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# Growth, Yield and Seed Quality of Caraway under Chemical, Organic or Biological Production in New Reclaimed Soil of Upper Egypt

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**Abstract:** The study was achieved to investigate the production of caraway (*Carum carvi, L.*) in new reclaimed soil using organic and biological fertilizers as alternatives for partial or full replacement of chemical fertilization. Experiments were carried out in new reclaimed soil at the Agriculture Experimental Farm of Sohag University, Egypt during two successive seasons. Twelve fertilization regimes were evaluated for their effects on vegetative growth, seed production and quality of seeds. Treatments included the chemical fertilization at full, half or quarter recommended dose in comparison with organic, double organic or biological fertilization alone or with half or quarter dose of chemical fertilization. The results showed the possibility of partial replacement of chemical fertilizers (50%) by organic ones. The addition of organic fertilization at single or double dose (20 or 40 $m^3$) supplemented with half recommended dose of chemical fertilizers allowed equal or higher vegetative growth parameters compared to the full recommended dose of chemical fertilization. However, the addition of single or double dose of organic fertilization with no chemical additions was insufficient and the biological fertilization showed the least results. Chemical fertilization at full recommended dose allowed the maximum seed yield followed by organic fertilization at single or double dose supplemented with half chemical fertilizers dose. These three treatments allowed the production of 1043, 764 and 642 kg seeds per feddan (4200 $m^2$), as average of two years, respectively. The production of volatile oil was also the best with these treatments where it was 9 - 10.6 litter per feddan for chemical fertilization versus 8.7 or 7.6 litter for its half quantity with double or single recommended dose of organic fertilization, respectively. The addition of organic or bio fertilizers alone also showed the least seed production and volatile oil content. The study of seed quality proved the superiority of organic production with reduced chemical fertilization where it showed significantly lower nitrate and nitrite contents compared to the full chemical dose or the double organic dose treatments. Therefore, the addition of 20 $m^3$ farmyard manure during soil preparation followed by 50% of chemical recommended dose, after 45 and 60 days from sowing, is the optimum treatment for good vegetative growth and seed yield in high quality. The reported results could be applied for increasing production of caraway and similar medicinal and aromatic crops in new reclaimed soil to avoid competition with other crops. It could also help in the reduction of pollution and chemical residuals and provide various possibilities of production depending on fertilizers availability, cost and marketing needs.

**Key words:** Caraway · Spices · Reclaimed Soil · Fertilization · Biofertilizers · Organic · Farmyard Manure · Volatile Oil · Nitrate and Nitrite · Residuals

## INTRODUCTION

Medicinal and aromatic plants are among the most important crops playing a vital role in people's life worldwide because of their great importance in herbal medicine as they offer safe, cost-effective and preventive therapies [1]. According to the World Health Organization, over 80% of the world's population relies on traditional medicine [2]. They also provide multiple uses in many fields including spicing, food industries, refreshing beverages, perfume production and insecticides [3]. The international market of herbal products is expected to reach 5 trillion US$ by the year 2050 [4]. Egypt is the sixth leading country exporting

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medicinal and aromatic plants [5]. It is also internationally classified as the seventh exporter of the most pharmaceutical plants to the world's market [6]. The value of its exports presents about 6.6% of the total value of the Egyptian agricultural exports as an average for the period (2003-2008). The cultivated area of medicinal and aromatic crops is about 57.4 thousand feddans representing around 0.39 % of the total cultivation area [7]. The most important Egypt's exports of medicinal and aromatic plants are aromatic seeds. The family *Apiaceae* (*Umbelliferae*) contains most aromatic seeds including cumin, anisum, fennel, coriander and caraway [8, 9]. Caraway (*Carum carvi*, L.) is one of the oldest medicinal and aromatic crops known as pleasant aroma used in pharmacy, perfumery and food industries. Its fruits are used in traditional Chinese medicine and other folk medicines as a carminative against spasmodic gastrointestinal complaints, flatulence, irritable stomach, indigestion, lack of appetite and dyspepsia in adults [10].

