horticulturae

Article

Composition of *Zingiber officinale* Roscoe (Ginger), Soil Properties and Soil Enzyme Activities Grown in Different Concentration of Mineral Fertilizers

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Citation: Jabborova, D.; Choudhary, R.; Azimov, A.; Jabbarov, Z.; Selim, S.; Abu-Elghait, M.; Desouky, S.E.; Azab, I.H.E.; Alsuhaibani, A.M.; Khattab, A.; et al. Composition of *Zingiber officinale* Roscoe (Ginger), Soil Properties and Soil Enzyme Activities Grown in Different Concentration of Mineral Fertilizers. *Horticulturae* **2022**, *8*, 43. https://doi.org/10.3390/horticulturae8010043

Academic Editors: Sławomir Michałek and Marzena Błażewicz-Woźniak

Received: 18 November 2021
Accepted: 23 December 2021
Published: 2 January 2022

Abstract: Ginger is rich in different chemical compounds such as phenolic compounds, terpenes, polysaccharides, lipids, organic acids, minerals, and vitamins. The present study investigated the effect of mineral fertilizers on the content of mineral elements in the rhizomes of *Zingiber officinale* Roscoe, soil enzymes activity, and soil properties in Surkhandarya Region, Uzbekistan. To the best of our knowledge, the present study is the first in Uzbekistan to investigate the mineral elements of ginger rhizome inhabiting Termez district, Surkhandarya region. A Field experiment was conducted at the Surkhandarya experimental station research Institute. Four treatments have been studied (Control with no fertilizers (T-1), $N_{75}P_{50}K_{50}$ kg/ha (T-2), $N_{125}P_{100}K_{100}$ kg/ha (T-3) and $N_{100}P_{75}K_{75}$ + $B_3Zn_6Fe_6$ kg/ha (T-4)). Results showed that T-4 treatment significantly increased ginger rhizome K, Ca, P, Mg, Fe, Na, Mn, Zn, Si, Li, and V content as compared to all other treatments and control. T-3 treatment significantly increased Mo, Ga, and Ag content in comparison to other treatments. Soil enzymes showed a significant increase for all treatments against control, while T-4 treatment has recorded the highest enzyme activity in comparison to all other treatments in urease, invertase, and catalase content. Soil chemical properties have significantly changed for all treatments against the non-cultivated soil and the zero fertilizers plantation with variation among different treatments. Results showed that ginger root is rich in minerals and can be used as a great potential for nutritional supplements and soil enrichment. This study suggest that combination of macro-microelements have the potential to increase the content of mineral elements in the rhizomes of ginger in field conditions.

Keywords: ginger; rhizome nutrients; soil nutrients; catalase; urease; invertase

1. Introduction

During the last five decades, the face of agriculture has been changed because of new technologies in both developed and developing countries [1]. Spices are the main commodities that are useful to increase the agricultural economy of any country due to their high impact value and export potentialities [2]. India is the top country for spices supply in the global market, followed by several other countries, including Indonesia, Malaysia, Pakistan, Australia, Spain, Egypt, and Tanzania. Herbal plants are a major source of traditional medicine and modern medicine and play a major role in the world [3–7]. Ginger is one of the most popular, high valued spices and is well known in human communities of the world [8]. The wet and dry root of ginger is widely used in the medicine and food industry [9]. Among all the spices, ginger is an important cash crop helpful in improving the economic level and livelihood of many farmers and stakeholders, including ginger growers from several countries such as India, Indonesia, Nigeria, and Bangladesh [10].

