Effect of organic and chemical fertilizers on morpho-physiological and biochemical properties of ajowan (Trachyspermum ammi L.)

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Abstract
Organic fertilizers play a significant role in organic systems and sustainable soil management. In general, organic fertilizers increase soil fertilization and can reduce the negative effects of the excessive use of chemical fertilizers and synthetic man-made fertilizers. This study was carried out in the Medicinal Plants Farm of Shahid Bakeri Higher Education Center of Miandoab during summer 2017. Thus, the main objective of the present investigation was to study the effect of organic and chemical fertilizers on the morpho-physiological features (diameter of plant, plant height, number of branch, 1000-seed weight, and seed yield), biochemical contents (amount of N, P, K, Soluble sugar, Carotenoids, Chlorophyll a, b, total phenol content, and Proline content) and essential oil content of ajowan. Results showed that the fertilizers could significantly enhance all determined factors as compared to control samples. Vermicompost had a better effect than the chemical fertilizer in some factors including total phenol, chlorophylls, carotenoids, total soluble sugar, nitrogen, phosphate, and potassium contents (P<0.05). The vermicompost as a potential source of plant nutrients for sustainable ajowan production can reduce health and environmental problems.

Keywords: Compost, Cow manure, total phenol, Trachyspermum ammi (L.), Soluble sugar, Vermi-compost.


Introduction
Ajowan (Trachyspermum ammi L.) is a medicinal plant that belongs to Apiaceae family with valuable secondary metabolites. The most valuable part of the ajowan in the food and pharmaceutical industries is its seeds (Rahimmalek et al., 2017). Ajowan seeds are widely used as spice in the curry powder because of their aromatic odor and spicy taste (Ishikawa et al., 2001). Ajowan seeds have an essential oil that contains about 50% thymol, which has a strong germicide, anti-spasmodic, and fungicidal effect (Noori et al., 2017). Different studies reported different components for essential oil of ajowan (Rasooli et al., 2008).

Chemical fertilizers are applied to soils to compensate for poor nutrients. However, this could lead to several problems such as water, air and, soil pollution.
Organic materials are eco-friendly natural sources. The idea behind applying these products is to overcome the disadvantages of the chemical fertilizers and development of agriculture (Mondal et al., 2017). A category of organic fertilizer, vermicompost treatment increases nutrient content and the main essential oil ingredients of the medicinal plants. Salehi et al. (2018) examined the impact of different chemical and organic fertilizers on German chamomile yield and essential oil composition. This experiment came up with the result which demonstrated that application of fertilizers especially vermicompost is among the main reasons which can limit herbage growth, yield and, quality. Based on this report, biochemical and physiological parameters improve under the influence of growth regulating agents which in turn increases the quantity and quality of essential oils in the herbage industry (Bano et al., 2016).

One of the best methods that have been identified today for sustainable agriculture, environmental protection against contamination, and reduced use of chemical fertilizers is organic farming. The purpose of application of organic fertilizer to the soil is to increase organic matter and soil fertility in the long run and plant production (Abadi et al., 2011).

This survey is done to specify the efficacy of fertilizers with different sources known as organic and chemical, on growth, flowering, and fruiting of ajwain plant (Trachyspermum ammi) in a soil with high pH to obtain a comprehensive view about this subject and to get new insights on the shifting from conventional nutrient management system to integrated nutrient management system.

Materials and Methods

Soil characteristics

This study was carried out on a silt loam soil (Table 1) during summer 2017. Hydrometer method was used for determination of soil texture (sand, silt, and clay contents) (Bouyoucos, 1962). Moreover, pH meter, electrical conductivity (EC), and the wet oxidation method were employed to identify pH, EC, and organic matter (OM), respectively (Nelson and Sommers, 1996). The total nitrogen (N) was assayed using the method described by Bremner (1996). Moreover, available phosphorus (P) and potassium (K) were determined according to the procedure reported by Olsen (1954) and Helmke and Sparks (1996), respectively.

Statistical Analysis

The experiment was set in a randomized complete block design (RCBD) with three replications. Analysis of variance was performed using SPSS software package, and the means were compared using Duncan test (p ≤ 0.05).

