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The Possibility of Ginger Production Under the Conditions of the New Egyptian Lands

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https://doi.org/10.37229/fsa.fjh.2025.12.01

CrossMark

Future Science Association

Available online free at www.futurejournals.org

Print ISSN: 2692-5826

Online ISSN: 2692-5834

Received: 5 October 2025
Accepted: 20 November 2025
Published: 1 December 2025

Publisher's Note: FA stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract: Recent climate changes in Egypt, characterized by a noticeable increase in temperature and reduced rainfall, have prompted the expansion of cultivating unconventional new crop species adapted to these emerging environmental conditions, such as ginger plants. Therefore, this experiment was conducted over two growing seasons, 2021/2022 and 2022/2023, at Ahmed Orabi Agricultural Cooperative Association, El-Obour City, Qalyubia Governorate, Egypt, with the application soil amendments improving, including control (without soil amendments), humic acid (3.5 kg per feddan), compost (15 m^3 per feddan) and iron sulfate $FeSo_4$ (1 kg per 10 m^2) to assess the adaptability and productivity of ginger (*Zingiber officinale* Roscoe) in the newly reclaimed Egyptian soils. It aimed to evaluate the feasibility of cultivating ginger under recent climate change and emerging environmental conditions. According to the results, ginger can be produced under the climate in newly reclaimed Egyptian soil by using soil amendments. Specifically, iron sulfate at a rate of 1 kg per 10 m^2 is the most effective amendment in enhancing soil suitability, reducing germination time, increasing germination %, improving rhizome parameters, increasing rhizome yield, altering volatile oil content and composition, and decreasing fiber and starch percentages.

Key words: *Zingiber officinale* Roscoe, iron sulfate, humic acid, compost.

1. Introduction

Ginger (*Zingiber officinale* Roscoe) is a perennial plant belonging to the family Zingiberaceae and the genus Zingiber. Ginger is considered one of the most important tropical spice crops with high economic and medicinal value **(Wagner, 1980)**, as it is widely used for culinary and pharmaceutical purposes and is incorporated into many traditional medicinal systems **(Weiss, 2002)**. Ginger plants exhibit an upright vegetative growth habit, reaching a height of approximately 1–3 feet, and form pseudo stems surrounded by the sheathing bases of leaves. The main economic part of the plant is the underground rhizome. Ginger cultivation requires a warm and humid climate and performs best in fertile, well-drained soils rich in organic matter. Ginger can be grown under both rain-fed and irrigated conditions; however, it is primarily propagated vegetatively using rhizome pieces containing viable buds. It grows best under warm and humid conditions, with temperatures ranging from 20 to 30°C, and prefers light, well-drained soils rich in organic matter (**Kandiannan *et al*., 1996**). Ginger rhizomes are rich in essential oils (1-3%), including zingiberone and oleoresins. Shogaols are formed from gingerol as the root dries, making it twice as pungent. They also contain fats, vitamins A and B, and minerals **(Keville,1999).**

Newly reclaimed soils in Egypt are often characterized by high pH and low availability of essential nutrients, particularly iron, which negatively affects crop establishment and productivity. Iron sulfate ($FeSO_4$) has been reported as an effective soil amendment for reducing soil pH through soil acidification processes. It releases hydrogen ions during oxidation, leading to a reduction in soil pH, thereby enhancing nutrient availability and improving soil chemical properties **(Park *et al*., 2020)**. Furthermore, the application of iron sulfate, either alone or in combination with organic amendments and mitigate the negative effects of high alkalinity, thereby improving soil conditions and plant performance under alkaline environments **(Fresno *et al*., 2016)**. Accordingly, the use of iron sulfate may play a crucial role in improving soil suitability.

