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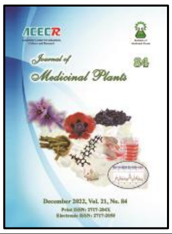

**Research Article**

# Investigating the effects of different fertilizers and cultivation media on the yield and active ingredients of *Zingiber officinale* Rosc.

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ABSTRACT

**Background:** *Zingiber officinale* (Zingiberaceae), is a tropical plant with knotted rhizomes. **Objectives:** The purpose of this research was to investigate the effect of using mineral and biological fertilizers based on algae on the quantitative and qualitative traits of the ginger plant and to choose the best cultivation medium. **Methods:** The experimental treatments included cultivation media in four levels and fertilizers in three levels. Hydrodistilled essential oil of the *Z. officinale* was analyzed by GC and GC-MS. **Results:** The largest amount of biological yield and yield per hectare was observed in the cultivation medium of vermicompost: perlite (70: 30) without fertilizers. The maximum harvest index with an average of 0.9 was estimated in the cultivation media of manure: soil (70: 30) combined with biofertilizer, vermicompost: perlite (70: 30) combined with biofertilizer, and manure: perlite (70: 30) combined with biofertilizer, respectively. The cultivation medium of animal manure: perlite (70: 30) combined with NPK chemical fertilizer produced the largest amount of essential oil. The highest proportion of geranial was observed in the cultivation medium of vermicompost: perlite (70: 30) combined with biofertilizer. The highest percentage of *α*-zingiberene was observed in the cultivation medium of vermicompost: perlite (70: 30) combined with NPK chemical fertilizer. The highest percentage of neral was obtained in the main treatments of animal manure: soil (70: 30) combined with biofertilizer. **Conclusion:** The use of chemical and biological fertilizers combined with organic cultivation media was fruitful and productive to meet the nutritional needs for the production of effective substances in ginger.

## 1. Introduction

In addition to ecological, economical, and cultural aspects, medicinal plants, are vital for medicinal purposes. Hence, they are used as the main tools in the world to treat many diseases and fight against infections. Since ancient times,

*Abbreviations:* GC-MS, Gas Chromatography-Mass Spectrometry; GC, Gas Chromatography

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these plants have been a rich source of effective and safe ingredients which could be used as medicines. Research reveals that more than 64 % of the population in the world relies on medicinal plants to treat their health problems [1].

Ginger belongs to the genus *Zingiber*, which is used for medicinal purposes such as the alleviation of nausea, treatment of abdominal pain, treatment of rheumatological and microbial diseases, and have different effects including anti-ulcer, anticholinergic, antioxidant, and anti-inflammatory effects. Moreover, ginger could be used for cooking, mosquito repellent, and as an aphrodisiac [2]. The main active compounds of *Zingiber officinale* Rosc. are gingerol (23-25 %), shogaol (18-19 %), zingerone and also $\alpha$-zingiberene [3].

Integrated nutrient management using balanced nutrients based on the needs of the soil and crops can be a good option for managing soil health and crop productivity. Maintaining the increase in soil and crop yield requires adequate fertilizer management, where chemical fertilizers with organic ones are incorporated [4]. The high yield and growth of ginger are a function of adequate agricultural technologies and a timely supply of plant nutrients. In addition, the imbalanced, low, and non-use of fertilizer are the most important factors in achieving poor performance [3].

The use of organic fertilizers can improve not only soil fertility but also the physical and chemical soil properties. Furthermore, it could enhance the storage capacity of water in the soil, which results in vegetative growth, the reproduction of plants, and an improvement in the quality of plants [5]. Organic resources such as animal manure, vermicompost, and biofertilizers combined with chemical fertilizers can be used to preserve the soil system health for long-term sustainability [4].

Perlite could promote the physical properties of growing media such as air space, container capacity, and apparent density. In addition, perlite can be used in various fields like agricultural lands due to its extremely high absorption capacity and dominant minerals. Perlite also could be used in agriculture as a fungicide, herbicide, and carrier of plant nutrients which leads to a decrease in the consumption of nutrients mainly nitrogen as the eutrophication of water resources [6].