Experimental site, soil preparation, planting, and harvesting

All experiments were done in the Medicinal Plants Farm of Shahid Bakeri Higher Education Center of Miandoab (36.5°N latitude, 46.6°E longitudes, and an altitude of 1314 meters above the sea level). Seeds of ajowan (Trachyspermum ammi) were planted in the prepared field at a depth of about 10-mm with a spacing of 4 cm and a row spacing of 50 cm. Seeds were carefully irrigated after planting. During the preparation of the field and the period of plant growth from planting to harvesting, no chemical fertilizers, herbicides, pesticides, and fungicides were used. The plants were harvested at the seed stage for relevant assays.
Effect of fertilizers on ajowan (*Trachyspermum ammi* L.)

### Essential oil extraction

The essential oil of the air-shade dried ajowan samples were extracted using the hydrodistillation in a Clevenger based on the method described by Tarakemeh et al. (2012). Briefly, the dry samples (50 g) were weighed, powdered, and subjected to Clevenger for 4 hours. The extracted essential oil was then dehydrated using anhydrous sodium sulfate. The collected samples were analyzed by gas chromatography mass spectrometry after being placed in hermetical glass vials at 4°C. The extracted essential oil was calculated by following equation (Tarakemeh et al., 2012):

\[
\text{Yield (\%)} = \left( \frac{\text{mass content of essential oil}}{\text{leafs dry weight (mass)}} \right) \times 100
\]

### Proline analysis

Proline content of leaf tissues was determined using the method described by Rowshan et al. (2014). Briefly, the homogenized fresh tissue of plant in 10 ml of aqueous sulphoacetic acid (3%) was weighed to 5 g. Filtration of the obtained suspension was done via Whatman filter paper Grade 1. Two ml of acid-ninhydrin and concentrated acetic acid were mixed with equal volume of the filtrated sample in a test tube. Four ml was added to test tube, and then the absorbance of the sample was measured at 520 nm through a spectrophotometer following shaking (UV Jenway 6300). The free proline content was measured using L-proline standard.

### Total phenol content

Following the method presented by Gao et al. (2000), the total content of phenolic compound was measured using Folin–Ciocalteu (FC). Then, 0.1 gram of each samples were ground in 2 ml methanol and centrifuged at 5000 g for 10 minutes at room temperature. Afterward, 50 μl of the resulting extract, 450 μl distilled water, and 2.5 ml 10% Folin–Ciocalteu reagent were mixed. The mixture was kept in a dark place for 6 minutes. Then, 2 ml of 7.5% (w/v) Na₂CO₃ was added. The solution was incubated at room temperature in the dark for 1.5 h and the absorbance was recorded at 765 nm with a spectrophotometer. Gallic acid was used as standard and the values were presented as milligram GAE (Gallic acid standard) equivalents per g of dry weight (mg GAE/g dw).

### Chlorophylls and carotenoids: Pigments of photosynthetic bio membranes

The extracted chlorophyll and carotenoid contents of the leaf tissues were determined using the method described by Arnon (1949). Before extraction, fresh leaf samples were rinsed in clean deionized water for the removal of surface contaminations. Photosynthetic pigment was extracted from the 4th fully expanded leaves from the top of the plant at the end of the experimental period. Then, 0.1 g of a fresh leaf was ground in 5 ml 80% (v/v) acetone in dark. Afterward, the filtrate slurry was centrifuged at 5,000 x g for 10 min. Then, the absorbance of the sample was determined at 645, 663, and 470 nm against acetone as blank with a spectrophotometer, for Chlorophyll a, Chlorophyll b, and carotenoids concentrations, respectively.

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### Table 2

Results of variance analysis of the effects of fertilizer treatments on the quantitative traits of ajowan

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Plant height</th>
<th>Diameter of stem</th>
<th>1000-seed weight</th>
<th>Seed yield</th>
<th>Essential oil %</th>
<th>Essential oil yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer treatment</td>
<td>4</td>
<td>84.527**</td>
<td>2.552**</td>
<td>0.015</td>
<td>1241.382*</td>
<td>0.931**</td>
<td>62.005**</td>
</tr>
<tr>
<td>Replication</td>
<td>2</td>
<td>0.254ns</td>
<td>0.007ns</td>
<td>0.003</td>
<td>91.008ns</td>
<td>0.005ns</td>
<td>0.116ns</td>
</tr>
<tr>
<td>Error</td>
<td>8</td>
<td>0.776</td>
<td>0.003</td>
<td>0.002</td>
<td>22.258</td>
<td>0.004</td>
<td>0.317</td>
</tr>
</tbody>
</table>

ns, *, and ** non-significant and significant at 5 and 1% probability level, respectively.
Plant height and diameter of stem

After harvest, stem diameters were measured by a caliper at three points: center and two ends of the plant and the average of the three points were recorded. The plant heights were also measured by a tape measure. The number of branches, and seed yield were determined.