Ginger (*Zingiber officinale* Roscoe) belongs to the *Zingiberaceae* family, which is a medicinal, herbaceous perennial spice indigenous cash crop native to warm tropical sub-tropical and humid climates, particularly Southeastern Asia, for that placid environment is suitable to flourish it [11]. Presently, India is the top ginger-growing country, followed by China, Japan, Jamaica, Indonesia, Fiji [12]. Ginger is a very much interested and economically important crop to all farmers, consumers, stakeholders, dieticians have attracted growing interest among both dietitians and consumers due to its large amount of uses, such as medicinal and high nutritional value ayurvedic medicine [13]. It is propagated through rhizome and can be grown up at an altitude of 1500 m with well-distributed rainfall [14]. Ginger rhizome crop has been commonly known as Ada, Adrak, Ingwer, and Zingiber in Asia since ancient times, for nearly 3000 years [15–20]. Ginger is an essential and valuable 1.2 m tall perennial herb such as a reed with erect, slender leaves annually grown along with one or more aerial leafy stems having up to 2 cm thick robust, fibrous, and fleshy rhizome with a striated texture. The ginger flesh color varies between red, white, and yellow, while the outer skin is brown in color [21]. Rain-fed and irrigated conditions along with well-drained soils, sandy loam, clay loam, red loam, or lateritic loam are most suitable for ginger cultivation [22]. It is consumed as a fresh and dried form which is very useful in both conventional and herbal medicine for the treatment of digestive tract, vomiting, motion sickness, headache, and nausea [23–25]. Due to antioxidant properties, ginger possesses several health benefits as it has edible oils and fats which protect them against oxidative rancidity [26]. It serves as an antitumorigenic, immunomodulatory effect, antimicrobial, antiviral agent, potent analgesic, a powerful stimulant, heating agent and also controls various diseases such as high blood cholesterol level, blood pressure, nausea and insomnia [20,27–29]. Ginger rhizome is a natural remedy for the treatment of migraine, headaches, and lower LDL cholesterol levels, and increases peristalsis due to its health-promoting properties [30]. As ginger has its medicinal, nutritional and therapeutic value, the demand for supply of ginger is increasing day by day, which is putting a heavy load on the market [31].

The ginger rhizome consists of a high amount of minerals such as phosphorus, potassium, and calcium, which is useful to control many physiological processes and also for health benefits in the human body [32,33]. Finding the best combination of fertilizers that enrich rhizome nutrients and improve soil quality is of high importance to fulfill the market need. Several studies have revealed that NPK fertilizers are important fertilizers for crop yield, production, and enhancement of whole agriculture production and regulate metabolic and regulatory activities of plants [34]. Few studies have examined the impact of mineral fertilizers on the mineral content of ginger rhizomes and the activity of enzymes in the soil.

The present study aims at investigating the effect of mineral fertilizers on macro, micro, and ultra-micro elements in ginger rhizomes. Evaluating the impact of the mineral fertilizers' application on soil chemical properties and enzyme activity is another major goal of the present study. We hypothesized that the combined macro-microelements would facilitate beneficial effects on plant growth, plant nutrients, soil properties and soil enzyme activities.

2. Materials and Methods

2.1. Experimental Design

A field experiment was conducted to study the effect of mineral fertilizers on the mineral nutrients of ginger and soil properties. The experiment was carried out in randomized block design with five replications at the Surkhandarya scientific experimental station of the vegetable, melon crops and potato research Institute (N 37°13′44″, E 67°16′34″), Uzbekistan (Figure 1). Experimental treatments included: Control with no fertilizers (T-1), $N_{75}P_{50}K_{50}$ kg/ha (T-2), $N_{125}P_{100}K_{100}$ kg/ha (T-3) and $N_{100}P_{75}K_{75}$ + $B_3Zn_6Fe_6$ kg/ha (T-4).

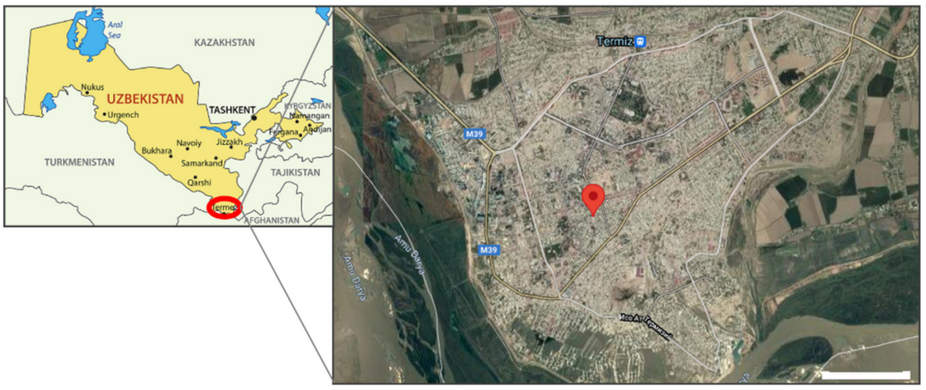

Figure 1. Location of the Surkhandarya scientific experimental station of vegetable, melon crops and potato research Institute, Termiz district, Uzbekistan (google.maps.com, (14 May 2020)).