The yield of ginger rhizome under vermicompost, as an integrated source of nutrient supply, was significantly higher (10.21 Mg/ha) compared to vermicompost (11.82 Mg/ha) [7]. During investigating the effect of organic fertilizers and biological stimulants on ginger, it was stated that the application of 50 % nitrogen (manure) + 25 % nitrogen (neem cake) + 25 % nitrogen (vermicompost) + azospirillum (5 kg/ha) + Panchakavya (3 %) resulted in the highest amount of essential oil with an average of 2.25 % [8]. In addition, the application of biological fertilizers combined with selenium produced the highest yield of saffron. As a consequence, biological fertilizers in lower concentrations of phosphorus could increase crocin, as the main active substance of saffron [9].

## 2. Materials and methods

This experiment was carried out in 2021 as the form of a randomized complete block design in three replications under pot conditions and inside the greenhouse, at the Faculty of Agricultural Technology (Aborihan) of Tehran University. The experimental treatments include cultivation substrates in four levels (70 % vermicompost + 30 % soil, 70 % vermicompost + 30 % perlite, 70 % manure + 30 % soil, and 70 % manure + 30 % perlite). In this research fertilizers in three levels (without fertilizer consumption, NPK consumption in the amount of 100-100-150 kg/ha, and bio-fertilizer based on algae in the amount of 2000 along with 500 g/m$^2$ of granulated humic acid and 5 g/m$^2$ of powdered humic acid) were used. To perform this test, pots with dimensions of 35 cm × 25 cm were prepared. Then the planting medium combined with twelve pots. Each pot has granulated humic acid to increase rooting, reduce soil acidity, amend the soil and make the plant resistant. Stresses such as Salt, frost, and pests were mixed and placed inside the pots. It should be noted that the NPK chemical fertilizers were used in the amount of 100-100-150 kg/ha combined with 20 % ammonium sulfate fertilizer at the rate of 8.3 g for each pot, 46 % triple superphosphate at the rate of 2.5 g for each pot, and 42 % potassium sulfate fertilizerat the rate of 2.6 g for each pot. The pots were placed in the greenhouse with controlled light and a temperature of 22-25 ºC. The relative humidity of the greenhouse was regulated by a cooler (Table 1).

**Table 1.** Breakdown of elements based on algae

| Elements | Volume (%) | Weight (%) |
|---|---|---|
| Total nitrogen | 20 | 13 |
| Nitrate nitrogen | 11.40 | 7.50 |
| Ammonia nitrogen | 8.6 | 5.70 |
| $P_2O_5$ | 20 | 13.20 |
| $K_2O$ | 20 | 13.20 |
| MgO | 1.5 | 1 |
| EDTA (Fe) | 0.146 | 0.1 |
| EDTA (Zn) | 0.073 | 0.05 |
| EDTA (Cu) | 0.073 | 0.05 |
| EDTA (Mn) | 0.073 | 0.05 |
| B | 0.029 | 0.019 |
| MO | 0.0012 | 0.0008 |
| Seaweed | 28 | 18.40 |

First, Thai sprouted ginger rhizomes were soaked in water for 24 h. Then they were divided into pieces with at least two buds. Each piece was a maximum of 65 g and placed in normal air and away from light for 24 h. Then the rhizomes were placed in a solution containing carbendazim, a fungicide, for 1 hour to protect against various fungal diseases. A solution of 10 g of fungicide in 5 liters of water was prepared for cultivation and left in the open air for 24 h. Cultivation of rhizomes was done on May 27 when the pots were immediately watered. At the time of cultivation, the rhizomes were planted in pots at a depth of about 5 cm. All recommended amounts of phosphate and potash fertilizers along with one-third of nitrogen fertilizer and granulated humic acid were mixed with the soil of each pot during planting. The rest of the nitrogen fertilizer was added to the pots in the form of vinegar during two stages of the 5-7 leaves of the plant. Biofertilizers, produced in England in the amount of 3-5 ml in one liter of water, with 0.5 g of powdered humic acid, produced in the United States, was used in two stages. Then 15 days after the first stage, biofertilizer along with powdered humic acid was used as a spraying solution. After the plants were fully established and entered the two stages, nitrogen fertilizer was allocated to the pots. Irrigation of water was done manually and every 5-7 days during these two stages. Sowing was done in three periods: 5/7/2021, 17/8/2021, and 4/10/2021.

