Egyptian Journal of Soil Science

http://ejss.journals.ekb.eg/

Maximizing Canola Productivity as a Promising Oil Crop in the Egyptian Agricultural Strategy: A Focus on Organic and Beneficial Elements ertilization

Mohamed A. E. Soliman[1], Mohamed A. El-Sherpiny[2] and **Shimaa M. Elmahdy[3]**

[1]*Soil and Water Dept., Faculty of Agriculture, Damietta University, 34517, Egypt*
[2]*Soil & Water and Environment Research Institute, Agriculture Research Center, Giza, 12619 Egypt*
[3]*Soil and Water Dept., Faculty of Agriculture, Kafrelsheikh University, Kafr El-Sheikh 33516, Egypt*

THE MINISTRY of Agriculture and Soil Reclamation (MASR) in Egypt is actively pursuing the sustainable expansion of oil crops, particularly through the cultivation of canola to shrank gap and decrease the import gap for various oil products and edible oils. Therefore, a field trials were executed to assess the potential impact of different soil additions, including a control group without soil additions (**T_1**), magnesium sulphate at a rate of 30 Kg Mg fed^{-1} (**T_2**), plant residues compost (rice straw + soybean stover) at a rate of 7.0 tons fed^{-1} (**T_3**), and a combined treatment of compost at a rate of 3.0 tons fed^{-1} plus magnesium sulphate at a rate of 15 Kg Mg fed^{-1} (**T_4**) as the main plots on canola plants. Subplots were also designated for foliar applications of beneficial elements, comprising four groups: **F_1** (control), **F_2** (Magnesium sulphate), **F_3** (Zn-EDTA), and **F_4** (Fe-EDTA) at a rate of 500 g per feddan for each beneficial element. Various parameters such as plant height (cm) No. of branches plant^{-1}, chlorophyll (SPAD reading), seed yield (ton ha^{-1}), straw yield (ton ha^{-1}), oil (%), oil yield (ton ha^{-1}), protein (%) and carbohydrates (%) were recorded during the trials. The combined treatment (**T_4**) emerged as the most effective soil addition, demonstrating optimal performance. Following closely in effectiveness was the use of compost alone (**T_3**), with magnesium sulphate (**T_2**) ranking third. In contrast, the control group, which did not receive compost and magnesium sulphate, exhibited the lowest performance among the treatments. As for foliar application treatments, the descending ranking order were: **F_2** (Mg element) > **F_3** (Zn element)> F_4 (Fe element), >**F_1** (without beneficial elements). Briefly, the combined treatment of **T_4 x F_2** emerged as the most superior among the various interactions studied. These findings underscore the importance of tailored soil amendments and foliar applications to maximize canola crop yields, providing valuable insights for the Ministry's strategic planning. Recommendations include widespread adoption of the **T_4 x F_2** combination, further research on optimal dosage and application methods, and ongoing support for farmers in implementing these practices to bolster Egypt's self-sufficiency in oil production.

Keywords: Canola, MASR, Compost, Mg, Zn, Fe, Magnesium sulphate.

1. Introduction

The global demand for edible oils and oil-based products has steadily risen, necessitating a strategic focus on enhancing domestic oil production to bridge the gap between demand and supply **(Tokel and Erkencioglu 2021).** In Egypt, the Ministry of Agriculture and Soil Reclamation (MASR) has proactively identified the cultivation of oil crops, particularly canola, as a pivotal avenue to bolster self-sufficiency in oil production (**Faiyad *et al.* 2023).** To achieve this goal, attention is directed not only towards increasing the overall yield of oil crops but also towards improving the composition and quality of the extracted oil (**Elsherpiny *et al.* 2023).** A critical component in optimizing oil crop production lies in the enhancement of soil health and fertility. Compost, derived from plant residues such as rice straw and soybean stover, serves as a valuable soil amendment (**Rashwan *et al.* 2024).** Its application enriches the soil, fostering a nutrient-rich environment that, in turn, contributes to improved plant growth and development (**Elbaalawy *et al.* 2023).** The intricate relationship between compost utilization and subsequent oil production underscores the importance of sustainable agricultural practices in meeting the

*Corresponding author e-mail: m_elsherpiny2010@yahoo.com
Received: 07/12/2023; Accepted: 28/12/2023
DOI: 10.21608/EJSS.2023.253944.1697

rising demands for edible oils (**Elsherpiny *et al.* 2023).** Magnesium, an essential macronutrient, plays a multifaceted role in the improvement of oil composition. Beyond its conventional function in chlorophyll synthesis and photosynthesis, magnesium exerts influence over the fatty acid profile of oils **(Chen *et al.* 2018).** The incorporation of magnesium sulphate into the soil not only enhances plant growth but also contributes to the development of oils with desirable attributes (**Elsherpiny *et al.* 2023).** Iron (Fe) and zinc (Zn), classified as micronutrients, hold pivotal roles in various biochemical pathways within plants. In the context of oil crops, these micronutrients are integral in the synthesis of proteins and enzymes involved in oil biosynthesis **(Emam 2020).** The availability of iron and zinc influences the overall nutritional quality of the oil extracted, making their precise application crucial for achieving optimal yields and nutritional benefits **(Faiyad *et al.* 2023).**

The primary purpose of this study is to comprehensively evaluate the impact of different soil additions, particularly compost and magnesium sulphate and foliar applications of magnesium, iron, and zinc on canola plants. By examining various parameters such as plant height, chlorophyll content, seed yield, and oil composition, the research aims to provide valuable insights into the synergistic effects of tailored soil amendments and micronutrient applications on canola crop performance. Ultimately, the study seeks to inform strategic planning by MASR, guiding the adoption of practices that will contribute to Egypt's self-sufficiency in oil production and address the persistent gap between demand and availability of edible oils.

2. Materials and Methods

A field trials were executed, over two consecutive summer seasons of 2021/2022 and 2022/2023 to assess the potential impact of different soil additions, including magnesium and plant residues compost as the main plots on canola plants. While, sub plots were also designated for foliar applications of beneficial elements such as magnesium, zinc and iron. The experimental set up utilized a split-plot design with three replicates. Table 1 show the studied treatments.

Experimental site

This investigation was implemented on a privately owned farm in Met-Antar Village, Talkha District, El-Dakahlia Governorate, Egypt, (31°4'54"N - 31°24'4"E).

Soil sampling and compost propertied

Table 2 displays the initial soil properties before the commencement of the experimental study, along with the characteristics of the examined compost. All analyses adhered to the methodologies outlined by **Tandon (2005).** A composting process was initiated six months before the start of the field experiment at the designated site, following the guidelines outlined by **Inckel *et al.* (2005).**

Table 1. Studied treatments.