Humic acid (HA), a key part of humic substances, plays an essential role in soil fertility and nutrient cycling because of its high content of humic compounds (MacCarthy, 2003; Sani, 2014). Humates, which contain between 30–60% humic acids, are commonly applied directly to soil since they can be easily absorbed by plant roots and leaves **(Stevenson and Cole, 1999)**. As a main component of soil organic matter, HA significantly contributes to increasing soil organic carbon, improving soil structure, water retention, and biological activity—all of which support plant growth and productivity **(Mahmoud and Hafez, 2010)**. Additionally, humic substances have been shown to affect soil pH. The acidic functional groups in HA can help moderate soil acidification, especially in alkaline soils, thereby boosting nutrient availability and microbial activity. Humic acid's ability to complex and buffer helps stabilize soil pH and alleviate high pH levels often found in calcareous or reclaimed soils **(Nardi *et al*., 2002; Chen *et al*., 2004)**.

Compost, which includes plant- and animal-based organic manures, is a rich source of macro- and micronutrients (N, P, K, Mg, S, Ca, and trace elements) and plays a key role in improving soil fertility, structure, and biological activity (**Amlinger *et al*., 2007 and Agegnehu *et al*., 2014)**. Adding compost raises soil organic matter, boosts water retention, decreases bulk density, increases soil porosity, and supports microbial diversity, all of which together promote plant growth and yield **(Doan *et al*., 2015)**.

Compost contains acidic functional groups and organic acids that can contribute to moderate soil acidification, especially in alkaline or calcareous soils. This results in a decrease in soil pH, which increases nutrient availability, enhances cation exchange capacity, and supports microbial activity **(Radovich and Arancon, 2011 and Islam *et al*., 2017)**. By altering both chemical and physical soil properties, compost and compost tea act as sustainable, environmentally friendly amendments that boost soil fertility and reduce the adverse effects of soil alkalinity.

2. Materials and Methods

2.1. Study Site

The study was conducted at Ahmed Orabi Agricultural Cooperative Association, located in El-Obour City, Qalyubia Governorate, Egypt, north of Cairo and south of the Ismailia Canal region, along the Cairo–Ismailia Desert Road, during the two seasons of 2021/2022 and 2022/2023.

2.2. Soil analysis

Random soil samples were collected from the experimental site at various depths (0–50 cm) to assess the soil's physical and chemical properties. Soil texture was determined following the methods described by **Black (1965)**. Soil chemical analyses, including cation exchange capacity (CEC) and soluble anions, were conducted according to procedures outlined by **Page *et al.* (1982)**. The results are presented in Table 1.

Table (1). Physical and chemical properties of the experimental soil

Mechanical analysis (%)		Chemical analysis (ppm)		Micro-elements (ppm)	
Soil texture	sandy	Available N	19.13	Fe++	0.12
Fine sand	70.2	Available P	2.53	Mn++	0.31
Silt	19.3	Available K	0.38	Zn++	0.42
Clay	4.18	pH	7.50	Cu++	0.19
Organic matter	1.09	CaCO3 %	---	E.C.	1.12
Soluble cations and anions (meq/ 100 g soil)					
Ca ++	**Mg ++**	**Na+**	**K+**	**CO_3 -**	**SO_4 -**
6.06	3.03	1.66	0.38	--	2.84