2.2. Measurement of Plant Nutrients

Ginger rhizomes were harvested after 240 days of cultivation (Figure 2). For six hours, plant samples were disintegrated using hydrogen peroxide and nitric acid in a special microwave oven until they were reduced to their atomic elements for examination. Accurate volumetric measurements were made for the samples before being subjected to the nitric acid solution. The analysis was carried out using an optical emission spectrometer with an inductively coupled argon plasma (2100DV Santa Clara, CA, USA).

Figure 2. Field experiment plantation and rhizomes of ginger after harvest. (**A**) Ginger plant in the field after 20 days. (**B**) Fresh harvested ginger plants. (**C**) Ginger rhizomes after dryness.

2.3. Analysis of Soil Nutrients

Soil samples were collected from a non-cultivated soil (T-0) and from the other four treatments (T-1, T-2, T-3, and T-4). Carbon and organic matter contents of soil were determined according to the method of Tyurin modified by CINAO (CINAO, 2003). Mobile compounds of phosphorus and potassium were determined by Machigin method modified by CINAO [35]. Compounds were extracted by ammonium carbonate in the ratio of 1:20. Total nitrogen, phosphorus, and potassium contents were determined using wet combustion with sulfuric acid, and the measurement was conducted by photo-colorimeter and a flame photometer, respectively [36,37]. The salinity level of soil was determined by water extraction methods [38], with 1:20 ratio, and salinity levels were calculated as the dry mass of salts, including the cations and anions expressed as water dissolved salts.

2.4. Analysis of Soil Enzymes

Urease activity of soil were assayed using the method by [39]. 2.5 g soil sample were added with 0.5 mL of toluene for 15min. Then mixed and added to 2.5 mL of 10% urea and 5mL citrate buffer in incubator at 38 °C for 24 h. Then with 38 °C distilled water diluted, filtered, then 4 mL of sodium phenate and 3 mL of sodium hypochlorite were added to 1 mL filtrate and diluted to 50 mL for 20 min. Urease activity of soil was measured at wavelengths of 578 nm using a spectrophotometer [40]. Urease activity was expressed as NH_4/g of soil/h.

Catalase activity was measured using H_2O_2 as a substrate, shaken for 20 min and the filtrate was titrated with 0.1 mol/L $KMnO_4$; catalase activity was expressed as ml 0.1 mol/L $KMnO_4$/g/h. Catalase activity of soil was measured at wavelengths of 480 nm using spectrophotometer [40].

Invertase activity was determined using sucrose as a substrate and incubation at 37 °C for 24 h, measuring the produced glucose with the colorimetric method, and invertase activity was expressed as mg glucose $kg^{-1}h^{-1}$. Invertase activity of soil was measured at wavelengths of 508 nm using spectrophotometer [40]. Invertase activity was taken as mg of glucose liberated/g soil.

2.5. Statistical Analyses

Data on plant macroelements, microelements and ultra-microelements, soil chemical properties, and enzyme activity have been analyzed using Excel 365 and Minitab 19 (Coventry, UK). Data were cleaned before running any statistical analyses. Data gaps and tyos have been addressed. For each level, five replicates have been used to compute descriptive statistics, such as the mean standard deviation. All Box-Cox assumptions have been tested using the optimal λ method for non-normal dependent variables was applied whenever needed. Different comparisons were carried out using one-way analysis of variance (ANOVA) under fit General linear model in Minitab ver.19.

3. Results

The present study aimed at assessing the effect of cultivating ginger under different treatments on the mineral composition of the growing plants as well as on the soil chemical properties and enzymatic activity.

3.1. Measurement of Plant Nutrients

Different macroelements including K, Ca, P, Mg, and Na have been detected and results showed that ginger rhizome macronutrients have increased under all treatments against control treatment (no fertilizers) from one to two and half folds for some elements. Results showed that T-4 treatment ($N_{125}P_{100}K_{100}$ + $B_3Zn_6Fe_6$ kg/ha) has increased all elements the most, followed by T-3 ($N_{100}P_{75}K_{75}$ kg/ha) and T-2 ($N_{75}P_{50}K_{50}$ kg/ha), respectively, except for calcium increase of T-2 over T-3 treatment. Macroelements results are presented in Table 1.

