EFFECT OF FERTILIZERS ON GROWTH AND ESSENTIAL OIL PRODUCTIVITY OF Coriandrum sativum L. AND Kaempferia galanga L. IN VIETNAM

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Abstract

This study aims to evaluate the effect of different fertilizers on the growth and essential oil productivity of coriander and sand ginger in Vietnam. Nutritional parameters including total N, total P, total K, humus and organic matter concentrations of the cultivated soil samples were suitable for the growth and development of crops. The contents of heavy metals including As, Cd, Pb, Cu, Zn and Hg in the cultivated soil and irrigation water samples were under the allowable value given in Vietnam standards. Under different condition of fertilizing formulas, coriander and sand ginger in formula F3 fertilized with decomposed chicken manure, N, P, K, combined with multi-functional microbial fertilizer gave the highest dry biomass yields (6.91 and 2.10 ton/ha) and essential oil productivities (32.51 and 14.39 L/ha) compared to the formula F1 and formula F2 fertilized only decomposed chicken manure or combined with N, P, K.

Keywords: Coriandrum sativum L., Kaempferia galanga L., fertilizers, essential oil yield.

1. INTRODUCTION

More than 3,000 species belonging to 120 families of higher vascular plants containing essential oils are known in the world, of which many species have been put into use with high value and efficiency. The demand for essential oils in the pharmaceutical, food, chemical and cosmetic industries and in daily life has increased rapidly in many countries around the world, leading to significantly promote oil production and trading activities. The price of essential oils on the world market depends on the quality, production level, and demand (Lawrence, 1994; Lawrence, 1997; Oyen and Nguyen, 1999).

According to Lawrence (1994, 1997) about 1,000 species of plants containing essential oils have been analyzed for chemical composition in the world. Oyen and Nguyen (1999) indicated that over 70 species of essential oil plants in Southeast Asian countries were analyzed for the chemical composition of essential oils, in which about 30 species have been studied relatively comprehensively in terms of biology, ecology, distribution, ability to grow, development, use, pests, yield, trade and chemical composition of the oils. On the basis of these studies, many plant species have been developed to serve as raw materials for commodities or to aid in the chemical synthesis of natural compounds.

Coriander (Coriandrum sativum L.; synonyms: Coriandrum sativum var. afghanicum Stolet., Coriandrum sativum var. africanum Stolet., Coriandrum sativum var. anatolicum Stolet.....) belonging to genus Coriandrum L., family Apiaceae Lindl. is a medicinal - essential oil plant that is famous for many studies on the chemical composition and biological activity of essential oils as announced by scientists (Bhuiyan et al., 2009; Ebrahimii et al., 2010; Khani and Rahdari, 2012; Nurzyńska-Wierdak, 2013; Freires et al., 2014; Mandal and Mandal, 2015; Mohamed et al., 2018).

In Vietnam, coriander is often used as a type of herbs and spices. This species is an essential oil plant and also a valuable medicinal plant (La et al., 2002). Commonly uses of coriander are to treat indigestion, flatulence, spasm, nervous fatigue, rheumatic pain, to help heat dissipation and pain relief (Vo, 2012b). All of the above ground parts of coriander contain essential oil, but the most is the fruit. Coriander is propagated mainly by seeds. In the northern provinces of Vietnam, coriander seeds can be sown from late autumn to mid-winter and early spring. The time for coriander to fully develop, give high fruit yield, and good oil content and quality is from 105 to 125 days. High temperature and drought conditions at fruit ripening stage are optimal for essential oil content and quality (La et al., 2002).

