D**	**365.54 C**	**399.99 B**	**422.10 A**	
LSD at 0.05level	**N=12.76**	**$CaCl_2$=11.15**	**N x $CaCl_2$=19.31**		
	2025/2026 season				
40 kg N/fed.	198.20 h	273.75 g	305.68 f	349.61 e	**281.81 B**
60 kg N/fed.	380.57 d	422.44 c	483.03 b	539.11 a	**456.29 A**
80 kg N/fed.	403.95 cd	427.34 c	496.95 b	501.96 b	**457.55 A**
Mean ($CaCl_2$)	**327.57 D**	**374.51 C**	**428.55 B**	**463.56 A**	
LSD at 0.05level	**N=16.03**	**$CaCl_2$=14.00**	**N x $CaCl_2$=24.26**		

Head yield

Effect of N rates

Data indicate that fertilizing with N at 80 kg/fed. gave the highest values for head diameter, average head weight, and head yield in both seasons compared to other treatments (Tables 8, 9 and 10).

The observed enhancement in lettuce productivity under a higher dose of nitrogen condition agrees with those findings of **Shams (2012) and Zaki *et al.* (2012**) who reported that plant productivity increased as N dose increased. The maximum yield under a higher supply of mineral nitrogen is due to increasing the photosynthetic rates and the assimilation rates, which leads to increasing the vegetative growth and head yield of lettuce **(Saleh *et al.,* 2010).** Results are in harmony with **Awaad *et a*l. (2016**), **Abd El-Ghany *et al*. (2022), and Hassan and El Nagy (2025).**

Effect of $CaCl_2$ foliar application

Spraying with $CaCl_2$ at 180 ppm increased head diameter and average head weight with no significant differences with $CaCl_2$ at 120 ppm. This means that $CaCl_2$ at 120 ppm increased head diameter and average head weight (Tables 8 and 9). As for head yield, data in Table 10 indicate that $CaCl_2$ at 120 ppm increased total yield in both seasons.

Foliar application of romaine lettuce cv. Balady with calcium chloride increased head yield **(Youssef *et al*., 2017).** In addition, **Attallah and Abdalla (2021**) indicated that foliar spray of calcium chloride either at 10 or 20 mM significantly increased yield parameters of lettuce.

Effect of the interaction

The interaction between N at 80 kg/fed. and spraying with $CaCl_2$ at 120 or 180 ppm increased head diameter in both seasons (Table 8). The interaction between N at 60 kg/fed. and spraying with $CaCl_2$ at 120 or 180 ppm and the interaction between N at 80 kg/fed. and spraying with $CaCl_2$ at 120 or 180 ppm increased average head weight in both seasons (Table 9)

The interaction between N at 80 kg/fed. and spraying with $CaCl_2$ at 120 or 180 ppm increased head yield/fed. in both seasons (Table 10).

Treating lettuce plants with mineral N at 40, 60, and 80 kg/fed. with $CaCl_2$ at 60, 120, and 180 ppm increased head diameter, average head weight, and total head yield compared to N at 40, 60, and 80 kg/fed. without $CaCl_2$ (spraying with water).This means that N is at 60 or 80 kg/fed. with $CaCl_2$ at 120 or 180 ppm, increased head diameter, average head weight, and head yield compared to N at 60 or 80 kg/fed. without $CaCl_2$.

In general, the interaction between N at 80 kg/fed. and $CaCl_2$ at 120 or 180 ppm increased head diameter, average head weight, and head yield with no significant differences with the interaction between N at 60 kg/fed. and $CaCl_2$ at 120 or 180 ppm with respect to average head weight. This means that N at 80 kg/fed and $CaCl_2$ at 120 or 180 ppm increased head diameter and head yield, whereas N at 60 kg/fed. and $CaCl_2$ at 120 or 180 ppm increased average head weight.

The stimulative effect of the interaction between N at 60 kg/fed. and foliar spray with $CaCl_2$ at 120 or 180 ppm on average head weight may be due to this interaction treatment, increased total dry weight (Table 2),total chlorophyll a+b (Table 4) and N, P, and K uptake by leaves (Tables 5, 6, and 7). **El-Shabrawy and Selim (2007)** reported that applying the rate of 80 kg N fed-1 and foliar spray with $CaCl_2$ (2000 ppm) followed by 80 kg N fed-1 and foliar spray significantly increased the productivity of lettuce plants as compared to the control treatment.