Different microelements including Fe, Mn, Zn, Cu, Cr, Mo, and Si have been detected in ginger rhizomes and results showed that all elements have increased under all treatment conditions except for chromium where only T-2 and T-4 treatments have produced almost the same chromium concentrations as of the control treatment (T-1) while T-3 showed significant lower concentration than control. All other elements showed significant increase with the highest ratio for the T-4 treatment with over 100% increase in comparison to the control treatment. Results of the microelements under different conditions is presented in Table 2.

Table 1. Mean ± Standard deviation and One-Way ANOVA results of the ginger rhizome macroelements content for the four treatments T-1 (No fertilizers), T-2 (N75P50K50), T-3 (N100P75K75), and T-4 ($N_{125}P_{100}K_{100}$ + $B_3Zn_6Fe_6$). Treatments that do not share superscript letters are significantly different.

Parameter	T-1	T-2	T-3	T-4
K	11,232 ± 4.31 ^{A}	13,322 ± 3.38 ^{B}	15,406 ± 1.85 ^{C}	27,474 ± 9.65 ^{D}
Ca	14,721 ± 2.39 ^{A}	24,570 ± 10 ^{B}	20,719 ± 4.15 ^{C}	35,885 ± 7.21 ^{D}
P	5209.6 ± 6 ^{A}	5544.2 ± 2.1 ^{B}	6592.4 ± 10.3 ^{C}	7542.7 ± 9.02 ^{D}
Mg	5534 ± 2.97 ^{A}	5774.3 ± 8.71 ^{B}	6374.3 ± 0.058 ^{C}	9055 ± 4.58 ^{D}
Na	1555.7 ± 0.972 ^{A}	1890 ± 0.998 ^{B}	1923.4 ± 2.78 ^{C}	3771.4 ± 3.46 ^{D}

Table 2. Mean ± Standard deviation and One-Way ANOVA results of the ginger rhizome microelements content for the four treatments T-1 (No fertilizers), T-2 (N75P50K50), T-3 (N100P75K75), and T-4 ($N_{125}P_{100}K_{100}$ + $B_3Zn_6Fe_6$). Treatments that do not share superscript letters are significantly different.

Parameter	T-1	T-2	T-3	T-4
Fe	375.61 ± 0.995 ^{A}	574.7 ± 7.9 ^{B}	602.35 ± 0.568 ^{C}	645.42 ± 3.06 ^{D}
Mn	69.146 ± 1.001 ^{A}	113.93 ± 2.04 ^{B}	134.18 ± 0.989 ^{C}	171.41 ± 1.58 ^{D}
Zn	3.371 ± 0.04 ^{A}	4.273 ± 0.115 ^{B}	5.262 ± 0.106 ^{C}	5.493 ± 0.005 ^{D}
Cu	2.779 ± 0.009 ^{A}	6.413 ± 0.09 ^{B}	5.242 ± 0.018 ^{C}	5.905 ± 0.005 ^{D}
Cr	1.663 ± 0.095 ^{A}	1.667 ± 0.015 ^{A}	1.452 ± 0.011 ^{B}	1.624 ± 0.005 ^{A}
Mo	0.16 ± 0.01 ^{A}	0.161 ± 0.009 ^{A}	0.261 ± 0.001 ^{B}	0.21 ± 0.01 ^{C}
Si	0.155 ± 0.011 ^{A}	0.213 ± 0.015 ^{B}	0.212 ± 0.012 ^{B}	0.309 ± 0.001 ^{C}

Different Ultra microelements including Li, Be, V, Co, Ga, Ge, Nb, Ag, Cd, In, Sn, Sb, Cs, Ta, W and Re have been investigated in ginger rhizomes. Results showed that indium, titanium, and rhenium were not detected under any treatments while tungsten, cesium, antimony, tin, beryllium, germanium, cadmium, neon remained non significantly different under all treatments. On the other side, lithium, gallium, vanadium, cobalt, and silver were significantly different under different conditions. T-4 has the highest increase in lithium, vanadium, cobalt while T-3 recorded the highest gallium and silver content. Results of the Ultra microelements under different conditions is presented in Table 3.