Sand ginger (Kaempferia galanga L.; synonyms: Alpinia sessilis J.Koenig, Kaempferia galanga var. galanga, Kaempferia galanga var. latifolia (Donn ex Homem.) Donn, ...) belonging to genus Kaempferia L., family Zingiberaceae Lindl. is also known as kencur, aromatic ginger, cutcherry, resurrection lily. This perennial, stemless herb is a medicinal - essential oil plant with many uses for life. The main parts of the plant are rhizomes. In the Philippines, the decoction of the sand ginger cures indigestion, malaria, and the leaves are pounded and heated to treat rheumatism. In Malaysia, the rhizome treats high blood pressure, ulcers, asthma, and colds. Some places use the leaves and rhizomes of sand ginger as vegetables (Do et al., 2004). The chemical composition and biological activity of the essential oil of sand ginger have been studied by many scientists (Bhuiyan et al., 2008; Umar et al., 2012; Kumar, 2014, 2020; Liu et al., 2014; Sahoo et al., 2014; Raina et al., 2015; Raina and Abraham, 2015; Li et al., 2017; Yang et al., 2018; Handiati et al., 2019).
In Vietnam, sand ginger is considered as a medicinal herb with spicy taste used as a digestive stimulant, helping to eat delicious, easy to digest, treating abdominal pain, diarrhea, chest pain, toothache, whooping cough, etc. Rhizome of sand ginger is pounded, soaked in alcohol to make massage for headaches, numbness and bone pain, ... Besides, sand ginger is also a valuable source of essential oils in the cosmetic industry (Do, 1995; La et al., 2002; Vo, 2012a). In the northern regions of Vietnam, sand ginger is usually planted in spring and harvested and at the end of the year, when sand ginger is about 1 year old (La et al., 2002).

The promotion of production and improvement of cultivation techniques of essential oil plants are necessary to effectively exploit essential oil resources from plants. In the current context, essential oil-related activities in Vietnam are quite active, many individuals and organizations in Vietnam have focused on producing and trading essential oils at different scales. However, studies related to growing conditions for essential oil plants in Vietnam are still very limited.

Fertilizer is one of the extremely important factors of plants, directly affecting the growth and development of the plant in general and the biochemical processes taking place in the plant. The present study aims to evaluate the effects of different fertilizers on the growth, biomass yields, content and productivity of essential oils of coriander and sand ginger in Vietnam. The study result will contribute to provide the practical basis for the farmers applying better condition of fertilizers for these two crops to get higher economic values.

2. MATERIALS AND METHODS

2.1. Materials

Coriander seeds were bought from Duc Thang Ltd. Company in Hanoi, Vietnam and were sown in November, 2020 in a field in Giai Pham commune, Yen My district, Hung Yen province. Corianders were harvested after 4 months in March, 2021 when their fruits became mature.

Sand gingers were cultivated from tubes of local farmers in February, 2021 under the canopy of pomelo and orange trees in a garden in Tu Dan commune, Khoai Chau district, Hung Yen province. Sand gingers were harvested after 11 months in January, 2021 when their leaves became yellow and dry.

2.2. Experiment set-up

Coriander and sand ginger experiment was set as randomized complete block design (RCBD) with 3 replications for each fertilizer formula (F). Table 1 presents the doses of different fertilizers for coriander and sand ginger in the experiment.

| Table 1. Doses of fertilizers* applied for coriander and sand ginger |
|------------------------|------------|------------|------------|----------|----------|
| **Formula** | **Plant** | **Basal fertilizing** | **Top dressing** | **Top dressing** | **Top dressing** |
|              |            | **DCM (ton/ha)** | **Ash (ton/ha)** | **P (kg/ha)** | **K (kg/ha)** | **N (kg/ha)** | **MFBF (kg/ha)** |
| F1           | Coriander  | 13          | 2.2          | 0           | 0          | 0           | 0          |
| F2           | Coriander  | 13          | 2.2          | 400         | 80         | 100         | 0          |
| F3           | Coriander  | 13          | 2.2          | 400         | 80         | 100         | 0          |
| F1           | Sand ginger| 16          | 3.3          | 0           | 0          | 0           | 0          |
| F2           | Sand ginger| 16          | 3.3          | 850         | 250        | 350         | 0          |
| F3           | Sand ginger| 16          | 3.3          | 850         | 250        | 350         | 100        |

* Based on the book of Do et al. (2004), and the experience of local farmers; DCM = decomposed chicken manure; MFBF = multi-functional microbiological fertilizer.