Treatments of the main factor			
Symbol	**Source**	**Properties**	**Rate**
T_1	A control group without soil additions	/	/
T_2	Magnesium sulphate from Agro Egypt for agricultural development company, Egypt	• Molecular mass of 120.366 g mol^{-1} • A purity level of 99%. • A melting point of 1.124 °C • A density value of 2.66 g cm^{3}	30 Kg Mg fed^{-1}
T_3	Plant residues compost (rice straw + soybean stover)	**Table 2**	7.0 tons fed^{-1}
T_4	A combined treatment of compost at a rate of 3.0 tons fed^{-1} plus magnesium sulphate at a rate of 15 Kg Mg fed^{-1}		
Treatments of the sub main factor			
Symbol	**Source**	**Percentage of beneficial element**	**Rate**
F_1	Without foliar application (control)	/	/
F_2	Magnesium sulphate	20.19% Mg^{2+} by mass	500 g per feddan
F_3	Zn-EDTA from Delta Fertilizers and Chemical Industries Company, Talkha District, El-Dakahlia Governorate, Egypt.	14%Zn	500 g per feddan
F_4	Fe-EDTA from Delta Fertilizers and Chemical Industries Company, Talkha District, El-Dakahlia Governorate, Egypt.	13 % Fe	500 g per feddan

Table 2. Properties of the initial soil and compost.

Property		Initial soil (at a depth of 0-30 cm)	Plant compost
Available N	$(mg\ kg^{-1})$	49.20	/
Available P		9.130	/
Available K		222.0	/
Fe		/	0.45
Zn		/	13.2
Organic matter,%		1.290	35.0
Sand		22.00	/
Clay		49.50	/
Silt		28.50	/
Textural		Clayey	/
pH		8.35 (suspension 1:2.5)	6. 33 (suspension 1: 10)
EC, dSm^{-1}		3.22	4.100
Total C, %		/	20.30
Total N, %		/	1.350
C:N ratio		/	15.04

Notes: The combined data over both studied seasons

Canola seeds

Canola seeds "**Serw 4**", were obtained from MASR.

Experimental set up

The experimental plot was planned with 14 rows in two rod. Planting was carried out at a rate of 3-4 seeds per hill on one side of the ridge, with a 10 cm spacing between hills. Subsequently, the thinning process was implemented, resulting in an approximate total of 70,000 plants per feddan. Specifically, on November 14th, seeds were sown at a rate of 5.0 Kg fed^{-1} during both growing seasons, and thinning occurred after the development of 4-6 true leaves.

Phosphorus fertilizer, in the form of calcium superphosphate (15.5% P_2O_5), was applied during soil tillage at a rate of 30 kg P_2O_5 per feddan. Nitrogen fertilizer, as urea (46.5% N), was applied at a rate of 30 kg N fed^{-1} in two equal doses: the first was administered after thinning, and the second dose followed one month later. Potassium fertilizer, in the form of potassium sulphate (48% K_2O), was applied as a single dose along with the first nitrogen dose at a rate of 24 kg K_2O per feddan.

Compost, in accordance with the studied treatments, was applied before ploughing. Additionally, magnesium sulphate was applied at the same time. Foliar applications were replicated three times throughout the experiment, commencing one month after sowing with two-week intervals between each application, utilizing a volume of 600 L fed^{-1}. All agricultural practices adhered to the recommendations of the Ministry of Agriculture and Soil Reclamation (MASR), Egypt. The harvest process was conducted after 6 months on May 12th in both seasons.

Measurement traits

At 80 days after sowing as well as at harvest time (after 6 month from sowing), five plants were randomly sampled from each replicate for measuring and determining the characteristics shown in Table 3.

Table 3. Methods, formula, and references of measurements.

Measurements	Methods and formula	References
After 80 days from sowing canola plants		
Plant height (cm), No. of branches $plant^{-1}$	Manually and visually	----------------
Chlorophyll SPAD reading	SPAD reading(SPAD-502, Soil-Plant Analysis Development (SPAD) Section, Minolta Camera, Osaka, Japan)	**Castelli *et al.* (1996)**
Leaf area index	LAI = unit leaf area per plant/unit ground area occupied by plant	**Adil (2012)**
Digested plant samples for NPK	Mixed of $HClO_4 + H_2SO_4$	**Peterburgski (1968)**
N, P, K (%)	Micro-kjeldahl, spectrophotometrically and flame photometer, respectively	**Walinga *et al.* (2013)**
At harvest stage (After 6 month)		
No of pods $plant^{-1}$, No of $seeds.pod^{-1}$,1000 seeds weight (g), seed yield($ton.ha^{-1}$) and straw yield ($ton.ha^{-1}$)	Manually and visually	----------------
Biological yield		
Harvest index	HI= (Economic yield/ Biological yield) x 100	
Protein, carbohydrates and oil (% & ton ha^{-1})		**A.O.A.C (2000)**

Statistical analyses

The collected data underwent statistical analysis utilizing the analysis of variance (ANOVA) technique through CoStat version 6.303 copyrighted (1998-2004). Treatment means and the significance of differences was computed and illustrated using the Least Significant Difference (L.S.D) method as per the approach outlined by **Gomez and Gomez (1984).** Duncan's multiple-range tests were carried out, following the methodology detailed by **Duncan (1995).**

3. Results

Growth criteria and chemical constituents

Table 4 depicts the impact of compost, magnesium, zinc and iron on canola growth criteria such as plant height (cm) No. of branches plant^{-1}, chlorophyll (SPAD reading), leaf area index during seasons of 2021/2022 and 2022/2023 at a period of 80 days from plant's life. While Table 5 shows the effect of the studied treatments on leaves chemical constituents of canola during seasons of 2021/2022 and 2022/2023 at a period of 80 days from plant's life. Regarding soil additions, the data reveal that the combined treatment (**T_4**) emerged as the most effective soil addition, demonstrating optimal performance. Following closely in effectiveness was the use of compost alone (**T_3**), with magnesium sulphate alone (**T_2**) ranking third. In contrast, the control group (**T_1**), which did not receive compost and magnesium sulphate, exhibited the lowest performance among the treatments. In terms of foliar application treatments, the ranking from most effective to least effective was as follows: **F_2** (Mg element) was the most effective, followed by **F_3** (Zn element), then **F_4** (Fe element), and lastly, **F_1** (without beneficial elements). Considering the overall context, the combined treatment of **T_4 x F_2** emerged as the most superior among the various interactions studied. The same trend was found during both studied seasons.