The demand of medicinal and aromatic crops is increasing continuously which resulted in a huge trade on national and international levels. To meet out this demand, the vertical expansion throughout maximizing yield was investigated by many authors [11-13], but it stills insufficient for covering the great demand. Furthermore, production of medicinal and aromatic plats faces some problems including the reduction of cultivation area, the competition with food and cloth crops, the chemical residuals in the products and the production cost. Most cultivated area of these crops is located in old lands (89.2 %) and in lower or middle Egypt (91.9 %) however, very limited cultures are concentrated in the huge area of new lands and in upper Egypt [14]. It seems very logic to invest this area to prevent this competition. Reclamation of this land was started in the early 1950s and is continuing [15]. It was reported that the cultivation of these crops in new lands is very suitable and helps to reclaim the degraded lands [16]. Chemical fertilization is the widest method used for the production of most medicinal and aromatic plants which causes, in many cases, negative environmental effects including soil, water and air pollution [17]. Many exports of these important crops were rejected because of chemical residuals. To avoid these problems, organic or biological fertilizers must be tested as alternatives to replace chemicals partially or fully, which could also increase the long term sustainability of agro ecosystems [18, 19]. Organic fertilizers improve the biodiversity, raise the abundance of soil organisms and they could be as effective as chemical fertilizers over longer periods of use [13]. Bio-fertilizers include plant growth promoting bacteria (PGPB) having the capacity to fix the atmospheric nitrogen, dissolve the phosphorus and potassium of the soil and control the pathogen via producing plant growth regulators [20]. Among the PGPBs, *Azotobacter chroococcum* and *Pseudomonas putida* are the greatest prevalent species, founding in the soil, that fix nitrogen and disssolve phosphorus, respectively [21, 22]. Using organic or bio-fertilizers could decrease the application of expensive chemical fertilizers leading to considerable reduction in production costs and pollution rates.

As a contribution for covering the great demand of medicinal and aromatic crops and resolving the related problems, we evaluated the production of five economically important crops including anise, black-cumin, caraway, coriander and cumin in new reclaimed soil of Upper Egypt region [14]. The results showed the possibility of economic production of the studied crops and recommended more deeply study to evaluate them using different techniques. To overcome the problems related to use of chemicals, the actual study aimed to evaluate production of caraway, in new reclaimed soil of Sohag Governorate as the lowest productive region in Upper Egypt, using organic or biological fertilizers as alternatives for partially or fully replacement of chemical fertilizers. The evaluation of crop production in new reclaimed soil could avoid its competition with other crops. The assessment of production using different agricultural techniques could help in the reduction of pollution in air, soil and water and the decrease of chemical residuals in products. It could also provide more possibilities of production according to fertilizers availability, cost and marketing needs.

## MATERIALS AND METHODS

**The Plant Material, Soil and Fertilizers:** The study was conducted on the economically important medicinal and aromatic crop (caraway, *Carum carvi*, L), in new reclaimed soil at the Agriculture Experimental Farm of Sohag University, Egypt. Physical and chemical characteristics of the soil is shown in Table (1). Caraway seeds were obtained from the Experimental Farm of Agriculture Faculty, Sohag University, Egypt. Three fertilizer types including chemical, organic and bio fertilizers were investigated during the study. The chemical fertilizers used as a source of Nitrogen, Phosphorus and Potassium were ammonium nitrate (33.5%N), calcium superphosphate (15.5% $P_2O_5$) and potassium sulfate (50% $K_2O$),

Table 1: Physical and chemical characteristics of the new reclaimed soil of the Floriculture Experimental Farm of Agriculture Faculty, Sohag University, Egypt