Table (8). Effect of nitrogen rates, calcium concentrations, and their interaction on head diameter (cm) of lettuce at 100 days after planting during 2024/2025 and 2025/2026 seasons

Treatments	0 (control)	60 ppm	120 ppm	180 ppm	Mean (N)
	2024/2025 season				
40 kg N/fed.	22.19 h	23.73 g	24.39 f	25.29 e	**23.90 C**
60 kg N/fed.	25.36 e	26.95 d	27.94 bc	27.56 c	**26.95 B**
80 kg N/fed.	27.53 cd	28.46 b	29.48 a	30.04 a	**28.87 A**
Mean ($CaCl_2$)	**25.02 D**	**26.38 C**	**27.27 B**	**27.63 A**	
LSD at 0.05level	**N= 0.38 $CaCl_2$=0.34 N x $CaCl_2$= 0.58**				
	2025/2026 season				
40 kg N/fed.	22.70 f	24.63 e	25.80 d	26.01 d	**24.78 C**
60 kg N/fed.	26.30 d	27.69 c	28.80 b	28.85 b	**27.91 B**
80 kg N/fed.	27.39 c	29.05 b	30.43 a	30.53 a	**29.35 A**
Mean ($CaCl_2$)	**25.46 C**	**27.12 B**	**28.34 A**	**28.46 A**	
LSD at 0.05level	**N=0.33 $CaCl_2$=0.28 N x $CaCl_2$=0.50**				

Table (9). Effect of nitrogen rates, calcium concentrations, and their interaction on average head weight (kg) of lettuce at 100 days after planting during 2024/2025 and 2025/2026 seasons

Treatments	0 (control)	60 ppm	120 ppm	180 ppm	Mean (N)
	2024/2025 season				
40 kg N/fed.	0.379 e	0.432 d	0.464 c	0.452 cd	**0.431 C**
60 kg N/fed.	0.448 cd	0.471 bc	0.522 a	0.505 a	**0.486 B**
80 kg N/fed.	0.497 ab	0.508 a	0.521 a	0.519 a	**0.511 A**
Mean ($CaCl_2$)	**0.441 C**	**0.470 B**	**0.502 A**	**0.492 A**	
LSD at 0.05level	**N=0.013 $CaCl_2$=0.016 N x $CaCl_2$=0.028**				
	2025/2026 season				
40 kg N/fed.	0.358 g	0.412 f	0.472 de	0.452 e	**0.423 C**
60 kg N/fed.	0.453 e	0.485 cd	0.519 ab	0.508 abc	**0.491 B**
80 kg N/fed.	0.509 abc	0.502 bcd	0.537 a	0.524 ab	**0.518 A**
Mean ($CaCl_2$)	**0.440 C**	**0.466 B**	**0.509 A**	**0.494 A**	
LSD at 0.05level	**N=0.015 $CaCl_2$=0.018 N x $CaCl_2$=0.031**				

Table (10). Effect of nitrogen rates, calcium concentrations, and their interaction on total yield (ton /fed.) of lettuce at 100 days after planting during 2024/2025 and 2025/2026 seasons (ha)

Treatments	0 (control)	60 ppm	120 ppm	180 ppm	Mean (N)
	2024/2025 season				
40 kg N/fed.	25.393 g	28.944 f	31.088 d	30.284 e	**28.927 C**
60 kg N/fed.	30.016 e	31.557 d	34.974 a	33.835 bc	**32.595 B**
80 kg N/fed.	33.299 c	34.036 b	34.907 a	34.773 a	**34.254 A**
Mean ($CaCl_2$)	**29.569 D**	**31.512 C**	**33.656 A**	**32.964 B**	
LSD at 0.05level	**N=0.356 $CaCl_2$=0.311 N x $CaCl_2$=0.538**				
	2025/2026 season				
40 kg N/fed.	23.986 h	27.604 g	31.624 e	30.284 f	**28.374 C**
60 kg N/fed.	30.351 f	32.495 d	34.773 b	34.036 c	**32.914 B**
80 kg N/fed.	34.103 c	33.634 c	35.979 a	35.108 b	**34.706 A**
Mean ($CaCl_2$)	**29.480 D**	**31.244 C**	**34.125 A**	**33.143 B**	
LSD at 0.05level	**N=0.339 $CaCl_2$=0.296 N x $CaCl_2$=0.513**				

Nitrate content in leaves

Effect of N rates

Nitrate content in leaves and stems increased with increasing N rates up to 80 kg/fed. (280.17 and 280.23 ppm) in both seasons. This means that N at 40 kg /fed. gave the lowest values of nitrate content in leaves (260.10 and 260.89 ppm in both seasons compared to other N rates (Table 11).
Similar results were reported by **Awaad *et al.* (2016**), **Aboud and Abd-Alrahman (2021**). In addition, **Ali (2024)** indicated that the lowest concentration of nitrate in leaves was produced from plants that were fertilized with N at 45 kg/fed., while the maximum concentration was obtained with 90 kg N/fed.