Seed and pod yield

The influence of compost, magnesium, zinc, and iron on the seed and pod yield of canola plants demonstrated significance in both seasons, as indicated by various parameters associated with yield [such as seed yield (ton.ha^{-1}), number of pods per plant, number of seeds per pod, 1000-seed weight (g)**,** straw yield (ton.ha^{-1}), biological yield (ton.ha^{-1}), and harvest index], as presented in Tables 6 and 7. The data illustrate that the superior soil addition treatment for achieving the maximum values of all studied parameters associated with yield was **T_4** treatment (compost + magnesium sulphate) followed by **T_3** treatment (compost alone) then **T_2** treatment (magnesium sulphate alone) and lately **T_1** treatment (without both compost and magnesium sulphate). Concerning foliar applications, the **F_2** (Mg element) was the superior treatment for achieving the maximum values of all studied parameters associated with yield, followed by **F_3** (Zn element), then **F_4** (Fe element), and lastly, **F_1** (without beneficial elements). In terms of interaction effect, the combined treatment of **T_4 x F_2** was the superior treatment for achieving the maximum values of all studied parameters associated with yield compared to other interactions. Consistent patterns were observed throughout the study across both seasons.

Oil yield and seed quality

The effect of compost, magnesium, zinc and iron on oil yield and seed quality of canola [oil (%), oil yield (ton ha^{-1}), protein (%), protein (ton ha^{-1}) and carbohydrates (%)] during seasons of 2021/2022 and 2022/2023 at a harvest is presented in Table 8. Also, Figs from 1 to 4 show the impact of the studied treatments on oil percentage and yield. Regarding soil additions, it is evident that the combined treatment **(T_4)** proved to be the most effective, exhibiting optimal performance in both oil yield and seed quality. Following closely in effectiveness was the use of compost alone **(T_3),** with magnesium sulphate alone **(T_2)** ranking third and lately the control group **(T_1).** For foliar application treatments, the **F_2** treatment (Mg element) came in the first order in terms of effectiveness, followed by **F_3** (Zn element), then **F_4** (Fe element), and lastly, **F_1** (without beneficial elements). Overall, the combined treatment of **T_4 x F_2** emerged as the most superior compared to other interactions studied, as this combined treatment led to the maximum improvements in oil yield and quality. The same trend was found during both studied seasons.

Table 4. Effect of compost, magnesium, zinc and iron on canola growth criteria during seasons of 2021/2022 and 2022/2023 at a period of 80 days from plant's life.

Treatemnts		Plant height, cm		No. of branches plant^{-1}		Chlorophyll, SPAD reading		Leaf area index	
		1st	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Main factor									
T_1		139.34d	143.54d	9.83d	11.17d	37.97d	38.38d	3.68d	3.73d
T_2		145.50c	150.23c	11.17c	12.42c	39.76c	40.25c	4.08c	4.12c
T_3		151.61b	156.39b	12.50b	13.67b	41.31b	41.84b	4.18b	4.50b
T_4		159.67a	165.41a	13.92a	15.17a	42.91a	43.47a	4.73a	4.78a
Sub main factor									
F_1		146.62c	150.80c	11.33b	12.58b	39.87d	40.35d	4.10c	4.14d
F_2		151.37a	156.59a	12.42a	13.58a	41.08a	41.57a	4.10c	4.41a
F_3		149.83ab	155.07a	12.00ab	13.33ab	40.68b	41.18b	4.28a	4.33b
F_4		148.30b	153.11b	11.67ab	12.92ab	40.31c	40.84c	4.19b	4.25c
Interact**ion**									
T_1	F_1	137.01l	141.15l	9.33k	10.67i	37.33n	37.74n	3.54k	3.57o
	F_2	141.44ijk	145.91ijk	10.33h-k	11.67f-i	38.54k	38.93k	3.82i	3.88l
	F_3	140.23jkl	144.39jkl	10.00ijk	11.33ghi	38.19l	38.60l	3.73ij	3.77m
	F_4	138.68kl	142.71kl	9.67jk	11.00hi	37.80m	38.25m	3.65j	3.69n
T_2	F_1	143.24hij	147.15ij	10.67g-k	12.00f-i	39.09j	39.63j	3.94h	3.99k
	F_2	147.81efg	153.32fg	11.67d-i	12.67d-h	40.32h	40.90g	4.22ef	4.26h
	F_3	146.35fgh	151.66gh	11.33e-j	12.67d-h	39.93i	40.41h	4.13fg	4.17i
	F_4	144.61ghi	148.77hi	11.00f-k	12.33e-i	39.69i	40.06i	4.03gh	4.07j
T_3	F_1	150.68ef	154.98fg	13.00c-h	13.33c-g	41.16g	41.53f	4.04e	4.43g
	F_2	153.58cd	158.37de	13.00a-e	14.33a-d	41.77e	42.39d	3.84k	4.59de
	F_3	151.86d	157.07e	12.33b-f	14.33a-e	41.37f	41.77e	4.45d	4.54e
	F_4	150.90de	155.12ef	12.50b-g	13.50b-f	41.03g	41.77e	4.41d	4.45f
T_4	F_1	157.21bc	161.73cd	13.33a-d	14.67abc	42.31d	42.78c	4.61c	4.66d
	F_2	162.14a	168.43a	14.67a	15.67a	43.52a	44.01a	4.83a	4.90a
	F_3	160.33ab	166.63ab	14.00ab	15.33a	43.11b	43.72a	4.77ab	4.83b
	F_4	158.99ab	164.82bc	13.67abc	15.00ab	42.71c	43.38b	4.70bc	4.75c

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

T_1: Control group without soil additions, **T_2**: Magnesium sulphate at a rate of 30 Kg Mg fed^{-1} ,**T_3**: Plant residues compost (rice straw + soybean stover) at a rate of 7.0 tons fed^{-1} ,**T_4**: Combined treatment of compost at a rate of 3.0 tons fed^{-1} plus magnesium sulphate at a rate of 15 Kg Mg fed^{-1}, **F_1**: Control group without foliar applications, **F_2**: Magnesium sulphate at a rate of 500 g per feddan , **F_3**: Zn-EDTA at a rate of 500 g per feddan and **F_4** : Fe-EDTA at a rate of 500 g per feddan.

Table 5. Effect of compost, magnesium, zinc and iron on leaves chemical constituents of canola during seasons of 2021/2022 and 2022/2023 at a period of 80 days from plant's life.