3.2. Analysis of Soil Nutrients

Soil chemical properties including total and active P_2O_5, total and active K_2O, NO_3, N, Humus, C, C:N ratio, CO_2, total HCO_3, chlorides, sulphates, calcium, magnesium have been determined for all treatments and for a non-cultivated soil. Results showed significant variation under different conditions. Carbon%, sulphates%, Humus%, N%, total and active P_2O_5 showed a constant increase for all treatments against T-0 and T-1 for the favor of T-4 followed by T-3 and T-2, respectively. C:N ratio, CO_2, and chlorides have significantly decreased under all treatments against both T-0 and T-1. Total and active K_2O, NO_3, HCO_3, calcium, and magnesium on the other side showed significant decrease under all treatment conditions against T-0 treatment. Total and active K_2O, NO_3, HCO_3, significantly increased under T2, 3, 4 treatments against T-1 treatment. Calcium and magnesium content under T-2 and T-3 conditions showed significant decrease against T-1 while under T-4 conditions both calcium and magnesium showed significant increase against T-1. Results of the soil chemical properties under different conditions is presented in Table 4.

Table 3. Mean ± Standard deviation and One-Way ANOVA results of the ginger rhizome ultra-microelements content for the four treatments T-1 (No fertilizers), T-2 (N75P50K50), T-3 (N100P75K75), and T-4 ($N_{125}P_{100}K_{100}$ + $B_3Zn_6Fe_6$). Treatments that do not share superscript letters are significantly different.

Parameter	T-1	T-2	T-3	T-4
Li	0.297 ± 0.012 ^{A}	0.29 ± 0.01 ^{A}	0.367 ± 0.002 ^{B}	0.44 ± 0.001 ^{C}
Be	0.02 ± 0.01 ^{A}	0.012 ± 0.002 ^{A}	0.012 ± 0.001 ^{A}	0.014 ± 0.004 ^{A}
V	0.332 ± 0.001 ^{A}	0.489 ± 0.01 ^{B}	0.568 ± 0.002 ^{C}	0.625 ± 0.005 ^{D}
Co	0.119 ± 0.003 ^{A}	0.144 ± 0.001 ^{B}	0.135 ± 0.003 ^{C}	0.155 ± 0.002 ^{D}
Ga	0.313 ± 0.005 ^{A}	0.355 ± 0.005 ^{B}	0.367 ± 0.003 ^{B}	0.314 ± 0.017 ^{A}
Ge	0.002 ± 0.001 ^{A}	0.002 ± 0.001 ^{A}	0.002 ± 0.001 ^{A}	0.002 ± 0.001 ^{A}
Nb	0.001 ± 0.001 ^{A}	0.001 ± 0.001 ^{A}	0.001 ± 0.001 ^{A}	0.001 ± 0.001 ^{A}
Ag	0.015 ± 0.001 ^{A}	0.025 ± 0.002 ^{AB}	0.03 ± 0.01 ^{B}	0.019 ± 0.001 ^{AB}
Cd	0.008 ± 0.001 ^{A}	0.008 ± 0.001 ^{A}	0.008 ± 0.001 ^{A}	0.008 ± 0.001 ^{A}
In	0 ± 0 ^{A}	0 ± 0 ^{A}	0 ± 0 ^{A}	0 ± 0 ^{A}
Sn	0.033 ± 0 ^{A}	0.033 ± 0 ^{A}	0.033 ± 0 ^{A}	0.033 ± 0 ^{A}
Sb	0.013 ± 0.006 ^{A}	0.013 ± 0.006 ^{A}	0.013 ± 0.006 ^{A}	0.013 ± 0.006 ^{A}
Cs	0.003 ± 0.001 ^{A}	0.003 ± 0.001 ^{A}	0.003 ± 0.001 ^{A}	0.003 ± 0.001 ^{A}
Ta	0 ± 0 ^{A}	0 ± 0 ^{A}	0 ± 0 ^{A}	0 ± 0 ^{A}
W	0.003 ± 0.001 ^{A}	0.003 ± 0.001 ^{A}	0.003 ± 0.001 ^{A}	0.003 ± 0.001 ^{A}
Re	0 ± 0 ^{A}	0 ± 0 ^{A}	0 ± 0 ^{A}	0 ± 0 ^{A}

Table 4. Mean ± Standard deviation and One-Way ANOVA results of the soil chemical properties under the four treatments T-1 (No fertilizers), T-2 (N75P50K50), T-3 (N100P75K75), and T-4 ($N_{125}P_{100}K_{100}$ + $B_3Zn_6Fe_6$) and non-cultivated soil (T-0). Treatments that do not share superscript letters are significantly different.