### *2.1. The method of evaluating traits and yield in ginger*

After harvesting the rhizomes, the number of rhizomes produced by each plant was measured with the help of a digital scale with an accuracy of 0.001 g.

The harvest index was calculated by dividing the economic yield by the biological yield as a percentage.

### *2.2. Biological function*

To calculate the biological yield of ginger, the whole plants were harvested. Then the roots, stems, leaves, and rhizomes as well as each plant were weighed using a digital scale with an accuracy of 0.001 g.

### *2.3. Extracting the essential oil and identifying its active compounds*

To extract essential oil in this research, the water distillation method and clevenger apparatus were used. For this purpose, 30 g of dried and powdered rhizome from each treatment was weighed and added to 1000 ml flasks. In the next step, 300 ml of distilled water was poured into the contents of the balloons. After boiling the water inside the balloons, the essential oil extraction was done after 3 h. The oily liquid obtained by boiling the solution was dried with a moisture-absorbent material (sodium sulfate). GC was used to separate and determine the percentage of each component in the essential oil. Then they were qualitatively identified with the help of GC-MS by different parameters such as time, inhibition index, and studying mass spectra. The spectra of Compounds in the essential oil were compared with standard compounds and a piece of information available in the computer library of the GC-MS device [10]. Ultimately the relative percentage of each compound in the essential oil was obtained according to its level under the curve in the GC chromatogram.

### *2.4. Qualitative analysis of the essential oil*

For qualitative analysis of the essential oil, the Agilent Technologies model 5975C device equipped with a DB-5 column with a length of 30 meters, an inner diameter of 0.25 mm, and a thickness of 0.25 micrometers was used.

### *2.5. Checking the number of compounds in the essential oil*

Quantitative analysis of the essential oil was done with the help of the Agilent Technologies 7890A GC device equipped with a DB-5 column with a length of 30 meters, an inner diameter of 0.32 mm, and a thickness of 0.25 µm [11].

### *2.6. Statistical analysis*

After data collection and recording, data analysis was performed using SAS Ver. 9.0. The figures were drawn by Excel 2016 software. The comparison of the means was done using the LSD test at the five percent probability level.

## 3. Results

### *3.1. Biological function*

The variance of seven traits including biological yield, yield per hectare, harvest index, the amount of essential oil, and effective ingredients in Table 2 showed that the main effects of culture media and fertilizer consumption were significant at the statistical probability level of one and five percent. Also, the reciprocal effect of cultivation substrate × fertilizer consumption was significant at the statistical probability level of one and five percent.

*3.2. Yield per hectare*

The comparison of average yield traits showed that the mutual effect of vermicompost + perlite (70: 30 % v/v) without using fertilizers had the highest yield per hectare with an average of 19.66 tons per hectare. However, the mutual effect of vermicompost + soil (70: 30 % v/v) combined with NPK chemical fertilizers with an average of 3.2 tons per hectare had the lowest yield per hectare. In addition, cultivation substrates of vermicompost + soil (70: 30 % v/v) and animal manure + perlite (70: 30 % v/v) would increase the yield per hectare if chemical and biological fertilizers are used (Table 3).

*3.3. Harvest index*

Examining the cultivation substrates and fertilizer consumption showed that the highest harvest index with an average of 0.9 was in the mutual effects of cultivation substrates of 70 % vermicompost + 30 % soil + biofertilizer, 70 %vermicompost + 30 % perlite + biofertilizer, and 70 % animal manure + 30% perlite + biofertilizer. Nevertheless, the lowest harvest index with an average of 0.53 was observed in the mutual effect of 70 %vermicompost + 30 % perlite + NPK chemical fertilizers. This treatment combination had no statistically significant differences in comparison to many other treatment combinations. As can be observed in economic and biological performance, mutual effects had a logical and correct procedure with the results of the attribute of harvesting index (Table 3).

*3.4. The amount of essential oil*

The results showed that the mutual effects of cultivation substrate of 70 % manure + 30 % perlite + NPK chemical fertilizers had the highest amount of essential oil with an average of 0.24 %. Nonetheless, cultivation substrate of 70 % manure + 30 % perlite without using fertilizer revealed the lowest amount of essential oil with an average of 0.11 % (Table 3).

