EFFECTS OF NITROGEN, PHOSPHORUS, POTASSIUM CONTENT ON GROWTH AND ESSENTIAL OIL PROPERTIES OF ROSEMARY (Rosmarinus officinalis L.) GROWN BY SEMI-HYDROPONIC METHOD IN NET-HOUSE

Ngkiem Thi Hue¹, Hoang Thi Hong Nga¹, Chu Thi Thu Ha²,³, Ha Thi Quyen⁴

¹Faculty of Agricultural Technology, VNU University of Engineering and Technology, Vietnam National University Hanoi, 144 Xuan Thuy, Ha Noi, Vietnam
²Institute of Ecology and Biological Resources, Vietnam Academy of Science and Technology (VAST), 18 Hoang Quoc Viet, Hanoi, Vietnam
³Graduate University of Science and Technology, VAST, 18 Hoang Quoc Viet, Hanoi, Vietnam
⁴Email: quyenhath76@gmail.com; quyentht@vnu.edu.vn

Abstract

Rosemary was used popularly in food industry; perfumery, cosmetic and pharmaceutical production. The content and chemical composition of rosemary essential oil were changed by cultivating condition aso by content and type of fertilizer applied. In this study, rosemary was planted on substrate 15% coco peat + 19% sand + 12 % rice husk ash + 12% rice husk + 27% vermicompost + 11% cow manure by semi-hydroponic method in net-house. Then, 4 fertilizer formulas with different N-P-K ratio, including F1 (N-P-K: 100-50-150 ppm); F2 (N-P-K: 150-50-250 ppm); F3 (N-P-K: 100-100-200 and F4 (N-P-K: 150-100-200) were applied. The highest values of plant height, number of branches, fresh and dry biomass were observed in formula F4 with 49.6 cm, 60.25 branches, 1.13 kg, and 0.25 kg, respectively proving that this is the most suitable growing condition. Followed by formula F2 (42.05 cm, 54.95 branches, 1.04 kg and 0.24 kg, respectively). The third was formula F3 (35.15 cm, 47.95 branches, 1.00 kg and 0.21 kg, respectively) and the lowest was formula F1 (35.95 cm, 47.3 branches, 0.8 kg and 0.18 kg). The essential oil content of rosemary in formulas F1, F3 and F4 reached 1.89%, 1.96%, and 1.93%, respectively, were higher than the one in formula F2 (1.56%). The rosemary essential oil content was accumulated in F3 > F4 > F1 > F2. The essential oils of rosemary in 4 formulas had the ability to inhibit 5/7 tested bacterial strains including Staphylococcus aureus, Bacillus cereus, Listeria monocytogenes, Pseudomonas aeruginosa, Salmonella enterica, and did not inhibit Enterococcus faecalis and Escherichia coli. However, at a concentration of 25%, essential oil of F2 did not resist P. aeruginosa and S. aureus, and essential oil of F4 did not resist P. aeruginosa. Antibacterial activity of 4 essential oil samples at both concentrations of 25% and 50% against B. cereus were higher than other strains (except essential oil sample of formula F4 at concentration of 25%). To sum up, the rosemary can be grown by semi-hydroponic method in net-house and the nutrient solution containing N-P-K (150-100-200 ppm) was the most suitable for growth of rosemary.

Keywords: Rosemary, Rosmarinus officinalis L., N-P-K ratio, essential oil, antibacterial activity, antibacterial spectrum.

1. INTRODUCTION

Rosemary (Rosmarinus officinalis L.) is an evergreen shrub belonging to the genus Rosmarinus, family Lamiaceae native to the Mediterranean region (T.K. John, Biota, 2014). Nowadays, Rosemary is cultivated around the world for obtaining essential oil, using as ornamental and spice plant. Rosemary is also used in the food industry; perfumery, cosmetic, and pharmaceutical producing. Essential oil content in rosemary ranges from 1 to 2%, mainly on leaves and flowers (B. Tongnuanchan, S. Benjakul, 2014). Essential oil of Rosemary has many medicinal properties, such as antibacterial activity (B.H. Abdullah et al., 2015; Tong Thanh Danh et al., 2020; D.C. José et al., 2000; R. Hamidpour et al., 2017), anti-cancer, antioxidant, anti-diabetic, anti-depressant, neuroprotective, anti-inflammatory, and anti-obesity (R. Hamidpou et al., 2017). Rosemary has been also used popularly in traditional medicine by stimulating hair growth, reducing uterine menstrual cramps and respiratory system disorders (M.R. Al-Sereiti et al., 2000). Essential oil of rosemary has ability to resist several pathogenic bacteria of both of Gram (-) and Gram (+) groups such as Staphylococcus aureus, Pseudomonas aeruginosa, Listeria monocytogenes, Salmonella enterica, Bacillus cereus, …

