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Evaluating the Response of Peanuts Plant Irrigated with Agricultural Drainage Water to Organic Fertilization and Foliar Application of Magnesium and Selenium, Along with Soil Property Assessment

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UTILIZING agricultural drainage water for irrigation purposes poses significant challenges, yet it's an unavoidable necessity driven by water scarcity in Egypt. Lately, the government's focus has shifted towards establishing a self-sustained vegetable oil industry within the country. This involves expanding the cultivation of oil-rich crops under stress conditions, like peanuts, which are a valuable source of oil and beneficial fatty acids. So, a research trial was performed during the seasons of 2022 and 2023 to evaluate the effect of some treatments on the growth performance and productivity of peanuts plants irrigated with agricultural drainage water. The impact of organic fertilizers [**T_1:** Control (without organic fertilizer), **T_2:** Plant compost PC (banana residues and sugar beet at ratio of 50:50), **T_3:** Farmyard manure compost FYMC, at rate of 10 Mg ha^{-1} for each one, was evaluated as main plots. Also, the foliar application of magnesium (Mg) and selenium (Se) elements [**F_1:** Control, **F_2:** Mg at rate of 840 g ha^{-1}, **F_3:** Mg at rate of 1680 g ha^{-1}, **F_4:** Se at rate of 5.0 mg L^{-1}, **F_5:** Se at rate of 10.0 mg L^{-1}, **F_6:** As a combined treatment ($F_2 + F_4$) **F_7:** As a combined treatment ($F_3 + F_4$)] was assessed as sub-main plots. The results indicate that the superior organic fertilization treatment for obtaining the highest values of growth performance (*e.g.*, plant height and chlorophyll content) and yield parameters (*e.g.*, seed oil yield and protein yield) was **T_2** treatment (PC) followed by **T_3** treatment (FYMC), surpassing the control group **(T_1).** Among the foliar spraying treatments, the combined treatment of magnesium and selenium **(F_7)** demonstrated the highest efficacy in promoting growth and yield, as the order sequence from the most effective to less was **F_7** ($F_3 + F_4$) > **F_6** ($F_2 + F_4$) **> F_3 > F_2 > F_4 > F_1** (control) **> F_5**. Regarding antioxidant production, the trend of catalase (CAT) looks just like the trend of growth performance. On the contrary, the plants grown without organic fertilizer possessed the highest values of proline, while the lowest values were achieved with PC treatment. Also, spraying of selenium at a rate of 10.0 mg L^{-1} (**F_5** treatment) led to the highest content of proline in leaves compared to other foliar treatments and the control group (**F_1**) which came in the second order. Regarding soil properties, both types of compost positively affected soil fertility (N, P, K, CEC), with the superiority of PC. Notably, the combined approach of using plant compost **(T_2)** along with the foliar application of magnesium and selenium **(F_7)** showed the most favorable outcomes in terms of growth performance and both quantitative and qualitative yield of peanut plants. Generally, it is recommended that farmers and agricultural practitioners in Egypt consider adopting the effective combinations of organic fertilization and beneficial foliar treatments identified in this study. By implementing these recommendations, Egypt can enhance its agricultural sustainability, mitigate the challenges posed by water scarcity, and establish a robust and self-sufficient vegetable oil industry.

Keywords: Plant compost, Farmyard manure compost, magnesium, selenium.

1. Introduction

In Egypt, the reliance on agricultural drainage water for irrigation purposes has reached a point of undeniable necessity (**Abbas *et al.* 2020).** The scarcity of freshwater resources has driven agricultural practices towards utilizing agricultural drainage water, despite the formidable challenges it presents **(Abuzaid and Jahin 2021**). The use of such water introduces complexities stemming from the water's composition. However, given the nation's water scarcity, this approach has become an inescapable reality **(Ashour *et al.* 2021).** The process of employing agricultural drainage water for irrigation is not devoid of issues. The challenges associated with it include the potential detrimental effects on plants due to the presence of salts, toxins, and other contaminants in the water **(Eltarabily, 2022).** Moreover, the exposure of plants to such water can lead to the generation of free radicals (ROS), causing oxidative stress and negatively

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impacting plant growth and productivity **(Moursi *et al.* 2023).**

To address these challenges and enhance the adaptability of plants to irrigation with agricultural drainage water, innovative strategies have been explored. Among these approaches, organic fertilization has emerged as a promising technique (**Tzortzakis *et al.* 2020**). Organic fertilizers offer a multifaceted approach to improving plant tolerance to any environmental stress (**Elsherpiny and Helmy 2022).** Through their positive influence on soil structure, nutrient availability, root growth, gene expression, and defence mechanisms, organic fertilizers contribute to plant resilience in the face of both abiotic and biotic stressors **(Elsherpiny *et al.* 2023).** In addition to its supply of nutrients to the grown plant under stress conditions. Incorporating organic fertilization practices can help optimize plant health, productivity, and sustainability in diverse agricultural systems **(Elsherpiny 2023).**

Concurrently, the application of specific elements such as selenium (Se) and magnesium (Mg) through foliar spraying has gained attention. Selenium serves as an essential antioxidant, counteracting the adverse effects of oxidative stress on plants **(Elsherpiny and Kany 2023).** It bestows considerable benefits upon various plants by affording protection against oxidative stress through the interception of free radicals and the reduction of reactive oxygen species (ROS) within cellular environments **(Xiang *et al.* 2022).** Its prowess as an efficient antioxidant extends to safeguarding cell integrity, bolstering defense mechanisms, and heightening stress tolerance **(Mansoor *et al.* 2022).** Nevertheless, it is imperative to acknowledge that an excess of selenium can exert detrimental effects on plants. Hence, a cautious approach is necessary, encompassing precise dosage and vigilant monitoring, to ensure both the safety and effectiveness of selenium application **(Mahmoud *et al.* 2023).**

Magnesium plays a vital role in various physiological processes, including its coenzyme participation in oil formation **(Elsherpiny *et al.* 2023).** Moreover, Mg, a fundamental constituent of chlorophyll, assumes a vital role not only in photosynthesis but also in contributing to the structural integrity of cell walls through the formation of magnesium pectates (**Chen *et al.* 2018**). It's important to note that a dynamic interaction exists between potassium and magnesium, wherein they exhibit antagonistic behavior. Consequently, the utilization of potassium-based fertilizers may potentially necessitate supplementary magnesium foliar spraying on the plant's vegetative parts **(Xie *et al.* 2021).** Oil crops are considered the primary source of vegetable oils, which are essential commodities for human consumption in Egypt. Additionally, they serve as vital productive elements that contribute to numerous industries **(Ahmed and El-Karamity 2020).** Oil crops hold a significant position within the Egyptian agricultural belief, deriving their importance from the fact that the demand for them stems from the demand to produce edible vegetable oils. These oils constitute a prevalent dietary pattern and a fundamental component for Egyptian consumers **(Elsherpiny *et al.* 2023).** There are many oil crops, which are often multi-usage, but also are grown for the purpose of producing oils, most notably cotton, sunflower, olive, and sesame **(El-Hamidi and Zaher 2018).** Oils have recently been extracted from peanuts due to the oil crisis in Egypt. For the highest oil-extracting crops, peanuts are at the top of the list, as the highest percentage of oil extraction is about 60%, followed by the sesame crop with a very high extraction rate of 55%, then the sunflower and canola crops with an extraction rate of about 45%, then come cotton seed and soybean with an extraction rate of 20% oils for each **(Gavrilova *et al.* 2020).** In this context, the cultivation of peanuts (*Arachis hypogaea* L.) gains particular significance. Peanuts are a valuable oil crop and hold the potential to contribute significantly to Egypt's oil production, which faces recurring crises **(Zahran and Tawfeuk, 2019; Elbaalawy 2020).** Expanding the cultivation of peanuts could provide a viable solution to address the annual oil shortages in the country **(Osman *et al*. 2020).** Additionally, exploring the adaptability of leguminous crops like peanuts to thrive under conditions of low-quality water (agricultural drainage water) is essential, given their agricultural importance and potential for sustained production.

Therefore, the main objective of this research work is to evaluate the response of peanut plants to the challenges posed by agricultural drainage water irrigation. Specifically, the research investigates the potential of organic fertilization and foliar application of selenium and magnesium to enhance peanut plant resilience and oil production. By understanding the intricate relationships between plant physiology, water quality, and nutrient availability, this study contributes to the advancement of sustainable agricultural practices in Egypt and potentially in similar water-scarce regions worldwide. The findings of this research work hold the potential to inform practical strategies that can facilitate agricultural sustainability and address the pressing challenges posed by water scarcity in Egypt.

2. Material and Methods

A research trial was carried out during the seasons of 2022 and 2023 to evaluate the effect of some treatments on the growth performance and productivity of peanuts plants irrigated with agricultural drainage water having EC and pH values of 3.15 dS m^{-1} and 7.85, respectively.

- Experimental location

This work research was executed in a private farm (31°4'54"N - 31°24'4"E) located in Met Antar village, Talkha district, El-Dakahlia Governorate, Egypt.

- Soil sampling

Prior to the commencement of the experiment, a soil specimen was gathered from a depth ranging between 0 to 30 cm. This sample was then subjected to analysis through conventional procedures. The outcomes of the soil examination are detailed in Table 1.

- Studied substances

Plant residues, such as banana tree components (peels, stems, leaves), along with the uppermost fresh parts of sugar beet plants (50:50), were collected from farms near the experimental area. Additionally, farmyard manure sourced from a nearby cow farm was also gathered. These two types of organic fertilizers were subjected to a composting process for a period of five months at the experimental location, utilizing the procedure detailed by **El-Hammady *et al.* (2003).** The analysis of both compost varieties was conducted according to the guidelines outlined by **Tandon (2005),** and the specific attributes of these composts are provided in Table 1. Sodium selenite (Na_2SeO_3, 45.56 %Se) as selenium source was obtained from Sigma Company. It had a molecular mass of 172.49 g mol^{-1}, while its density was measured at 3.10 g cm^{-3}.