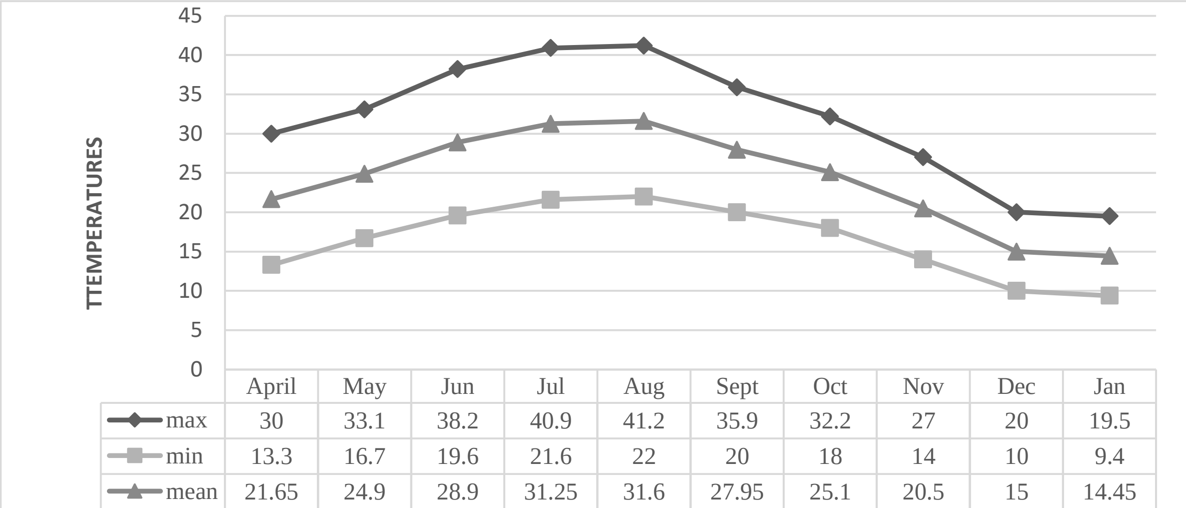
2.3. Irrigation water analysis

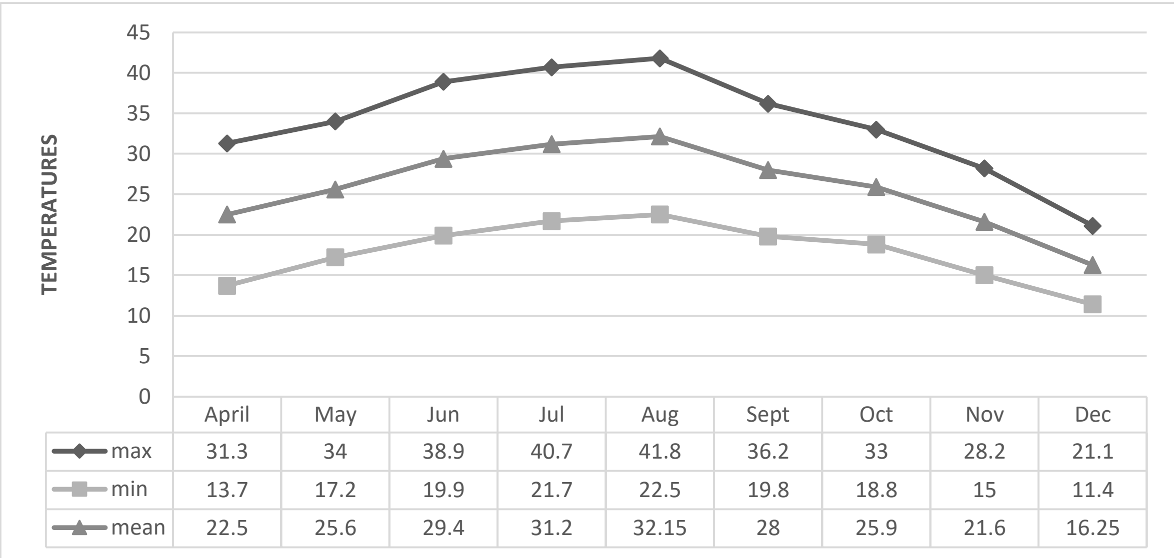
Irrigation water	EC (dSm^1)	pH	cations (meqL^1)				anions (meqL^1)			
			Ca^{2+}	Mg^{2+}	Na^+	K^+	SO^{2-}_4	CO_3^{2-}	Cl	HCO_3
	0.35	7.90	1.84	0.55	0.92	0.17	1.87	---	0.09	1.02

Samples of irrigation was collected and analyzed to determine their EC, pH, dissolved cations, and anions in Table 2.

2.3. Metrological data

Air temperature records for the two growing seasons (2021-2022 and 2022-2023) are presented in Figs. 1 and 2. Maximum and minimum air temperatures were obtained from the El-Qalyubia Weather Station and subsequently averaged monthly. These data were provided by the Central Laboratory for Agricultural Climate (CLAC).