In the process of cultivating rosemary like other essential oil plants, the macroelements including Nitrogen (N), Phosphorus (P) and Potassium (K) play a very important role in the growth, biosynthesis, and accumulation of bioactive compounds in plants. (R. Jamshidi et al., 2009; M. Singh & S. Ramesh, 2000; A. Tawfeeq et al., 2016). According to the study of T.H. Boyle et al. (1991), for a fragrant plant like rosemary, the type and content of fertilizer have affected on their growth more than type of soil does. Proper fertilization will increase the chlorophyll content and the speed of metabolic reactions, helping plants grow faster. Many studies have shown that fertilizer type and amount, harvest time, climatic and environmental conditions, and cultivation methods can significantly vary growth rates and essential oil content. A. Tawfeeq et al. (2016) reported that there was a significant difference in yield and quality of rosemary essential oil when organic fertilizer was applied in rosemary cultivation. Another study showed that using vermicompost and nitrogen irrigation at a concentration of 100 ppm had a more positive impact on plant height and number of branches than not using vermicompost or using cow manure combined with nitrogen irrigation at concentrations of 50, 150, 200, 250, and 300 (ppm) (Pham Thi Minh Tam & Nguyen Thi Bich Phuong, 2018). M. Singh & S. Guleria (2013) confirmed that rosemary grew very well on the substrate containing vermicompost (10 tons/ha) and N:P:K fertilizer (100:25:25 kg/ha); yield increased 66.1%, and essential oil content increased 54.9% compared to only applying inorganic fertilizer. H.S. Mostafa (2019) stated the rosemary cultivation by using N:P:K fertilizer (150:100:50 kg/ha) combined with cattle fertilizer (40 m³/ha) increased significantly in plant height, number of branches, and essential oil content compared to using N:P:K fertilizer combined cattle manure at a dose increased or decreased by 2 times. T.H. Boyle et al. (1991) assumed that rosemary was sensitive to fertilizers in high doses.
In addition, the content and composition of fertilizers also affected on the content, composition and bioactivity of compounds in rosemary. When using a combination of four types of fertilizers including organic compost, mineral fertilizer, biofertilizer, and Biogmic, the inhibitory effect of essential oils against bacteria including S. aureus (ATCC 6538), S. epidermidis (ATCC 12228), E. faecalis (ATCC 29212), P. aeruginosa (ATCC 27853), S. typhimurium (ATCC 14028), Proteus mirabilis (ATCC 12453), P. vulgaris (ATCC 8427) and Klebsiella pneumoniae (ATCC 13883) were higher than not using Biogmic or not using Biogmic and biofertilizers (M.A. El-Sibaie et al. (2018). Rosemary essential oil was also evaluated to have antibacterial ability against two species of cyanobacteria (Microcystic aeruginosa and Chorococcus minor) at concentrations of 0.05%, 0.1% and 1.5% (A.M. Najem et al., 2016). In the study of N. Karaca et al. (2023), the main components of rosemary essential oil obtained from different growing regions were identified as 1.8-cineole (47.2-27.5%) and camphor (12.9-27.9%). The MIC value of rosemary essential oil was 2.5 mg/mL, while the MIC value of 1.8-cineole was > 5 mg/mL for strain S. aureus ATCC 11632.

In this report, liquid fertilizers with different concentrations of N, P, K were used to grow rosemary by semi-hydroponic method in a net house for evaluating the influence of N, P, and K content on growth, essential oil content and antibacterial activity of essential oil.