| Soil properties | | Soluble elements in saturated soil paste extract | |
|---|---|---|---|
| Property | Value | Element | Value (mmol/L) |
| Sand (%) | 51.5 | $Ca^{+2}$ | 2.5 |
| Silt (%) | 29.9 | $Mg^{+2}$ | 1.5 |
| Clay (%) | 18.6 | $Na^{+1}$ | 18 |
| Texture class | Loam | $K^{+1}$ | 0.18 |
| Saturation percentage (%) | 60 | $CO_3^{2-}+HCO_3^-$ | 5.7 |
| pH (1:2.5) in water | 7.56 | $SO_4^-$ | 1.6 |
| $EC_e$ (ds/m) | 0.885 | $Cl^-$ | 5 |
| Calcium carbonate (%) | 6.5 | DTPA-extractable Fe (ppm) | 12.6 |
| Organic matter (%) | 1.1 | DTPA-extractable Mn (ppm) | 6.4 |
| Nitrogen N (%) | 0.09 | DTPA-extractable Cu (ppm) | 2.6 |
| Available P (ppm) | 20.96 | DTPA-extractable Zn (ppm) | 1.7 |

Table 2: Characteristics of organic fertilizer (farmyard manure) used during the study

| Manure characteristic | pH | Organic C (%) | E.C ($dsm^{-1}$) | Total N (%) | Total P (%) | Total K (%) | C/N Ratio |
|---|---|---|---|---|---|---|---|
| Value | 7.7 | 15.83 | 2.56 | 0.83 | 0.24 | 1.26 | 19.08 |

Table 3: The twelve studied treatments

| Treatments | Specification |
|---|---|
| Chem. Rec. (control) | Full recommended dose of NPK fertilizers |
| Chem. ½ Rec. | ½ recommended dose of NPK fertilizers |
| Chem. ¼ Rec. | ¼ recommended dose of NPK fertilizers |
| Organic only | Recommended dose of organic fertilizer alone |
| Organic+½ Chem. | Recommended dose of organic fertilizer +½ recommended dose of NPK |
| Organic+¼ Chem. | Recommended dose of organic fertilizer +¼ recommended dose of NPK |
| D. Organic only | Double recommended dose of organic fertilizer alone |
| D. Organic+½ Chem. | Double recommended dose of organic fertilizer+½recommended dose of NPK |
| D. Organic+¼ Chem. | Double recommended dose of organic fertilizer+¼recommended dose of NPK |
| Biological only | Recommended dose of bio-fertilizer alone |
| Biological+½ Chem. | Recommended dose of bio-fertilizer +½recommended dose of NPK |
| Biological+ ¼ Chem. | Recommended dose of bio-fertilizer +¼ recommended dose of NPK |

Recommended dose of NPK is 300 Kg $fed^{-1}$ ammonium nitrate, 200 Kg $fed^{-1}$ calcium superphosphate and 100 Kg $fed^{-1}$ potassium sulphate and recommended dose of organic fertilizer is 20 $m^3$ $fed^{-1}$.

respectively. Organic fertilizer was added as farmyard manure (FYM) obtained from Animal Production Dept. of Agriculture Faculty, South Valley University, Egypt. Characteristics of organic fertilizer (farmyard manure) used during the study are shown in Table (2) according to Abd El-Lattief [23]. The bio fertilizers used as inoculums for seeds were *Azospirrillum lipoferum* ($6\times10^6$ cfu/gm) as a nitrogen fixing bacteria and *Bacillus polymyxa* ($3\times10^8$ cfu/gm ) as a phosphate dissolving bacteria (Bio-fertilizer Unit, Agriculture Faculty, South Valley University). An equal volume of both inoculants was mixed then added at a rate of 10% of seeds weight [24].

**Establishment of Study and the Experimental Design:** The study was carried out during two successive seasons of 2010/2011 and 2011/2012 where caraway seeds were sown on mid October of both years. The experiment was divided into plots of 5 $m^2$ area (2.5 m length and 2 m width) and contained three ridges at 60 cm spacing. Each ridge was planted on its southern side by 10 hills at 25 cm plant spacing. Thinning was performed after two weeks of culture to maintain two plants per hill and 60 plants per plot. Twelve fertilization treatments were applied during the study as shown in Table (3). Treatments were arranged in randomized complete-blocks design (RCBD) as simple experiment with four replicates. Control treatment was supplied with the full recommended dose of NPK (300 Kg $fed^{-1}$ ammonium nitrate, 200 Kg $fed^{-1}$ calcium superphosphate and 100 Kg $fed^{-1}$ potassium sulphate). Chemical fertilizers were added to plants at two equal doses at the day 45 and 60 from sowing. For bio-fertilizer treatments, seeds were coated by

10 % Arabic gum as an adhesive agent and rolled in the bio-fertilizers directly before planting followed by irrigation to provide suitable moisture for the inoculated seeds. Organic fertilizer (FYM) was added to the soil at 20 $m^3$ per feddan during soil preparation as recommended by Hassanein [14]. The other agricultural practices were performed similarly for all treatments. At the end of experiment, when fruits became greenish yellow in colour (six months after planting), 10 plants were selected at random from each plot to measure growth, seed yield and seed quality characteristics.