Figs. (1) and (2). Monthly means of air temperature (Max., Min., and Mean) in El-Qalyubia Weather Station metrological station during the two growing seasons (2021-2022 and 2022-2023

2.4. Plant Material

Rhizomes were obtained from the experimental farm at El-Qanater El-Khayriya, Medicinal and Aromatic Plants Department, Agricultural Research Center, Cairo. Choose healthy rhizomes free from signs of pests and disease, mature, firm, and not dried. Soak the rhizomes in clean water for 10-12 hours to encourage sprouting. Cut the rhizomes into 5 cm sections with a few developing buds. The sections were soaked in a solution of copper-based fungicide, insecticide, and nematicide for 10 minutes, then drained and planted in the last week of April. The experimental unit covered an area of 5 m² (2 × 2.5 m), consisting of three planting rows, each 2 m long and 0.5 m wide. Space the sections 30 cm apart within the rows and were planted at a depth of 3-5 cm, with the growing buds facing up **(Mohansingh, 2016)**.

2.5. Cultural practices

Irrigation was applied at intervals of 4–5 days, and during the hot summer days. However, during high temperatures in the summer season, irrigation frequency was increased to every other day.

An NPK fertilizer was applied at a rate of 50:25:25 kg fed^{-1}. The total recommended doses of phosphorus (P_2O_5) and potassium (K_2O) were applied at planting, together with half of the nitrogen (N) dose. The remaining nitrogen was applied in two equal split applications at 30 and 45 days after planting.

2.6. Experimental Design

The experiment was conducted in a completely randomized block design in three replicates and nine plants/ replicate. Four treatments were used in this experiment, involving the application of soil amendments, including a control (without soil amendments), humic acid (3.5 kg per feddan), compost (15 m^3 per feddan), and iron sulfate (FeSO4) (1 kg per 10 m^2).

Iron sulfate $FeSo_4$, humic acid, and compost were obtained from El-Ahram Company for Mining and Natural Fertilizers, Maadi, Cairo, Egypt.

Soil amendments were incorporated into the experimental plots before planting to ensure uniform distribution and effective soil interaction.

Iron sulfate ($FeSO_4$) was applied at a rate of 1 kg per 10 m^2 and thoroughly mixed with the topsoil (0–20 cm) two weeks before planting **(Park *et al*., 2020)**.

Humic acid, at a rate of 3.5 kg per feddan, was also incorporated into the topsoil (0–20 cm) and uniformly mixed during land preparation **(Mahmoud and Hafez, 2010).**

Compost was applied at 15 m^3 per feddan and evenly spread on the soil surface, then thoroughly mixed into the soil to a depth of 20–25 cm during final land preparation before planting **(Agegnehu *et al*., 2014; Doan *et al*., 2015).** All amendments were applied once before planting to ensure homogeneous conditions across all experimental plots.

2.7. Data recorded

Morphological attributes

- Sprouting percentage (%)

The number of rhizomes that successfully produced shoots relative to the total number of planted rhizomes.

- Sprouting time (days)

Sprouting in ginger plants was recorded as the emergence of shoots from planted rhizomes.

- Plant height (cm)

The measurement of plant height started from the surface of the ground to the plant stem apex**.**

- Number of tillers

Number of shoots emerging from the rhizome per plant.

Rhizomes parameters

After 30 weeks of planting, when leaves turn yellow and start falling to the ground, the rhizomes are ready for harvest**.** To estimate the number of rhizomes/plants, the weight of rhizomes/plant(g), and the rhizome yield (ton/fed).

Chemical Composition Analysis

- Volatile Oil Content and Compositions

Essential oil (%) of the fresh rhizome samples (100 g) by subjecting to hydro distillation using modified Clevenger traps in the **British Pharmacopoeia (2000)**. The essential oil percentage was calculated as follows:

$$\text{Oil percentage} = \frac{\text{Volume of oil in gradated tube (ml)}}{\text{Weight of sample}} \times 100$$

Essential oil yield (ml/ plant)

$$\text{Per plant} = \frac{\text{Oil percentage} \times \text{fresh rhizome samples/plant}}{100}$$

The essential oil compositions (%) were determined using a DsChrom gas chromatograph equipped with a flame ionization detector (FID). The analysis was at the Medicinal and Aromatic Plants Department, Institute of Horticultural Research. Separation of the essential oil components was achieved under standard operating conditions. The obtained chromatograms were used to calculate the relative percentage of each compound based on peak area normalization. Identification of the essential oil constituents was accomplished by comparing their retention times (RT) with those of authentic reference compounds analyzed under identical conditions, following the methodology described by **Guenther and Joseph (1978).**

Starch and fiber content

Starch content (%) and crude fiber content (%) were determined according to the standard method described by **AOAC (1975).**

2.8. Statistical analysis

One-way analysis of variance for a randomized complete block design was performed on the collected data using the COSTAT program. When the F-value in the (ANOVA) table is significant, Fisher's protected least significant difference (LSD) was used for means separation at the 5% level. The data were pooled for analysis **(Snedecor and Cochran, 1980)**.

