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and on soil enzymes activities and soil properties

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Original article
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A B S T R A C T

Ginger is used as one of the important ingredients in traditional as well as modern medicine besides as a spice. It boosts immunity and is a rich source of many biologically active substances and minerals. Although it is a medicinally important crop, its productivity is, however, affected due to poor nutrient management and therefore it requires an adequate supply of nutrients in the form of inorganic fertilizers or organic manuring, or a mixture of both. In this context, the present study was aimed to investigate the effect of mineral fertilizers on the content of mineral elements in the ginger rhizome, on soil enzyme activity, and soil properties. Lysimeter experiments were conducted at the Institute of Genetics and Plant Experimental Biology, Kibray, Tashkent region, Uzbekistan. The experiment comprised of four treatments T1 – Control, T2 - N 75P50K50 kg/ha, T3 - and T4 - N 100P75K75 + B 3Zn6Fe6 kg/ha. The results showed that the application of N 125P100K100 kg/ha increased rhizome K content by 49%, P content by 20%, and Na content by 58% as compared to control without fertilizer. While the application of N 100P75K75 + B 3Zn6Fe6 kg/ha showed a significant enhancement in rhizome K, Ca, P, Mg, Na, Fe, Mn, Zn, Cu, Cr, Mo, and Si contents over the control. This treatment also improved active P content by 29%, total P content by 80%, total K content 16%, and N content by 33% content, and the activities of urease, invertase, and catalase activities as compared to control of without mineral fertilizer and control respectively. Thus the application of NPK + BZnFe at the rate of 100:75:75:3:6:6 kg/ha helps in improving macroelements and microelements in the ginger rhizome and activities of soil enzymes that helps in mineral nutrition of the rhizome.

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1. Introduction

Medicinal plants are a major source of traditional as well as modern medicine and play a major role in the world (Egamberdieva and Jabborova, 2020; Jabborova et al., 2020a; Mamarasulov et al., 2020; Jabborova et al., 2021). Ginger (Zingiber officinale Rosc.) is a spice and medicinal plant belonging to the Zingiberaceae family. Ginger has long been used in folk medicine in India and China. Especially, the wet and dry root of ginger is widely used in the medicine and food industry (Jabborova and Egamberdieva, 2019). It has been used in folk medicine for colds, sore throats, asthma, and joint pain and stimulates appetite (Egamberdieva and Jabborova, 2018). Ginger is also rich in

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beneficial nutrients for example phosphorus, potassium, and calcium, which play important roles in human physiological processes. These substances play an important role in boosting human immunity and maintaining health (Jabborova et al., 2021; Zadeh and Kor, 2014). The dry rhizome of ginger is medicinal contains biologically active compounds. The rhizome contains carbohydrates, fats, proteins, vitamins, minerals, amino acids, monoterpenoids (camphene, sinearil, borneol, citral curcumin, and linalool), gingerol, and sesquiterpenoids.

The spice ginger is one of the most widely used species of the family Zingiberaceae. It is a common condiment for various foods and beverages (Jabborova et al., 2021). Both fresh and dried ginger rhizomes are used worldwide as a spice, and ginger extracts are used extensively in the food, beverage, and confectionery industries (Jabborova and Egamberdieva, 2019; Zingiber officinale, 2010). It is also chiefly used medicinally for indigestion, stomachache, malaria, fevers, common cold, and motion sickness. Besides being a key ingredient in many world cuisines and food processing industry, ginger possesses anti-carcinogenic, antioxidant, and anti-inflammatory properties (Zhao et al., 2016; Grzanna et al., 2005).

The production of this spice has been expanding in most parts of the world, as it can be grown under varied climatic conditions (Asfaw and Demissew, 2009). The productivity of ginger is, however, affected due to poor nutrient management (Dinesh et al., 2012). Effective nutrient management can help in reducing the overuse of chemical fertilizers, thereby safeguarding environmental quality. However, there are very few reports on the influence of different nutrient schedules on ginger yield and quality. Plant-derived foods have the potential to serve as dietary sources for all human-essential minerals (Minerals-Learn, 2010; Lokeshwari and Chandrappa, 2006).