2. MATERIALS AND METHODS

2.1. Materials
- Rosemary seedlings: Choosing rosemary seedlings that are about 10 cm tall and have not yet branched to conduct the experiment.
- Pot for planting: size 25×20 cm.
- Growing substrate: 19% coco peat + 19% sand + 12% rice husk ash + 12% rice husk + 27% vermicompost + 11% cow manure. Growing substrate was mixed and incubated for one month before planting.
- Fertilizer solutions: 4 formulas of nutrient solutions for drip irrigation containing different N, P, K contents (calculated in ppm unit) as follows: F1 (control): N:100; P:100-50-150 (according to Nguyen Hoang Duy Luu & Le, Thien Viet Hung, 2018); F2: N-P-K:150-50-250; F3: N-P-K:100-100-200; F4: N-P-K: 150-100P-200.
- Bacterial strains: including 3 strains of Gram (-): Escherichia coli, Pseudomonas aeruginosa, Salmonella enterica and 4 strains of Gram (+): Enterococcus faecalis, Staphylococcus aureus, Bacillus cereus, Listeria monocytogenes.

2.2. Methods
- Planting rosemary: Rosemary plants were grown in the pots containing substrate as described above and the pots were put in the net-house: 1 plant/1 pot, planting distance 40×40 cm, 30 plants/formula/4.5 m². Each formula was irrigated by nutrient solutions following the 4 mentioned formulas. The auto drip-irrigation system was applied. In the first month, irrigating 80 mL of nutrient solution/plant/day, 4 times/day, divided equally from 7 am to 4 pm. From the 2nd to the 4th month, irrigating 140 mL nutrient solution/plant/day, 7 times/day divided equally from 7 am to 7 pm. After 4 months of experiment, the branches of rosemary were harvested.

The experiment was conducted from February 2023 to June 2023 in a net house at the Experimental Center for Agricultural Technology, Hoa Lac, Vietnam.

- Determining growth indicators:
  Plant height (cm) and number of branches/plant were determined after 4 months of planting.
  Fresh biomass/formula (g) = total weight of 30 plants/formula
  Dry biomass (g) = Fresh biomass×(100 - water content)/100.

- Determining water content: After harvesting, each rosemary sample was measured water content by using A&D Weighing AD-4714A General for purpose moisture determination balance at 105°C for 30 minutes.

- Essential oil extraction: Rosemary essential oil was distilled from fresh biomass by hydrossitillation using Clevenger equipment according to the previous procedure (Ministry of Health of Vietnam, 2017). The essential oils were stored at 4 °C for further studies.
  Essential oil content (% v/w calculated on dry sample weight) = Volume of extracted oil (mL)×100×0.9/Weight of fresh sample (g)×100 (100% - % Water content)².

In which: 0.9 - normal value of essential oil density; 100 - for calculating unit % of essential oil content (the number of mL of essential oil obtained from 100 grams of fresh sample); 100/(100% - % Water content) - for calculating from the essential oil content in the fresh sample to the essential oil content in the dry sample.

- Antibacterial activity test: Essential oil of each experimental formulation was diluted in DMSO at ratios of 25% and 50%. Positive control was 10 mg/mL ampicillin solution. Negative control was DMSO. The antibacterial test was performed by diffusion on agar plates: 100 µL of bacterial culture solution was spread onto a petri dish containing LB medium. Making wells on agar plate with diameter of 8 mm (d). Adding 50 µL of each concentration of diluted essential oil, DMSO, and Ampicillin into respective wells. The plates were stored at 4 °C for 1h for diffusion and then incubated at 37 °C for 24 h. Measuring the diameter of the non-bacteria ring (D, mm). The antibacterial activity was evaluated by D - d (mm).

- Statistical Analysis: Data were analyzed using Microsoft Excel 2016 software. ANOVA analysis of variance was performed for data of plant height and number of branches using SPSS software version 20.0 (IBM Company, Chicago, IL,
USA), IRRIstat 5.0. The difference in mean values was evaluated by the Tukey Post Hoc test and Tamhance’s T2 Post Hoc test at a 5% significance level.

3. RESULTS AND DISCUSSION

3.1. Effect of N, P, K contents on height and number of branches of Rosemary

The effect of N, P, K contents on rosemary plant height was presented in Figure 1.