3. Results and Discussion

3.1. Morphological attributes

Sprouting percentage (%), Sprouting time (days), plant height, and Number of tillers

The data in Table 3 clearly show the effect of different soil amendment treatments on morphological attributes, including sprouting percentage, sprouting time, plant height, and number of tillers during two growing seasons.

According to the sprouting percentage of ginger rhizomes, the data show that the ginger sprouting percentage was relatively low under the conditions of newly reclaimed soils, as seen in the control (without soil amendments). This low may be attributed to the unfavorable physical and chemical properties of newly reclaimed soils, such as low organic matter content.

All soil amendment treatments significantly increased the sprouting percentage in both seasons compared with the control. The application of $FeSO_4$ (1 kg / 10 m²) recorded the highest sprouting percentage (81.94 and84.72 %) in both seasons, followed by compost (77.77 and 79.05 %) and humic acid (77.22 and 75 %). Application of iron sulfate ($FeSO_4$) has led to a decrease in soil pH, contributing to soil acidification and reduction of ammonia volatilization in arable soils, with higher application rates resulting in greater pH decline, which helped raise sprouting percentage **(Sale *et al*., 2018** and **Park *et al*., 2020**) as well as compost and humic acid in enhancing seed vigor and improving soil conditions. These improvements may be related to the role of organic amendments and micronutrients in enhancing soil structure, nutrient availability, and enzymatic activity associated with germination (**Mahmoud *et al*., 2017).**

Table (3). Effect of different soil amendment treatments on morphological attributes of ginger (*Zingiber officinale* Roscoe) plants in two seasons

Treatments	Sprouting percentage (%)		Sprouting time (days)		Plant height (cm)		Number of tillers	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	63.88	65.27	41.66	40.33	37	38.5	4.66	5
Humic acid (3.5 kg / fed)	77.22	75	39.66	39	40.66	40.66	5.33	5
Compost (15 m³ / fed)	77.77	79.05	38.33	38.33	42	42.66	6	6.33
FeSO4 (1 kg / 10 m²)	81.94	84.72	37	35.33	43.66	44.66	6.66	6.66
L.S.D. at 5 %	**3.67**	**3.92**	**0.74**	**1.37**	**2.90**	**2.13**	**1.10**	**1.10**

The data presented in Table 3 show the effect of different soil amendment treatments on the time taken for sprouting (days) of ginger plants. All treatments significantly reduced sprouting time, reflecting faster emergence compared to the control.

Data showed that soil amendment treatment with iron sulfate ($FeSO_4$) was significantly earlier in sprouting after (37 and 35.33days) than the compost soil amendment (38.33 and 38.33 days) and humic acid (39.66 and 39 days). However, unamended soil (control) took the longest time to sprout (41.66 and 40.33 days), respectively, in both seasons. These results are in accordance with those obtained by **Khan *et al*. (2019),** the Mung bean seed priming with 100ppm of $FeSO_4$ showed maximum values of germination percentage, and **Sale *et al*., (2018)** reported that the application of compost significantly accelerated the germination of ginger as well as the same results obtained from **Nair *et al*. (2024)** on the Mung bean while, humic acid was more effective to improve and acceleration the germination of the summer vegetables **Nisar *et al*. (2025).**