**Table 2.** Variance analysis (mean square) of biological yield traits, yield per hectare, harvest index, and some effective substances under the influence of biological and non-biological fertilizers in different Culture medium

| Source of Variation | df | Biological Yield | Yield per hectare | Harvest Index | The amount of essential oil | Geranial | α-Zingiberene | Neral |
|---|---|---|---|---|---|---|---|---|
| Replicate | 2 | $73.45^{ns}$ | $0.58^{ns}$ | $0.0011^{ns}$ | $0.00003^{ns}$ | $1.40^{ns}$ | $0.52^{ns}$ | $0.27^{ns}$ |
| Culture medium | 3 | $47020.66^{**}$ | $121.99^{**}$ | $0.071^{**}$ | $0.0004^{**}$ | $21.08^{*}$ | $37.85^{**}$ | $21.46^{**}$ |
| Fertilizer | 2 | $16320.58^{**}$ | $18.15^{**}$ | $0.158^{**}$ | $0.0020^{**}$ | $5.71^{ns}$ | $32.47^{**}$ | $16.64^{*}$ |
| Culture medium × Fertilizer | 6 | $12824.13^{**}$ | $32.79^{**}$ | $0.036^{**}$ | $0.0077^{**}$ | $36.10^{**}$ | $13.30^{**}$ | $2.49^{ns}$ |
| Error | 22 | 207.67 | 1.37 | 0.0017 | 0.00007 | 4.59 | 0.70 | 3.64 |
| Coefficient of Variation (%) | | 11.50 | 14.89 | 5.56 | 5.40 | 11.17 | 6.53 | 20.94 |

ns, * and ** indicate non-significance and significance at the 5% and 1% probability levels, respectively

**Table 3.** Comparison of the mean of biological yield traits, yield per hectare, harvest index and some effective substances under the influence of biological and non-biological fertilizers in different Culture medium

| Treatment | Biological Yield (g/m$^{-2}$) | Yield per hectare (ton/ha$^{-1}$) | Harvest Index | The amount of essential oil (%) | Geranial (%) | α-Zingiberene (%) |
|---|---|---|---|---|---|---|
| C1F1 | 118.53 ± 9.13$^{cd}$ | 5.76 ± 0.61$^{ef}$ | 0.53 ± 0.017$^{c}$ | 0.15 ± 0.003$^{ef}$ | 16.86 ± 1.38$^{e}$ | 14.21 ± 0.12$^{bc}$ |
| C1F2 | 110.67 ± 10.48$^{cde}$ | 8.16 ± 0.81$^{cd}$ | 0.8 ± 0.010$^{b}$ | 0.17 ± 0.003$^{cd}$ | 18.08 ± 0.41$^{de}$ | 16.03 ± 0.20$^{a}$ |
| C1F3 | 87.53 ± 7.09$^{ef}$ | 6.1 ± 0.60$^{e}$ | 0.8 ± 0.014$^{b}$ | 0.16 ± 0$^{de}$ | 20.6 ± 2.16$^{abcd}$ | 12.91 ± 0.54$^{cd}$ |
| C2F1 | 375.07 ± 15.15$^{a}$ | 19.66 ± 1.1$^{a}$ | 0.6 ± 0.012$^{c}$ | 0.22 ± 0.012$^{b}$ | 16.04 ± 0.30$^{ef}$ | 14.02 ± 0.42$^{bc}$ |
| C2F2 | 194.07 ± 8.61$^{b}$ | 10.36 ± 0.84$^{b}$ | 0.56 ± 0.022$^{c}$ | 0.17 ± 0.003$^{cd}$ | 19.17 ± 0.60$^{bcde}$ | 16.67 ± 0.19$^{a}$ |
| C2F3 | 125.67 ± 4.45$^{c}$ | 10 ± 0.34$^{bc}$ | 0.9 ± 0.0008$^{a}$ | 0.12 ± 0.005$^{g}$ | 22.89 ± 1.51$^{a}$ | 11.79 ± 0.30$^{de}$ |
| C3F1 | 94.5 ± 11.14$^{def}$ | 7.6 ± 0.98$^{de}$ | 0.9 ± 0.013$^{a}$ | 0.16 ± 0.003$^{de}$ | 21.73 ± 0.31$^{abc}$ | 12.26 ± 0.33$^{de}$ |
| C3F2 | 42 ± 2.64$^{g}$ | 3.2 ± 0.31$^{g}$ | 0.83 ± 0.03$^{ab}$ | 0.12 ± 0.005$^{g}$ | 19.15 ± 0.83$^{bcde}$ | 11.09 ± 0.10$^{ef}$ |
| C3F3 | 77.63 ± 3.88$^{f}$ | 6.4 ± 0.29$^{de}$ | 0.9 ± 0.005$^{a}$ | 0.18 ± 0.003$^{c}$ | 22.75 ± 1.02$^{ab}$ | 6.43 ± 0.26$^{g}$ |
| C4F1 | 73.83 ± 0.92$^{f}$ | 4.1 ± 0.06$^{fg}$ | 0.6 ± 0.012$^{c}$ | 0.11 ± 0.003$^{g}$ | 19.01 ± 1.87$^{cde}$ | 9.9 ± 1.37$^{f}$ |
| C4F2 | 122.27 ± 7.82$^{c}$ | 6.73 ± 0.73$^{de}$ | 0.6 ± 0.030$^{c}$ | 0.24 ± 0.003$^{a}$ | 21.15 ± 1.56$^{abcd}$ | 14.4 ± 0.08$^{bc}$ |
| C4F3 | 81.33 ± 3.45$^{f}$ | 6.26 ± 0.26$^{de}$ | 0.9 ± 0.003$^{a}$ | 0.14 ± 0.003$^{f}$ | 12.73 ± 0.115$^{f}$ | 13.98 ± 0.005$^{bc}$ |