Parameter	T-0	T-1	T-2	T-3	T-4
Active P_2O_5 mg/kg	31.33 ± 0.58 ^{A}	35.3 ± 1 ^{B}	37.6 ± 0.1 ^{BC}	39.5 ± 1 ^{C}	42.6 ± 1.1 ^{D}
Active K_2O mg/kg	351.67 ± 0.76 ^{D}	120.57 ± 1.03 ^{C}	135.66 ± 1.88 ^{B}	140.69 ± 0.09 ^{B}	152.45 ± 1.05 ^{A}
N-NO_3 mg/kg	89.13 ± 1.03 ^{A}	10.25 ± 0.05 ^{E}	28.483 ± 0.9 ^{D}	33.44 ± 0.06 ^{C}	35.12 ± 1.02 ^{B}
Total P_2O_5%	0.19 ± 0.02 ^{A}	0.19 ± 0.01 ^{D}	0.241 ± 0.001 ^{C}	0.21 ± 0.01 ^{B}	0.32 ± 0.02 ^{B}
Total K_2O%	1.87 ± 0.02 ^{CD}	0.837 ± 0.012 ^{C}	0.92 ± 0.02 ^{B}	0.96 ± 0.02 ^{BC}	0.98 ± 0.02 ^{A}
N%	0.09 ± 0 ^{A}	0.124 ± 0.002 ^{D}	0.128 ± 0.001 ^{C}	0.137 ± 0.012 ^{BC}	0.195 ± 0.002 ^{B}
Humus, %	1.7 ± 0 ^{CD}	1.996 ± 0.005 ^{B}	2.02 ± 0.01 ^{B}	2.013 ± 0.015 ^{B}	2.41 ± 0.01 ^{A}
C%	0.98 ± 0 ^{CD}	1.157 ± 0.004 ^{B}	1.172 ± 0.002 ^{B}	1.166 ± 0.006 ^{B}	1.396 ± 0.005 ^{A}
C/N	10.4 ± 0.1 ^{D}	9.367 ± 0.116 ^{C}	9.1 ± 0.3 ^{B}	8.9 ± 0.1 ^{BC}	7.733 ± 0.153 ^{A}
CO_2%	8.92 ± 0.07 ^{A}	6.45 ± 0.05 ^{B}	6.4 ± 0.01 ^{BC}	6.01 ± 0.01 ^{C}	6.013 ± 0.006 ^{D}
Total HCO_3%	0.02 ± 0 ^{A}	0.014 ± 0.004 ^{B}	0.013 ± 0.001 ^{B}	0.011 ± 0.002 ^{C}	0.021 ± 0.001 ^{C}
Cl%	0.09 ± 0 ^{A}	0.008 ± 0.001 ^{B}	0.006 ± 0.001 ^{D}	0.004 ± 0.001 ^{D}	0.005 ± 0.001 ^{C}
SO_4%	0.28 ± 0.01 ^{C}	1.003 ± 0.006 ^{A}	0.98 ± 0.01 ^{B}	0.743 ± 0.006 ^{C}	1.122 ± 0.001 ^{C}
Ca%	0.24 ± 0 ^{A}	0.14 ± 0.01 ^{A}	0.12 ± 0.01 ^{B}	0.133 ± 0.058 ^{B}	0.213 ± 0.006 ^{C}
Mg%	0.06 ± 0 ^{A}	0.032 ± 0.002 ^{B}	0.03 ± 0.01 ^{C}	0.013 ± 0.006 ^{D}	0.054 ± 0.001 ^{C}

3.3. Analysis of Soil Enzymes

Soil enzymes including catalase, invertase and urease have been detected for all treatments. Results showed significant variation ranged between 1.5 and almost five folds increase under different conditions against T-1 for the favor of T-4 followed by T-3 and T-2, respectively. Results of the soil enzyme activity under different conditions is presented in Figure 3.