The result showed that formula F4 exhibited the highest plant height (46.9 cm), followed by F2 (42.05 cm) and F1 (36.65 cm), and the lowest value is formula F3 (35.15 cm). Statistical analysis of plant height of F4 compared to F3, F2, and F1 or of the formulas pair F3 and F2, F2 and F1 showed significant differences with p-value < 0.01. However, the difference between F1 and F3 was not significant. The plant height in this study was higher than the studies of T.H. Boyle et al. (1991) and G. Mwithiga et al. (2022) due to the different fertilizer contents and types, and fertilization times applied. According to the study of T.H. Boyle et al. (1991), the using liquid fertilizer NPK with ratio of 20N:4.3P:16.7K, dosage of 150 mg N/liter/time/week resulted in the highest plant height of rosemary (39 cm) but lower than the F4 formula (46.9 cm) and F2 (42.05 cm) of the present study. G. Mwithiga et al. (2022) found that the plant height of rosemary increased 23.3 cm and 22 cm after 180 days of cultivation using cow manure and cow manure (Cm) combined with NPK (Cm + NPK), respectively. However, our study revealed that the plant height increased 25.15 cm, 26.65 cm, 32.05 cm and 36.9 cm, respectively, in F3, F1, F2 and F4 treatments. The increasing in plant height of the fertilizer formulas in the current study may be due to N:P:K ratio being used appropriately, along with the adding vermicompost in the growing substrate.

In addition, compared to control formula F1, formulas F4, F3, and F2 gave significantly higher number of branches/plant (60.25, 47.95 and 54.95 compared to 47.30 branches/plant). The number of branches/plant between formulas was significantly different at p-value < 0.01 except between F1 and F3. The number of branches/plant in this study was higher than previous researches by G. Mwithiga et al. (2022) and H.S. Mostafa (2019). According to the study of G. Mwithiga et al. (2022), after 180 days of planting with Cm and Cm + NPK, number of branches/plant were 33.1 and was 30.8 branches. In the study of H.S. Mostafa (2019), the highest number of branches was only 40.32 branches. The increase of plant height and number of branches in the different fertilizer formulas in the current study was greater than that in the previous studies mentioned above. It may be because this study used fertilizer with more reasonable N:P:K ratio, also used growing substrate mixing with vermicompost and cow manure, so this could be more suitable for the growth of rosemary. Formulas F4 and F2 containing 150 ppm N content, while formulas F1 and F3 containing 100 ppm N content and the plant height and number of branches of F4 and F2 were higher than F1 and F3. This can be seen that the N content of 150 ppm was appropriate to the growth of rosemary in this study. In general, using a nutrient solution with ratio of N:P:K as in formula F4 was very suitable for rosemary grow under the semi-hydroponic condition in the net-house.

![Figure 1. Effect of N, P, K content on height and number of branches of Rosemary](image1.png)

**Figure 1.** Effect of N, P, K content on height and number of branches of Rosemary

*Note: Different letters on the column in the same indicator (plant height, number of branches) represent statistically significant differences with p-value < 0.05.*

![Figure 2. Rosemary in the experiment](image2.png)

**Figure 2.** Rosemary in the experiment
3.2. Effect of N, P, K content on biomass of rosemary

All branches of rosemary in each formula were harvested to determine biomass after four months of planting. The average fresh biomass in formula F4 was the highest (37.56 g/plant and 1.13 kg/formula), followed by F2 (34.56 g/plant and 1.04 kg/formula), F3 (33.17 g/plant and 1.00 kg/formula), and F1 was the lowest (26.52 g/plant and 0.80 kg/formula). Statistical analysis showed that the difference in average fresh biomass values in formulas F3 and F2 are not significant, while the difference in fresh biomass of formula F4 compared to the remaining formulas was significant with p-value < 0.05, and the difference between formulas F2 and F3 compared to F1 was also significant.

Table 1 showed that the water content of rosemary in formula F3 was the highest (78.9%) and formula F2 was the lowest. The difference of plant water content among formulas F4, F2, and F1 (77.60%, 76.9%, and 77.20%) was insignificant. From the water content, the dry biomass of rosemary in each formula was determined, in which the dry biomass of F4 still reached the highest value (0.25 kg), followed by F2 (0.24 kg), F3 (0.21 kg) and F1 was still the lowest (0.18 kg). Thus, formula F4 with NPK ratio of 150-100-200 and formula F2 with NPK ratio of 150-50-250 appeared more suitable for the growth of rosemary in semi-hydroponic growing condition in the net-house. More specifically, the N concentration of 150 ppm was appreciate for rosemary growing in the early stages (from seedling) and growing by semi-hydroponic method in the net-house.