Magnesium sulphate ($MgSO_4$, consisting of 20.19 Mg % by mass) was gotten from Agro Egypt for Agricultural Development Company, Egypt. It had a molecular mass of 120.366 g mol^{-1}, boasting a purity level of 99 %. Its melting point stood at 1.124°C, while its density was measured at 2.66 g cm^{-3}. A stander solution was prepared for both selenium (Se) and magnesium (Mg) separately, utilizing a specific concentration. This was achieved by dissolving an exact quantity of sodium selenite or magnesium sulfate in the chosen solvent, separately. Subsequently, these standard solutions were employed to prepare the different concentrations required for the research.

Table 1. Properties of the initial soil, plant compost and farmyard manure compost.

Property	Initial soil	*PC	**FYMC
pH	7.2 (Suspension 1:2.5)	6.16 (Suspension 1:10)	6.4 (Suspension 1: 10)
EC, dSm^{-1}	2.23 (Soil paste)	3.54 (Extract 1:10)	4.5 (Extract 1:10)
Total C, %	/	18.30	20.4
C:N ratio	/	11.02	14.06
Organic matter, %	1.56	31.5	35.16
Nitrogen	44.2 (Available, mg kg^{-1})	1.66 (Total, %)	1.45 (Total, %)
Phosphorus	10.9 (Available, mg kg^{-1})	1.47 (Total, %)	0.89 (Total, %)
Potassium	222 (Available, mg kg^{-1})	1.33 (Total, %)	1.02 (Total, %)
Fe, mg kg^{-1}	2.50	1.21	1.20
Zn, mg kg^{-1}	1.30	29.0	19.0
CEC, cmol kg^{-1}	42.6	145	139
Sand	22.0	/	/
Clay	34.0	/	/
Silt	44.0	/	/
Textural	Clay loam	/	/

Note: The data presented in this Table is the combined data over both studied seasons
***PC:** Plant compost (banana residues and sugar cane at ratio of 50:50)
****FYMC**: Farmyard manure compost

- Peanuts seeds

The seeds used in the experiment were specifically "Giza 6, early cultivar". Prior to sowing, these seeds were treated with the Rizolex-T antiseptic, applying a rate of 3.0 grams per kilogram of seeds. These seeds were sourced from the Agriculture Research Center (ARC) in Giza, Egypt.

- Treatments and experimental design

The current research trial was executed under a split-plot design with three replicates. The impact of organic fertilizers treatments were studied as the main factor as follows;

T_1: Control (without organic fertilizer)
T_2: Plant compost at rate of 10 Mg ha^{-1}
T_3: Farmyard manure compost at rate of 10 Mg ha^{-1}

While the foliar application of magnesium (Mg) and selenium (Se) elements were studied as the sub-main factor as follows;

F_1: Control (without exogenous application)
F_2: Mg at rate of 840 g ha^{-1}
F_3: Mg at rate of 1680 g ha^{-1}
F_4: Se at rate of 5.0 mg L^{-1}
F_5: Se at rate of 10.0 mg L^{-1}
F_6: As a combined treatment ($F_2 + F_4$)
F_7: As a combined treatment ($F_3 + F_4$)]

- Experimental set up

The sub-plot area was 12.25 m^2 with dimensions of 3.5 m × 3.5 m. Peanuts seeds were sown at a rate of 110 kg ha^{-1} on 14th April in both studied seasons. These seeds underwent Okadean inoculation at rate of 1.5 kg inoculant per hectare and were subsequently hand-sown directly into hills. Each hill received one seed and was positioned on the shoulder bed within the lower third of the row ridge. Effective nitrogen dose as ammonium nitrate (33.5% N) was applied at a rate of 48 kg N ha^{-1} before the irrigation as a starter dose. Immediate irrigation followed the sowing process. After one week of sowing, a reseeding procedure was executed under a flooding irrigation system.

After 25 days from planting, the success of inoculation was identified. This was achieved by examining the roots of several plants in various locations across the inoculated field. The plants were uprooted with a portion of the soil to prevent losing nodules while extracting them. There were 10 or more nodules per plant with reddish color from the inside, thus the inoculation was deemed successful. In this case, it is enough to add the starter nitrogen dose only, as exceeding this nitrogen amount could hinder the inoculant's effectiveness and suppress its function.

The application of the designated compost treatments, as previously indicated, was carried out one month before sowing on the respective plots. Potassium sulfate (48 % K_2O, at a rate of 120 kg ha^{-1}) and calcium superphosphate (6.6%P, at a rate of 360 kg ha^{-1}) were applied before ploughing (during preparation) according to the recommendations of Ministry of Agriclural and Soil Reclamation in Egypt. The exogenous application of both Se, Mg was performed 35 days after planting and then repeated three times at 15-day intervals with a volume of 1050 L ha^{-1} for each treatment, by hand sprayer. The harvesting was manually conducted on August 5th in both seasons.

- Measurements

a- At 70 days from sowing

- Plant height (cm), fresh and dry weights (g $plant^{-1}$)
- Chlorophyll a and b (mg g^{-1} FW)
- N, P, K, Mg (% DW) and Se (mg kg^{-1} DW)
- Catalase (CAT, unit g^{-1} $protein^{-1}$) and proline (µmol.g^{-1} FW)

b- At harvest stage (110 days from planting)

- No. of pods $plant^{-1}$, weight of pods g $plant^{-1}$, weight of 100 pods (g), pods and seeds yield (Mg ha^{-1}).
- Seeds N, P and K content (%)
- Oil (%), oil yield (kg ha^{-1}), protein (%), Protein yield (kg ha^{-1}) and carbohydrates (%)
- Soil available nitrogen, phosphorus, and potassium ($mgkg^{-1}$) as well as cation exchange capacity of soil (CEC, cmol kg^{-1}) were determined as formerly mentioned with the initial soil.

- Methods

a- Analysis of initial soil and soil samples at harvest

Particle size distribution was done using the pipette method, while the soil texture was identified *via* a soil texture triangle **(Kroetsch and Wang 2008).** Soil available N, P, K were determined *via* Kjeldahl, spectrophotometric and flame photometer, respectively, while soil available Fe and Zn were determined *via* atomic absorption spectrophotometer **(Dewis and Freitas 1970).** Cation exchange capacity was assessed following the method outlined by **Black (1965),** employing ammonium acetate at a pH of 7.0. Organic matter was identified by Walkly and Balck method **(Miyazawa *et al.* 2000).** Electric conductivity was measured using EC-meter, Model TDS can 3 while soil reaction (pH) was measured using a Gallen Kamp pH-meter.

b- Analysis of leaves and seeds

To digest the plant samples (either leaves or seeds) for determining the content of N, P, K and Mg, mixed of $HClO_4 + H_2SO_4$ was used as described by **Peterburgski (1968)**, while to digest the plant samples (leaves) for determining the content of Se, mixed of HF $+HNO_3+$ H_2O_2 was used as described by **Kumpulainen *et al*. (1983).**

The nitrogen, phosphorus, and potassium content in the plant samples (leaves or seeds) were evaluated using distinct techniques. Nitrogen levels were determined using the Kjeldahl method, phosphorus levels were analyzed through the spectrophotometric method, and potassium levels were ascertained using the flame photometer method. These chosen methods were in accordance with **Ashworth *et al*. (1997).** Meanwhile, the levels of selenium and magnesium in the leaves were gauged using Atomic Absorption Spectroscopy (AAS) as per the protocol by the **Soil Science Research Institute of Sinica (1983).**

Leaves chlorophyll (a and b) was measured using methanol (100%) as described by **Aminot and Rey (2000).** Catalase enzyme (CAT) activity was assessed by observing the breakdown of hydrogen peroxide at a wavelength of 240 nm through a spectrophotometer as described by **Alici and Arabaci (2016)**. The determination of proline was achieved using a colorimetric approach, following the methodology outlined by **Ábrahám *et al.* (2010).**

The seeds oil, total carbohydrate and protein content within the peanut seed samples were assessed in accordance with the instructions provided by **AOAC (2000).** The seed protein percentage was derived by multiplying the total nitrogen percentage by a factor of 6.25. To determine the seed oil and protein yields per hectare, the seed oil percentage and protein percentage were multiplied by the seed yield per hectare.

- Statistical analysis

To comparing the means among various treatments, Duncan's Multiple Range Test was executed with a significance threshold set at $P \leq 0.05$. This analysis was carried out utilizing the **CoStat computer software package (Version 6.303, CoHort, USA, 1998-2004)** based on **Gomez and Gomez (1984).**

Fig. 1. Some photos in different stages were taken by El-Sherpiny and Baddour.

3. Results

1. Peanuts performance at 70 days from sowing

- Growth criteria and photosynthetic pigment

Table 2 points out the impact of applying organic fertilization via two different types (PC and FYMC) and foliar application of magnesium and selenium on the growth performance of peanuts plants at the period of 70 days from sowing expressed in plant height (cm), fresh and dry weights (g plant^{-1}), chlorophyll a and b (mg g^{-1} FW) during two successive seasons of 2022 and 2023. The results indicate that the superior organic fertilization treatment for obtaining the highest values was T_2 treatment (PC) followed by T_3 treatment (FYMC), surpassing the control group (**T_1**). Among the foliar spraying treatments, the combined treatment of magnesium and selenium (**F_7**) demonstrated the highest efficacy in promoting growth performance, as the order sequence from the most effective to less was **F_7 (**F_3 + F_4**) > F_6 (**F_2 + F_4**) > F_3 > F_2 > F_4 > F_1 (**control**) > F_5.** Notably, the combined approach of using plant compost (**T_2**) along with the foliar application of magnesium and selenium (**F_7**) showed the most favorable outcomes in terms of plant height (cm), fresh and dry weights (g plant^{-1}), chlorophyll a and b (mg g^{-1} FW) compared to the other interventions. The same trend was found for both studied seasons.