Plant height and number of tillers were also significantly increased by all treatments relative to the control in both seasons. The superior performance observed and achieved the highest plant and a high number of tillers with $FeSO_4$ and compost treatments. These results may be due to improved nutrient uptake and better early vegetative growth under amended soil conditions. These results agree with those of **Sale *et al*. (2018)** on ginger**; Saleem *et al*. (2022)** on *Oryza sativa* L. and **Waqas *et al*. (2024)** on Sponge gourd, who reported that $FeSO_4$ soil amendment had a positive effect on vegetative growth, such as plant height and number of shoots. **Abdou *et al*. (2023)** and **Al-Fraihat *et al*. (2023)** confirmed that Compost was more effective for plant growth of *Nigella sativa* L.; additionally, humic acid improved all vegetative parameters of *Nigella sativa* L. **(Mazrou, 2019).** While the results of cultivating ginger in the exposed field are in accordance with those obtained by **Aly *et al*. (2019).**

Rhizomes parameters

Regarding the effect of different soil amendment treatments on the number of rhizomes per plant, rhizome weight per plant, and total rhizome yield (ton/fed) of the (*Zingiber officinale* Roscoe) plant during the two growing seasons, data are presented in Table 4.

The results clearly indicate that all soil amendment treatments, humic acid (3.5 kg per feddan), compost (15 m³ per feddan), and iron sulfate $FeSo_4$ (1 kg per 10 m²) significantly increased rhizome parameters and yield compared with the unamended soil.

According to the results, ginger can be produced under the climate in newly reclaimed conditions (control treatment), although the low values for all measured traits reflect the limited productivity under untreated conditions. In contrast, soil amendments with humic acid, compost, and $FeSO_4$ significantly increased the number of rhizomes per plant, their fresh weight, and total yield per feddan, with variations among treatments.

Table (4). Effect of different soil amendment treatments on rhizome parameters of ginger (*Zingiber officinale* Roscoe) plants in two seasons

Treatments	Number of rhizomes/plants		Weight of rhizomes/plant(g)		Rhizome yield (ton/fed).)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	2	3	196.55	208.92	3.96	4.01
Humic acid (3.5 kg / fed)	3	4.33	211.22	238.84	4.24	4.58
Compost (15 m³ / fed)	3.66	5	222.62	270.72	4.63	5.19
FeSO4 (1 kg / 10 m²)	3.66	5.66	294.70	311.94	5.85	5.98
L.S.D. at 5 %	**0.66**	**0.94**	**14.77**	**19.41**	**0.28**	**0.37**

Among the soil amendments treatments, iron sulfate $FeSO_4$ application (1 kg/10 m²) produced the greatest values in both seasons, recording the highest number of rhizomes per plant (3.66 and 5.66), rhizome weight per plant (294.70 and 311.94 g), and the maximum rhizome yield per feddan (5.85 and 5.98 tons). This superior performance may be attributed to the role of iron in enhancing photosynthetic efficiency, enzyme activation, and overall plant metabolic activity, which directly supports rhizome development and biomass accumulation. followed by Compost application (15 m³ per feddan), significantly increasing rhizome number (3.66 and 5) and yield per feddan (4.63 and 5.19 tons) compared to the control and humic acid treatments. The improvement can be attributed to enhanced soil structure, increased nutrient availability, and increased microbial activity associated with organic amendments. Humic acid also exerted a positive effect on rhizome traits. The aforementioned results of soil amendment treatments, including iron sulfate $FeSo_4$, compost, and humic acid on yield attributes, are in accordance with those of **Saleem *et al*. (2022)** on *Oryza sativa* L. and **Waqas *et al*. (2024)** on Sponge gourd, in addition to **Abdou *et al*. (2023)** and **Al-Fraihat *et al*. (2023)** on *Nigella sativa* L.

Chemical Composition Analysis

Volatile Oil Content and Compositions

As shown in Table 5, the volatile oil percentage and volatile oil yield per plant were significantly influenced by soil amendment treatments in both seasons.

The results demonstrate that ginger cultivation under newly reclaimed soil conditions (control) resulted in relatively low volatile oil percentages and oil yields, and did not achieve the high volatile oil percentages or oil yields expected. Similar findings were previously recorded by **Sale *et al*. (2018) and Aly *et al*. (2019)**, who found that oil quality and climatic conditions play a critical role in determining volatile oil production in ginger. change in weather microclimate, such as temperature, humidity, rainfall and other meteorological factors (Figs. 1 and 2) during growing seasons leads to an effect on essential oil percent.