The outcome of this study will ultimately help to ensure the dietary safety of society and improving both the quality and quantity of ginger. This study aimed to determine the levels of mineral nutrients (Minerals-Learn, 2010; Lokeshwari and Chandrappa, 2006). Both fresh and dried ginger rhizomes were assayed according to the method of Guo et al. (2012) and Xaziev and Xaie, 2005), respectively. For the estimation of enzyme activities, a 2.5 g soil sample was added with 0.5 mL of toluene and incubated for 15 min. Then mixed and added to 2.5 mL of 10% urea and 5 mL citrate buffer in an incubator at 38 °C for 24 h. after incubation, it was filtered, then 4 mL of sodium phosphate and 3 mL of sodium hypochlorite were added to 1 mL filtrate and diluted to 50 mL for 20 min. Enzyme activities were measured at 578 nm using a spectrophotometer. Urease activity was defined as the amount of enzyme that liberate NH4 per g of soil per h. Catalase activity was defined as the amount of enzyme that liberate oxygen per g soil while invertase activity was defined as mg of glucose liberated per g soil

2. Materials and methods

2.1. Experimental design

Ginger (Zingiber officinale) rhizome was used for lysimeter experiments. A lysimeter experiment was conducted to study the effect of mineral fertilizers on mineral nutrients of ginger and soil properties. The experiment was carried out in randomized block design with three replications a lysimeter experiments at the Institute of Genetics and Plant Experimental Biology, Kibray, Tashkent region, Uzbekistan. Experimental treatments included

- **T1 - Control**
- **T2 - N75P30K50 kg/ha**
- **T3 - N125P100K100 kg/ha**
- **T4 - N100P75K75 + B2Zn6Fe6 kg/ha**

Rhizomes were sown on 14 March for the year 2019. Harvesting was performed after 8 months of sowing.

2.2. Measurement of plant nutrients

Ginger rhizomes were harvested after 240 days of cultivation. Ginger rhizomes samples were prepared for analysis and were carried out in a special autoclave under the influence of hydrogen peroxide and nitric acid as disintegrating reagents for 6 h using a special microwave oven until the plant samples were converted into atomic elements. Sample volumes were accurately measured and 2% nitric acid (HNO3) was added. The analysis was carried out on an optical emission spectrometer with an inductively coupled argon plasma (2100DV (USA), (Sarabekov et al., 2021).

2.3. Analysis of soil nutrient and soil properties

Soil samples were collected from a lysimeter of the Institute of Genetics and Plant Experimental Biology, Kibray district, Tashkent province. To determination the soil properties before experimenting, soil samples took of soil. The mechanical components of the soil were determined by Kachinsky's method (Tursunov, 2003). Carbon and organic matter contents of soil were determined according to the method of Tyurin modified by CINAO (Soil, 2003). Mobile compounds of phosphorus and potassium were determined by the Machigin method modified by CINAO (Soil, 2005a). The total phosphorus and potassium contents were determined (Soils, 2005b). The total nitrogen content was determined according to the method of Soils (2002). The salinity level of soil was determined by water extraction methods (Pancu and Gauthreyrou, 2006). Analysis of soil properties is shown in Tables 1–3.

2.4. Analysis of soil enzymes

The urease activity, and invertase, and catalase activity of soil were assayed according to the method of Guo et al. (2012) and Xaziev and Xaie, 2005), respectively. For the estimation of enzyme activities, a 2.5 g soil sample was added with 0.5 mL of toluene and incubated for 15 min. Then mixed and added to 2.5 mL of 10% urea and 5 mL citrate buffer in an incubator at 38 °C for 24 h. after incubation, it was filtered, then 4 mL of sodium phosphate and 3 mL of sodium hypochlorite were added to 1 mL filtrate and diluted to 50 mL for 20 min. Enzyme activities were measured at 578 nm using a spectrophotometer. Urease activity was defined as the amount of enzyme that liberate NH4 per g of soil per h. Catalase activity was defined as the amount of enzyme that liberate oxygen per g soil while invertase activity was defined as mg of glucose liberated per g soil

2.5. Statistical analyses

All the experiments were performed in five replicates and the mean values of five replicates were considered. The data were statistically analyzed by one-way analysis of variance (ANOVA) and multiple comparisons of HSD employing the Tukey test with Stat View Software (SAS Institute, Cary, NC, USA). The significance of the effect of various treatments on plant growth parameters, plant nutrients, crop yield, and soil nutrients was determined by the magnitude of the p-value ($p < 0.05 < 0.001$).