Table 2. The impact of applying organic fertilization *via* two different types (PC and FYMC) and foliar application of magnesium and selenium on the growth criteria and photosynthetic pigments of peanuts plants at the period of 70 days from sowing during two successive seasons of 2022 and 2023.

Treatments		Plant height, cm		Fresh weight g plant^{-1}		Dry weight, g		Chlorophyll a, mg g^{-1} FW		Chlorophyll b, mg g^{-1} FW	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Main factor: Organic fertilization											
T_1		43.24c	45.01c	54.08c	55.92c	16.22c	16.53c	0.807c	0.841b	0.603c	0.628c
T_2		54.26a	56.99a	65.35b	67.92a	20.34a	20.79a	0.886a	0.921a	0.702a	0.731a
T_3		50.88b	53.53b	62.13a	64.63b	19.07b	19.44b	0.877b	0.915a	0.681b	0.708b
LSD at 5%		**1.30**	**2.36**	**2.85**	**0.22**	**0.49**	**0.07**	**0.009**	**0.015**	**0.007**	**0.004**
Sub main factor: Foliar applications of Mg and Se											
F_1		46.50e	48.62d	57.86cd	59.80d	17.38e	17.73e	0.830e	0.865e	0.638d	0.664d
F_2		50.04cd	52.42bc	60.99b	63.43c	18.78cd	19.19cd	0.890a	0.927a	0.666c	0.693c
F_3		50.82bc	53.45abc	61.85ab	64.33bc	19.12bc	19.49bc	0.862c	0.897c	0.675b	0.703b
F_4		49.32d	51.89c	60.40bc	62.67c	18.41d	18.76d	0.850d	0.885d	0.659c	0.686c
F_5		45.02f	46.83d	55.98d	57.95e	16.87f	17.22f	0.820f	0.854f	0.626e	0.652e
F_6		51.78ab	54.18ab	62.65ab	65.31ab	19.46ab	19.87ab	0.869bc	0.906bc	0.683a	0.711a
F_7		52.73a	55.52a	63.91a	66.29a	19.80a	20.19a	0.875b	0.912b	0.689a	0.716a
LSD at 5%		**1.21**	**2.25**	**2.64**	**1.68**	**0.46**	**0.51**	**0.009**	**0.009**	**0.008**	**0.008**
Bilateral interaction (TxF)											
T_1	**F_1**	41.39	42.41	52.03	53.33	15.36	15.66	0.791	0.823	0.579	0.605
	F_2	43.34	45.23	53.87	55.57	16.32	16.64	0.808	0.845	0.601	0.626
	F_3	44.06	46.28	54.96	57.24	16.66	16.94	0.813	0.847	0.616	0.640
	F_4	42.46	44.83	53.51	55.60	15.87	16.19	0.800	0.835	0.592	0.618
	F_5	40.38	40.49	50.92	51.90	14.91	15.19	0.786	0.817	0.570	0.595
	F_6	44.93	47.29	56.00	58.50	17.05	17.40	0.819	0.857	0.628	0.653
	F_7	46.12	48.57	57.28	59.34	17.36	17.72	0.828	0.862	0.637	0.661
T_2	**F_1**	49.42	52.41	61.27	63.44	18.51	18.91	0.853	0.888	0.670	0.696
	F_2	55.63	58.41	66.81	69.57	20.87	21.39	0.896	0.931	0.713	0.741
	F_3	56.47	59.35	67.43	70.04	21.12	21.56	0.901	0.934	0.717	0.745
	F_4	55.06	57.61	65.92	68.35	20.54	20.92	0.889	0.924	0.708	0.737
	F_5	47.71	50.62	58.94	61.28	18.01	18.42	0.839	0.874	0.657	0.685
	F_6	57.33	59.59	68.01	70.84	21.52	22.00	0.909	0.944	0.723	0.755
	F_7	58.20	60.94	69.06	71.94	21.83	22.31	0.913	0.950	0.726	0.757
T_3	**F_1**	48.69	51.04	60.28	62.62	18.28	18.62	0.847	0.885	0.663	0.690
	F_2	51.17	53.62	62.30	65.15	19.16	19.53	0.965	1.006	0.684	0.712
	F_3	51.92	54.70	63.16	65.73	19.56	19.96	0.870	0.908	0.691	0.722
	F_4	50.44	53.22	61.77	64.06	18.82	19.18	0.861	0.895	0.675	0.703
	F_5	46.98	49.39	58.08	60.68	17.69	18.05	0.834	0.873	0.650	0.676
	F_6	53.07	55.66	63.95	66.60	19.82	20.22	0.879	0.916	0.699	0.726
	F_7	53.88	57.05	65.39	67.60	20.19	20.55	0.884	0.924	0.703	0.730
	LSD	**2.09**	**3.91**	**4.57**	**2.91**	**0.79**	**0.88**	**0.017**	**0.016**	**0.013**	**0.015**

Means within a column followed by a different letter (s) are statistically different at 5%

T_1: Control (without organic fertilizer), **T_2:** Plant compost (banana residues and sugar beet at ratio of 50:50) PC, **T_3:** Farmyard manure compost FYMC, **F_1:** Control, **F_2:** Mg at rate of 840 g ha^{-1}, **F_3:** Mg at rate of 1680 g ha^{-1}, **F_4:** Se at rate of 5.0 mg L^{-1}, **F_5:** Se at rate of 10.0 mg L^{-1}, **F_6:** As a combined treatment (F_2 + F_4) **F_7:** As a combined treatment (F_3 + F_4).

- Leaf chemical constituents

Table 3 illustrates the effects of two different types of organic fertilizers (PC and FYMC) and the foliar application of magnesium and selenium on the chemical composition of peanut leaves [N, P, K, Mg (%) and Se (mg kg^{-1})] at the period of 70 days from sowing, during both the 2022 and 2023 seasons. Concerning the individual impact of organic fertilization treatments, it is evident that the $\mathbf{T_2}$ treatment (PC) resulted in the highest recorded values for the chemical constituents in the leaves, followed by the $\mathbf{T_3}$ treatment (FYMC). Conversely, the corresponding peanut plants that were grown without the application of organic fertilizers (control group which has been given $\mathbf{T_1}$ code) exhibited the lowest levels of N, P, K, Mg (%), and Se (mg kg^{-1}).

Table 3. The impact of applying organic fertilization *via* two different types (PC and FYMC) and foliar application of magnesium and selenium on the chemical composition of peanut leaves at the period of 70 days from sowing during two successive seasons of 2022 and 2023.

Treatments		N,%		P,%		K,%		Mg,%		Se, mg kg^{-1}	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Main factor: Organic fertilization											
$\mathbf{T_1}$		3.48c	3.66c	0.362c	0.380c	2.03c	2.14c	0.87c	0.91c	1.91c	1.96c
$\mathbf{T_2}$		4.23a	4.45a	0.487a	0.512a	2.96a	3.11a	1.16a	1.21a	2.93a	3.01a
$\mathbf{T_3}$		4.02b	4.22b	0.447b	0.471b	2.71b	2.84b	1.03b	1.08b	2.81b	2.91b
LSD at 5%		**0.10**	**0.01**	**0.005**	**0.005**	**0.12**	**0.07**	**0.02**	**0.02**	**0.09**	**0.06**
Sub main factor: Foliar applications of Mg and Se											
$\mathbf{F_1}$		3.69f	3.88e	0.397f	0.421f	2.34e	2.45d	0.73e	0.76e	1.70f	1.76g
$\mathbf{F_2}$		3.96d	4.17cd	0.437d	0.460d	2.60cd	2.73c	1.17c	1.22c	2.21e	2.26f
$\mathbf{F_3}$		4.02c	4.22bc	0.450c	0.472c	2.69bc	2.83b	1.22b	1.28b	2.30e	2.37e
$\mathbf{F_4}$		3.91e	4.10d	0.429e	0.450e	2.55d	2.67c	0.79d	0.83d	2.62d	2.71d
$\mathbf{F_5}$		3.59g	3.77f	0.381g	0.400g	2.20f	2.31e	0.67f	0.70f	3.21a	3.31a
$\mathbf{F_6}$		4.08b	4.28ab	0.460b	0.483b	2.76ab	2.90a	1.25ab	1.31ab	2.80c	2.88c
$\mathbf{F_7}$		4.14a	4.34a	0.470a	0.493a	2.83a	2.97a	1.29a	1.36a	3.01b	3.11b
LSD at 5%		**0.004**	**0.11**	**0.005**	**0.006**	**0.12**	**0.07**	**0.04**	**0.04**	**0.11**	**0.07**
Bilateral interaction (TxF)											
$\mathbf{T_1}$	$\mathbf{F_1}$	3.28	3.45	0.335	0.353	1.83	1.93	0.61	0.64	1.40	1.47
	$\mathbf{F_2}$	3.53	3.71	0.361	0.379	2.01	2.12	1.01	1.05	1.58	1.61
	$\mathbf{F_3}$	3.57	3.73	0.375	0.393	2.13	2.23	1.05	1.10	1.67	1.72
	$\mathbf{F_4}$	3.51	3.68	0.354	0.371	1.97	2.06	0.64	0.67	2.03	2.10
	$\mathbf{F_5}$	3.21	3.37	0.331	0.348	1.82	1.91	0.60	0.63	2.30	2.36
	$\mathbf{F_6}$	3.62	3.80	0.384	0.404	2.21	2.33	1.08	1.14	2.10	2.15
	$\mathbf{F_7}$	3.69	3.87	0.393	0.411	2.26	2.37	1.11	1.17	2.27	2.34
$\mathbf{T_2}$	$\mathbf{F_1}$	3.93	4.15	0.433	0.457	2.64	2.75	0.81	0.85	1.89	1.94
	$\mathbf{F_2}$	4.31	4.53	0.501	0.528	3.03	3.18	1.34	1.40	2.64	2.70
	$\mathbf{F_3}$	4.38	4.61	0.514	0.540	3.13	3.29	1.40	1.47	2.75	2.81
	$\mathbf{F_4}$	4.25	4.44	0.495	0.518	2.96	3.11	0.90	0.94	2.95	3.05
	$\mathbf{F_5}$	3.81	4.01	0.410	0.431	2.46	2.57	0.73	0.77	3.66	3.78
	$\mathbf{F_6}$	4.46	4.67	0.524	0.550	3.22	3.38	1.44	1.50	3.19	3.27
	$\mathbf{F_7}$	4.51	4.72	0.533	0.558	3.31	3.48	1.46	1.54	3.42	3.52
$\mathbf{T_3}$	$\mathbf{F_1}$	3.88	4.05	0.423	0.453	2.55	2.67	0.76	0.80	1.80	1.87
	$\mathbf{F_2}$	4.05	4.27	0.450	0.473	2.75	2.90	1.16	1.22	2.42	2.48
	$\mathbf{F_3}$	4.10	4.32	0.461	0.485	2.83	2.97	1.22	1.28	2.49	2.58
	$\mathbf{F_4}$	3.98	4.18	0.437	0.460	2.73	2.85	0.84	0.88	2.87	2.97
	$\mathbf{F_5}$	3.74	3.93	0.402	0.422	2.33	2.45	0.68	0.71	3.66	3.77
	$\mathbf{F_6}$	4.16	4.36	0.473	0.497	2.85	3.00	1.24	1.30	3.12	3.23
	$\mathbf{F_7}$	4.21	4.44	0.485	0.510	2.92	3.04	1.30	1.38	3.34	3.45
LSD at 5%		**0.08**	**0.19**	**0.009**	**0.011**	**0.20**	**0.12**	**0.08**	**0.08**	**0.19**	**0.11**