Decomposed chicken manure (DCM) was bought from Chicken farm in Yen My district, Hung Yen province. Ash, P, K, N fertilizers were bought at the local fertilizer shops. Multi-functional microbial fertilizer (MFBF) was bought from the Institute of Biotechnology, Vietnam Academy of Science and Technology, that contains the following strains of microorganisms with a density of > 10^6 CFU/g in its ingredients: Azotobacter chroococcum, Acetobacter diazotrophicus, Azospirillum brasilense (have the role of nitrogen fixation and synthesis of AIA (Auxin - growth promoter β-indol acetic acid)), Bacillus subtilis, Aspergillus tubingensis (have the role of phosphorus resolution and AIA synthesis).

After 1.5 month of seeding with density of 20×20 cm, corianders in F2 and F3 were fertilized with K, N, and/or MFBF 5 times, once every 7 days until 1 month before harvest. For sand gingers, after 3 months of planting with density of 15×20 cm, plants in F2 and F3 were fertilized with K, N, and/or MFBF 4 times, once every 2 months until 2 months before harvest.

2.3. Methods

Soils before planting were collected according to Vietnam standard TCVN 7538-1 (ISO 10381-1), in the surface soil layer at a depth of 0-20 cm using a small shovel following the diagonal method: 5 soil samples were collected in each study area, with four samples at the four corners of the area and 1 sample at the middle point.
Water used for irrigation in the study area was collected at 3 and 4 points along the area and stored in four 500ml plastic bottles, refrigerated.

The moisture content of soil samples was determined according to Vietnam standard TCVN 4048:2011.

The pH of the soil and water samples was determined using a SI Analytics Lab 845 pH meter.

Soil samples before analyzing nutrients were preliminarily treated according to Vietnam standard TCVN 6647 (ISO 11464) and processed (Le et al., 2001). Soil samples to be analyzed for heavy metals after pretreatment were digested by the US EPA 3052 method using a mixture of HNO₃ (65%) acid and concentrated HF.

Determination of organic matter according to Vietnam standard TCVN 8941:2011 (Walkley-Black method), taking a representative soil sample according to Vietnam standard TCVN 7538-1 (ISO 10381-1); Determination of humus using Chiurin method (Le et al., 2001).

Determination of total N according to Vietnam standard TCVN 6498:1999 (modified Kjeldahl method), of total P according to Vietnam standard TCVN 8940:2011 (colorimetric method “molybdenum blue”) and of total K according to Vietnam standard TCVN 8660:2011.

Analysis of heavy metal content in soil and water samples according to Standard method APHA 2012 using the Inductive Plasma Source Mass Spectrometry (ICP-MS). The heavy metal elements were selected based on the Vietnam Pharmacopoeia V (Ministry of Health, 2017).

Collecting plant samples for analysis: After 4 months of experimental seeding, coriander above ground biomass was harvested using scissors. After eleven months of experimental planting, sand ginger tubers were harvested using a shovel digging deep into the ground. Tubers were shaken off soil and washed under spray water.

Hydrodistillation of essential oils: In this process a total of 1.8-4.3 kg of each of the shredded samples were used for the hydrodistillation. A weighed sample was separately introduced into a 5 L flask and distilled water was added until it covers the sample completely. Hydrodistillation was carried out with a Clevenger-type distillation unit designed according to the specification as previously described (Ministry of Health, 2017) to obtain essential oils. The distillation time was 3.5 h. The volatile oils distilled over water and were collected separately into clean weighed sample bottles.