3. Results

3.1. Rhizome nutrient contents

Ginger rhizome macroelements increased to NPK applications rate (125:100:100 kg/ha) and NPK + BZnFe applications rate (100:75:75:3:6:6 kg/ha). The NPK applications rate (125:100:100 kg/ha) increased significantly rhizome K content by 48%, P content by 20%, and Na content by 58% as compared to control no fertilizer. However, NPK + BZnFe applications rate
Table 1
The mechanical composition of irrigated soil in the Kibray district.

| Land use types | Size of mechanical particle/mm | Physical mud | The mechanical content |
|----------------|-------------------------------|--------------|------------------------|
|                | 1–0.25 | 0.25–0.1 | 0.1–0.05 | 0.05–0.01 | 0.01–0.005 | 0.005–0.001 | <0.001 |
| Cultivated land | 4.35 | 6.89 | 10.99 | 36.18 | 12.64 | 14.99 | 13.96 | 41.59 |

Table 2
The agrochemical properties of irrigated soil in the Kibray district.

| Land use types | Active phosphorus and potassium, mg/kg | \( \text{N-NO}_3 \), mg/kg | Total, % | N, % | Humus, % | C, % | C/N |
|----------------|----------------------------------------|--------------------------|---------|-----|---------|-----|-----|
|                | \( \text{P}_2\text{O}_5 \) | \( \text{K}_2\text{O} \) | \( \text{P}_2\text{O}_5 \) | \( \text{K}_2\text{O} \) |
| Cultivated land | 33.0 | 481.60 | 95.10 | 0.170 | 0.69 | 0.091 | 1.656 | 0.960 | 10.5 |

Table 3
The chemical properties of irrigated soil in the Kibray district.

| Land use types | \( \text{CO}_2 \), % | Alkalinity | Total \( \text{HCO}_3 \), % | Total \( \text{HCO}_3 \), mg/eq | \( \text{Cl} \), mg/eq | \( \text{SO}_4 \), mg/eq | \( \text{Ca} \), mg/eq | \( \text{Mg} \), mg/eq |
|----------------|------------------|-----------|------------------------|-------------------------|-----------------|-----------------|---------------|---------------|
| Cultivated land | 5.41 | 0.023 | 0.08 | 0.056 | 0.20 | 0.080 | 0.230 | 11.48 | 0.07 | 5.73 |

Table 4
The effect of mineral fertilizers on macroelements content of ginger rhizome.

| Macroelements (mg/kg) | Treatments | Control | \( \text{N}_7\text{P}_{50}\text{K}_{50} \) | \( \text{N}_{125}\text{P}_{100}\text{K}_{100} \) | \( \text{N}_{100}\text{P}_{75}\text{K}_{75} + \text{B}_3\text{Zn}_6\text{Fe}_6 \) |
|-----------------------|------------|---------|-----------------|-----------------|------------------|
| K                     | 10654.457 | 12243.321 | 15889.364* | 20676.535* |
| Ca                    | 2125.117 | 2414.534 | 10963.939* | 20727.670* |
| P                     | 3547.535 | 3791.722 | 4271.406* | 5071.341* |
| Mg                    | 4320.018 | 6185.985 | 8197.549* | 8351.973* |
| Na                    | 2332.383 | 3686.449 | 3479.408* | 4250.860* |

Data are means of three replicates (n = 3). * asterisk differed significantly at P < 0.05.
3.3. Soil enzyme activity

The results showed that mineral fertilizers improved the invertase activity in the soil. The NPK applications rate (125:100:100 kg/ha) had significantly higher invertase activity by 23% than the control without fertilizer (Fig. 2). The maximum invertase activity was recorded in the NPK + BZnFe (100:75:3:6:6 kg/h) treatment. The NPK + BZnFe (100:75:3:6:6 kg/h) treatment increase significant invertase activity by 36% higher compared to control.