Means within a column followed by a different letter (s) are statistically different at 5%

$\mathbf{T_1}$**:** Control (without organic fertilizer), $\mathbf{T_2}$**:** Plant compost (banana residues and sugar beet at ratio of 50:50) PC, $\mathbf{T_3}$**:** Farmyard manure compost FYMC, $\mathbf{F_1}$**:** Control, $\mathbf{F_2}$**:** Mg at rate of 840 g ha^{-1}, $\mathbf{F_3}$**:** Mg at rate of 1680 g ha^{-1}, $\mathbf{F_4}$**:** Se at rate of 5.0 mg L^{-1}, $\mathbf{F_5}$**:** Se at rate of 10.0 mg L^{-1}, $\mathbf{F_6}$**:** As a combined treatment ($F_2 + F_4$) $\mathbf{F_7}$**:** As a combined treatment ($F_3 + F_4$).

Furthermore, the findings reveal that the application of **F_7** treatment (a combination of F_3 and F_4) displayed superior results in terms of achieving elevated levels of N, P, K and Mg. Notably, the content of Se in leaves increased proportionally with its application rate, and a similar pattern was observed for Mg. In simpler terms, all foliar application treatments, except for **F_5**, led to significant enhancements in the chemical composition of peanut leaves when compared to the control group. The **F_5** treatment demonstrated the lowest values across all essential and beneficial elements under investigation, excluding Se content. Additionally, the same Table highlights that the combined treatments involving both Mg (at both studied doses) and Se (at 1st studied dose) outperformed all single applications. Generally, when excluding the leaf content from the investigated elements (Se and Mg), it becomes evident that **F_7** (F_3 + F_4) was the most effective in achieving the highest levels of N, P, K, followed by **F_6 (F_2 + F_4), F_3, F_2, F_4, F_1** (control) and **F_5** treatments, respectively. As for the bilateral interaction, the applying plant compost (**T_2**) along with the foliar application of magnesium and selenium (**F_7**) realized the best peanuts leaves chemical constituents, surpassing the outcomes of other interventions. The same trend was found for 1st and 2nd seasons.

- Catalase (CAT) and proline

Table 4 and Figs 2, 3, 4 and 5 indicate the individual and interaction effects of the different types of organic fertilizers (PC and FYMC) and the foliar application of magnesium and selenium on the plant's self-production from antioxidants [either enzymatic (CAT) or non-enzymatic (proline)]. It is worth mentioning that the trend of catalase (CAT) looks just like the trend of growth performance parameters, as the **T_2** treatment (PC) recorded the maximum values as well as **F_7** treatment led to the highest values of CAT.

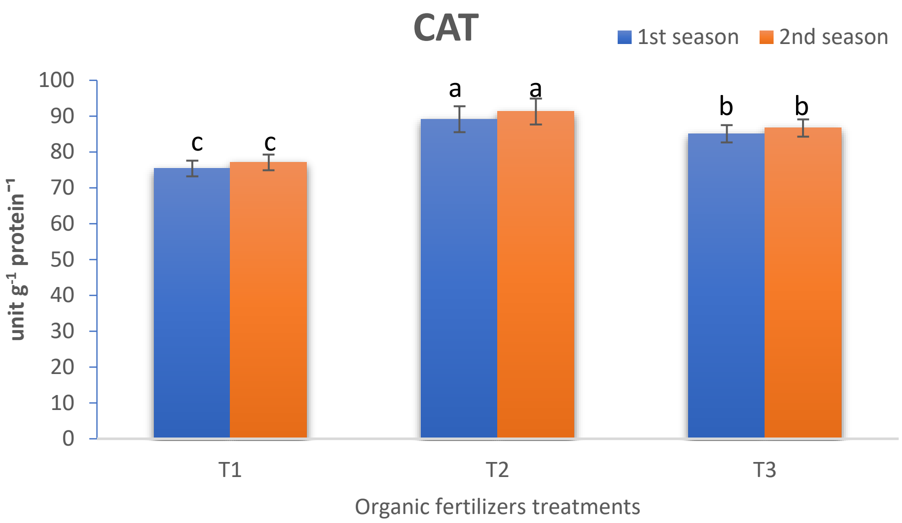

Fig. 2. The individual impact of applying organic fertilization *via* two different types (PC and FYMC) on the content of CAT in peanut leaves at the period of 70 days from sowing during two successive seasons of 2022 and 2023. T_1: Control (without organic fertilizer), T_2: Plant compost (banana residues and sugar beet at ratio of 50:50) PC, T_3: Farmyard manure compost FYMC.

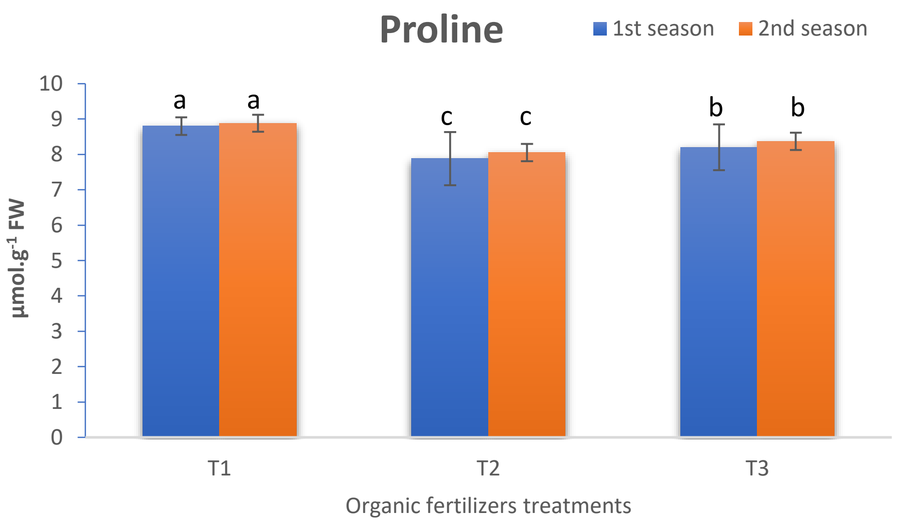

Fig. 3. The individual impact of applying organic fertilization *via* two different types (PC and FYMC) on the content of proline in peanut leaves at the period of 70 days from sowing during two successive seasons of 2022 and 2023. T_1: Control (without organic fertilizer), T_2: Plant compost (banana residues and sugar beet at ratio of 50:50) PC, T_3: Farmyard manure compost FYMC

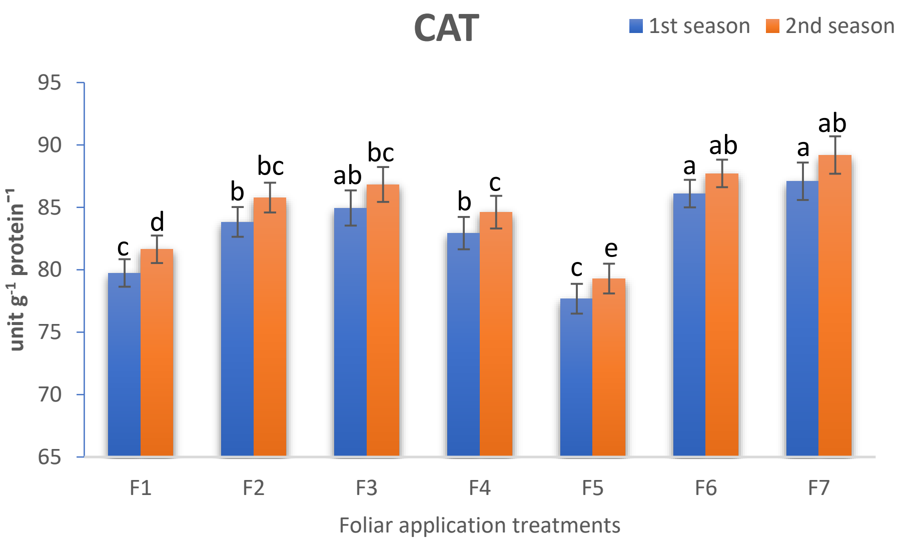

Fig. 4. The individual impact of foliar application of magnesium and selenium on the content of CAT in peanut leaves at the period of 70 days from sowing during two successive seasons of 2022 and 2023. F_1: Control, F_2: Mg at rate of 840 g ha^{-1}, F_3: Mg at rate of 1680 g ha^{-1}, F_4: Se at rate of 5.0 mg L^{-1}, F_5: Se at rate of 10.0 mg L^{-1}, F_6: As a combined treatment ($F_2 + F_4$) F_7: As a combined treatment ($F_3 + F_4$).