Treatemnts		N,%		P,%		K,%	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Main factor							
T_1		3.11d	3.14d	0.415d	0.423d	2.24d	2.26d
T_2		3.31c	3.35c	0.451c	0.454c	2.42c	2.45c
T_3		3.52b	3.58b	0.484b	0.493b	2.63b	2.66b
T_4		3.72a	3.77a	0.519a	0.530a	2.80a	2.84a
Sub main factor							
F_1		3.34c	3.38c	0.455d	0.459d	2.46d	2.49d
F_2		3.48a	3.52a	0.479a	0.489a	2.58a	2.61a
F_3		3.43ab	3.48b	0.471b	0.481b	2.54b	2.57b
F_4		3.40b	3.45b	0.464c	0.471c	2.51c	2.54c
Interaction							
T_1	F_1	3.03k	3.06k	0.403o	0.411l	2.20k	2.22k
	F_2	3.18ij	3.23hi	0.427l	0.435j	2.29i	2.31i
	F_3	3.13j	3.16ij	0.420m	0.428jk	2.26ij	2.28ij
	F_4	3.10jk	3.13jk	0.411n	0.419kl	2.22jk	2.24jk
T_2	F_1	3.25hi	3.28gh	0.439k	0.432j	2.35h	2.38h
	F_2	3.37gh	3.40f	0.462h	0.471gh	2.49f	2.53f
	F_3	3.32gh	3.36f	0.454i	0.463hi	2.44fg	2.47g
	F_4	3.30hi	3.34fg	0.448j	0.452i	2.40gh	2.43gh
T_3	F_1	3.49ef	3.57e	0.480g	0.487g	2.60e	2.61e
	F_2	3.56cd	3.59cd	0.492e	0.502de	2.68bc	2.73c
	F_3	3.53d	3.63d	0.486f	0.495ef	2.63cd	2.67cd
	F_4	3.51de	3.55d	0.482f	0.488f	2.62d	2.65d
T_4	F_1	3.64bc	3.69bc	0.505d	0.516cd	2.74b	2.78b
	F_2	3.78a	3.83ab	0.532a	0.544a	2.85a	2.88a
	F_3	3.74a	3.80a	0.524b	0.534ab	2.82a	2.86a
	F_4	3.71ab	3.75a	0.514c	0.524bc	2.80a	2.84a

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

T_1: Control group without soil additions, **T_2**: Magnesium sulphate at a rate of 30 Kg Mg fed^{-1} ,**T_3**: Plant residues compost (rice straw + soybean stover) at a rate of 7.0 tons fed^{-1} ,**T_4**: Combined treatment of compost at a rate of 3.0 tons fed^{-1} plus magnesium sulphate at a rate of 15 Kg Mg fed^{-1}, **F_1**: Control group without foliar applications, **F_2**: Magnesium sulphate at a rate of 500 g per feddan , **F_3**: Zn-EDTA at a rate of 500 g per feddan and **F_4** : Fe-EDTA at a rate of 500 g per feddan

Table 6. Effect of compost, magnesium, zinc and iron on seed yield, No of pods and seeds and 1000seeds weight of canola during seasons of 2021/2022 and 2022/2023 at harvest.

Treatemnts		Seed yield, ton ha^{-1}		No of pods $plant^{-1}$		No of seeds pod^{-1}		1000 seeds weight,g	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Main factor									
T_1		1.79d	1.82d	297.17d	300.33c	19.33d	21.58d	3.63d	3.70d
T_2		2.02c	2.06c	318.67c	322.17b	21.75c	23.17c	3.84c	3.91c
T_3		2.26b	2.30b	337.00b	342.33a	23.33b	24.75b	4.04b	4.11b
T_4		2.48a	2.52a	353.08a	339.33a	24.83a	26.33a	4.25a	4.34a
Sub main factor									
F_1		2.05c	2.09d	319.00c	323.42b	21.50c	23.33c	3.86c	3.93d
F_2		2.22a	2.26a	333.25a	338.08a	23.00a	24.58a	4.02a	4.09a
F_3		2.17b	2.20b	328.50ab	332.67a	22.67ab	24.17ab	3.97ab	4.05b
F_4		2.12b	2.16c	325.17bc	310.00c	22.08bc	23.75c	3.92bc	4.00c
Interaction									
T_1	F_1	1.70m	1.73n	288.33j	291.67kl	18.00k	21.00k	3.52m	3.60l
	F_2	1.88jk	1.91kl	305.67ghi	309.00ij	20.33hij	22.33h-k	3.71jkl	3.78j
	F_3	1.83kl	1.86lm	300.00hij	302.67jk	20.00ij	21.67ijk	3.67klm	3.75jk
	F_4	1.76lm	1.79mn	294.67ij	298.00jk	19.00jk	21.33jk	3.60lm	3.68k
T_2	F_1	1.94ij	1.97jk	310.67fgh	314.00hij	21.00ghi	22.67g-j	3.75il	3.82ij
	F_2	2.10gh	2.14hi	325.33de	328.67e-h	22.33d-g	23.67e-h	3.91fi	3.99fg
	F_3	2.05h	2.09i	321.00ef	324.67f-i	22.00eh	23.33fgh	3.87gj	3.95gh
	F_4	2.01hi	2.05ij	317.67efg	321.33ghi	21.67fi	23.00ghi	3.83hk	3.89hi
T_3	F_1	2.23fg	2.31gh	334.33de	334.33dg	22.33cg	25.00dg	4.02eh	4.05ef
	F_2	2.33cd	2.33de	342.33abc	354.00ad	24.67ad	25.00bcd	4.09be	4.19d
	F_3	2.26de	2.34ef	337.67cd	336.67be	23.00ae	25.00cde	4.04cf	4.11d
	F_4	2.24ef	2.26fg	335.50de	345.00cf	23.50bf	25.00cf	4.03dg	4.09de
T_4	F_1	2.39bc	2.44cd	347.33abc	353.00abc	24.33abc	25.67abc	4.17ad	4.28c
	F_2	2.55a	2.60a	358.00a	364.33a	25.33a	27.00a	4.33a	4.42a
	F_3	2.51a	2.56ab	354.33a	359.67ab	25.00a	26.67ab	4.27ab	4.37ab
	F_4	2.46ab	2.50bc	352.67ab	280.33l	24.67ab	26.00abc	4.22abc	4.31bc

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

T_1: Control group without soil additions, **T_2**: Magnesium sulphate at a rate of 30 Kg Mg fed^{-1} ,**T_3**: Plant residues compost (rice straw + soybean stover) at a rate of 7.0 tons fed^{-1} ,**T_4**: Combined treatment of compost at a rate of 3.0 tons fed^{-1} plus magnesium sulphate at a rate of 15 Kg Mg fed^{-1}, **F_1**: Control group without foliar applications, **F_2**: Magnesium sulphate at a rate of 500 g per feddan, **F_3**: Zn-EDTA at a rate of 500 g per feddan and **F_4** : Fe-EDTA at a rate of 500 g per feddan

Table 7. Effect of compost, magnesium, zinc and iron on straw and biological yield and harvest index during seasons of 2021/2022 and 2022/2023 at harvest.