3. RESULTS AND DISCUSSIONS

3.1. The pH and nutritional parameters of the soil

The pH affects the solubility of nutrients and the activity of microorganisms in the soil (organic degrading, phosphorus solubilizing, nitrogen fixing microorganisms). When the pH range reaches a standard level, plants will thrive because the process of absorbing and exchanging nutrients between the roots and the soil is done smoothly. If the pH of the environment exceeds the physiological limit, the roots will be damaged, inhibiting the nutrient absorption process. Therefore, the determination of the pH value in agricultural soil samples is necessary to assess its suitability for the crop and take corrective measures if necessary. Most important thing to ensure good growth of plant is an adequate nutrient environment, especially macronutrients. The analysis of the content of nutrients in the soil is necessary to have a reasonable fertilizer plan for plants.

The results of analysis of pH and nutrients in soil samples taken in the study field in Giai Pham commune, Yen My district, Hung Yen province before seeding coriander and in the study garden in Tu Dan commune, Khoai Chau district, Hung Yen province before planting sand ginger are presented in the table 2.

Table 2. The pH and contents of nutritional parameters in the soil samples (n = 5)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Coriander growing soil</th>
<th>Sand ginger growing soil</th>
<th>Indicator values</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.98±0.11</td>
<td>6.66±0.14</td>
<td>4.11-7.57</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>0.22±0.02</td>
<td>0.24±0.02</td>
<td>0.095-0.27</td>
</tr>
<tr>
<td>Total P (%)</td>
<td>0.03±0.01</td>
<td>0.10±0.01</td>
<td>0.03-3.35</td>
</tr>
<tr>
<td>Total K (%)</td>
<td>0.04±0.01</td>
<td>0.12±0.02</td>
<td>0.03-3.35</td>
</tr>
<tr>
<td>Humus (%)</td>
<td>2.94±0.10</td>
<td>1.08±0.05</td>
<td>1.00-2.00</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>4.02±0.08</td>
<td>1.33±0.07</td>
<td>1.00-2.85</td>
</tr>
</tbody>
</table>


The average pH values in the coriander and sand ginger soil samples were 5.98 and 6.66, rated as mildly acidic to neutral. At these pH values, plants can grow well and do not need applying amendment materials. The average contents of nutrients including total N, total P, total K, humus, and organic matter in the soil samples ranged from 0.22-0.24 %, 0.03-0.10 %, 0.04-0.12 %, 1.08-2.94 %, and 1.33-4.02 %, respectively. Compared to the data given by Vietnam Standards and document,
all studied soil samples at the time of sampling had pH and concentration of nutrients (N, P, K, humus, organic matter) within the ranges of indicator values in Vietnam soil. Thus, the soils in the researched areas were suitable for the growth and development of plants in general. The application of additional fertilizers (basal fertilizing, top dressing) will be based on the needs of the plant.

3.2. Contents of some heavy metals in the soil

Standard clean agricultural soil in Vietnam must do not contain pollutants, or contains pollutants at concentrations below the allowable limit according to Vietnam standards. Heavy metals are substances that cannot be biodegraded and have very long half-lives. The analysis and determination of the content of heavy metal elements in the soil play an important role in deciding the use of land in cultivation, especially the cultivation of food, vegetable and medicinal plants. In the study area, 5 soil samples at each of two areas were taken to analyze content of 6 heavy metals including As, Cd, Pb, Cu, Zn, Hg. The analysis results are presented in Table 3.

The average contents of As, Cd, Pb, Cu, Zn, Hg in studied soil samples ranged from 5.66 to 8.19 mg/kg, 0.33-0.38 mg/kg, 31.97-36.98 mg/kg, 43.48-44.10 mg/kg, 73.17-78.13 mg/kg, 0.36-0.56 mg/kg, respectively. Compared to the data given by National Technical Regulations, all studied soil samples at the time of sampling contained heavy metal concentrations under the allowable limit according to the National Technical Regulations. Particularly for Hg, there is no limit specified in the National Technical Regulation, but the analysis results showed that the Hg contents in the soil samples were very low (Table 3). Therefore, it can be concluded that at the time of sampling, soils in the studied areas met the standards of heavy metal limit for the purpose of cultivating agricultural crops.