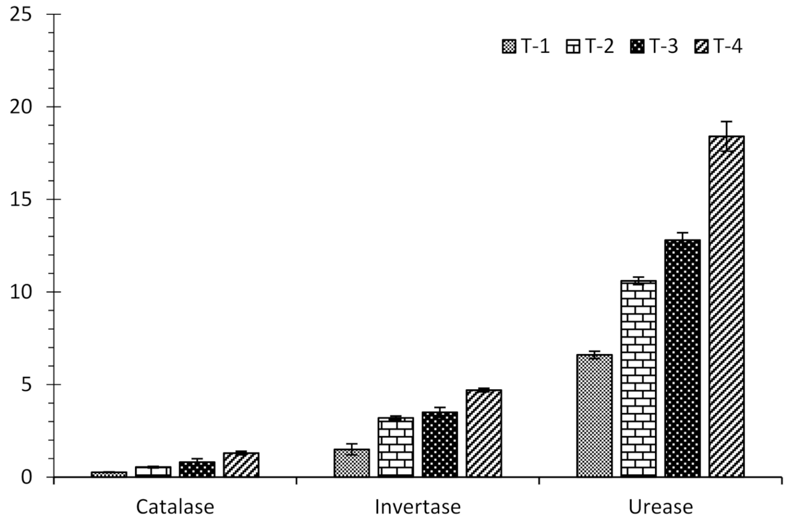

Figure 3. Mean ± Standard deviation of the soil enzyme activity under the four treatments T-1 (No fertilizers), T-2 (N75P50K50), T-3 (N100P75K75), and T-4 ($N_{125}P_{100}K_{100}$ + $B_3Zn_6Fe_6$).

4. Discussion

Many reporters have studied macro-micro elements in plants [41–46]. For the first time, the study of the content of macro-elements and microelements of ginger in the soil climatic conditions of the Surkhandarya Region, Uzbekistan, revealed that N, P, K, Ca, Mg, Na, Mn, Fe, Zn, and Cu are high amount in the rhizome (Tables 1 and 2). Numerous studies have been conducted on analyzing the essential and non-essential metal content of ginger in Nigeria [47,48], India [49], Saudi Arabia [50,51], and Ethiopia [52]. Macro and micronutrient fertilizer NPK + BZnFe applications rate (100:75:75:3:6:6 kg/ha) showed a significant increase in ginger rhizome K, Ca, P, Mg, Na contents over the control (Table 1). Similar findings corroborate increased ginger nutrients such as N content, P content, and K content by the NPK applications rate (100:60:60 kg/h) [53]. Similar results were also observed by Yanthan et al. [54]. Thakur and Sharma [55] reported that mineral fertilizers significantly increased the nutrients in ginger. A large amount of minerals, especially K are beneficial for the successful cultivation of ginger in China, and an imbalance of N, P and K applications revealed low rhizome yield and inferior ginger quality [56,57]. Similar results were obtained in turmeric rhizome after using mineral fertilizer revealed increased nutrients, namely, Na, K, Mg, Ca, Fe in rhizome, which showed the significant effect in plants [58]. Likewise, Kavitha [59] revealed in their study in Kacholam crop and found that maximum rhizome yield obtained with extra nutrients. Earlier, Chhibba et al. [60] also used Fe fertilizer to increase the yield in fenugreek. Halder et al. [61] were observed better growth and yield in turmeric using Zn, Fe, and B, similarly in ginger by Roy et al. [62]. A positive effect of inorganic fertilizers on the uptake of nutrients in ginger was observed by Singh [25].