**Vegetative Growth and Seed Yield:** Ten plants were selected at random per replicate to determine plant height (cm), as the length of main stem from soil surface and number of branches per plant. Herb fresh weight per plant (gm) was determined by weighing of the ten randomizally selected plants per replicate directly after harvesting and dividing by 10. Those plants were dried then weighed to estimate herb dry weight per plant (gm). Dry seeds of ten randomizally selected plants were weighed per replicate to estimate seed yield per plant (gm) after the division by 10. Total seed yield per feddan (kg) was calculated by multiplying seed yield per plant by the number of plants per plot, to determine seed yield per plot, then related to feddan (4000 $m^2$).

**Extraction and Determination of Volatile Oil:** Fifty grams of dried seeds were crushed then their volatile oil (essential oil) content was extracted, in 500 ml water, by water distillation for 3 hours according to Gunther [25]. Volatile oil was determined as percentage (%), ml of oil per 100 gm of seeds and as yield in litter per feddan (L $fed^{-1}$) by multiplying this percentage by seed yield per feddan.

**Determination of Nitrate and Nitrite (mg/gm):** Nitrate and nitrite were estimated in caraway seeds resulted from different treatments to evaluate their quality. The nitrate content ($NO_3$) was determined spectrophotometrically using Spekol11 Prod Carl Zeiss Jena, Germany according to the hydrazine reduction method described by Kamphake *et al.* [26]. The nitrite content ($NO_2$) was determined following to the method illustrated by Pearson [27].

**Statistical Analysis:** All data were subjected to analysis of variance (ANOVA) for the determination of significant differences among treatments using SAS program version 9.1.3. The differences among means were compared using the least significant difference (LSD) at $\alpha$= 0.05.

## RESULTS AND DISCUSSION

**Vegetative Growth:** The effect of different fertilization regimes on plant height and number of branches per plant for caraway plants cultivated in new reclaimed soil is shown, for the two studied seasons, in Table (4). The addition of double recommended dose of organic fertilizer as farmyard manure (40 $m^3$ per feddan) supplemented with half recommended dose of chemical fertilizers showed the tallest plants and the highest branches number per plant in both seasons. Similar results were obtained with the full recommended dose of chemical fertilizers, or its half quantity plus the recommended dose of organic fertilizer. However, the addition of biological or organic fertilizer with no chemical additions showed the shortest plants with the least branches number in both seasons and thus with the double recommended dose of organic fertilizers. These results showed the possibility of partial replacement of chemical fertilizers by organic ones and the importance of the addition of chemical fertilizers at small quantity, as activation dose, to stimulate plant growth at the first stages till the analysis of organic compounds and the release of nutrients. It was previously reported that organic fertilizers were effective over longer periods of use [13]. The reduction of chemical fertilization with no other additions resulted in tall plants with significantly lower branches number. Also, the addition of quarter dose of chemical fertilizers to organic or biological ones gave similar results. It seems that these quantities were not sufficient enough for the growth of caraway plants. It also indicates that the organic fertilization could replace the half quantity of chemical fertilizers and its presence at this quantity is critical. This result is in agreement with that reported on roselle by Abo-Baker and Mostafa [28].