Culture medium (C1, C2, C3, and C4 were 70 % vermicompost + 30 % soil, 70 % vermicompost + 30 % perlite, 70 % animal manure + 30 % soil, and 70 % animal manure + 30 % perlite respectively.)
Fertilizer (F1, F2, and F3 were non-use of fertilizer, NPK chemical fertilizers and bio-fertilizer based on algae respectively.)
Non-common letters in each column indicate significant differences.
Values represent means ± SE of triplicate measurement.

### *3.5. The amount of geranial*

The results revealed that the mutual effect of 70 % vermicompost + 30 % perlite + biofertilizer had the highest amount of geranial with an average of 22.89 %. However, the mutual effect of 70 % livestock manure + 30 % perlite + biofertilizer with an average of 12.73 % had the lowest amount of geranial (Table 3).

### *3.6. The amount of α-zingiberene*

As could be observed, the highest amount of *α*-zingiberene was in the mutual effect of 70 % vermicompost + 30 % perlite + NPK chemical fertilizers with an average of 16.67 %. By contrast, the mutual effect of 70 %vermicompost + 30 % soil + NPK chemical fertilizers with an average of 16.03 % was not statistically significant. On the other hand, the planting substrate of 70 % vermicompost + 30 % soil + biofertilizer with an average of 6.43 % had the lowest percentage of *α*-zingiberene (Table 3).

### *3.7. The amount of neral*

The highest and lowest amount of neral was observed with averages of 11.21 % and 7.83 %, respectively, in the cultivation substrates of 70 % manure + 30 % soil and 70 % manure + 30 % perlite.

The results divulged that the use of biological fertilizers with an average of 10.42 % accounted for the highest amount of neral, as opposed to the use of NPK chemical fertilizer or without using fertilizers. The lowest amount of neral with an average of 13.8 % was obtained in the main effect of using NPK chemical fertilizer (Table 2).