Table 5
The effect of mineral fertilizers on microelements content of ginger rhizome.

| Microelements (mg/kg) | Treatments                              |
|-----------------------|-----------------------------------------|
|                       | Control | N125P100K100 | N100P75K75 + B3Zn6Fe6 |
| Fe                    | 178.717 | 196.228      | 225.672*               |
| Mn                    | 78.266  | 80.944       | 118.724*               |
| Zn                    | 2.277   | 2.808        | 3.166*                 |
| Cu                    | 1.317   | 1.720        | 1.727*                 |
| Cr                    | 0.608   | 0.733        | 1.116*                 |
| Mo                    | 0.123   | 0.143        | 0.249*                 |
| Si                    | 0.125   | 0.140        | 0.214*                 |

Data are means of three replicates (n = 3), * asterisk differed significantly at P < 0.05.

Table 6
The effect of mineral fertilizers on ultramicroelements content of ginger rhizome.

| Ultramicroelements (mg) | Treatments                              |
|-------------------------|-----------------------------------------|
|                        | Control | N125P100K100 | N100P75K75 + B3Zn6Fe6 |
| Li                      | 0.261   | 0.264        | 0.264                 |
| Be                      | 0.007   | 0.009        | 0.013                 |
| V                       | 0.234   | 0.302        | 0.777                 |
| Co                      | 0.047   | 0.047        | 0.047                 |
| Ni                      | 0.351   | 0.361        | 0.361                 |
| Ga                      | 0.150   | 0.183        | 0.212                 |
| Ge                      | 0.001   | 0.001        | 0.001                 |
| Nb                      | 0.003   | 0.003        | 0.003                 |
| Ag                      | 0.007   | 0.010        | 0.018                 |
| Cd                      | 0.001   | 0.001        | 0.001                 |
| In                      | 0.000   | 0.000        | 0.000                 |
| Sn                      | 0.116   | 0.239        | 0.370                 |
| Sb                      | 0.008   | 0.009        | 0.009                 |
| Cs                      | 0.002   | 0.002        | 0.003                 |
| Ta                      | 0.000   | 0.000        | 0.000                 |
| W                       | -0.001  | -0.001       | -0.001                |
| Re                      | 0.000   | 0.000        | 0.000                 |
| Hg                      | -0.288  | -0.287       | -0.287                |
| Tl                      | -0.003  | -0.003       | -0.003                |
| Pb                      | 0.092   | 0.093        | 0.065                 |

Data are means of three replicates (n = 3), * asterisk differed significantly at P < 0.05.

Table 7
The effect of mineral fertilizers on the mechanical components of irrigated soil in the Kibray district.

| Treatments                   | Factions, %     | Physical mud (%) | Mechanical content |
|------------------------------|-----------------|------------------|--------------------|
|                              | 1–0.25 | 0.25–0.1 | 0.1–0.05 | 0.05–0.01 | 0.01–0.005 | 0.005–0.001 | <0.001 |
| Control                      | 1.35   | 1.88    | 12.55  | 38.68   | 10.00    | 20.99    | 14.55   | 45.34 |
| N125P100K100                 | 2.05   | 2.00    | 15.40  | 36.53   | 9.20     | 19.60    | 15.22   | 44.02 |
| N100P75K75 + B3Zn6Fe6        | 3.01   | 2.20    | 15.11  | 38.40   | 10.52    | 15.36    | 14.10   | 40.31 |

Data are means of three replicates (n = 3), * asterisk differed significantly at P < 0.05.

Table 8
The effect of mineral fertilizers on agrochemical properties of irrigated soil in Kibray district.

| Treatments                   | Active phosphorus and potassium, mg/kg | N-N2O3, mg/kg | Total, % | N, % | Humus % | C, % | C/N |
|------------------------------|----------------------------------------|---------------|----------|-----|---------|-----|-----|
|                             | P2O5 | K2O |             | P2O5 | K2O |
| Control                      | 34.88 | 245.46 | 12.01 | 0.21 | 0.84 | 0.09 | 1.65 | 0.96 | 9.7 |
| N125P100K100                 | 41.0  | 248.10 | 25.10 | 0.22 | 0.85 | 0.09 | 1.66 | 0.96 | 9.7 |
| N100P75K75 + B3Zn6Fe6        | 42.4  | 254.10 | 36.10 | 0.21 | 0.88 | 0.10 | 1.67 | 0.97 | 9.7 |