Among the surveyed fertilizer formulas, formulas F3 and F4 contained the same amount of P and K contents (100 ppm and 200 ppm, respectively), only different in N content (100 ppm and 150 ppm, respectively). However, the plant height, number of branches, and biomass of F3 were all much lower than those of F4. This proved that P and K nutrition did not much impact on the growth in the early stage of rosemary (about 4 months of growing from seedlings). This is also further confirmed when the plant height, number of branches, and rosemary biomass in formula F2 (N content of 150 ppm, P content of 50 ppm, and K content of 250 ppm) were only behind formula F4.

Table 1. Effect of N, P, K contents on biomass of Rosemary

<table>
<thead>
<tr>
<th>Formula</th>
<th>Fresh Weight of Plant (g/plant)</th>
<th>Fresh biomass (kg/formula)</th>
<th>Water Content (%)</th>
<th>Dry biomass (kg/formula)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>26.52±0.98&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.80</td>
<td>77.20±0.75&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.18</td>
</tr>
<tr>
<td>F2</td>
<td>34.56±1.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.04</td>
<td>76.90±0.81&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.24</td>
</tr>
<tr>
<td>F3</td>
<td>33.17±0.82&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.00</td>
<td>78.90±0.50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.21</td>
</tr>
<tr>
<td>F4</td>
<td>37.56±1.25&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.13</td>
<td>77.60±0.79&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.25</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>2.30</td>
<td>1.62</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Mean values followed by the different letter within a column are statistically different for 0.05 significant level.

3.3. Effect of N, P, K content on essential oil content of rosemary

To determine the effect of N, P, K contents on the essential oil content of rosemary, essential oil was extracted from the rosemary samples of 4 formulas using the hydrodistillation method. The essential oil content of each formula was presented in Figure 2. After 4 months, rosemary in the formulas F3 and F4 achieved essential oil content of 1.96% and 1.93%, respectively, higher than F1 (control formula) (1.89%). Meanwhile, the essential oil content of the formula F2 was much lower than other formulas. Among 4 formulas, the difference between formula F2 and the others was formula F2 containing the highest K content (250 ppm compared to the one in remaining formulas ≤ 200 ppm). This may be the reason that the essential oil content of formula F2 was the lowest (1.56%). Thus, rosemary can accumulate essential oils with a higher content when using hydroponic nutrition with N content from 100ppm to 150ppm, P content from 50 ppm to 100 ppm, and K content from 150 to 200 ppm. According to the study of G. Mwihiga et al. (2022), the essential oil contents of rosemary were only 0.45-0.59% (v/w) after 180 days of planting, that were much lower than the essential oil content in this study after four months of planting.

Figure 3. Effect of N, P, K contents on essential oil content of rosemary

3.4. Antibacterial activity of essential oil samples obtained from experimental formulas

The content and composition of fertilizers have affected the chemical composition of rosemary essential oil and essential oil of rosemary has been known to have the ability to resist both G (+) and G (-) bacterial strains (M.A. El-Sibaie et
The antibacterial activity of 4 essential oil samples in this experiment was presented in Table 2. All of the essential oil samples inhibited against 5 strains of bacteria, including *P. aeruginosa*, *S. enterica*, *S. aureus*, *B. cereus* and *L. monocytogenes* except 2 strains of *E. faecalis* and *E. coli*. In addition, at concentration of 25%, the essential oil of rosemary in formula F2 did not inhibit *S. aureus* and *P. aeruginosa*, and the essential oils of rosemary in formula F4 did not inhibit *P. aeruginosa*. This result was even more confirmed when using Ampicillin antibiotic as the positive control sample at concentration of 10μg/mL (Ampicillin exhibited antimicrobial activity against all test bacterial strains).