The purpose of the study was to examine the influence of mineral fertilizers on soil enzyme activity, agrochemical and chemical characteristics in the Termez area of Uzbekistan. According to a number of studies, mineral fertilizers can boost the nutritional content of plants and soils [18,43,45]. The soil's agrochemical qualities were improved by applying mineral fertilizer at various amounts. Soil with mineral fertilizer treatments had considerably lower levels of total P, total K, humus and active phosphorus and potassium than soil with the NPK + BZnFe application rate (100:75:75:3:6:6 kg/ha). Inorganic fertilizers have been shown to have a negative impact on soil nutrients, according to a number of publications [56–58]. Numerous researchers have found that inorganic fertilizers have an effect on soil agrochemical and chemical characteristics [63–65]. According to Dinesh et al. [66], chemical fertilizer management had a favorable effect on the soil's nitrate content in rainfed conditions (*Zingiber officinale Rosc.*). The NPK application rate (100:60:60 kg/h) was found to enhance soil N, P, and K concentrations, according to Yanthan et al. [54]. High mineral fertilizer reduced the N, P, K, Ca, Mg, and Fe concentration in the soil according to Srinivasan et al. [67].

Some enzyme activities such as urease, alkaline phosphatase, and catalase are sensitive to changes in environmental conditions. The hydrolysis of organic matter having nitrogen promote urease activity and show a positive effect with available nitrogen in soil as urease activity is much sensitive for alkaline and saline environment so that it can suggest the soil quality [68,69]. The urease, invertase, and catalase activity in soil was greatly boosted by applying NPK + BZnFe at a rate of 100:75:75:3:6:6 kg/ha (Figure 3). According to Srinivasan et al., the NPK treatment rate of 75:50:50 kg/h was observed to increase soil urease activity by 27.0% [67]. Urease enzyme activity in soil was shown to be stimulated by the application of mineral fertilizers, according to Singh [70] and Allison et al. [71]. The NPK application rate (75:50:50kg/ha) decreased urease activity compared to T-3 and T-4. A previous study by Dinesh et al. [66] showed a reduction in urease activity when the NPK treatment rate was 75:50:50 kg/h. Researchers found that mineral fertilizer boosted soil urease and catalase activity considerably [72,73]. Similarly, Liu et al. [74] revealed that organic fertilizer enhanced urease and catalase activity as compared to chemical fertilizer alone. Chen and Huang (2020) [75] reported that mineral fertilizers increase the invertase enzyme activity in soil. In addition, they observed a positive correlation between soil organic matter or available nitrogen in soil with urease, alkaline phosphatase, and catalase activity, while it was non-significant with soil salinity and pH. However, negative effect was observed with available phosphorus from catalase activity

5. Conclusions

Results of the present study have showed that the NPK + BZnFe application rate of (100:75:75:3:6:6 kg/ha) has significantly enhanced the content macro and micronutrients of the ginger rhizome. The combined application of the NPK + BZnFe (100:75:75:3:6:6 kg/ha) significantly improved soil nutrients and soil enzyme activity. These results suggest that the NPK + BZnFe applications rate of (100:75:75:3:6:6 kg/ha) can be used for producing larger yield with high-quality ginger plants as well as improving soil properties under soil-climate conditions. Results showed that ginger root is rich in minerals and can be used as a great potential for nutritional supplements and soil enrichment. This study suggest that combination of macro-microelements have the potential to increase the content of mineral elements in the rhizomes of ginger in field conditions.

Author Contributions: D.J. have contributed in developing the research ideas, analyzing the data, conducting the research and writing the manuscript; designed the experiments and wrote the manuscript; R.C., A.K., S.S., I.H.E.A., A.M.A., M.A.-E. and A.A. have contributed in writing the manuscript. A.E., S.S., I.H.E.A., A.M.A. and S.E.D. interpreted the data and edited the paper; A.A., S.S., I.H.E.A., A.M.A., M.A.-E. and Z.J. performed the methodology; A.K., S.S., M.A.-E., I.H.E.A., A.M.A. has conducted the statistical analyses and participated in manuscript writing and editing. S.S., I.H.E.A., A.M.A. conceived the funding. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Ministry of Innovational Development of the Republic of Uzbekistan [project number A-ФА-2019-33, 2019–2022].

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The authors extend their appreciation to the Deanship of Scientific Research at Taif University for funding this work through Researchers Supporting Project number (TURSP–2020/27), Taif University, Taif, Saudi Arabia. We thank colleagues at the Institute of Genetics and Plant Experimental Biology, Kibray, Tashkent region, Uzbekistan, for providing necessary support and laboratory and field facilities.

Conflicts of Interest: The authors declare no conflict of interest.

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