Data are means of three replicates (n = 3), * asterisk differed significantly at P < 0.05.
The data indicated that the increased fertilizers combinations of the NPK applications rate (75:50:50 kg/ha), NPK applications rate (125:100:100 kg/ha), and NPK + BZnFe applications rate (100:75:75:3:6:6 kg/ha) enhanced catalase activity in the soil (Fig. 3). The NPK applications rate (125:100:100 kg/ha) and NPK (125:100:100 kg/ha) treatments increased significantly the catalase activity by 27% and 47% compared to control without fertilizer. Combined macro and micronutrients NPK + BZnFe (100:75:75:3:6:6 kg/ha) significantly enhanced the urease activity by 67% compared to control.

### Table 9

| Treatments          | CO₂ (%) | Alkalinity | Cl | SO₄ | Ca | Mg |
|---------------------|---------|------------|----|-----|----|----|
|                     | Total HCO₃ | Total HCO₃, mg/eq | % | mg/eq | % | mg/eq | % | mg/eq |
| Control             | 8.20    | 0.02       | 0.36 | 0.05 | 0.22 | 1.06 | 0.50 | 0.21 | 10.40 | 0.07 | 5.12 |
| N₇₅P₅₀K₅₀          | 7.98    | 0.01       | 0.35 | 0.04 | 0.22 | 1.02 | 0.48 | 0.18 | 9.45 | 0.06 | 4.88 |
| N₁₂₅P₁₀₀K₁₀₀       | 8.15    | 0.23       | 0.32 | 0.03 | 0.21 | 1.00 | 0.46 | 0.17 | 9.88 | 0.05 | 4.62 |
| N₁₀₀P₇₅K₇₅+B₃Z₆Fe₆ | 8.54    | 0.21       | 0.30 | 0.03 | 0.19 | 1.10 | 0.45 | 0.16 | 9.87 | 0.04 | 4.52 |

Data are means of three replicates (n = 3), * asterisk differed significantly at P < 0.05.

Fig. 1. The effect of mineral fertilizers on urease activity of irrigated soil. Data are means of three replicates (n = 3), * asterisk differed significantly at P < 0.05*, P < 0.01**, P < 0.001***.

Fig. 2. The effect of mineral fertilizers on invertase activity of irrigated soil. Data are means of three replicates (n = 3), * asterisk differed significantly at P < 0.05*, P < 0.01**, P < 0.001***.

Fig. 3. The effect of mineral fertilizers on catalase activity of irrigated soil district. Data are means of three replicates (n = 3), * asterisk differed significantly at P < 0.05*, P < 0.01**, P < 0.001***.

### 4. Discussion

#### 4.1. Impact of mineral fertilizers on rhizome nutrients of ginger

Mineral elements are important for human, animal, and plant nutrition. Several scientists have been studied macro–micro elements in plants (Egamberdieva et al., 2016; Egamberdieva et al., 2017; Egamberdieva et al., 2018; Sarabekov et al., 2021). N, P, K are an important role play plant growth, development, and yield productivity (Jabborova et al., 2018; Egamberdieva et al., 2018). The studied ginger rhizomes in this study are a source of macroelements, microelements, and ultramicroelements cultivating in the Tashkent Region, Uzbekistan. For the first time the study of the content of macro-elements and microelements of ginger in the soil climatic conditions of the Tashkent region, Uzbekistan, revealed that N, P, K, Ca, Mg, Na, Mn, Fe, Zn, and Cu are high amount in the rhizome (Tables 4, 5). Many studies have been conducted on analyzing the essential and non-essential metal content of ginger in Nigeria (Obiajunwa et al., 2002; Ogunwande and Olawore, 2004; Aiwonegbie and Ikhuoria, 2007), India (Devi et al., 2008), Saudi Arabia (Al-Eed et al., 2002; Alwakeel, 2008) and Ethiopia (Wagesho and Chandravanshi, 2015). Olubunmi et al. (2013) reported that nutrient analysis of ginger indicated their richness in calcium, magnesium, sodium, potassium, phosphorous, manganese, iron, zinc, and copper. The literature showed that there are no studies on the determination of mineral nutrients in ginger cultivated in Uzbekistan. N, P, and K fertilizers play an important role in plant growth, plant nutrition, and yield. The study showed that The NPK applications rate (125:100:100 kg/ha) enhanced significantly rhizome K content by 49%, P content by 20%, and Na content by 58% as compared to control. 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 4). Similar findings corroborating increased ginger nutrients such as N content, P content, and K content by the NPK applications rate (100: 60: 60 kg/h) were reported by Yanthan et al. (2010). A positive effect of mineral fertilizers on the uptake of nutrients by ginger was observed by Thakur and Sharma (1997). Singh and Singh (2007) reported that enhanced uptake of nutrients in ginger by inorganic fertilizers.