Treatemnts		Straw yield, ton ha^{-1}		Biological yield, ton ha^{-1}		Harvest index	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Main factor							
T_1		2.58d	2.62d	4.38d	4.45d	40.95v	40.96a
T_2		2.86c	2.92c	4.89c	4.98c	41.40ab	41.39a
T_3		3.18b	3.23b	5.44b	5.53b	41.55a	41.57a
T_4		3.53a	3.55a	6.01a	6.07a	41.24ab	41.58a
Sub main factor							
F_1		2.96c	2.97d	5.01d	5.05d	41.01a	41.28a
F_2		3.13a	3.19a	5.35a	5.44a	41.45a	41.46a
F_3		3.07ab	3.12b	5.23b	5.33b	41.35a	41.35a
F_4		3.00bc	3.05c	5.12c	5.20c	41.33a	41.40a
Interaction							
T_1	**F_1**	2.46k	2.50n	4.16k	4.23o	40.90a	40.90a
	F_2	2.68hij	2.71lm	4.56i	4.62l	41.19a	41.27a
	F_3	2.62ijk	2.67m	4.45ij	4.52m	41.16a	41.05a
	F_4	2.58jk	2.62mn	4.34j	4.41n	40.55a	40.62a
T_2	**F_1**	2.77ghi	2.82kl	4.71h	4.79k	41.15a	41.09a
	F_2	2.96ef	3.01hi	5.06f	5.14i	41.53a	41.55a
	F_3	2.91efg	2.97ij	4.95fg	5.05i	41.32a	41.30a
	F_4	2.82fgh	2.88jk	4.83gh	4.93j	41.59a	41.61a
T_3	**F_1**	3.14de	3.15gh	5.37e	5.46h	41.56a	42.32a
	F_2	3.27bc	3.38de	5.60c	5.71e	41.58a	40.77a
	F_3	3.19cd	3.19ef	5.46d	5.53f	41.48a	42.35a
	F_4	3.14cd	3.24fg	5.38d	5.49g	41.59a	41.08a
T_4	**F_1**	3.53a	3.42cd	5.93b	5.86d	40.42a	41.61a
	F_2	3.60a	3.67a	6.15a	6.26a	41.44a	41.46a
	F_3	3.54a	3.60ab	6.04ab	6.15b	41.48a	41.55a
	F_4	3.45ab	3.50bc	5.91b	6.00c	41.61a	41.69a

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

T_1: Control group without soil additions, **T_2**: Magnesium sulphate at a rate of 30 Kg Mg fed^{-1} ,**T_3**: Plant residues compost (rice straw + soybean stover) at a rate of 7.0 tons fed^{-1} ,**T_4**: Combined treatment of compost at a rate of 3.0 tons fed^{-1} plus magnesium sulphate at a rate of 15 Kg Mg fed^{-1}, **F_1**: Control group without foliar applications, **F_2**: Magnesium sulphate at a rate of 500 g per feddan , **F_3**: Zn-EDTA at a rate of 500 g per feddan and **F_4** : Fe-EDTA at a rate of 500 g per feddan

Table 8. Effect of compost, magnesium, zinc and iron on oil yield and seed quality of canola during seasons of 2021/2022 and 2022/2023 at a harvest.

Treatemnts		Oil, %		Oil yield, ton ha^{-1}		Protein, %		Protein, ton 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											
T_1		35.57d	36.12d	0.637d	0.658d	17.88d	18.08d	0.321d	0.329d	12.16d	12.30d
T_2		36.42c	36.99c	0.737c	0.762c	19.03c	19.24c	0.385c	0.397c	12.82c	12.97c
T_3		37.32b	38.00b	0.844b	0.874b	20.22b	20.56b	0.457b	0.473b	13.54b	13.76b
T_4		38.08a	38.62a	0.944a	0.974a	21.38a	21.65a	0.530a	0.546a	14.26a	14.44a
Sub main factor											
F_1		36.54b	37.07c	0.752d	0.776d	19.21c	19.43c	0.398c	0.409d	12.96d	13.11d
F_2		37.15a	37.72a	0.827a	0.854a	19.99a	20.26a	0.447a	0.461a	13.42a	13.61a
F_3		36.94ab	37.58a	0.802b	0.831b	19.74ab	20.02b	0.431b	0.445b	13.27b	13.45b
F_4		36.76ab	37.36b	0.781c	0.808c	19.57b	19.81b	0.418b	0.431c	13.13c	13.30c
Interaction											
T_1	**F_1**	35.20j	35.69m	0.598o	0.617n	17.42k	17.60k	0.296n	0.304n	12.00n	12.12k
	F_2	35.93hij	36.47jk	0.674lm	0.695kl	18.29ij	18.57hi	0.343kl	0.354kl	12.33lm	12.53ij
	F_3	35.66ij	36.31k	0.653mn	0.674lm	18.00j	18.17ij	0.329lm	0.337lm	12.22mn	12.33jk
	F_4	35.48ij	36.02l	0.625no	0.645mn	17.83jk	17.98jk	0.314mn	0.322mn	12.10mn	12.21k
T_2	**F_1**	36.16hi	36.73ij	0.700kl	0.722jk	18.69hi	18.88gh	0.362jk	0.371jk	12.58kl	12.73hi
	F_2	36.71e-h	37.26g	0.771hi	0.796h	19.36fg	19.55f	0.407hi	0.418hi	13.03hi	13.17fg
	F_3	36.fgh52	37.07gh	0.747ij	0.774hi	19.11gh	19.34f	0.391i	0.404i	12.92ij	13.07g
	F_4	36.3ghi0	36.90hi	0.729jk	0.756ij	18.98gh	19.19fg	0.381ij	0.393ij	12.75jk	12.91gh
T_3	**F_1**	37.24dg	37.68f	0.832gh	0.871g	20.05ef	20.53e	0.448gh	0.475g	13.43gh	13.62e
	F_2	37. 52 ad	38.33cde	0.873de	0.892de	20.49cd	20.66cd	0.477de	0.481de	13.75de	13.98d
	F_3	37.35be	38.02de	0.845ef	0.890ef	20.28d	20.87d	0.459ef	0.488ef	13.57ef	13.83de
	F_4	37.27cf	38.08e	0.833fg	0.859fg	20.18de	20.38d	0.451fg	0.460fg	13.46fg	13.62e
T_4	**F_1**	37.78ad	38.30cd	0.904cd	0.933cd	20.95bc	21.20bc	0.502cd	0.516cd	14.01cd	14.15cd
	F_2	38.37a	38.89a	0.979a	1.010a	21.74a	22.00a	0.554a	0.571a	14.51a	14.71a
	F_3	38.18ab	38.75ab	0.957ab	0.991ab	21.52a	21.85a	0.539ab	0.559ab	14.33ab	14.52ab
	F_4	38.00abc	38.52bc	0.935bc	0.963bc	21.31ab	21.56ab	0.524bc	0.539bc	14.19bc	14.37bc