Table 3. Contents of some heavy metals in the soil samples (n = 5)

<table>
<thead>
<tr>
<th>Heavy metals</th>
<th>Coriander growing soil</th>
<th>Sand ginger growing soil</th>
<th>Allowable values(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As (mg/kg)</td>
<td>8.19±2.63</td>
<td>5.66±0.36</td>
<td>15</td>
</tr>
<tr>
<td>Cd (mg/kg)</td>
<td>0.33±0.02</td>
<td>0.38±0.04</td>
<td>1.5</td>
</tr>
<tr>
<td>Pb (mg/kg)</td>
<td>36.98±0.84</td>
<td>31.97±0.71</td>
<td>70</td>
</tr>
<tr>
<td>Cu (mg/kg)</td>
<td>43.48±3.50</td>
<td>44.10±3.12</td>
<td>100</td>
</tr>
<tr>
<td>Zn (mg/kg)</td>
<td>73.17±3.17</td>
<td>78.13±2.82</td>
<td>200</td>
</tr>
<tr>
<td>Hg (mg/kg)</td>
<td>0.56±0.02</td>
<td>0.36±0.02</td>
<td></td>
</tr>
</tbody>
</table>

Note: \(^1\)National Technical Regulation QCVN 03-MT.2015/BTNMT.

3.3. The pH and content of some heavy metals in irrigation water

Table 4. The pH and contents of some heavy metals in the irrigation water samples (n=3-4)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Coriander irrigation water</th>
<th>Sand ginger irrigation water</th>
<th>Allowable values(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.99±0.17</td>
<td>7.40±0.19</td>
<td>5.5-9</td>
</tr>
<tr>
<td>As (mg/kg)</td>
<td>0.001±0.000</td>
<td>0.002±0.001</td>
<td>0.050</td>
</tr>
<tr>
<td>Cd (mg/kg)</td>
<td>0.001±0.000</td>
<td>0.001±0.000</td>
<td>0.010</td>
</tr>
<tr>
<td>Pb (mg/kg)</td>
<td>0.034±0.006</td>
<td>0.027±0.005</td>
<td>0.050</td>
</tr>
<tr>
<td>Cu (mg/kg)</td>
<td>0.057±0.006</td>
<td>0.058±0.006</td>
<td>0.500</td>
</tr>
<tr>
<td>Zn (mg/kg)</td>
<td>0.077±0.006</td>
<td>0.075±0.006</td>
<td>1.500</td>
</tr>
<tr>
<td>Hg (mg/kg)</td>
<td>0.000±0.000</td>
<td>0.000±0.000</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Note: \(^1\)National Technical Regulation QCVN 08-MT.2015/BTNMT (used for irrigation purposes)

Three and four irrigation water samples collected at the canals around the coriander seeding area and sand ginger planting area, were stored in plastic bottles, kept cold and transferred to the laboratory for measure and analysis. The results of pH and contents of some heavy metals in these water samples are presented in Table 4.

The contents of As, Cd, Pb, Cu, Zn, Hg in irrigation water samples collected in the studied areas ranged from 0.001-0.002 mg/L, 0.001 mg/L, 0.027-0.034 mg/L, 0.057-0.058 mg/L, 0.075-0.077 mg/L, and 0.000 mg/L, respectively. The pH values ranged from 6.99-7.40 which is rated as neutral (Table 4). Compared to the values given in the National Technical Regulation, pH values were all in the allowable range, heavy metal concentrations were under the allowable limit for irrigation purposes.

3.4. Effect of some fertilizers on biological yields of coriander and sand ginger

In cultivation, crop yield is one of the most important characteristics related to the economic value of that crop. Biological yield of an interested part of plant is an indicator reflected by its yield constituents such as length, weight, ... The yields of coriander above ground parts and sand ginger tubes in different formulas are presented in Table 5.
So, at the time of harvest, different fertilizers affected the growth and yield of coriander. Fertilizing N, P, K resulted in increasing in the coriander height and fertilizing N, P, K, combined with MFBF resulted in increasing in the coriander yield in comparison to the one without these fertilizers.