All soil amendment treatments (humic acid, compost, and $FeSO_4$) caused more significant increases in the volatile oil percentage and oil yield per plant than the control treatment (without soil amendments) in both seasons. A maximum volatile oil percentage (1.98 and 2.09%) and oil yield per plant (6.05 and 6.52 ml/ plant), respectively, were recorded from soil amendment with iron sulfate $FeSO_4$ application (1 kg/10 m²). Followed by soil amendment with compost application (15 m³ per feddan) was recorded (1.97 and 2.05 %) and oil yield per plant (4.77 and 5.57ml/ plant) compared with soil amendment with humic acid (3.5 kg per feddan) gave (1.96 and 2.03 %) and oil yield per plant (04.33 and 4.85 ml/ plant) respectively in both seasons., indicating its positive role in enhancing metabolic activity and essential oil biosynthesis. However, despite this improvement, the overall volatile oil content and yield remained below the expected levels commonly reported under more favorable soil conditions **Sale *et al*., 2018.**

Table (5). Effect of different soil amendment treatments on chemical composition of ginger (*Zingiber officinale* Roscoe) plants in two seasons

Treatments	Volatile oil percentage (%)		Volatile oil yield (ml/ plant)		Starch content (%)		Crude fiber content (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	1.91	1.95	3.95	4.07	44.03	43.77	5.18	5.05
Humic acid (3.5 kg / fed)	1.96	2.03	4.33	4.85	40.58	40.59	5.01	4.85
Compost (15 m³ / fed)	1.97	2.05	4.77	5.57	38.41	38.58	4.71	4.59
FeSO4 (1 kg / 10 m²)	1.98	2.09	6.05	6.52	35.82	36.28	4.21	4.09
L.S.D. at 5 %	0.033	0.17	0.29	0.72	1.07	1.37	0.29	0.22

Volatile Oil Compositions

G.L.C. of the volatile oil of the ginger rhizomes revealed a total of 11 compounds were identified as α-pinne, camphene, β-phyllandrene, geraniol, geranyl acetate, zingiberene, β-Sesquiphellandrene, α-Farnesene, geraniol, neral, and β-bisaboleneand **Mahboub, 2019**. These components ranged from 52.66 in the control to 53.76 from humic acid to53.95 from compost and the highest value 55.06 % from $FeSO_4$ of the volatile oil rhizome.

In the table 6 the major component in the essential oil was zingiberene, accounting for approximately 20.88–20.99% of the total components, which wasn't markedly influenced by the applied treatments. In addition, other constituents included geraniol, β-sesquiphellandrene, β-phellandrene, and geranyl acetate, which together contributed substantially to the characteristic aroma profile of ginger oil.

Table (6). Effect of different soil amendment treatments on volatile oil compositions of ginger (*Zingiber officinale* Roscoe) plants in two seasons

Components	Essential oil constituents (%)			
	control	humic acid (3.5 kg / fed)	Compost (15 m³ / fed)	FeSO4 (1 kg / 10 m²)
α-pinne	0.16	0.15	0.20	0.21
Camphene	0.53	0.55	0.54	0.60
β-phyllandrene	0.71	0.77	0.78	0.81
Geraniol	9.06	9.02	9.22	9.28
Geraly Acetate	1.82	1.94	1.90	1.91
Zingiberene	20.88	20.90	20.90	20.99
β-Sesquiphellandrene	6.30	6	6.34	6.47
α-Farnesene	1.47	1.52	1.50	1.55
geraniol	7.93	9.11	9.26	9.33
neral	3.29	3.30	3.31	3.32
β-bisabolene	0.51	0.50	--	0.59
known	**52.66**	**53.76**	**53.95**	**55.06**

All soil amendments caused slight increases in essential oil components compared to the control (without amendments). The application of $FeSO_4$ showed the highest total of identified compounds and the major compound zingiberene, along with increased levels of monoterpenes and sesquiterpenes such as camphene, β-phellandrene, α-farnesene, and β-bisabolene. This is due to the stimulatory role of iron in enzymatic activities related to terpene biosynthesis. Additionally, compost and humic acid treatments showed moderate improvements in oxygenated compounds like geraniol and neral, which are known to enhance oil quality. The absence or low levels of certain minor constituents, such as β-bisabolene in the compost treatment, may indicate the sensitivity of specific biosynthetic pathways to soil nutrient and environmental conditions.