Effect of $CaCl_2$ foliar application
Data in Table 11 illustrate that nitrate content in leaves decreased with decreasing $CaCl_2$ asa foliar application. This means that $CaCl_2$ at 180 ppm gave the highest values of nitrate content in leaves (279.74 and 279.83 ppm), whereas the control and $CaCl_2$ at 60 ppm gave the lowest values in leaves (259.82 and 259.68 ppm) in both seasons.

Effect of the interaction
The interaction between N at 80 kg/fed. and spraying with $CaCl_2$ at 180 ppm recorded the maximum values of nitrate content in leaves, followed by the interaction between N at 80 kg/fed and $CaCl_2$ at 120 ppm (Table 11).The interaction between N at 40 kg and spraying with water, followed by N at 40 kg/fed and $CaCl_2$ at 60 ppm, recorded the minimum values of nitrate content in leaves.

Table (11). Effect of nitrogen rates, calcium concentrations, and their interaction on nitrate concentrations (mg /kg FW) in leaves of lettuce at 100 days after planting during 2024/2025 and 2025/2026 seasons

Treatments	0 (control)	60 ppm	120 ppm	180 ppm	Mean (N)
	2024/2025 season				
40 kg N/fed.	237.14 g	263.08 f	269.15 def	271.03 cde	**260.10 C**
60 kg N/fed.	267.14 ef	272.23 cde	276.11 bc	281.02 ab	**274.13 B**
80 kg N/fed.	275.17 bcd	277.22 bc	281.15 ab	287.16 a	**280.17 A**
Mean ($CaCl_2$)	**259.82 D**	**270.84 C**	**275.47 B**	**279.74 A**	
LSD at 0.05level	**N=4.25**	**$CaCl_2$=3.71**	**N x $CaCl_2$=6.43**		
	2025/2026 season				
40 kg N/fed.	237.02 g	266.14 f	269.26 ef	271.14 def	**260.89 C**
60 kg N/fed.	266.81 ef	272.14 cde	276.28 bcd	281.14 b	**274.09 B**
80 kg N/fed.	275.22 cd	277.31 bc	281.18 b	287.22 a	**280.23 A**
Mean ($CaCl_2$)	**259.68 D**	**271.86 C**	**275.57 B**	**279.83 A**	
LSD at 0.05level	**N=3.59**	**$CaCl_2$=3.14**	**N x $CaCl_2$=5.44**		

Calcium content in leaves
Effect of N rates
The highest calcium content in leaves was obtained from N at 80 kg/fed. in both seasons (Table 12). This means that N at 80 kg/fed increased Ca content (3.64 and 3.62 %), followed by N at 60 kg/fed and 40 kg/fed. in both seasons.
These results are in accordance with those obtained by **Awaad *et al.* (2016)** indicated that the highest values of Ca in the lettuce plant were achieved in the plants that received 90 kg N/ha as compared to 0, 60 and 120 kg /ha.

Effect of $CaCl_2$ foliar application
Data in Table 12 indicate that Ca content in leaves and stems significantly increased with increasing $CaCl_2$ up to 180 ppm (3.49 and 3.55 percent) in both seasons.
In this respect, previous studies indicated that increasing application of calcium chloride as a foliar spray up to 40 mM significantly increased the contents of calcium in leaves of lettuce as compared to 0, 10, 20, and 30 mM in lettuce cv. Balady **(Youssef *et al*., 2017). Also, Almeida *et al*. (2016)** came to similar results in this concern.

Effect of the interaction
The interaction between N at 80 kg/fed. and $CaCl_2$ at 180 ppm as a foliar application increased Ca content in leaves with no significant differences with the interaction between N at 80 kg/fed and $CaCl_2$ at 120 ppm in both seasons (Table 12).