The studied fertilization treatments gave similar effects on fresh and dry weights of caraway plants (Table 5). The highest fresh and dry weights per plant were obtained with the double recommended dose of organic fertilization supplemented with half quantity of chemical fertilizers. This best treatment was followed by the addition of full chemical recommended dose then the half chemical recommended dose with organic fertilizer. It means that the half quantity of chemical fertilizers could be replaced by the addition of either 20 or 40 $m^3$ farmyard manure per feddan during soil preparation. The low nutrients content in farmyard manure (0.8% N, 0.2% P and 1.3 % K) compared to chemical fertilizers (33.5% N, 15.5% $P_2O_5$ and 50% $K_2O$) could explain this result. It is also well known that organic fertilization improve soil

Table 4: Vegetative growth of caraway as affected by different fertilization regimes in new reclaimed soil under Sohag Governorate conditions

| | Plant height (cm) | | Number of branches per plant | |
|---|---|---|---|---|
| Treatments | 2011 | 2012 | 2011 | 2012 |
| Chem. Rec. (control) | 108.97 ab | 86.82 ab | 17.76 a | 11.10 bc |
| Chem. ½ Rec. | 110.41 ab | 87.54 a | 13.23 bcd | 9.84 bcd |
| Chem. ¼ Rec. | 104.21 ab | 87.27 a | 9.45 def | 9.26 bcde |
| Organic only | 88.69 cd | 74.35 de | 9.46 def | 6.38 ef |
| Organic+½ Chem. | 111.15 ab | 82.77 abc | 13.97 bc | 14.02 a |
| Organic+¼ Chem. | 101.13 bc | 70.65 cde | 10.50 cdef | 7.89 def |
| D. Organic only | 89.10 cd | 68.33 ef | 8.97 f | 7.08 def |
| D. Organic+½ Chem. | 117.63 a | 87.44 a | 15.76 ab | 11.90 ab |
| D. Organic+¼ Chem. | 99.59 bc | 81.75 ab | 10.13 def | 9.63 bcd |
| Biological only | 83.97 d | 61.00 f | 7.20 f | 6.13 f |
| Biological+½ Chem. | 97.13 bcd | 80.81 bcd | 12.89 bcde | 9.43 bcd |
| Biological+ ¼ Chem. | 102.74 bc | 83.02 abc | 9.40 ef | 8.56 cdef |

Means with the same letter in the same column are not significantly different.

Table 5: Vegetative growth of caraway as affected by different fertilization regimes in new reclaimed soil under Sohag Governorate conditions

| | Herb fresh weight per plant (gm) | | Herb dry weight per plant (gm) | |
|---|---|---|---|---|
| Treatments | 2011 | 2012 | 2011 | 2012 |
| Chem. Rec. (control) | 114.93 b | 25.13 ab | 40.37 ab | 13.55 a |
| Chem. ½ Rec. | 113.68 b | 24.89 ab | 37.54 b | 11.28 ab |
| Chem. ¼ Rec. | 84.28 cde | 14.36 de | 23.46 de | 7.23 c |
| Organic only | 60.54 ef | 8.75 fg | 20.38 def | 1.28 g |
| Organic+½ Chem. | 111.63 bc | 24.25 b | 33.03 bc | 11.67 ab |
| Organic+¼ Chem. | 59.63 ef | 10.4 ef | 19.46 def | 3.48 efg |
| D. Organic only | 50.06 f | 7.86 fg | 16.06 ef | 3.39 fg |
| D. Organic+½ Chem. | 149.46 a | 29.02 a | 47.26 a | 13.91 a |
| D. Organic+¼ Chem. | 96.3 bcd | 17.5 cd | 26.2 cd | 6.00 def |
| Biological only | 31.98 f | 5.48 g | 13.32 f | 2.61 g |
| Biological+½ Chem. | 67.84 def | 20.59 bc | 25.87 cd | 8.75 bc |
| Biological+ ¼ Chem. | 56.28 ef | 14.83 de | 16.94 ef | 6.44 de |

Means with the same letter in the same column are not significantly different.

characteristics besides its favorable effects on plant growth. In the other hand, the least results were obtained when organic or biological fertilizers were added with no chemical additions. The addition of quarter quantity of chemical recommended dose was also inefficient. The addition of half chemical recommended dose to biological fertilization did not give good results which proves its inefficiency as alternative in comparison with organic fertilization. It may relate to the different mechanism of plant growth promoting rizobacteria as biofertilizers [22].