Starch and fiber content

Concerning starch and fiber content % in ginger rhizome under the effect of soil amendment applications in both seasons, as represented in Table 5.

Data clearly shows that ginger produced in newly reclaimed conditions without soil amendments (control treatment) recorded the highest starch content, 44.03% and 43.77%, and fiber content, 5.18% and 5.05%. In accordance with **Aly *et al*. (2019)**, it was reported that the control treatment recorded the highest starch and fiber percentages. It is evident from the data that all soil amendment applications decreased starch and fiber content percentages, especially $FeSO_4$, which resulted in the lowest values: 35.82% and 36.28% for starch content, and 4.21% and 4.09% for fiber content. Additionally, compost significantly reduced starch and crude fiber accumulation compared to the control. This reduction may be due to the enhanced utilization of carbohydrates for growth and secondary metabolite production under improved nutrient availability, leading to improved rhizome quality.

4. Conclusions

The present study concluded that, although there was only a slight increase in rhizome and volatile oil production in newly reclaimed Egyptian soils, the results suggest that ginger (*Zingiber officinale* Rosc.) can be successfully grown under these conditions with proper soil amendments. Using soil enhancers such as humic acid, compost, and $FeSO_4$ helped improve soil properties and partially boosted plant growth, rhizome yield, and essential oil content.

The lower-than-expected percentage of volatile oil and oil yield compared to traditional ginger-producing areas may be due to local climate and soil quality, which are vital for essential oil production and accumulation. Factors like temperature changes, soil type, nutrient levels, and organic matter significantly affect both yield and oil composition.

Therefore, further research is needed to refine farming practices and make ginger cultivation more adaptable in Egyptian conditions, especially in newly reclaimed soils. Future studies should focus on soil conditioning, nutrient management, and climate-resilient farming methods to increase rhizome productivity and essential oil yield, particularly given ongoing climate changes.

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الملخص العربى

أدت التغيرات المناخية الحديثة في مصر، والمتمثلة في الارتفاع الملحوظ في درجات الحرارة وانخفاض معدلات هطول الأمطار، إلى التوسع في زراعة محاصيل غير تقليدية قادرة على التكيف مع هذه الظروف البيئية المستجدة، ومن بينها نبات الزنجبيل. لذا أُجريت هذه الدراسة خلال موسمي الزراعة ٢٠٢١/٢٠٢٢ و٢٠٢٢/٢٠٢٣ في جمعية أحمد عرابي الزراعية بمدينة العبور، محافظة القليوبية، مصر، وذلك لتقييم إمكانية زراعة وإنتاج الزنجبيل (*Zingiber officinale* Roscoe) تحت ظروف الأراضي المصرية المستصلحة حديثًا، مع استخدام بعض محسنات التربة. اشتملت معاملات التجربة على الكنترول (بدون إضافة محسنات تربة)، حمض الهيوميك بمعدل ٣,٥ كجم/فدان، الكمبوست بمعدل ١٥ م³/فدان، وكبريتات الحديدوز ($FeSO_4$) بمعدل ١ كجم/١٠ م². وهدفت الدراسة إلى تقييم مدى تكيف وإنتاجية الزنجبيل في ظل التغيرات المناخية الحديثة والظروف البيئية الناشئة. أوضحت النتائج أنه يمكن زراعة الزنجبيل تحت الظروف المناخية السائدة في الأراضي المصرية المستصلحة حديثًا عند استخدام محسنات التربة. وقد سجلت معاملة كبريتات الحديدوز بمعدل ١ كجم/١٠ م² أفضل النتائج، حيث ساهمت في تحسين خواص التربة، وتقليل مدة الإنبات، وزيادة نسبة الإنبات، وتحسين صفات الريزومات، وزيادة محصول الريزومات، بالإضافة إلى تحسين محتوى وتركيب الزيت الطيار، وتقليل نسب النشا والألياف.