Table (12). Effect of nitrogen rates, calcium concentrations, and their interaction on Ca (%) in leaves of lettuce at 100 days after planting during 2024/2025 and 2025/2026 seasons

Treatments	0 (control)	60 ppm	120 ppm	180 ppm	Mean (N)
	2024/2025 season				
40 kg N/fed.	2.07 i	3.04 h	3.15 g	3.26 f	**2.88 C**

60 kg N/fed.	3.21 fg	3.35 e	3.48 d	3.51 cd	**3.38 B**
80 kg N/fed.	3.57 bc	3.63 b	3.64 b	3.72 a	**3.64 A**
Mean (CaCl₂)	**2.95 D**	**3.34 C**	**3.42 B**	**3.49 A**	
LSD at 0.05level	**N= 0.04**	**CaCl₂= 0.04**	**N x CaCl₂=0.07**		
	2025/2026 season				
40 kg N/fed.	2.02 i	3.07 h	3.19 g	3.31 f	**2.89 C**
60 kg N/fed.	3.38 ef	3.42 e	3.52 d	3.58 cd	**3.47 B**
80 kg N/fed.	3.34 ef	3.67 bc	3.69 ab	3.78 a	**3.62 A**
Mean (CaCl₂)	**2.91 D**	**3.38 C**	**3.46 B**	**3.55 A**	
LSD at 0.05level	**N=0.06**	**CaCl₂=0.05**	**N x CaCl₂=0.09**		

Tipburn percentage

Effect of N rates

Treating lettuce plants with N at 60 kg/fed. gave the lowest values of tipburn percentage, 5.03 and 5.20%, in both seasons, whereas N at 40 kg/fed. gave the highest values of tipburn (7.55 and 7.65% in both seasons) (Table 13).
These results are in conformity with those reported by **Zandvakili *et al.* (2022)**indicated that increasing nitrogen rates up to 180 kg/h reduced the tip burn in lettuce leaves as compared to other nitrogen rates (0,60 and 120 kgN/h).

Effect of $CaCl_2$ foliar application

Tipburn percentage decreased with increasing $CaCl_2$ up to 180 ppm. This means that $CaCl_2$ at 180 ppm gave the lowest values of tip burn percentage (5.38 and 5.54 %) in both seasons compared to the other treatments (Table 13).
Tipburn is a physiological disorder that is characterized by Ca deficiency mainly on the inner leaves of head-forming vegetables like lettuce (**Olle and Bender, 2009**) .Results are in harmony with those obtained by **Yap *et. al.* (2022).** They showed that increasing the concentration of Ca reduced the tip burn in lettuce leaves**.**

Effect of the interaction

The interaction between N at 60 kg/fed. and foliar spray with $CaCl_2$ at 180 ppm recorded minimum values of tipburn percentage (4.39 and 4.45% in both seasons), followed by the interaction between N at 60 kg/fed. and $CaCl_2$ at 120 ppm, whereas the interaction between N at 40 kg/fed. and foliar spray with water recorded maximum values of tipburn percentage (9.45 and 9.06%) in both seasons (Table 13).
Fertilizing lettuce plants with N at 40, 60, and 80 kg/fed. with foliar application with $CaCl_2$ at 60, 120, and 180 ppm reduced tipburn percentage and increased calcium content in leaves and stems compared to N at 60 and 80 kg/fed. without calcium (spraying with water).This means that N at 60 kg fed with $CaCl_2$ at 120 or 180 ppm increased Ca contents in leaves and stems, therefore reducing tipburn percentage in leaves compared to N at 60 or 80 kg/fed. without $CaCl_2$.

Table (13). Effect of nitrogen rates, calcium concentrations, and their interaction on tip burn percentage of lettuce plants at 100 days after planting during 2024/2025 and 2025/2026 seasons

Treatments	**0 (control)**	**60 ppm**	**120 ppm**	**180 ppm**	**Mean (N)**
	2024/2025 season				
40 kg N/fed.	9.45 a	7.14 b	6.95 b	6.67 bc	**7.55A**
60 kg N/fed.	5.61 def	5.45 def	4.67 fg	4.39 g	**5.03C**
80 kg N/fed.	6.33 bcd	6.20 bcd	5.81 cde	5.08 efg	**5.85B**
Mean (CaCl₂)	**7.13A**	**6.26B**	**5.81BC**	**5.38C**	
LSD at 0.05level	**N=0.49**	**CaCl₂=0.55**	**N x CaCl₂=0.95**		
	2025/2026 season				
40 kg N/fed.	9.06 a	7.56 b	7.22 bc	6.78 bcd	**7.65A**
60 kg N/fed.	6.06 def	5.22 fgh	5.07 gh	4.45 h	**5.20C**
80 kg N/fed.	6.79 bcd	6.39 cde	5.83 efg	5.39 fg	**6.10B**
Mean (CaCl₂)	**7.30A**	**6.39B**	**6.04B**	**5.54C**	
LSD at 0.05level	**N= 0.42**	**CaCl₂=0.49**	**N x CaCl₂=0.84**		