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

T_1: Control group without soil additions, **T_2**: Magnesium sulphate at a rate of 30 Kg Mg fed^{-1} ,**T_3**: Plant residues compost (rice straw + soybean stover) at a rate of 7.0 tons fed^{-1} ,**T_4**: Combined treatment of compost at a rate of 3.0 tons fed^{-1} plus magnesium sulphate at a rate of 15 Kg Mg fed^{-1}, **F_1**: Control group without foliar applications, **F_2**: Magnesium sulphate at a rate of 500 g per feddan , **F_3**: Zn-EDTA at a rate of 500 g per feddan and **F_4** : Fe-EDTA at a rate of 500 g per feddan

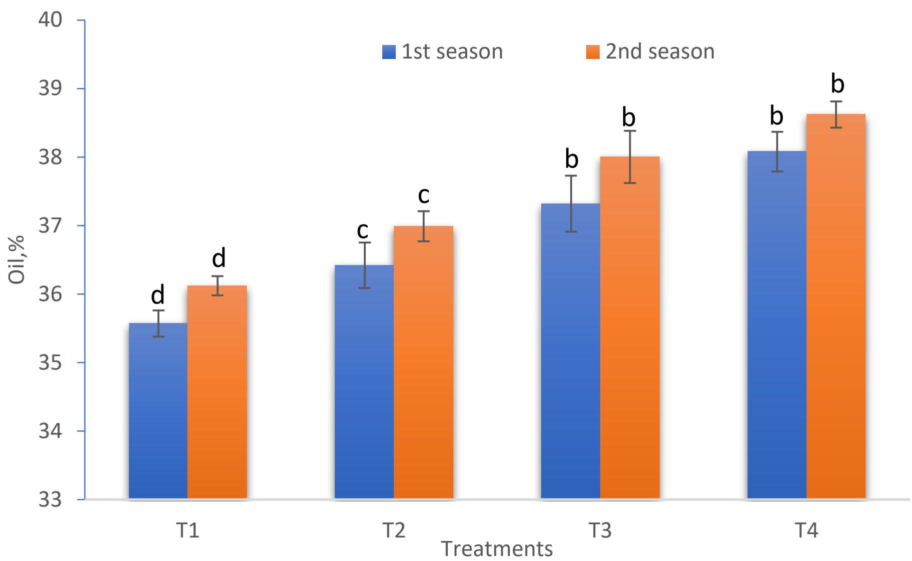

Fig. 1. Effect of compost and magnesium sulphate as soil additions on oil percentage of canola during seasons of 2021/2022 and 2022/2023 at a harvest.

T_1: Control group without soil additions, **T_2**: Magnesium sulphate at a rate of 30 Kg Mg fed^{-1}, **T_3**: Plant residues compost (rice straw + soybean stover) at a rate of 7.0 tons fed^{-1}, **T_4:** Combined treatment of compost at a rate of 3.0 tons fed^{-1} plus magnesium sulphate at a rate of 15 Kg Mg fed^{-1}.

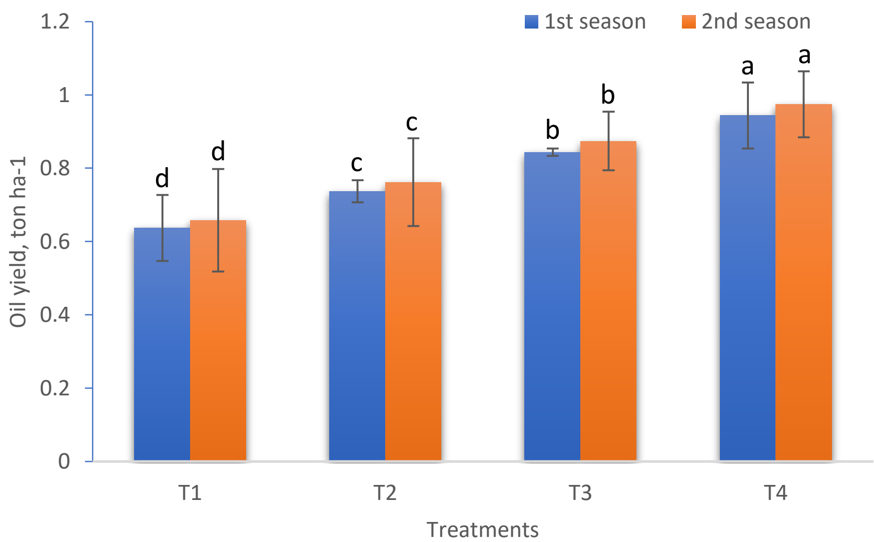

Fig. 2. Effect of compost and magnesium sulphate as soil additions on oil yield of canola during seasons of 2021/2022 and 2022/2023 at a harvest.

T_1: Control group without soil additions, **T_2**: Magnesium sulphate at a rate of 30 Kg Mg fed^{-1}, **T_3**: Plant residues compost (rice straw + soybean stover) at a rate of 7.0 tons fed^{-1}, **T_4:** Combined treatment of compost at a rate of 3.0 tons fed^{-1} plus magnesium sulphate at a rate of 15 Kg Mg fed^{-1}.