Soluble carbohydrate content

Soluble carbohydrates were determined based on phenol sulfuric acid method. First, 100 mg of the weighed samples were put into a boiling tube containing 5 ml of 2.5 N-HCl. The tubes were placed in a water bath for 3 hours. Upon completion of hydroxylation, the samples were cooled to room temperature. Solid sodium carbonate was used for neutralization of samples. The ultimate content was increased to 100 ml by adding deionized water and centrifuged. In a series of test tubes, 0.2, 0.4, 0.6, 0.8, and 1 ml of the standard were applied. Then, 0.1 and 0.2 ml of the solutions were poured into separate tubes. Each tube volume was increased to 1 ml by adding distilled water. Then, 1 ml and 5 ml of phenol solution and sulfuric acid (96%) were added to each tube, respectively before they were completely shaken. After 10 minutes, the tubes were put in a water bath at a temperature of 27±2° C for 20 minutes. The absorbance of the samples was recorded at 490 nm. Finally, the total carbohydrate content of the samples was measured via the standard chart. The blank sample was prepared with 1 ml of water instead of phenol solution.

Leaf N, P, and K contents

Nitrogen, phosphorous, and potassium contents in each treatment were measured via the methods described by Hashmi et al. (2012). First, the leaves from each treatment were well washed and dried and then completely powdered. Samples were digested to measure phosphorus and potassium contents. In short, 0.5 g of powdered dry samples and 10 ml of concentrated nitric acid 65% were mixed in digestive tubes. Sample tubes with two tubes as control (nitric acid only) were stored for 12 hours without any treatment. After 12 hours, the tubes were heated for 3 h at 60° C and then, the temperature was slowly augmented up to 110° C. The completion of digestion was determined using the indication of color clarity (yellow amber) of samples. Afterwards, the samples were immediately cooled to room temperature. The ultimate content was increased to 100 ml by adding distilled water. This solution was used to measure the amount of phosphorus and potassium. Measurement of phosphorus was done by vanadium-molybdenum colorimetric method. In the orthophosphate ions in the acidic medium with vanadium-molybdate the yellow complex of vanadium molybdate was formed, which showed the maximum absorption at 430 nm. Flame emission was used to measure potassium. Potassium was first measured using flame photometry and then its calibration curve was drawn (Hashmi et al., 2012). After that, leaf nitrogen content was determined by the Kjeldhal method (Khalid and Shedeed, 2015). One gram of powdered dry samples was used in a Pyrex digestion tube (30 ml of concentration). Then H$_2$SO$_4$ was added with caution to 10 g potassium sulfate and 14 mg copper sulfate. The resulting mixture was placed on sand and gently heated with a low flame to make it boil. Then, further heating was applied to turn it into a clear and colorless solution. After cooling and diluting the solution with distilled water, the contents were transferred into an 800 ml Kjeldhal flask. The digestion flask was washed and a piece of catalyst tablet, 100 ml of granulated zinc, and 40% caustic soda were added, respectively. Next, the flask was connected with a condenser to a splash-head distillation apparatus. Then, 25 ml of 0.1 N sulfuric acid was collected in the receiving flask on distillation system. Upon being removed and following the completion of reaction, the solution was titrated against 0.1 N caustic soda solution via methyl red indicator to measure nitrogen.

Results

Analysis of variance indicated the significant effects of fertilizer treatments, on plant height, diameter of stem, 1000-seed weight, seed yield, essential oil %, essential oil yield, proline, chlorophyll a, nitrogen, phosphorous, and
Effect of fertilizers on ajowan (Trachyspermum ammi L.)

The vegetative growth properties of ajowan are given in Table 3. Results showed that all treatments significantly improved vegetative properties compared to the control (P<0.01). The height of plants, number of branches, and diameter of stem were increased (Table 3 and Fig. I.). Results indicated that 1000-Seed weight was strongly affected by vermicompost. The effect of different treatments of fertilizer on seed yield is presented in Table 3.

The essential oil extracted from ajowan treated with fertilizer was yellow (similar to the control). Findings of the essential oil in terms of dry matter (v/w) and oil yield (Lit/ha) are also presented in Table 3. The control sample had an essential oil content of 1.94% whereas the essential oil contents of samples treated with cow manure, compost, vermicompost, and chemical fertilizer were 2.50%, 2.86%, 3.31, and 3.22, respectively.