The values of length, fresh weight and dry weight of the tube biomass of sand ginger cultivated in formulas F1, F2, F3 were also different (Tables 5). The average length of sand ginger tube was in order F3 < F2 < F1 that ranged from 6.8-8.1 cm/tube. In terms of fresh weight and fresh yield, sand ginger tubes in formula F2 gave the highest values that were 42.1 g/tube and 10.95 ton/ha, followed by the ones in F1 with 41.5 g/tube and 10.80 ton/ha and F3 with 40.6 g/tube and 10.56 ton/ha. However, the dry yield of sand ginger in formula F3 was highest with 2.10 ton/ha, followed by the one in F1 with 2.09 ton/ha and F2 with 1.49 ton/ha. This can be understood because sand ginger tube fertilized with DCM, N, P, K contained higher humidity than those fertilized with only DCM or with DCM, N, P, K, combined with MFBF (Table 5).

In general, fertilizing DCM, N, P, K, in combination with MFBF in formula F3 brought on the highest dry yields of coriander and sand ginger compared to the F2 and F1 fertilized without MFBF or neither N, P, K nor MFBF.

### 3.5. Effect of some fertilizers on essential oil productivity of coriander and sand ginger

In addition to the biomass yields of interested parts crops, the quality of the harvested products is also a very important characteristic related to the economic value of that crop. In case of coriander and sand ginger, their qualities are expressed by the content of essential oils. Based on the yield and oil content, the essential oil productivities of coriander and sand ginger were calculated and presented in Table 6.

The essential oil extracted from the above ground part of coriander in formula F1 that was fertilized with only DCM gave the highest essential oil content of 0.62% calculated on the dry weight basis. Followed by the one in F3 that was fertilized with DCM, N, P, K, combined with MFBF (0.47%) and the one in F2 that was fertilized with DCM, N, P, K (0.32%) (Table 6).

The previous studies indicated that the essential oil content of coriander leaves was 0.1-0.2% (Bhuiyan et al., 2009; Neffati and Marrouzouk, 2009), of the above ground parts ranged from 0.14-0.37% depending on the development stages (Ramezani et al., 2009), of the fruit was 0.2-2.5% (Olle and Bender, 2010; Mahendra and Bisht, 2011). The difference between these previous studies and the present study may due to the different origins, locations, development stages, parts, etc. of investigated coriander (Mandal and Mandal, 2015).

The essential oil content extracted from the tube of sand ginger in formula F2 that was fertilized with DCM, N, P, K gave the highest essential oil content of 0.77% calculated on the dry weight basis. Followed by the one in F3 that was fertilized with DCM, N, P, K, combined with MFBF (0.69%) and F1 that was fertilized with DCM, N, P, K (0.66%) (Table 6).

### Table 5. Biological yields of coriander and sand ginger

<table>
<thead>
<tr>
<th>Formula</th>
<th>Plant</th>
<th>Height/Length (cm/plant, tube)</th>
<th>Fresh weight (g/plant, tube)</th>
<th>Humidity (%)</th>
<th>Fresh yield (ton/ha)</th>
<th>Dry yield (ton/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Coriander</td>
<td>132.0±18.0</td>
<td>94.8±2.2</td>
<td>76.97</td>
<td>18.49±0.43</td>
<td>4.26±0.10</td>
</tr>
<tr>
<td>F2</td>
<td>Coriander</td>
<td>138.1±14.4</td>
<td>107.6±2.9</td>
<td>73.66</td>
<td>21.98±0.57</td>
<td>5.53±0.15</td>
</tr>
<tr>
<td>F3</td>
<td>Coriander</td>
<td>130.7±8.4</td>
<td>144.1±3.8</td>
<td>75.40</td>
<td>28.10±0.75</td>
<td>6.91±0.18</td>
</tr>
<tr>
<td>F1</td>
<td>Sand ginger</td>
<td>8.1±1.3</td>
<td>41.5±1.51</td>
<td>80.67</td>
<td>10.80±0.39</td>
<td>2.09±0.08</td>
</tr>
<tr>
<td>F2</td>
<td>Sand ginger</td>
<td>7.0±1.1</td>
<td>42.1±1.57</td>
<td>86.40</td>
<td>10.95±0.41</td>
<td>1.49±0.06</td>
</tr>
<tr>
<td>F3</td>
<td>Sand ginger</td>
<td>6.8±1.0</td>
<td>40.6±1.40</td>
<td>80.16</td>
<td>10.56±0.37</td>
<td>2.10±0.07</td>
</tr>
</tbody>
</table>