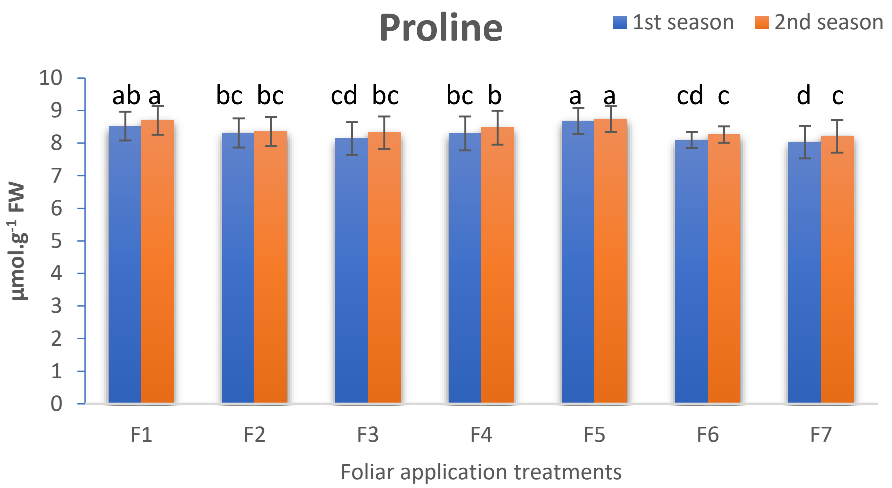

Fig. 5. The individual impact of foliar application of magnesium and selenium on the content of proline in peanut leaves at the period of 70 days from sowing during two successive seasons of 2022 and 2023. F_1: Control, F_2: Mg at rate of 840 g ha^{-1}, F_3: Mg at rate of 1680 g ha^{-1}, F_4: Se at rate of 5.0 mg L^{-1}, F_5: Se at rate of 10.0 mg L^{-1}, F_6: As a combined treatment ($F_2 + F_4$) F_7: As a combined treatment ($F_3 + F_4$).

On the contrary, the plants grown without organic fertilizer possessed the highest values of proline, while the lowest values were achieved with PC treatment. Also, spraying of selenium at a rate of 10.0 mg L^{-1} (**F_5** treatment) led to the highest content of proline in leaves compared to other foliar treatments and the control group (**F_1**) which came in the second order. generally, it can be noticed that the application of magnesium (at both tested doses) and selenium (at a concentration of 5.0 mg L^{-1} only), whether they were sprayed solely or in combinations, significantly enhanced the production of CAT (catalase) and reduced the necessity for the synthesis of proline in substantial quantities as an osmoprotectant. Similar trend was found for both studied seasons.

Table 4. The interaction impact of applying organic fertilization *via* two different types (PC and FYMC) and foliar application of magnesium and selenium on the content of antioxidants in peanut leaves at the period of 70 days from sowing during two successive seasons of 2022 and 2023.

Treatments		Catalase (CAT, unit g^{-1} protein $^{-1}$)		Proline (μmol.g^{-1} FW)	
		1st Season	2nd Season	1st Season	2nd Season
	F_1	73.45	75.14	8.84	9.05
	F_2	74.93	76.42	9.05	8.86
	F_3	76.08	77.90	8.68	8.86
T_1	F_4	74.44	75.93	8.76	8.95
	F_5	71.83	73.56	9.04	8.86
	F_6	77.32	78.86	8.64	8.81
	F_7	79.53	81.76	8.61	8.80
	F_1	83.52	85.69	8.32	8.48
	F_2	90.91	93.37	7.75	7.90
	F_3	92.24	94.36	7.66	7.82
T_2	F_4	89.92	91.81	7.87	8.03
	F_5	81.19	83.21	8.43	8.62
	F_6	92.87	95.09	7.62	7.79
	F_7	93.31	95.37	7.53	7.70
	F_1	82.27	84.08	8.38	8.55
	F_2	85.65	87.54	8.14	8.28
	F_3	86.52	88.25	8.06	8.27
T_3	F_4	84.45	86.14	8.26	8.44
	F_5	80.02	81.14	8.57	8.74
	F_6	88.14	89.20	8.01	8.17
	F_7	88.45	90.47	7.96	8.13
LSD at 5%		**3.85**	**3.94**	**0.43**	**0.29**

T_1: Control (without organic fertilizer), **T_2:** Plant compost (banana residues and sugar beet at ratio of 50:50) PC, **T_3:** Farmyard manure compost FYMC, **F_1:** Control, **F_2:** Mg at rate of 840 g ha^{-1}, **F_3:** Mg at rate of 1680 g ha^{-1}, **F_4:** Se at rate of 5.0 mg L^{-1}, **F_5:** Se at rate of 10.0 mg L^{-1}, **F_6:** As a combined treatment ($F_2 + F_4$) **F_7:** As a combined treatment ($F_3 + F_4$).

- Yield and its components

The application of various organic fertilization treatments and foliar spraying of magnesium and selenium, whether applied individually or in combination, had a significant impact on multiple factors related to peanut yield and composition such as No. of pods $plant^{-1}$, weight of pods (g $plant^{-1}$), weight of 100 pods (g), pods and seeds yield (Mg.ha^{-1}) (**Table 5**) as well as seeds N, P and K content, (%) (**Table 6**) and oil (%), oil yield (kg ha^{-1}), protein (%), protein yield (kg ha^{-1}) and carbohydrates (%) (**Table 7**). These effects were observed during the harvest stage in both the 2022 and 2023 growing seasons. The outcomes reveal that among the organic fertilization treatments, the most effective in achieving the highest values was the **T_2** treatment (PC), followed closely by the **T_3** treatment (FYMC), both of which surpassed the control group **(T_1).** In terms of foliar spraying treatments, the combined application of magnesium and selenium **(F_7)** demonstrated the most favorable results, ranking first for all the mentioned characteristics. The sequence of effectiveness from the most to the least impactful was found to be: **F_7 (**$F_3 + F_4$**) > F_6 (**$F_2 + F_4$**) > F_3 > F_2 > F_4 > F_1 (**control) **> F_5.** Remarkably, the synergistic approach involving the use of plant compost **(T_2)** in conjunction with the foliar application of magnesium and selenium **(F_7)** showed the most favorable outcomes in terms of No. of pods $plant^{-1}$, weight of pods (g $plant^{-1}$), weight of 100 pods (g), pods and seeds yield (Mg.ha^{-1}), seeds N, P and K content (%), oil (%), oil yield (kg ha^{-1}), protein (%), protein yield (kg ha^{-1}) and carbohydrates (%) compared to the other interventions. Similar trend was found for both studied seasons.

- Post-harvest analyses

Table 8 shows the effects of utilizing organic fertilization through two types (PC and FYMC) and the application of magnesium and selenium *via* foliar spraying on the soil's nutrient availability (N, P, and K, mg kg^{-1}) and cation exchange capacity (CEC, cmol kg^{-1}) following the peanut harvest in the 2022 and 2023 seasons. The data reveal that the values of available N, P, K, and CEC during the harvest stage exceeded those of the initial soil (before sowing). Furthermore, Table 8 demonstrates that incorporating plant compost into the soil led to the highest values for all the aforementioned soil properties in both seasons, followed by FYMC, and finally the corresponding soil from the control group. Conversely, the data also indicate that the foliar treatments had a subtle impact on the available N, P, and K. Also, these treatments had a non-significant effect on the CEC values of the soil. To put it differently, the most effective treatment (**F$_7$**) for achieving optimal growth performance and yield also coincided with a reduction in the availability of N, P, and K in the soil. Generally, the data indicate the pivotal role of both organic fertilizers in enhancing the chemical properties of the soil, with the superior of PC, as well as the vital role of foliar application of both Se (at the first dose only) and Mg (either solely or in combination) in raising the nutrient availability.

Table 5. The impact of applying organic fertilization *via* two different types (PC and FYMC) and foliar application of magnesium and selenium on the yield and its component of peanuts at harvest stage during two successive seasons of 2022 and 2023.