The changes in proline contents of ajowan are presented in Table 4. The findings indicated that the vermicompost and chemical fertilizer showed the highest proline content.

Analysis of variance showed that fertilizers application significantly changed total phenol, chlorophyll b, and carotenoids contents (Figs. II, III, IV). The maximum content of photosynthetic pigments was observed in vermicompost while the minimum contents were observed in the control.

In addition, the correlations between total soluble sugars (TSS) of the samples are given in Fig.

Table 3
Comparison of means for the effects of fertilizer treatments on the quantitative and qualitative traits of ajowan

<table>
<thead>
<tr>
<th>Fertilizer treatments</th>
<th>Plant height (cm)</th>
<th>Diameter of stem</th>
<th>1000-seed weight (g)</th>
<th>Seed yield (kg ha⁻¹)</th>
<th>Essential oil %</th>
<th>Essential oil yield (lit ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>50.62 ± 7.25c</td>
<td>2.85 ± 0.53d</td>
<td>1.5 ± 0.11c</td>
<td>686.02 ± 29.53d</td>
<td>1.94 ± 0.52d</td>
<td>13.45 ± 5.04d</td>
</tr>
<tr>
<td>Cow manure</td>
<td>55.78 ± 5.90b</td>
<td>3.10 ± 0.65c</td>
<td>1.57 ± 0.11c</td>
<td>735.77 ± 11.38bc</td>
<td>2.50 ± 0.51c</td>
<td>18.43 ± 5.01c</td>
</tr>
<tr>
<td>Compost</td>
<td>57.67 ± 5.31b</td>
<td>3.42 ± 0.69b</td>
<td>1.55 ± 0.10c</td>
<td>730.01 ± 17.73c</td>
<td>2.86 ± 0.53b</td>
<td>21.00 ± 4.66b</td>
</tr>
<tr>
<td>Vermicompost</td>
<td>64.21 ± 5.22a</td>
<td>4.91 ± 0.75a</td>
<td>1.69 ± 0.07a</td>
<td>744.22 ± 27.11a</td>
<td>3.31 ± 0.44a</td>
<td>24.68 ± 5.42a</td>
</tr>
<tr>
<td>Chemical fertilizer</td>
<td>61.81 ± 7.14a</td>
<td>4.72 ± 0.86a</td>
<td>1.64 ± 0.06b</td>
<td>739.77 ± 10.62ab</td>
<td>3.22 ± 0.50a</td>
<td>23.86 ± 3.70a</td>
</tr>
</tbody>
</table>

* Means in each row or column followed by the same lowercase or capital letters are not significantly different (P<0.05) by Duncan’s Multiple Range Test.

Fig. I. The effect of fertilizer treatments on the number of branches of ajowan; means followed by the same letter(s) are not significantly different at p<0.05 as determined by Duncan test. The data shown are means of three replicates.

Fig. II. The effect of fertilizer treatments on total phenol content of ajowan; means followed by the same letter(s) are not significantly different at p<0.05 as determined by Duncan test. The data shown are means of three replicates.
**Table 4**
Comparison of means for the effect of fertilizer treatments on the quantitative and qualitative traits of ajowan.

<table>
<thead>
<tr>
<th>Fertilizer treatments</th>
<th>Proline</th>
<th>Chlorophyll a</th>
<th>Nitrogen</th>
<th>Phosphorous</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.08 ± 0.14c</td>
<td>0.025 ± 0.030d</td>
<td>19.19 ± 0.92e</td>
<td>5.31 ± 0.34d</td>
<td>22.39 ± 1.89c</td>
</tr>
<tr>
<td>Cow manure</td>
<td>1.12 ± 0.14bc</td>
<td>0.086 ± 0.049c</td>
<td>20.43 ± 1.15d</td>
<td>5.49 ± 0.57c</td>
<td>22.42 ± 1.27c</td>
</tr>
<tr>
<td>Compost</td>
<td>1.16 ± 0.13b</td>
<td>0.093 ± 0.043b</td>
<td>21.03 ± 1.66c</td>
<td>5.89 ± 0.58b</td>
<td>22.50 ± 1.24c</td>
</tr>
<tr>
<td>Vermi- compost</td>
<td>1.27 ± 0.08a</td>
<td>0.125 ± 0.032a</td>
<td>21.98 ± 1.58a</td>
<td>6.15 ± 0.43a</td>
<td>24.23 ± 1.47a</td>
</tr>
<tr>
<td>Chemical fertilizer</td>
<td>1.24 ± 0.07a</td>
<td>0.125 ± 0.033a</td>
<td>21.22 ± 1.60b</td>
<td>5.85 ± 0.70b</td>
<td>23.78 ± 1.34b</td>
</tr>
</tbody>
</table>

* Means in each row or column followed by the same lowercase or capital letters are not significantly different (P<0.05) by Duncan’s Multiple Range Test.