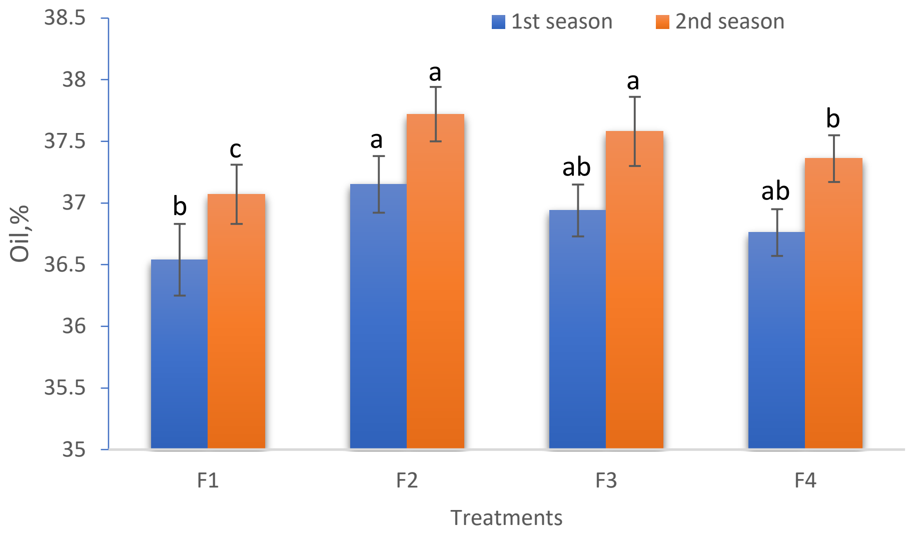

Fig. 3. Effect of iron, zinc and magnesium as foliar application on oil percentage of canola during seasons of 2021/2022 and 2022/2023 at a harvest.

F$_1$: Control group without foliar applications, **F$_2$**: Magnesium sulphate at a rate of 500 g per feddan, **F$_3$**: Zn-EDTA at a rate of 500 g per feddan and **F$_4$**: Fe-EDTA at a rate of 500 g per feddan.

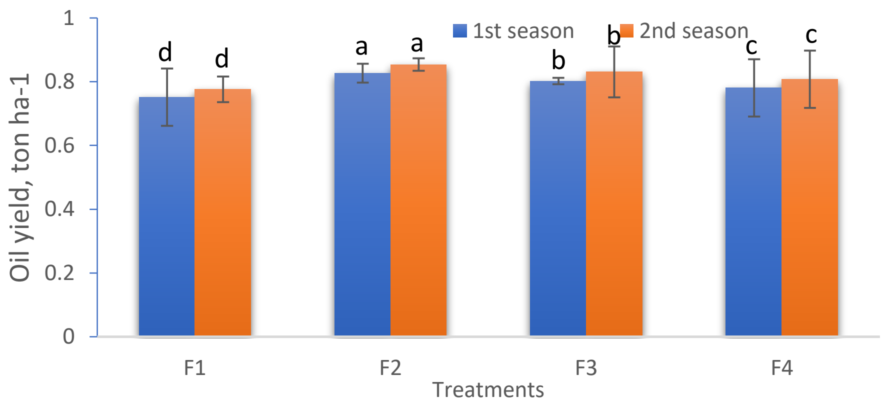

Fig. 4. Effect of iron, zinc and magnesium as foliar application on oil yield of canola during seasons of 2021/2022 and 2022/2023 at a harvest.

F$_1$: Control group without foliar applications, **F$_2$**: Magnesium sulphate at a rate of 500 g per feddan, **F$_3$**: Zn-EDTA at a rate of 500 g per feddan and **F$_4$**: Fe-EDTA at a rate of 500 g per feddan.

4. Discussion

Growth criteria and chemical constituents

The observed results can be attributed to several scientific factors related to the impact of compost, magnesium, zinc, and iron on canola growth and chemical constituents. The combined treatment (compost + magnesium sulphate) likely provided a balanced and optimal mix of magnesium and other nutrients, enhancing nutrient availability and uptake by canola plants. Compost, being an organic amendment, can improve soil structure and fertility. The positive effects of $\mathbf{T_4}$ and $\mathbf{T_3}$ may be attributed to enhanced soil conditions, promoting better root development and nutrient absorption. Magnesium ($\mathbf{F_2}$) is a crucial component of the chlorophyll molecule, which is vital for photosynthesis. The higher effectiveness of $\mathbf{F_2}$ in the foliar application may have resulted in improved chlorophyll content (SPAD reading) and subsequently enhanced plant growth. Zinc ($\mathbf{F_3}$) and iron ($\mathbf{F_4}$) play key roles in activating enzymes involved in various metabolic processes. Their effectiveness in foliar applications might have positively influenced biochemical reactions within the plant, contributing to overall growth and development. The superior performance of the combined treatment **($\mathbf{T_4}$ x $\mathbf{F_2}$)** suggests synergistic effects. Magnesium ($\mathbf{F_2}$) might have complemented the nutrient balance provided by **$\mathbf{T_4}$,** resulting in enhanced growth criteria and optimized chemical constituents in canola plants. The consistent trend observed in both seasons reinforces the reliability and robustness of the observed effects. It indicates that the positive interactions between soil additions and foliar applications were not influenced by seasonal variations but held true across different growing conditions. The results are in harmony with those of **Chen *et al.* (2018), Emam (2020), Hussein *et al.* (2022) and Elbaalawy *et al.* (2023).**

Seed and pod yield

The observed results in the context of the impact of compost, magnesium, zinc, and iron on the seed and pod yield of canola plants can be explained through various scientific principles. The combination of compost and magnesium sulphate ($\mathbf{T_4}$) likely provided a synergistic effect, offering a balanced supply of essential nutrients. Compost enhances soil organic matter, while magnesium is crucial for photosynthesis and enzyme activation. The combined treatment promotes overall plant growth, resulting in improved seed and pod yield. Compost alone **($\mathbf{T_3}$)** came in the second order due to the compost, being an organic source of nutrients, enhancing soil structure, water retention, and microbial activity. These factors contribute to improved nutrient availability, root development, and ultimately higher seed and pod yield. Regarding magnesium sulphate alone **($\mathbf{T_2}$)** as well as magnesium element **($\mathbf{F_2}$),** magnesium is a vital component of chlorophyll, essential for photosynthesis. Both soil application **($\mathbf{T_2}$)** and foliar application **($\mathbf{F_2}$)** of magnesium contribute to chlorophyll synthesis, leading to increased energy production and higher yields. Zinc and iron play key roles in enzyme activation and various metabolic processes. Foliar application of these elements ($\mathbf{F_3}$ and $\mathbf{F_4}$) likely enhances nutrient uptake and enzymatic reactions, positively influencing seed and pod yield. The superior performance of the combined treatment **($\mathbf{T_4}$ x $\mathbf{F_2}$)** may result from a harmonious interaction between soil additions and foliar applications. Magnesium, in particular, seems to play a crucial role in maximizing the benefits of both treatments, leading to enhanced yield parameters. The consistent patterns observed across both seasons suggest that the positive effects of the treatments are not influenced by seasonal variations. This stability indicates the robustness and reliability of the observed results. The results align with those reported by **Elsherpiny *et al.* (2023) and Faiyad *et al.* (2023).**