In F2, coriander fertilized DCM, N, P, K, gave the highest height with the average value 138.1 cm/plant. In F3, coriander fertilized DCM, N, P, K, combined with MFBF gave the highest yield with the respective average values of fresh weight, fresh yield and dry yield were 144.1 g/plant, 28.1 ton/ha and 6.91 ton/ha. So, at the time of harvest, different fertilizers affected the growth and yield of coriander. Fertilizing N, P, K resulted in increasing in the coriander height and fertilizing N, P, K, combined with MFBF resulted in increasing in the coriander yield in comparison to the one without these fertilizers.

The previous researches showed that the essential oil content of sand ginger from India was 0.6% (Sahoo et al., 2008), from Bangladesh was 1.05% (Bhuiyan et al., 2008), from China ranged from 0.83-2.19% (Liu et al., 2014; Raina et
al., 2015). The difference between these previous studies and the present study may due to the difference of geographical area, climatic and soil conditions, and may be cultivars within the same species (Munda et al., 2018; Subaryanti et al., 2021).

To evaluate the essential oil productivity of each coriander and sand ginger fertilized with different fertilizers, we calculated the essential oil production per one ha cultivation of each plant species based on biomass yield and essential oil yield (Table 6).

The essential oil of coriander in formula F3 fertilized with DCM, N, P, K in combination with MFBF gave the highest efficiency (32.51 L/ha). Followed by the one in formula F1 fertilized with only DCM (26.47 L/ha) and formula F2 fertilized with DCM, N, P, K (17.77 L/ha).

The essential oil of sand ginger in formula F3 fertilized with DCM, N, P, K in combination with MFBF gave the highest efficiency (14.93 L/ha). Meanwhile, when using only DCM for sand ginger in the formula F1, production of essential oil was 13.27 L/ha, slightly less than the one in F3 but greater than the one in F2 applied DCM, N, P, K (6.34 L/ha).

Thus, fertilizing DCM, N, P, K, in combination with MFBF in formula F3 brought on the highest essential oil productivities of coriander and sand ginger compared to the F1 and F2 fertilized only DCM or combined with N, P, K.

4. CONCLUSION

The pH and concentrations of total N, total P, total K, humus and organic matter of the cultivated soil samples were in the range of indicator values in soil in Vietnam that were suitable for the growth and development of the crops in general and of coriander and sand ginger in particular. The contents of heavy metals in the cultivated soil and irrigation water samples were under the allowable value given in Vietnam standards.

Under different condition of fertilizing formulas, fresh yields and dry yields of coriander varied obviously. In the formula F3 fertilized with DCM, N, P, K, combined with MFBF, yields of coriander obtained highest, followed by the one in F2 and lowest in F1. For sand ginger, the fresh yields changed slightly between fertilizer formulas but the dry yields were different markedly with the one in F2 much lower than the others.

In the condition of this study, fertilizing DCM, N, P, K, in combination with MFBF in formula F3 brought on the highest dry yields and essential oil productivities of coriander and sand ginger. This fertilizer formula provides not only enough nutritional dose but also the microorganisms to promote the breakdown of nutrients into easily digestible forms for plants.

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REFERENCES


25. QCVN 03-MT:2015/BTNMT. National technical regulation on the allowable limits of heavy metals in the soils.