**Table 5**
Results of variance analysis of the effects of fertilizer treatments on some traits of ajowan

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Proline</th>
<th>Chlorophyll a</th>
<th>Nitrogen</th>
<th>Phosphorous</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer treatment</td>
<td>4</td>
<td>0.025**</td>
<td>0.005**</td>
<td>3.278**</td>
<td>0.332**</td>
<td>2.74**</td>
</tr>
<tr>
<td>Replication</td>
<td>2</td>
<td>0.001**</td>
<td>0.0001**</td>
<td>0.011**</td>
<td>0.002**</td>
<td>0.002**</td>
</tr>
<tr>
<td>Error</td>
<td>8</td>
<td>0.000</td>
<td>0.0007</td>
<td>0.003</td>
<td>.001</td>
<td>.011</td>
</tr>
</tbody>
</table>

ns, *, and **: non-significant and significant at 5 and 1% probability levels, respectively

V. Results indicated that the fertilizer treatments on ajowan significantly increased TSS content (P<0.05). Also, Vermicompost demonstrated the highest improvement on the nitrogen, phosphorous, and potassium contents of ajowan leaves (Table 4 and Table 5).

**Discussion**

A significant (p≤0.01) positive correlation was found between plant height, diameter of stem, 1000-seed weight, seed yield, essential oil %, proline, Chlorophyll a, Nitrogen, Phosphorous and Potassium (Table 6).

Yadav et al. (2002) also reported an increase in the height of the medicinal herbs due to the use of animal fertilizer. Similarly, Chiane et al. (2014) observed an enhancement in plant height and vegetative growth of ajowan (*Trachyspermum ammi*) after fertilizer treatments. Increases in the number of branches per plant under fertilizer treatments of ajowan and barley plants have been due to improved soil structure and more nutritional value for these plants (Mahdavi et al., 2014). Moradi et al. (2009) studied the effect of various organic and biologic

![Fig. III](image1.png)

Fig. III. The effect of fertilizer treatments on chlorophyll b content of ajowan; means followed by the same letter(s) are not significantly different at p<0.05 as determined by Duncan test. The data shown are means of three replicates.

![Fig. IV](image2.png)

Fig. IV. The effect of fertilizer treatments on carotenoid content of ajowan; means followed by the same letter(s) are not significantly different at p<0.05 as determined by Duncan test. The data shown are means of three replicates.
Effect of fertilizers on ajowan (Trachyspermum ammi L.)

The application of animal fertilizer, especially in deep soils, resulted in increased porosity and improvement of the soil structure and aeration and increased the soil water availability. These factors increase the growth and expansion of roots, absorption of nutrients, and the production of growth hormones. Plant growth and development are improved, and eventually increase plant height (Ghosh et al., 2004). The results of this survey confirmed the results of Sanchez Govin et al. (2005). He showed that the application of biological fertilizers in medicinal plants increased the yield of flowers. Mahfouz and Sharaf-Eldin (2007) also presented similar results for Foeniculum vulgare. They found that biological fertilizers had an impact on the enhancement of growth cycle, yield, and monoterpenes biosynthesis and developed content of essential oil in the plants.

Table 6
Pearson’s correlation coefficients (r) between on some traits of ajowan under fertilizer treatment.

<table>
<thead>
<tr>
<th>Traits</th>
<th>Plant height (cm)</th>
<th>Diameter of stem</th>
<th>1000-seed weight (g)</th>
<th>Seed yield (kg ha⁻¹)</th>
<th>Essential oil %</th>
<th>Essential oil yield</th>
<th>Proline</th>
<th>Chlorophyll a</th>
<th>N</th>
<th>P</th>
<th>K</th>
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<tbody>
<tr>
<td>Plant height(cm)</td>
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<td>Diameter of stem</td>
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<td>1000-seed weight (g)</td>
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<td>Seed yield (kg ha⁻¹)</td>
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<td>Essential oil %</td>
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<td>Essential oil yield</td>
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<tr>
<td>Chlorophyll a</td>
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</table>