Conclusion

From the foregoing results, it could be concluded that, fertilizing lettuce plants*cv*American grown in sandy soil during winter plantation with mineral nitrogen at 60 kg/ fed. and foliar spray with $CaCl_2$ at 120 ppm increased total dry weight, dry matter in leaves, and total chlorophyll in leaf tissues at 75 days after planting as well as average head weight at harvesting time . Whereas fertilizing with mineral nitrogen at 80 kg/ fed. and foliar spray with $CaCl_2$ at 180 ppm increased head yield/ha., head diameter, and calcium contents in leaves. Fertilizing with mineral nitrogen at 60 kg/ fed. and foliar spray with $CaCl_2$ at 180 ppm increased N , P and K uptake by leaves and reduced tip burn percentage in leaves. Mineral nitrogen at 40 kg /fed. and spraying with water was the best treatment for reducing nitrate concentration in leaves.

References

1. **Abd El-Ghany, M. F., El–Kherbawy, M.I., Abdel-Aal, Y.A., and Abbas, M. H. (2022).** Effect of growth seasons and nitrogen fertilization on the growth, yield and nitrate accumulation of lettuce (*Lactuca sativa* L.) plants. *International Journal of Health Sciences,* 6(S4), 7053– 7066.
2. **Aboud, F.S. and Abd-Alrahman, H.A. (2021**). Effect of nitrogen mineral fertilizer, vermicompost and biofertilizer on lettuce yield and quality. *Middle East J. Agric. Res.,* 10 (2): 588-603.
3. **Ali, M. A.M., (2024).** Response of yield and head quality of lettuce to nitrogen fertilization and seaweed extract foliar application under new valley conditions. *Zagazig J. Agric. Res.,* 51 (3) :461-478.
4. **Almeida, P.H., Mógor, Á.F., Ribeiro, A.Z., Heinrichs, J. and Amano, E. (2016).** Increase in lettuce (*Lactuca sativa* L.) production by foliar calcium application. *Aust. J. Basic & Appl. Sci.,* 10 (16), 161-167.
5. **Asem, A. S. A. Hassan and El Nagy, M. (2025).** effect of mineral nitrogen levels and foliar spray with (*spirulina platensis*) extract on growth, yield and quality of lettuce plants. *Zagazig J. Agric. Res.,* Vol. 52 No. (4) : 735-750.
6. **Attallah, Shreen Y. and Reham M. Abdalla (2021).** Influence of Foliar Spray with Calcium Chloride on Growth, Yield and Quality of Lettuce (*Lactuca sativa* L.). *Assiut J. Agric. Sci.,* 52 (4) :116-128 .
7. **Awaad, M.S., Badr, R.A., Badr, M.A. and Abd-elrahman, A.H. (2016**). Effects of different nitrogen and potassium sources on lettuce (*Lactuca sativa* L.) yield in a sandy soil. Eurasian J. Soil Sci., 5(4): 299-306.
8. **Bremner, J. M. and C. S. Mulvaney (1982).** Total nitrogen. In: Page, A. L., R. H. Miller and D. R. Keeney(Eds.). Methods of Soil Analysis. Part 2. Chemical and Microbiological properties. Amer. Soc. Agron., Madison, Wisconsin, USA, pp: 595-624.
9. **Collier, G.F. and Tibbitts, T.W. (1982).** Tipbum of lettuce. Hort. Rev. 4:49-65.
10. **Duncan, D.B.(1958).**Multiple range and Multiple F test. Biometrics, 11: 1-42.
11. **El-Bassyouni, M. S. S. (2016).** Effect of different nitrogen sources and doses on lettuce production. *Middle East J. Agric. Res.,* 5(4): 647-654
12. **El-Shabrawy, A. R.I. and Selim, E. M. (2007).** Combined effect of N-fertilization levels and foliar application with $CaCl_2$ and citric acid on yield and nitrate content of lettuce plants. *J. Agric. Sci. Mansoura Univ.,* 32 (8): 6907 - 6919, 2007
13. **Inkham, C., Panjama, K., Seehanam, P. and Ruamrungsri, S. (2021).** Effect of nitrogen, potassium and calcium concentrations on growth, yield and nutritional quality of green oak lettuce. DOI. 10.17660/ActaHortic. 2021.1312.59.
14. **Jackson, M. L. (1970**). Soil Chemical Analysis. Prentice Hall, Englewood Cliffs, N. J.
15. **Marschner, H. (2012).** Mineral nutrition of higher plants. 3rd Edition, Academic press San Diego, USA.
16. **Marschner, H., 1995.** Mineral Nutrition of Higher Plant. 2nd (ed.), Academic Press Limited. Text Book. pp.
17. **Ministry of Agriculture and Land Reclamation (2024**). Economic Affairs Sector, Cairo, Egypt.
18. **Niari, S.M., Bahri, M.H. and Rashidi, M. 2012**. Chemical materials application and storage periods' effects on vitamin C of ambient stored lettuce. *Amer.-Eurasian J. Agr. Environ. Sci.*, 12(8):1081–1084.
19. **Olsen, S. R. and Sommers, L.E. (1982).** Phosphorus. In:Page. A. L., R. H. Miller and D. R. Keeney (Eds.). *Methods of Soil Analysis*. Part 2.
20. **Saah, K. J. A., Kaba, J. S. and Abunyewa, A. A. (2022**). Inorganic nitrogen fertilizer, biochar particle size and rate of application on lettuce (*Lactuca sativa* L.) nitrogen use and yield, All Life, 15:1, 624-635.
21. **Saleh, S.A., Galala, A.A., Ezzo, M.I. and Ghoname, A.A. (2010**). An attempt to reduce mineral fertilization in lettuce production by using bio-organic farming system. *Acta Hort.,* 852: 311-318.
22. **Schlagnhaufer, B.E., Holcomb, E.J. and Orzolek, M.D. (1987).** Effects of supplementary light, solution heating, and increased solution calcium levels on lettuce production in the nutrient film technique. *Appl. Agr. Res.,* 2:124–129.
23. **Shams, A.S. (2012).** Effect of mineral, organic, and bio-fertilizers on growth, yield, quality and sensory evaluation of Kohlrabi. Research Journal of Agriculture and Biological Sciences, 8 (2): 305-314.
24. **Snedecor, G.W. and Cochran, W.G. (1980).** "Statistical Methods" 7th Ed. The Iowa State Univ. Press, Iowa, USA.
25. **Taha, A. A., El-Shazly, M. M. and Nadia M. M. Ali (2017).** Impact of Nitrogen and Organic Fertilization on Nutrients Uptake by Lettuce Plants . *J. Soil Sci. and Agric. Eng.,* Mansoura Univ., Vol. 8 (7): 341 – 346.
26. **Wettesteien, D. (1957).** Chlorophyll, Letal and der submicroskopische. Formmech Sell der Platiden . Exptl. Cell. Res., 12: 427-433.