**Seeds Production:** Seed yield of caraway plants as affected by different fertilization regimes, in both studied seasons, is shown in Table (6). The chemical fertilization of caraway plants by the full recommended dose allowed the highest seed yield per plant and per feddan in both seasons. This result could be explained by the rapid absorption of chemical minerals available directly for seed production compared to the time needed for the analysis of organic fertilization. Indeed, flowering and fruit production require more available nutrient requirements than vegetative growth. The following best treatments were the half quantity of chemical fertilizers supplanted by single or double recommended dose of organic fertilization. However, the addition of organic or biological fertilizers alone showed the worst results. The slow release of nutrients from the organic fertilizers may explain this result [13, 21]. The recommended dose of chemical fertilization allowed the production of 1043 kg seeds per feddan, as the average of both studied years, versus 764 or 642 kg for the half chemical recommended dose with double or single dose of organic fertilization, respectively.

Table 6: Seed yield of caraway as affected by different fertilization regimes in new reclaimed soil under Sohag Governorate conditions

| | Seed yield per plant (gm) | | Total seed yield per feddan (kg) | |
|---|---|---|---|---|
| Treatments | 2011 | 2012 | 2011 | 2012 |
| Chem. Rec. (control) | 25.94 a | 17.50 a | 1245.13 a | 840.00 a |
| Chem. ½ Rec. | 19.81 b | 6.66 cde | 951.04 b | 319.48 cde |
| Chem. ¼ Rec. | 11.66 d | 8.47 c | 559.70 d | 406.40 c |
| Organic only | 8.07 e | 2.78 g | 387.28 e | 133.33 g |
| Organic+½ Chem. | 15.22 c | 11.28 b | 742.92 c | 541.49 b |
| Organic+¼ Chem. | 14.68 cd | 6.07 def | 691.71 cd | 291.20 def |
| D. Organic only | 11.67 d | 4.75 ef | 560.13 d | 227.97 ef |
| D. Organic+½ Chem. | 21.17 b | 10.67 b | 1016.22 b | 511.96 b |
| D. Organic+¼ Chem. | 13.58 cd | 7.91 cd | 652.04 cd | 379.68 cd |
| Biological only | 3.78 f | 4.15 ef | 181.21 f | 199.20 ef |
| Biological+½ Chem. | 13.83 cd | 5.40 ef | 663.84 cd | 259.26 ef |
| Biological+ ¼ Chem. | 12.04 cd | 4.29 fg | 578.04 cd | 205.80 fg |

Means with the same letter in the same column are not significantly different.

Table 7: Quality of caraway seeds as affected by different fertilization regimes in new reclaimed soil under Sohag Governorate conditions

| Treatments | Volatile oil (%) | Volatile oil per feddan (L) | Nitrate content (mg/gm) | Nitrite content (mg/gm) |
|---|---|---|---|---|
| Chem. Rec. (control) | 0.80 cd | 10.58 a | 6.215 a | 0.330 a |
| Chem. ½ Rec. | 1.00 abc | 9.03 a | 3.852 ab | 0.121 b |
| Chem. ¼ Rec. | 0.80 cd | 4.31 bc | 2.437 b | 0.088 b |
| Organic only | 1.00 abc | 4.00 bc | 2.044 b | 0.069 b |
| Organic+½ Chem. | 1.00 abc | 7.64 ab | 2.987 b | 0.123 b |
| Organic+¼ Chem. | 1.10 abc | 7.42 ab | 3.380 ab | 0.116 b |
| D. Organic only | 1.30 a | 7.55 ab | 4.717 ab | 0.207 ab |
| D. Organic+½ Chem. | 0.90 bcd | 8.70 a | 5.031 ab | 0.184 ab |
| D. Organic+¼ Chem. | 1.20 ab | 7.29 ab | 3.066 b | 0.116 b |
| Biological only | 0.90 bcd | 1.45 c | 2.594 b | 0.084 b |
| Biological+½ Chem. | 1.10 abc | 7.05 ab | 3.066 b | 0.093 b |
| Biological+ ¼ Chem. | 1.30 a | 7.29 ab | 5.110 ab | 0.212 ab |

Means with the same letter in the same column are not significantly different.