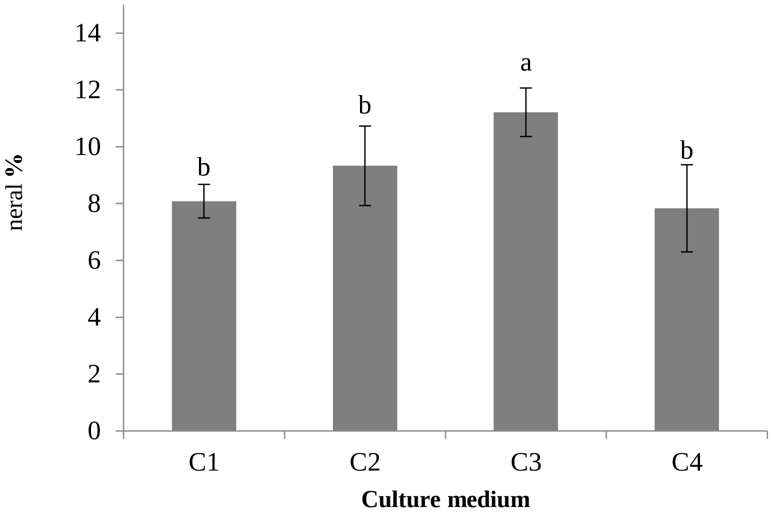


**Fig. 1.** Comparison of the average amount of neral under the influence of culture medium
Planting substrates (C1, C2, C3, and C4 were 70 % vermicompost + 30 % soil, 70 % vermicompost + 30 % perlite, 70 % animal manure +30 % soil, and 70 % animal manure + 30 % perlite respectively.)
Different letters indicate a significant difference at the probability level of LSD$\alpha$ = 5 %.
The error bars are ± SE.

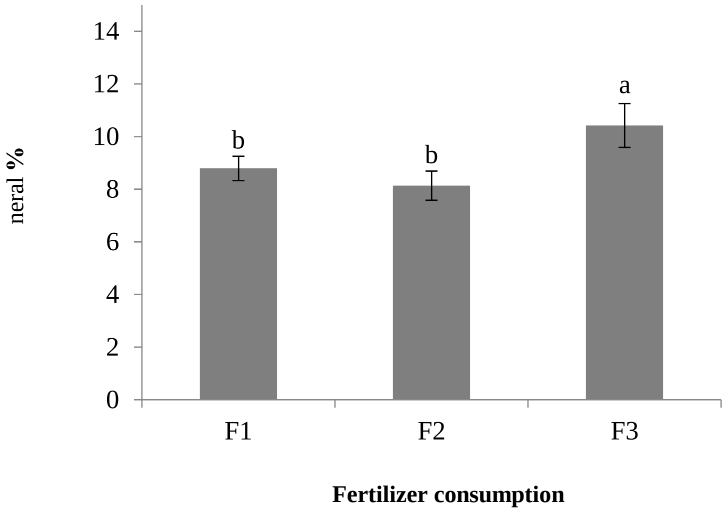


**Fig. 2.** Comparison of the average amount of neral under the influence of fertilizer consumption
F1, F2, and F3 were non-use of fertilizer, NPK chemical fertilizers and bio-fertilizer based on algae respectively.
Different letters indicate a significant difference at the probability level of LSD$\alpha$ = 5 %.
The error bars are ± SE.

## 4. Discussion

The cultivation substrate of vermicompost + perlite (70: 30 % v/v) has improved the physical conditions of the soil. In addition, it has provided conditions for the growth and development of ginger. As a consequence, it has increased the biological performance and yield per hectare of ginger (Table 3). Vermicomposts are rich in organic materials which could increase the porosity, aeration, and holding capacity of water. Moreover, they could decrease the density of soil particles and improve the physical properties of soil. Therefore, they significantly can promote better plant growth and performance. Also, vermicomposts contain a large and diverse microbial population which could produce plant growth regulators, enzymes, and useful hormones like cytokinins and auxins for plant growth [12]. Access to sufficient nutrients and water would improve the general condition of soil properties. As a result, it would increase the growth and performance of ginger rhizomes. It is stated that the performance of ginger rhizomes are related to the increase of carbohydrate synthesis, the transfer of photosynthates to the reservoirs, the improvement of soil properties, and the availability of necessary nutrients [13]. A study showed that the use of vermicompost in fennel increased the biological yield (4999 tons per hectare) in comparison to the non-use of vermicompost (1980 tons per hectare). Hence, the use of vermicompost increases the growth rate of fennel due to the increase in water absorption and nutrients such as nitrogen and phosphorus [14]. Ginger requires proper nutrients to maintain its growth and maximum performance. The use of organic fertilizers is one of the cutting-edge technologies which results in restoring soil fertility, stabilizing soil pH, and providing the main plant nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium [15]. The application of integrated sources of nutrients supplies an efficient treatment (50 % N from FYM + 50 % N from VC) which could increase the yield of ginger rhizomes by 58 % [7]. Another study revealed that the use of perlite + peat moss (1:1, v/v) results in obtaining the highest yield of potato mini tubers in the greenhouse with an appropriate environment including EC, pH, and optimal porosity [16].