For essential oil samples at concentration of 50%, the antibacterial ability of rosemary essential oil in formula F1 against *B. cereus* was the highest, followed by *L. monocytogenes* and *S. enterica* (the diameter of the non-bacteria zone reached 40.63 mm, 30.88 mm and 24.38 mm, respectively). The essential oil sample of rosemary in formula F2 also showed the highest resistance to *B. cereus*, followed by *L. monocytogenes* and *S. enterica* (the diameter of the non-bacteria zone reached 35.65 mm, 19.13 mm and 18.18 mm, respectively). In formula F3, *B. cereus* showed the most sensitive possibility to essential oil samples, followed by *S. enterica* and *L. monocytogenes* (the diameter of the non-bacteria zone reached 37.06 mm, 25.19 mm and 17.63 mm, respectively). In formula F4, the antibacterial ability of essential oil was also the highest against *B. cereus*, followed by *S. enterica* (the diameter of the non-bacteria zone was 37.06 mm and 24 mm). Thus, all the essential oil samples of rosemary in 4 fertilizer formulas had the highest resistance to *B. cereus*.

For *B. cereus*, rosemary essential oil in formula F1 at concentration of 50% had the highest bacterial inhibition zone (40.63 mm), followed by F3 (37.06 mm), F2 (35.65 mm), and F4 (26.63 mm); For *L. monocytogenes*, essential oil in formula F1 had the highest bacterial inhibition zone (30.88 mm), followed by F2 (19.13 mm), F3 (17.63 mm), and F4 (15.88 mm); For *S. enterica* bacteria, essential oil in formula F1 had the highest bacterial inhibition zone (24.38 mm), followed by F3 (25.19 mm), F4 (24 mm) and F2 (18.18 mm).

At a concentration of 25%, *B. cereus* was more sensitive to essential oil samples in formulas F1, F2, and F3 (non-bacterial zones were 36.25 mm, 35.67 mm, and 27.33 mm, respectively); *L. monocytogenes* was more sensitive to essential oil samples of F2 and F4 (16.25 mm and 11.50 mm), and *S. enterica* was more sensitive to essential oil samples of F1 and F3 (24.38 mm and 25.19 mm).

The difference in antibacterial activity between essential oil samples for each tested bacterial strain showed that the NPK ratio changed the properties and composition of rosemary essential oil, leading changes of the antibacterial activity. The essential oil samples of 4 formulas are resistant to 6/7 strains of investigated bacteria at 50% concentrate.

### Table 2. Effects of nutritional formulas on antibacterial activity

<table>
<thead>
<tr>
<th>Inhibition zone (mm)</th>
<th>DMSO</th>
<th>Ampicillin 10 mg/mL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concentration</strong></td>
<td></td>
<td>25%</td>
</tr>
<tr>
<td><strong>Gram positive bacteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Enterococcus faecalis</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>39±1.20</td>
<td>1.75±0.35</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>0</td>
<td>37±0.95</td>
</tr>
<tr>
<td><em>Bacillus cereus</em></td>
<td>0</td>
<td>41±1.70</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>0</td>
<td>40±1.20</td>
</tr>
<tr>
<td><strong>Gram negative bacteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>0</td>
<td>39±0.72</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>0</td>
<td>38±1.5</td>
</tr>
<tr>
<td><em>Salmonella enterica</em></td>
<td>0</td>
<td>40±1.3</td>
</tr>
</tbody>
</table>

(−) No appeared non-bacterial zone.
2. Antibacterial activity, formula F4 containing NPK ratio of 150, e and nitrogen fertilizer different NPK content. Experimental results showed that rosemary grew well under the above described planting conditions. The first, formula F4 containing NPK ratio of 150-100-200 ppm represented the most suitable with growth of rosemary because it gave the highest plant height, number of branches, fresh and dry biomass (49.6 cm and 60.25 branches, 1.13 kg, and 0.25 kg, respectively). The second was formula F2 with NPK ratio of 150-0-200 ppm (plant height, number of branches, fresh and dry biomass were 42.05 cm, 54.95 branches, 1.04 kg and 0.24 kg, respectively). However, the essential oil content of formulas F1 (NPK ratio: 100-50-150), F3 (NPK: 100-100-200), and F4 (reaching 1.89%, 1.96%, and 1.93%, respectively) was higher than the essential oil content of formula F2 (1.56%). Characteristics of rosemary essential oil grown by using different nutritional formulas have changed significantly through their antibacterial activity against some tested bacterial strains: All essential oil samples (1.56%).

REFERENCES