** and *: correlation is significant at the 0.01 and 0.05, respectively.

Among the qualitative traits of medicinal plants, the main attributes are essential oil percentage and yield. Environmental conditions and soil fertility are the main factors in determining the qualitative characteristics of plants. Manure contains many micronutrients that can increase the amount of effective ingredient and improve its quality in medicinal plants (Kafi. 2002). In short, transgenic approaches have proline accumulation during stress. Occasionally,
proline accumulation is considered as part of a developmental program in plant tissues (Verbruggen and Hermans, 2008). During stress, proline prevents degradation of enzymes and macromolecular degradation, interferes with maintaining cell wall strength and purifies the hydroxyls produced under tension in the plant (Haddad and Moshiri, 2011). In addition, Szabados and Savoure in 2010, demonstrated that proline has different uses in herbal physiology. For example, it is used as an important substance to make proteins, it has protective application for herbs just like osmolyte, helps the herb to maintain redox at an effective level; It also contributes to development, regulation of some Intracellular organs like controlling mitochondrial functions, decreasing in stress level and development.

The chlorophyll content of the plants is an important factor because of its significant role in photosynthesis and production of corps (Banerjee et al., 2011). Plants increase the soluble sugars to maintain cellular structure and modulate the osmotic potential (Nedjimi and Davoud, 2006).

The highest content of total soluble sugar (TSS) was observed in vermicompost treatment. The role of the photosynthesis in the leaves has a direct effect on variable total sugar content. In general, this rate enhanced by many factors such as supplementation of a nutrient. Our results matched with the findings reported by Ram Rao et al. (2007) and Mondal et al. (2017) for the mulberry mustard crop. They concluded that bio fertilizers had significant effects on carbohydrate biosynthesis in leaves. There is a direct relationship between sugar content of leaves and physiological processes such as respiration, photosynthesis and, translocation. Thus, vermicompost as a nitrogen source in the soil increased biosynthesis and accumulation of sugar in the leaves. Considering the significant increase of N P K elements in fertilizer treatments, especially in vermicompost treatment, increasing these elements resulted in increased yield and improved physiological characteristics. These treatments improved the physicochemical properties of the soil and created a suitable environment for better growth and higher yields and quality.

Conclusion

In recent years, the ecological characteristics and beneficial effects of vermicompost have been clearly demonstrated. Vermicompost is a kind of green manure that is made of organic matter with useful microorganisms. It contains enough nutrients to produce a healthy product. It is evident that vermicompost can improve physical, chemical and biological properties of soil and it is an excellent organic fertilizer. In fact, an optimized way, not to waste any agricultural residue, is to use them as fertilizer in organic cultivation. This approach leads to a higher population of bacterial and fungal organisms in the soil. This approach not only helps the plants to grow better, but it also helps the soil to be richer. The high rate of agricultural residue and waste should be used as an alternative to chemical fertilizers in order to improve organic agriculture and, it needs higher processing technologies for better results. Therefore, to preserve the environment and produce more valuable medicinal herbs such as ajowan, vermicomposting is recommended because it is described as an excellent soil amendment and a biocontrol agent which makes it the best organic fertilizer and more eco-friendly as compared to chemical fertilizers.

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References


grass during wilting'. *Biochemical Journal*, 58(1), 46.


Mahdavi, T., A. Ghahbari and M. R. Asgharipor. 2014. 'Investigation of Ajowan and barley crop cultivation under the influence of livestock and chemical fertilizers'. *Journal of Plant Ecophysiology*, 4, 63-78.


Mondal, T., J. K. Datta and N.K. Mondal. 2017. 'Chemical fertilizer in conjunction with bio fertilizer and vermicompost induced changes in morpho-physiological and biochemical traits of mustard crop'. *Journal of the Saudi Society of Agricultural Sciences*, 16(2), 135-144.


Nedjimi, B. and Daoud, Y. 2006. 'Effect of Na$_2$SO$_4$ on the growth, water relations, proline, total soluble sugars and ion content of *Atriplex halimus* subsp. schweinfurthii through in vitro culture. *Annuls Biology* 28: 35–43.


Olsen, SR. 1954. 'Estimation of available phosphorus in soils by extraction with sodium bicarbonate'. United States Department of Agriculture; Washington.


Sanchez Govín, E., H. Rodríguez González, C. Carballo Guerra and M. Milanes Figueredo. 2005. 'Influencia de los abonos orgánicos y biofertilizantes en la calidad de las especies medicinales *Calendula officinalis* L. *Matricaria recutita* L'. Revista Cubana de Plantas Medicinales, 10(1), 0-0.

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