The cultivation substrates of 70 % manure + 30 % soil + biofertilizer, 70 % vermicompost + 30 % perlite + biofertilizer, and 70 % manure + 30 % perlite + biofertilizer caused the highest ginger harvest index. Furthermore, the application of the combination of 75 % RDN (100 % recommended dose of nitrogen) + 25 % N through vermicompost on an equivalent basis + pine mulch resulted in the highest harvest index with an average of 71.4 in ginger [17]. The consumption of 2.5 kg/ha of biological fertilizers compared to 3.75 and 5 kg/ha led to the highest harvest index with an average of 54.3 in ginger [18].

It seems that the role of fertilizer consumption was more influential than the planting medium in maintaining the quality of essential oil. For instance, the highest and lowest amount of active compounds were obtained in one type of planting medium and with different levels of fertilizer consumption. In all cultivation substrates (except 70 % vermicompost + 30 % perlite), the use of fertilizer has always increased the amount of essential oil compared to the absence of fertilizer (Table 3). The quality of crops is controlled by the complex interaction of environment, genotype, soil type, the ratio of minerals, and using organic fertilizers [19]. It was also found that the highest amount of essential oil was in the combination of azospirulolum + phosphorus + wood ash [20]. Another research shows that organic and inorganic fertilizers could increase the yield of thyme essential oil due to the impact of vital elements such as nitrogen or cation exchange capacity (CEC). These elements might increase the accumulation of nutrients in thyme, which leads to more production of biomass and secondary metabolites [21].

As can be observed in this experiment, 70 % vermicompost + 30 % perlite + biofertilizer resulted in the highest amount of geranial in ginger. It seems that the effect of the type of planting medium on the quality of geranial was more important than the use of fertilizer. Therefore, the highest and lowest percentage of geranial were both obtained through using biofertilizers. It was also observed that the cultivation substrates of 70 % vermicompost + 30 % soil and 70 % vermicompost + 30 % perlite combined with NPK and biological fertilizers increased the percentage of geranial compared to the absence of fertilizer. It was also discovered that the use of both NPK and biological fertilizers in cultivation substrate of 70 % manure + 30 % perlite increased the percentage of $\alpha$-zingiberene in comparison to the non-use of fertilizers (Table 3). Nutrition plays an essential role in the growth and development of all agricultural plants, especially medicinal plants which synthesize essential oils [22]. Organic fertilizers have a positive effect on plant secondary metabolites through the management of fertilization (micronutrients) [23]. A study reveals that the highest percentage of 6-gingerol was obtained after 9 months of growth in coconut fiber ash (coir dust) [24].

In this experiment, planting medium of 70 % vermicompost + 30 % perlite combined with NPK chemical fertilizers produced the highest amount of $\alpha$-zingiberene in ginger (Table 3). Nitrogen increases the synthesis of essential oil, which is directly or indirectly involved in plant metabolism and increases the production of plant metabolites [25]. The investigation of nutrient management (biological, chemical, and organic + biological fertilizers) in ginger revealed that the highest amount of zingiberene with an average of 20.41 % was in the treatment combination of organic + biological fertilizer [26].

As could be seen in this experiment, the use of 70 % manure + 30 % soil combined with biofertilizer caused the highest production of neral in ginger (Fig. 1 and 2). Biofertilizers are more compatible with the environment than mineral fertilizers. Also, they have the same or even better efficiency compared to mineral fertilizers in many cases. In addition, biofertilizers mainly contain nitrogen-fixing, phosphate-solubilizing, and plant growth-promoting microorganisms which could provide more balanced nutrition for plants [27]. Numerous studies on aromatic and medicinal plants have shown that the use of organic fertilizers increases the content of biomass, essential oils, and chemical compounds of these plants [28]. During the examination of organic fertilizers (sheep, cattle, chicken, and chemicals) in lemongrass (*Dracocephalum kotschyi* Boiss.), the highest percentage of neral with an average of 28.2 % was observed in sheep manure [29].