Treatments		No. of pods, plant^{-1}		Weight of pods, g plant^{-1}		Weight of 100 Pods, g		Pods yield, Mg ha^{-1}		Seeds yield, Mg ha^{-1}	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Main factor: Organic fertilization											
T$_1$		23.81c	25.19c	37.84c	38.59c	139.58c	141.98c	3.44c	3.52c	2.07c	2.11c
T$_2$		31.57a	32.81a	42.49a	43.42a	157.98a	160.12a	4.74a	4.83a	3.18a	3.22a
T$_3$		30.10b	31.24b	41.15b	41.96b	152.46b	154.78b	4.36b	4.44b	2.89b	2.94b
LSD at 5%		**0.97**	**0.43**	**0.74**	**0.36**	**3.76**	**4.28**	**0.07**	**0.06**	**0.06**	**0.05**
Sub main factor: Foliar applications of Mg and Se											
	F$_1$	26.56d	27.89e	39.29e	40.13e	145.33e	147.44d	3.87f	3.94f	2.43f	2.47f
	F$_2$	29.11bc	30.22cd	40.76cd	41.66cd	151.10cd	153.49bc	4.24d	4.33d	2.77d	2.82d
	F$_3$	29.56b	30.67bc	41.09bc	41.89bc	152.55bc	154.62abc	4.35c	4.44c	2.86c	2.90c
	F$_4$	28.22c	29.67d	40.38d	41.19d	149.54d	152.02c	4.17e	4.25e	2.69e	2.74e
	F$_5$	25.44e	26.44f	38.63f	39.40f	142.51f	144.86d	3.65g	3.72g	2.29g	2.32g
	F$_6$	29.89ab	31.44ab	41.46ab	42.35ab	153.85ab	156.38ab	4.44b	4.53b	2.93b	2.98b
	F$_7$	30.67a	31.89a	41.84a	42.64a	155.17a	157.27a	4.53a	4.62a	3.00a	3.06a
LSD at 5%		**1.05**	**0.94**	**0.44**	**0.49**	**1.69**	**3.70**	**0.04**	**0.05**	**0.02**	**0.03**
Bilateral interaction (TxF)											
	F$_1$	22.33	23.33	37.15	37.89	136.70	138.98	3.27	3.32	1.85	1.88
	F$_2$	23.67	25.33	37.86	38.64	139.83	142.08	3.45	3.53	2.10	2.14
	F$_3$	24.33	26.00	38.20	38.85	141.10	143.15	3.57	3.64	2.19	2.23
T$_1$	**F$_4$**	23.00	24.67	37.48	38.23	138.08	140.53	3.36	3.43	1.98	2.02
	F$_5$	21.67	22.00	36.58	37.29	134.67	137.27	3.08	3.14	1.74	1.76
	F$_6$	25.00	27.33	38.58	39.46	142.73	145.79	3.63	3.72	2.29	2.32
	F$_7$	26.67	27.67	39.02	39.81	143.94	146.05	3.73	3.82	2.35	2.39
	F$_1$	29.00	30.33	40.56	41.54	150.41	152.38	4.20	4.28	2.77	2.80
	F$_2$	32.67	33.67	43.03	44.11	159.94	162.27	4.90	5.00	3.29	3.35
	F$_3$	33.00	34.00	43.38	44.22	161.64	163.60	5.00	5.11	3.39	3.43
T$_2$	**F$_4$**	32.33	33.33	42.67	43.58	158.69	161.11	4.81	4.92	3.22	3.28
	F$_5$	27.67	29.00	39.88	40.72	147.32	149.57	4.00	4.08	2.60	2.63
	F$_6$	33.00	34.33	43.77	44.78	163.19	165.27	5.08	5.18	3.45	3.50
	F$_7$	33.33	35.00	44.13	45.01	164.67	166.65	5.15	5.25	3.52	3.58
	F$_1$	28.33	30.00	40.16	40.96	148.87	150.96	4.13	4.22	2.68	2.73
	F$_2$	31.00	31.67	41.40	42.24	153.53	156.13	4.38	4.47	2.93	2.98
	F$_3$	31.33	32.00	41.69	42.61	154.90	157.11	4.48	4.57	3.00	3.05
T$_3$	**F$_4$**	29.33	31.00	41.00	41.76	151.85	154.40	4.32	4.41	2.88	2.93
	F$_5$	27.00	28.33	39.43	40.21	145.53	147.73	3.87	3.94	2.53	2.57
	F$_6$	31.67	32.67	42.02	42.81	155.61	158.06	4.61	4.70	3.06	3.12
	F$_7$	32.00	33.00	42.38	43.10	156.90	159.09	4.71	4.80	3.15	3.22
LSD at 5%		**1.81**	**1.62**	**0.76**	**0.85**	**2.93**	**6.41**	**0.07**	**0.09**	**0.03**	**0.05**

Means within a column followed by a different letter (s) are statistically different at 5%.

T$_1$: Control (without organic fertilizer), **T$_2$:** Plant compost (banana residues and sugar beet at ratio of 50:50) PC, **T$_3$:** Farmyard manure compost FYMC, **F$_1$:** Control, **F$_2$:** Mg at rate of 840 g ha^{-1}, **F$_3$:** Mg at rate of 1680 g ha^{-1}, **F$_4$:** Se at rate of 5.0 mg L^{-1}, **F$_5$:** Se at rate of 10.0 mg L^{-1}, **F$_6$:** As a combined treatment (F$_2$ + F$_4$) **F$_7$:** As a combined treatment (F$_3$ + F$_4$).

Table 6. The impact of applying organic fertilization *via* two different types (PC and FYMC) and foliar application of magnesium and selenium on the seeds chemical constitutes (macronutrients) of peanut at harvest stage during two successive seasons of 2022 and 2023.

Treatments		N, %		P, %		K, %	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Main factor: Organic fertilization							
T_1		3.27c	3.34c	0.326c	0.343c	1.74c	1.83c
T_2		3.84a	3.93a	0.393a	0.412a	2.20a	2.30a
T_3		3.69b	3.76b	0.373b	0.392b	2.06b	2.16b
LSD at 5%		**0.05**	**0.07**	**0.004**	**0.004**	**0.09**	**0.06**
Sub main factor: Foliar applications of Mg and Se							
F_1		3.48e	3.55e	0.346e	0.364f	1.90d	1.98e
F_2		3.63cd	3.72c	0.368c	0.387d	2.02bc	2.12cd
F_3		3.66bc	3.74bc	0.375b	0.393c	2.05abc	2.16bc
F_4		3.59d	3.67d	0.362d	0.379e	1.99c	2.09d
F_5		3.40f	3.47f	0.335f	0.353g	1.82d	1.91f
F_6		3.70ab	3.78b	0.378b	0.398b	2.08ab	2.18ab
F_7		3.74a	3.83a	0.384a	0.402a	2.12a	2.23a
LSD at 5%		**0.04**	**0.04**	**0.004**	**0.004**	**0.09**	**0.05**
Bilateral interaction (TxF)							
T_1	F_1	3.21	3.25	0.316	0.333	1.67	1.75
	F_2	3.28	3.35	0.328	0.344	1.76	1.84
	F_3	3.30	3.38	0.334	0.350	1.77	1.87
	F_4	3.25	3.32	0.320	0.335	1.71	1.80
	F_5	3.15	3.22	0.306	0.323	1.62	1.70
	F_6	3.35	3.42	0.337	0.355	1.80	1.88
	F_7	3.38	3.46	0.342	0.358	1.86	1.96
T_2	F_1	3.65	3.74	0.366	0.386	2.02	2.11
	F_2	3.90	4.00	0.400	0.421	2.25	2.35
	F_3	3.95	4.04	0.407	0.427	2.28	2.39
	F_4	3.86	3.93	0.395	0.413	2.21	2.32
	F_5	3.56	3.65	0.353	0.371	1.96	2.06
	F_6	3.98	4.07	0.412	0.433	2.31	2.42
	F_7	4.02	4.10	0.418	0.436	2.33	2.45
T_3	F_1	3.60	3.68	0.356	0.373	2.00	2.09
	F_2	3.72	3.80	0.377	0.396	2.06	2.18
	F_3	3.74	3.81	0.383	0.403	2.11	2.22
	F_4	3.68	3.75	0.371	0.390	2.05	2.15
	F_5	3.48	3.52	0.347	0.364	1.88	1.97
	F_6	3.79	3.84	0.386	0.405	2.14	2.26
	F_7	3.83	3.92	0.392	0.412	2.17	2.28
LSD at 5%		**0.07**	**0.07**	**0.008**	**0.007**	**0.15**	**0.09**

Means within a column followed by a different letter (s) are statistically different at 5%

T_1: Control (without organic fertilizer), **T_2:** Plant compost (banana residues and sugar beet at ratio of 50:50) PC, **T_3:** Farmyard manure compost FYMC, **F_1:** Control, **F_2:** Mg at rate of 840 g ha^{-1}, **F_3:** Mg at rate of 1680 g ha^{-1}, **F_4:** Se at rate of 5.0 mg L^{-1}, **F_5:** Se at rate of 10.0 mg L^{-1}, **F_6:** As a combined treatment ($F_2 + F_4$) **F_7:** As a combined treatment ($F_3 + F_4$)

Table 7. The impact of applying organic fertilization *via* two different types (PC and FYMC) and foliar application of magnesium and selenium on the peanut seeds quality in terms of their content from oil, protein and carbohydrate at harvest stage during two successive seasons of 2022 and 2023.