Oil yield and seed quality

This study delves into the intricate mechanisms by which magnesium influences oil composition, shedding light on its potential to be harnessed as a tool for quality enhancement in the context of oil crops. The combined application of compost, and magnesium sulphate **($\mathbf{T_4}$)** likely provided a comprehensive nutrient supply. This balanced combination promotes optimal plant growth, influencing both oil yield and seed quality positively. Compost alone **($\mathbf{T_3}$),** derived from plant residues, contributes organic matter to the soil. This enrichment fosters a nutrient-rich environment, supporting improved plant growth and, subsequently, enhancing oil yield and seed quality. Magnesium, in addition to its traditional roles in chlorophyll synthesis and photosynthesis, influences the fatty acid profile of oils. The effectiveness of $\mathbf{T_2}$ and $\mathbf{F_2}$ treatments suggests that magnesium plays a crucial role in achieving desirable oil attributes. Magnesium, an essential macronutrient, plays a multifaceted role in the improvement of oil composition. It exerts influence over the fatty acid profile of oils. The incorporation of magnesium sulphate into the soil not only enhances plant growth but also contributes to the development of oils with desirable attributes.

Foliar application of magnesium **(F_2),** zinc **(F_3)** and iron **(F_4)** demonstrates the importance of these micronutrients in influencing oil yield and quality. Magnesium, in particular, emerges as the most effective, followed by zinc and iron. Iron (Fe) and zinc (Zn), classified as micronutrients, hold pivotal roles in various biochemical pathways within plants. In the context of oil crops, these micronutrients are integral in the synthesis of proteins and enzymes involved in oil biosynthesis. Generally, the observed results can be attributed to a combination of nutrient synergy, organic enrichment, the specific role of magnesium in oil composition, and the influence of micronutrients on oil biosynthesis. The interaction effects further emphasize the importance of considering multiple factors for optimizing oil yield and quality in canola plants. The results are in harmony with those of **Chen *et al.* (2018), Emam (2020), Elbaalawy *et al.* (2023), Elsherpiny *et al.* (2023) and Faiyad *et al.* (2023).**

5. Conclusion

According to the obtained results, it can be concluded that the combined treatment of compost and magnesium sulphate (**T_4)** was the most effective soil addition, showcasing optimal performance across various parameters. In terms of foliar application treatments, magnesium **(F_2)** was identified as the most effective. Generally, these findings underscore the importance of tailored soil amendments and foliar applications to maximize canola crop yields, providing valuable insights for the Ministry's strategic planning. Recommendations include widespread adoption of the **T_4 x F_2** combination, further research on optimal dosage and application methods, and ongoing support for farmers in implementing these practices to bolster Egypt's self-sufficiency in oil crops.

Conflicts of interest

Authors have declared that no competing interests exist.

Formatting of funding sources: The research was funded by the personal efforts of the authors.

5. References

Adil, A. M. (2012). An evaluation for some methods of measuring leaf area for a group of ornamental plants &compare it with traditional methods. Journal of Kirkuk University For Agricultural Sciences, 3(1).

AOAC (2000).″ Official Methods of Analysis‶. 18th Ed. Association of Official Analytical Chemists, Inc., Gaithersburg, MD, Method 04.

Castelli, F., Contillo, R., & Miceli, F. (1996). Non-destructive Determination of Leaf Chlorophyll Content in Four Crop Species 1. Journal of Agronomy and Crop Science, 177(4): 275-283.

Chen, Z. C., Peng, W. T., Li, J., & Liao, H. (2018). Functional dissection and transport mechanism of magnesium in plants. In Seminars in cell & developmental biology (Vol. 74, pp. 142-152). Academic Press

Duncan, D. B. (1955). Multiple range and multiple F tests. Biometrics, 11(1), 1-42.

Elbaalawy, A. M., Tantawy, M. F., Abd Elhafez, E., & Nada, W. M. (2023). Sulphur compost properties and its amelioration effect on salt affected soil characteristics and productivity. Egyptian Journal of Soil Science, 63(3), 339-354.

Elsherpiny, M. A., Baddour, A., & Kany, M. (2023). Effect of organic and bio fertilization and magnesium foliar application on soybean production. Egyptian Journal of Soil Science, 63(1), 127-141.

Emam, S. (2020). Estimation of straw, seed and oil yields for flax plants (*Linum usitatissimum* L.) cultivars of foliar application of Mn, Fe and Zn under dry environment. Egyptian Journal of Agronomy, 42(1), 35-46.

Faiyad, R.M, El-Azeiz, E.H. & Yousif, E.E (2023). Effect of Sulfur, Boron, Zinc and Iron on Canola under Salt Affected Soils. Egyptian Journal of Soil Science, 63(4).

Gomez; K. A and Gomez, A.A (1984). "Statistical Procedures for Agricultural Research". John Wiley and Sons, Inc., New York.pp:680.

Hussein, M., Ali, M., Abbas, M. H., & Bassouny, M. A. (2022). Composting animal and plant residues for improving the characteristics of a clayey soil and enhancing the productivity of wheat plant grown thereon. Egyptian Journal of Soil Science, 62(3), 195-208.

Inckel, M., de Smet, P., Tersmette, T., & Veldkamp, T. (2005). The preparation and use of compost (Vol. 27). Wageningen, The Netherlands: Agromisa.

Peterburgski, A. V. (1968)."Handbook of Agronomic Chemistry". Kolos Puplishing House, Moscow (in Russian, pp. 29-86).

Rashwan, B. R. (2024). Impact of cultivation methods and fertilization by EM (Effective microorganisms) and/or compost on Productivity and water use efficiency of wheat (*Triticum aestivum* L.). Egyptian Journal of Soil Science, 64(1).

Tandon, H. L. S. (2005). Methods of analysis of soils, plants, waters, fertilizers & organic manures. Fertilizer Development and Consultation Organization.

Tokel, D., & Erkencioglu, B. N. (2021). Production and trade of oil crops, and their contribution to the world economy. Oil crop genomics, 415-427.

Walinga, I., Van Der Lee, J. J., Houba, V. J., Van Vark, W. and Novozamsky, I. (2013). Plant analysis manual. Springer Science & Business Media.