27. Yanagi, A. A, Bullock, R.M. and Cho, J.J. 1983. Factor involved in the development of tipburn in crisp head lettuce in Hawaii. *J. Amer. Soc. Hort. Sci.,* 108(2): 234-237

28. **Yap, M. Y., Lim, M. W. and Brendan, L. K. W. (2022).** Influence of calcium macronutrient on tip burn occurrence in hydroponically cultivated lettuces. IOP Conf. Ser.: Mater. Sci. Eng. 1257 012003.

29. **Youssef, S.M.S., Abd El-Hady S.A., Nashwa A.I. Abu El-Azm and El-Shinawy, M.Z. (2017).** Foliar Application of Salicylic Acid and Calcium Chloride Enhances Growth and Productivity of Lettuce (*Lactuca sativa*). *Egypt. J. Hort.* Vol. 44, No. 1, pp. 1-16

30. **Zaki, M.F., Tantawy, A.S., Salah, S.A. and Yomna I. Helmy (2012**). Effect of biofertilization and different levels of nitrogen sources on growth, yield components and head quality of two broccoli cultivars. *Journal of Applied Sciences Research*, 8 (8): 3943-3960.

31. **Zandvakili, O. R., Barker, A.V., Hashemi, M., Autio, W.R., Etemadi, F. and Sadeghpour, A. (2022).** Influence of nitrogen source and rate on lettuce yield and quality . *Agronomy Journal*,114:1401–1414.