Treatments		Oil, %		Oil yield, kg ha^{-1}		Protein, %		Protein yield, kg ha^{-1}		Carbohydrates, %	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Main factor: Organic fertilization											
T$_1$		41.39c	43.49c	858.24c	917.50c	20.45c	20.90c	424.18c	441.01c	18.65c	18.95c
T$_2$		46.61a	48.91a	1486.44a	1583.18a	24.03a	24.59a	766.80a	796.27a	20.80a	21.10a
T$_3$		45.14b	47.39b	1305.95b	1396.10b	23.06b	23.49b	667.57b	692.62b	20.26b	20.59b
LSD at 5%		**0.25**	**0.56**	**36.11**	**42.36**	**0.28**	**0.43**	**21.66**	**20.53**	**0.05**	**0.11**
Sub main factor: Foliar applications of Mg and Se											
F$_1$		43.02e	45.04e	1054.62f	1121.78f	21.77e	22.22e	534.90f	554.85f	19.39e	19.67e
F$_2$		44.64cd	46.91cd	1250.20d	1335.62d	22.70cd	23.23c	637.65d	663.60d	19.99cd	20.30cd
F$_3$		45.05bc	47.32bc	1299.30c	1386.98c	22.89bc	23.40bc	662.73c	688.33c	20.18bc	20.50bc
F$_4$		44.29d	46.40d	1204.99e	1286.09e	22.47d	22.92d	613.18e	637.19e	19.84d	20.18d
F$_5$		42.39f	44.58e	975.78g	1039.85g	21.24f	21.66f	489.96g	506.38g	19.12f	19.36f
F$_6$		45.44ab	47.74ab	1344.62b	1433.93b	23.15ab	23.60b	686.98b	711.23b	20.30ab	20.63ab
F$_7$		45.84a	48.17a	1388.63a	1488.23a	23.40a	23.93a	711.21a	741.51a	20.49a	20.83a
LSD at 5%		**0.55**	**0.55**	**17.14**	**20.96**	**0.27**	**0.26**	**0.77**	**0.94**	**0.22**	**0.25**
Bilateral interaction (TxF)											
T$_1$	**F$_1$**	40.38	42.24	745.77	795.69	20.04	20.31	370.12	382.51	18.27	18.55
	F$_2$	41.43	43.55	870.21	930.72	20.48	20.94	430.14	447.31	18.62	18.93
	F$_3$	41.87	44.03	915.51	981.75	20.61	21.15	450.53	471.61	18.85	19.21
	F$_4$	41.08	43.06	811.92	871.34	20.31	20.73	401.42	419.37	18.45	18.84
	F$_5$	40.10	42.23	696.49	741.94	19.67	20.15	341.56	353.84	18.02	18.26
	F$_6$	42.21	44.42	966.73	1028.99	20.92	21.38	479.12	495.15	19.03	19.30
	F$_7$	42.66	44.86	1001.03	1072.04	21.15	21.65	496.39	517.27	19.27	19.54
T$_2$	**F$_1$**	44.53	46.51	1233.42	1304.01	22.79	23.35	631.47	654.79	20.03	20.32
	F$_2$	47.19	49.65	1554.34	1661.71	24.36	25.02	802.26	837.25	21.03	21.31
	F$_3$	47.57	50.00	1611.23	1716.87	24.69	25.25	836.26	867.02	21.20	21.51
	F$_4$	46.89	49.01	1511.73	1605.99	24.11	24.58	777.15	805.40	20.85	21.16
	F$_5$	43.73	45.83	1135.66	1205.53	22.27	22.81	578.34	600.03	19.76	20.00
	F$_6$	47.98	50.42	1655.49	1763.07	24.86	25.46	857.53	890.31	21.28	21.58
	F$_7$	48.39	50.93	1703.24	1825.07	25.13	25.65	884.56	919.09	21.43	21.78
T$_3$	**F$_1$**	44.14	46.35	1184.68	1265.63	22.48	22.98	603.12	627.24	19.87	20.15
	F$_2$	45.30	47.52	1326.05	1414.43	23.25	23.73	680.54	706.24	20.32	20.66
	F$_3$	45.70	47.94	1371.17	1462.33	23.38	23.81	701.38	726.36	20.48	20.77
	F$_4$	44.88	47.14	1291.31	1380.93	22.98	23.44	660.96	686.80	20.22	20.54
	F$_5$	43.35	45.67	1095.18	1172.06	21.77	22.02	549.99	565.28	19.56	19.83
	F$_6$	46.13	48.38	1411.63	1509.75	23.67	23.98	724.29	748.24	20.59	21.02
	F$_7$	46.46	48.73	1461.63	1567.57	23.92	24.50	752.68	788.18	20.75	21.17
LSD at 5%		**0.95**	**0.95**	**29.68**	**36.31**	**0.46**	**0.45**	**15.18**	**15.47**	**0.39**	**0.43**

Means within a column followed by a different letter (s) are statistically different at 5%

T$_1$: Control (without organic fertilizer), **T$_2$:** Plant compost (banana residues and sugar beet at ratio of 50:50) PC, **T$_3$:** Farmyard manure compost FYMC, **F$_1$:** Control, **F$_2$:** Mg at rate of 840 g ha^{-1}, **F$_3$:** Mg at rate of 1680 g ha^{-1}, **F$_4$:** Se at rate of 5.0 mg L^{-1}, **F$_5$:** Se at rate of 10.0 mg L^{-1}, **F$_6$:** As a combined treatment ($F_2 + F_4$) **F$_7$:** As a combined treatment ($F_3 + F_4$).

Table 8. The impact of applying organic fertilization *via* two different types (PC and FYMC) and foliar application of magnesium and selenium on the soil nutrient availability and CEC following peanuts plant during two successive seasons of 2022 and 2023.

Treatments		Available-N, mg kg^{-1}		Available-P, mg kg^{-1}		Available-K, mg kg^{-1}		CEC, cmol kg^{-1}	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Main factor: Organic fertilization									
T_1		45.00c	45.75b	11.06c	11.62b	223.73c	230.68b	42.69c	43.52b
T_2		46.89a	47.54a	11.66a	12.24a	231.84a	238.96a	44.64a	45.57a
T_3		46.54b	47.22a	11.56b	12.13a	230.43b	238.19a	43.99b	44.82a
LSD at 5%		**0.10**	**0.42**	**0.05**	**0.14**	**0.53**	**1.2**	**0.38**	**0.82**
Sub main factor: Foliar applications of Mg and Se									
F_1		46.61a	47.27a	11.57a	12.16a	230.70a	238.02a	43.77a	44.62a
F_2		45.92b	46.65b	11.37ab	11.96ab	227.94b	234.87b	43.74a	44.69a
F_3		45.93b	46.54b	11.35ab	11.93ab	227.73bc	234.77b	43.54a	44.40a
F_4		46.51a	47.24a	11.55ab	12.09ab	230.31a	237.70a	43.74a	44.55a
F_5		46.71a	47.47a	11.59a	12.17a	230.67a	238.81a	43.79a	44.65a
F_6		45.70b	46.51b	11.29ab	11.87ab	226.99cd	233.99b	43.90a	44.82a
F_7		45.60b	46.18b	11.26b	11.79b	226.36d	233.44b	43.93a	44.73a
LSD at 5%		**0.53**	**0.53**	**0.31**	**0.31**	**0.91**	**2.72**	**N.S**	***N.S**
Bilateral interaction (TxF)									
T_1	F_1	45.23	45.90	11.16	11.74	225.18	232.39	42.64	43.45
	F_2	44.97	45.68	11.07	11.63	223.84	231.01	42.47	43.39
	F_3	44.86	45.57	11.01	11.56	223.16	229.79	42.26	43.04
	F_4	45.07	45.83	11.12	11.64	224.56	231.14	42.76	43.54
	F_5	45.35	46.20	11.19	11.77	224.71	232.49	42.90	43.68
	F_6	44.77	45.72	10.95	11.52	222.72	229.32	42.83	43.73
	F_7	44.72	45.32	10.95	11.45	221.98	228.60	42.98	43.83
T_2	F_1	47.38	48.03	11.80	12.44	233.62	240.44	44.56	45.47
	F_2	46.75	47.43	11.62	12.23	231.48	238.04	44.54	45.62
	F_3	46.64	47.26	11.59	12.15	231.01	238.06	44.44	45.33
	F_4	46.91	47.57	11.66	12.21	232.03	239.31	44.70	45.49
	F_5	47.71	48.43	11.88	12.49	234.74	242.75	44.84	45.87
	F_6	46.47	47.16	11.54	12.14	230.41	236.99	44.58	45.57
	F_7	46.36	46.92	11.51	12.03	229.61	237.14	44.79	45.64
T_3	F_1	47.23	47.89	11.75	12.31	233.28	241.24	44.09	44.93
	F_2	46.06	46.84	11.42	12.01	228.50	235.56	44.20	45.07
	F_3	46.28	46.78	11.45	12.07	229.02	236.47	43.92	44.82
	F_4	47.56	48.31	11.86	12.44	234.34	242.64	43.75	44.62
	F_5	47.06	47.77	11.70	12.26	232.56	241.18	43.63	44.39
	F_6	45.87	46.64	11.38	11.94	227.84	235.65	44.29	45.17
	F_7	45.70	46.29	11.33	11.90	227.48	234.59	44.03	44.73
LSD at 5%		**0.91**	**0.92**	**0.53**	**0.53**	**1.59**	**4.71**	**0.90**	**0.87**

Means within a column followed by a different letter (s) are statistically different at 5%.

T_1: Control (without organic fertilizer), **T_2:** Plant compost (banana residues and sugar beet at ratio of 50:50) PC, **T_3:** Farmyard manure compost FYMC, **F_1:** Control, **F_2:** Mg at rate of 840 g ha^{-1}, **F_3:** Mg at rate of 1680 g ha^{-1}, **F_4:** Se at rate of 5.0 mg L^{-1}, **F_5:** Se at rate of 10.0 mg L^{-1}, **F_6:** As a combined treatment ($F_2 + F_4$) **F_7:** As a combined treatment ($F_3 + F_4$).

*NS is not significant

4. Discussion

The underperformance observed in the control groups can be attributed to the adverse effects of agricultural drainage water on peanuts plants, encompassing several detrimental factors **(Ashour *et al.* 2021).** These harmful effects include salinity stress, nutrient imbalances, altered soil conditions, toxicity from heavy metals and ions, poor water quality, disease susceptibility, and disruptions in essential physiological processes **(Eltarabily, 2022; Moursi *et al.* 2023).** These factors collectively impeded the peanuts plant's growth and development, resulting in suboptimal performance under control treatments compared to treatments involving organic fertilization and targeted foliar applications of magnesium and selenium.