## 5. Conclusion

Fertilizer programs for no-soil or low-soil cropping systems should include all nutrients required by plants. Carbon, hydrogen, and oxygen are supplied from water and carbon dioxide in the air, while nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and micronutrients must be supplied by growers. In this regard, the use of cultivation substrates of organic fertilizers can be effective and reliable. The results of this research also confirm the use of planting materials such as vermicompost and perlite in sustainable agriculture, providing the nutrients needed by the plant and increased the traits. In other words, the use of fertilizer resources (chemical and biological) combined with organic cultivation substrates was effective for the production of essential materials.

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## Ethical considerations

In compiling this work, ethical considerations such as trustworthiness and other ethical principles have been observed in the research.

## Author contribution

Conceptualization: GhA; Data collection and Laboratory analysis: GhA, AM; Interpretation of results: GhA, AM; Writing the original draft: GhA, AM; Writing, review and editing: GhA, AM, HZ. All authors read and approved the article manuscript.

## Conflicts of interest

This study has no conflict with the interests of real or legal persons.

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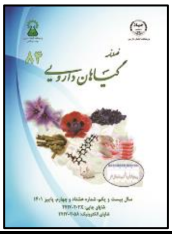

**مقاله تحقیقاتی**

# بررسی تأثیر کودها و بسترهای مختلف کشت بر عملکرد و مواد مؤثره گیاه زنجبیل

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**اطلاعات مقاله**

*گل‌واژگان:*
اسانس
زنجبیل
ژرانیال
نرال
آلفا- زینجیبرن

**چکیده**

**مقدمه:** زنجبیل از خانواده Zingiberaceae، گیاهی گرمسیری و دارای ریزوم‌های گره‌دار است. **هدف:** هدف از این تحقیق بررسی تأثیر مصرف کودهای معدنی و زیستی بر پایه جلبک بر صفات کمی و کیفی گیاه زنجبیل و انتخاب بهترین بستر کشت بود. **روش بررسی:** تیمارهای آزمایشی شامل محیط کشت در چهار سطح و کود در سه سطح بود. اسانس تقطیر شده با آب زنجبیل توسط کروماتوگرافی گازی و کروماتوگرافی گازی متصل به طیف‌سنج جرمی آنالیز شد. **نتایج:** بیشترین میزان عملکرد بیولوژیکی و عملکرد در هکتار در اثر متقابل بستر کاشت ورمی‌کمپوست: پرلیت (۷۰: ۳۰) و عدم مصرف کود مشاهده شد. بیشترین شاخص برداشت به ترتیب در بسترهای کاشت کود دامی: خاک (۷۰: ۳۰) همراه کود زیستی، ورمی‌کمپوست: پرلیت (۷۰: ۳۰) همراه کود زیستی و کود دامی: پرلیت (۷۰: ۳۰) همراه کود زیستی با میانگین ۰/۹ برآورد شد. بستر کاشت کود دامی: پرلیت (۷۰: ۳۰) همراه با مصرف کود شیمیایی NPK بیشترین میزان اسانس را تولید کرد. بیشترین میزان ماده مؤثره ژرانیال در اثر متقابل بستر کاشت ورمی‌کمپوست: پرلیت (۷۰: ۳۰) همراه با مصرف کودزیستی مشاهده گردید. بیشترین میزان ماده مؤثره آلفا- زینجیبرن در اثر متقابل بستر کاشت ورمی‌کمپوست: پرلیت (۷۰: ۳۰) همراه با کودهای شیمیایی NPK مشاهده شد. بیشترین میزان ماده مؤثره نرال در تیمارهای اصلی کود دامی: خاک (۷۰: ۳۰) و تیمار اصلی کود زیستی حاصل شد. **نتیجه‌گیری:** کاربرد منابع کودی شیمیایی و زیستی توأم با بسترهای کاشت آلی با افزایش حاصل‌خیزی بیشتر جهت تأمین رفع نیازهای غذایی زنجبیل جهت تولید مواد مؤثره، مثمر ثمر بود.

*مخففها:* GC-MS، کروماتوگرافی جرمی متصل به طیف سنج جرمی؛ GC، کروماتوگرافی گازی

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