4.2. Impact of mineral fertilizers on agrochemical and chemical properties of soil

Soil nutrients are an important role play for plant growth and yield. Many authors reported that the nutrient contents in soil were analyzed plant cultivating before and after (Jabborova et al., 2019; Jabborova et al., 2020b). In the present study, we used mineral fertilizers application different levels to improve soil agrochemical properties of soil (Table 7). Mineral fertilizer treatments NPK applications rate (125:100:100 kg/ha) and NPK + BZnFe applications rate (100:75:75:3:6:6 kg/ha) was found to increase the soil agrochemical properties such as total P content, total K content, N content, organic matter, active phosphorus, and active potassium compared to the control treatment (Table 7). The impact of inorganic fertilizers on agrochemical and chemical properties in soil was observed by several researchers (McDowell et al., 2004; Fang et al., 2009; Monaco et al., 2008; Wang et al., 2008). This finding is consistent with the report of Dinesh et al. (2012) who observed chemical nutrient management as a positive enhance total N of soil under rainfed ginger (Zingiber officinale Rosc.). Similar findings confirming increased the N content, P content and K content in soil by the NPK applications rate (100: 60: 60 kg/h) was reported by Yanthan et al. (2010). A recent study from Srinivasan et al. (2019) indicated that high mineral fertilizer decreased the N, P, K, Ca, Mg, and Fe content in the soil.

4.3. Impact of mineral fertilizers on soil enzymes

For the first time study of soil enzyme activity in soil cultivation ginger in Uzbekistan. Many studies have been conducted to determine soil enzyme activity in soil under cultivation ginger in India (Yanthan et al., 2010; Dinesh et al., 2012; Srinivasan et al., 2019). The data showed that the NPK + BZnFe applications rate (100:75:75:3:6:6 kg/ha) significantly increased urease (Fig. 1), invertase (Fig. 2), and catalase activity (Fig. 3) in soil. Similar findings confirming the NPK applications rate (75: 50: 50 kg/h) increased the urease activity by 27.0% in the soil as was reported by Srinivasan et al. (2019). This finding confirms earlier studies by Singh (2015) and Allison et al. (2007) both observed urease enzyme activity in soil by mineral fertilizers application. The NPK application rate (75:50:50 kg/ha) decrease urease activity compared to T-3 and T-4. Dinesh et al. (2012) reported that the NPK application rate (75: 50: 50 kg/h) decreases urease activity. The literature showed that there are no studies on the determination of soil enzyme activity in cultivated ginger in Uzbekistan.

5. Conclusion

For the first time in Uzbekistan was studied the content of mineral elements of ginger rhizome cultivating in Uzbekistan. The NPK + BZnFe applications rate (100:75:75:3:6:6 kg/ha) increased significantly rhizome macro and micronutrients N, P, K, Ca, Mg, Na, Mn, Fe, Zn and Cu contents. A higher rate of NPK + BZnFe applications rate (100:75:75:3:6:6 kg/ha) mostly increased soil agrochemical properties total P content, total K content, N content, organic matter, active phosphorus, and active potassium compared to the control and other treatments. The highest activity of urease, invertase, and catalase in soil by the NPK + BZnFe (100:75:75:3:6:6 kg/ha) fertilization rate was observed. The combined application of the NPK + BZnFe (100:75:75:3:6:6 kg/ha) is a better source of nutrient input for obtaining higher ginger yield as well as in sustaining soil fertility under the Uzbekistan soil-climate conditions.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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