The results highlight that the application of organic fertilization had a significant impact on the growth performance and yield of peanuts. Notably, the treatment involving plant compost exhibited superior effects, followed closely by the farmyard manure compost treatment, both outperforming the control group that lacked organic fertilization. This suggests that the addition of organic fertilizers positively influenced the growth of peanuts plants during this period by providing a range of nutrients and improving soil health. Also, they may have contributed to improving soil structure. Both studied organic fertilizers enhanced the soil's water-holding capacity, drainage, aeration, and microbial activity, creating an optimal environment for root growth and nutrient uptake **(Tzortzakis *et al.* 2020).** On the other hand, both studied organic fertilizers might foster beneficial soil microorganisms that form symbiotic relationships with peanuts' plant roots. These relationships enhance nutrient uptake and provide plants with growth-promoting substances **(Elsherpiny and Helmy 2022).** These facts reflected on the peanut's performance and its yield.

The superiority of plant compost over farmyard manure compost can be attributed to several factors, including differences in nutrient content, nutrient release rates, soil structure improvement, and potential for disease suppression **(Singh *et al.* 2020).** Plant compost can be tailored to have a more balanced nutrient composition compared to farmyard manure, which can vary widely in nutrient content depending on the diet of the animals producing the manure. Also, plant composting can involve selected plant residues that are rich in essential nutrients required for plant growth. This can result in a higher concentration of nutrients like nitrogen, phosphorus, and potassium in the plant compost compared to farmyard manure, leading to a more efficient nutrient supply to plants **(Elsherpiny 2023).** Also, perhaps the plant compost tends to break down more rapidly than farmyard manure, releasing nutrients at a faster rate. This faster nutrient release can provide a timely supply of nutrients during critical growth stages, potentially leading to enhanced plant growth and yield **(Zhou and Yao 2020).** Plant composting allows for the inclusion of materials that can help adjust soil pH to more optimal levels for plant growth. Farmyard manure might not have the same pH-modifying capabilities. Plant materials used in composting tend to break down more readily compared to tougher materials like straw or bedding found in farmyard manure. This faster breakdown releases nutrients more quickly into the soil, enhancing their availability to plants **(Elsherpiny *et al.* 2023).**

The favorable outcomes observed in the case of the selenium treatment **(F_4)** and magnesium treatments **(F_2, F_3)** can be attributed to their roles as essential micronutrients tailored for the specific needs of peanut plants. In appropriate concentrations, selenium and magnesium serve as catalysts for a range of vital physiological and biochemical processes, effectively bolstering plant growth. For instance, selenium, when provided at lower concentrations, assumes a pivotal role as a component within specific enzymes that actively engage in antioxidant defense mechanisms. By effectively counteracting the harmful impact of reactive oxygen species (ROS), selenium acts as a guardian, shielding plant cells from oxidative damage and, in turn, elevating the plant's capacity to endure stressors **(Wu *et al.* 2020).** Notably, selenium's involvement extends to chloroplasts and photosynthetic enzymes, orchestrating improvements in photosynthetic efficiency. This enhancement culminates in heightened energy generation and the accumulation of biomass **(Rady**

***et al.* 2020).** Selenium further facilitates the uptake and distribution of essential nutrients within the plant system, thus augmenting the overall availability of vital nutrients crucial for plant health and function **(Xiang *et al.* 2022).** Moreover, the supplementation of selenium empowers plants to effectively confront a spectrum of challenges, including drought, salinity, and heavy metal exposure. This is achieved by instigating the activation of stress-responsive genes and metabolic pathways, a response that empowers plants to tackle diverse stressors more adeptly. Additionally, selenium's involvement in protein synthesis emerges as a cornerstone for growth and development **(Elsherpiny and Kany 2023).** It actively contributes to the production of proteins integral to a multitude of cellular functions. Furthermore, selenium's role as an enhancer of plant resistance to specific diseases emerges as a significant attribute. This action is orchestrated through the stimulation of the production of defense compounds that bolster the plant's ability to fend off disease-causing agents **(Mansoor *et al.* 2022).** By harnessing these diverse mechanisms, selenium contributes to the overall health and vigor of peanut plants, fostering a more robust growth trajectory and a heightened ability to withstand environmental challenges. On the other hand, magnesium is a central component of chlorophyll molecules, essential for photosynthesis **(Peng *et al.* 2020).** Therefore, the peanuts plant performance gradually increased with increasing magnesium dose. Adequate magnesium levels ensure efficient energy production and carbohydrate synthesis. Mg is required as a cofactor for numerous enzymes involved in various metabolic processes. Its presence enhances enzyme activity, leading to improved nutrient uptake and utilization **(Elsherpiny *et al.* 2023).** Also, it is crucial for the synthesis of adenosine triphosphate (ATP), the energy currency of cells **(Wang *et al.* 2020).** Adequate ATP production supports essential cellular functions and growth. Moreover, its vital role as a co-enzyme in oil formation and these explains the improvement in oil and protein yield (**Chen *et al.* 2018**; **Xie *et al.* 2021**).

The synergistic approach involving the use of magnesium and selenium ($\mathbf{F_6}$ and $\mathbf{F_7}$) implies that the simultaneous application of both magnesium and selenium has a combined effect that is greater than the sum of their individual effects. In other words, when magnesium and selenium are applied together, their interactions create a positive influence on the plant that goes beyond what each nutrient would achieve independently. This could manifest as enhanced growth, improved physiological functions, increased stress tolerance, or other desirable outcomes that are more pronounced when magnesium and selenium are used together compared to their separate application. This synergistic approach seeks to optimize plant responses and achieve more efficient and effective results by leveraging the combined benefits of different elements or treatments.

The negative effect observed with the application of selenium at a concentration of 10.0 mg L^{-1} ($\mathbf{F_5}$ treatment) on peanuts can be attributed to selenium toxicity. While selenium is an essential micronutrient for plants, it is required in very small amounts. Excess selenium can become toxic and detrimental to plant growth **(Hasanuzzaman *et al.* 2020)**. It's important to note that the concentration of selenium that is beneficial or toxic can vary depending on the plant species, soil conditions, and environmental factors **(Elsherpiny and Kany 2023).** In the case of the $\mathbf{F_5}$ treatment, the concentration of 10.0 mg L^{-1} appears to have exceeded the threshold for selenium's beneficial effects and resulted in toxic effects on the peanuts, contributing to the observed negative impact on their growth and health **(Mahmoud *et al.* 2023).**

The trends observed in the catalase (CAT) activity closely parallel the patterns witnessed in the growth performance parameters and this may be the vital role of the studied treatments in raising the peanut's self-production of enzymatic antioxidants to scavenge the free radicals resulting due to the irrigation with agricultural drainage water **(Elsherpiny and Kany 2023).**

Regarding proline as an osmoprotectant, the plants cultivated without the aid of organic fertilizer showed elevated proline content, while the plant's need for significant proline synthesis as an osmoprotectant reduced due to the studied organic fertilizers, which raised the peanut's tolerance to harmful effects of agricultural drainage water. Notably, the application of selenium at a concentration of 10.0 mg L^{-1} ($\mathbf{F_5}$ treatment) induced the highest proline content in leaves, outpacing other foliar treatments as well as the control group (**F1**), which ranked second in proline production. Conversely, the application of the best treatments resulted in the lowest proline levels. Remarkably, the inclusion of magnesium (at both tested doses) and selenium (at a concentration of 5.0 mg L^{-1}) substantially augmented catalase (CAT) production, consequently reducing the plant's need for significant proline synthesis as an osmoprotectant. Generally, the notable contribution of magnesium and selenium in enhancing catalase production, while simultaneously mitigating the need for extensive proline synthesis, underscores their potential roles in bolstering the plant's stress tolerance mechanisms.

The concentrations of available nitrogen (N), phosphorus (P), potassium (K), and cation exchange capacity (CEC) in the soil were higher during the harvest stage compared to the initial soil conditions before sowing. This increase could be attributed to various factors, including organic matter decomposition, and the release of nutrients especially N due to beneficial soil microorganisms that form symbiotic relationships with peanuts roots. Perhaps the success of the process of bacterial inoculation with Okadean led to an increase in symbiotic N fixation, and this reflected positively on the soil's nitrogen content. Moreover, the activity in the root zone may lead to reduce the soil pH value and cause the raising of nutrient availability **(Baddour *et al.* 2021).**

The incorporation of plant compost into the soil resulted in the most substantial improvements in all measured soil properties across both seasons. This effect was followed using farmyard manure compost (FYMC), and the least improvement was seen in the control group. This trend may be attributed to that the studied organic fertilizers contributed organic matter and essential nutrients to the soil, enhancing its fertility and CEC. Foliar treatments had a limited impact on soil nutrients. Foliar treatments generally have a direct effect on the plant's nutrient uptake through its leaves and this positively affected the general status of the peanuts plant. This behavior led to reducing the nutrient residues in soil due to plant uptake. So, the most effective treatment (**F_7**) for achieving optimal growth performance and yield also coincided with a reduction in the availability of N, P, and K in the soil. The foliar treatments did not lead to significant changes in the cation exchange capacity (CEC) of the soil. CEC relates to the soil's ability to retain and exchange nutrients for plant uptake. While organic fertilizers can impact CEC by enhancing soil structure and organic matter content, the foliar treatments might not have influenced this particular property **(Elsherpiny and Kany 2023)**.

5. Conclusion

The combined strategy that combines the utilization of plant compost along with the application of selenium (at a low concentration) and magnesium demonstrated the most advantageous results in terms of growth performance and various yield attributes. Notably, this approach exhibited significant enhancements in oil yield. Moreover, this approach displayed a noteworthy capability in augmenting soil nutrient availability and cation exchange capacity (CEC). Generally, continuous research and innovation in water-efficient irrigation practices and stress-tolerant crop varieties should be prioritized to enhance agricultural sustainability and mitigate the challenges posed by water scarcity. By implementing these recommendations, Egypt can enhance its agricultural sustainability, mitigate the challenges posed by water scarcity, and establish a robust and self-sufficient vegetable oil industry.

Conflicts of interest

Authors have declared that no competing interests exist.

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