**Quality of Seeds:** The study of seed quality including its content of volatile oil, nitrate and nitrite as a result of different fertilization treatments is illustrated in Table (7). Few significant differences were found among the studied treatments in seed content of volatile oil expressed as percentage or litter per feddan. The double dose of organic fertilization and the bio-fertilization supplemented with quarter recommended dose of chemical fertilization showed significantly higher volatile oil percentage in seeds compared to the full recommended dose of chemical fertilization and the double dose of organic fertilization plus half chemical fertilization dose. These treatments were also significantly better than bio-fertilization alone and the quarter recommended dose of chemical fertilization. The low volatile oil percentage with the good treatments could be explained by their high production of seeds. Therefore, volatile oil volume per feddan was the highest with full recommended dose of chemical fertilizers and its half quantity alone or with double dose of organic fertilization. However, biological fertilization showed the least volatile oil content in seeds. The production of volatile oil was 9 - 10.6 litter per feddan for full chemical fertilization versus 8.7 or 7.6 litter for its half quantity with double or single recommended dose of organic fertilization.

Treatments also had the same effect on nitrate and nitrite content but the full recommended dose of chemical fertilization showed the highest levels of nitrate and nitrite. This treatment was followed by the treatments contained double dose of organic fertilization alone or with half dose of chemical fertilizers, both resulting in high seed content of nitrate and nitrite. However, the other treatments including the half recommended dose of chemical fertilizers supplemented with normal dose of organic fertilization showed significantly lower level of nitrate and nitrite. It was previously reported that the organic fertilization reduce seed content of nitrate and nitrite [29]. This treatment allowing high vegetative

growth and seed yield in good quality, high volatile oil and low nitrate and nitrite contents, could be selected as the best treatment.

## CONCLUSION

It can be concluded that caraway could be economically produced in new reclaimed soil using different fertilization regimes. Different doses of chemical fertilizers were compared to organic and biological fertilizers alone or with reduced dose of chemical fertilization. The study proved the possibility of partial replacement of chemical fertilizers by organic ones for reducing pollution, residuals and cost. The addition of organic fertilization at single or double recommended dose (20 or 40 $m^3$) supplemented with half recommended dose of chemical fertilizers allowed similar or better vegetative growth characteristics of caraway compared to the full recommended dose of chemical fertilization. So, the addition of 20 $m^3$ at soil preparation stage with half chemical fertilizers dose is recommended. However, the addition of single or double dose of organic fertilization alone with no chemical additions was inefficient and the biological fertilization showed the least results. The supplement of these alternatives with quarter dose of chemical fertilizers was also insufficient. Concerning seed production, chemical fertilization at full recommended dose allowed the maximum yield followed by organic fertilization at single or double dose supplemented with half dose of chemical fertilizers. These three treatments allowed the production of 1043, 764 and 642 kg seeds per feddan, as average of both studied years, respectively. The production of volatile oil was also the best with these treatments where it was 9-10.6 litter per feddan for chemical fertilization versus 8.7 or 7.6 litter for its half quantity with double or single recommended dose of organic fertilization, respectively. The addition of organic or bio fertilizers alone also showed the least seed production and volatile oil content. However, the study of seed quality proved the superiority of organic production, using single dose, with reduced chemical fertilization. The seeds resulted from fully chemical fertilization contained the maximum nitrate and nitrite contents, followed by treatments harbored double dose of organic fertilization alone or with half chemical fertilization dose. Therefore, the addition of 20 $m^3$ farmyard manure during soil preparation followed by half chemical fertilization, at two equal doses after 45 and 60 days from sowing, is the optimum treatment for good vegetative growth and seed yield in high quality. The reported results could encourage the production of caraway and similar crops in new reclaimed soil to avoid their competition with other crops. The production using organic or biological fertilizers as alternatives to chemical fertilizers could help in the reduction of pollution in air, soil and water, and the decrease of chemical residuals in products. It could also provide various possibilities of production depending on fertilizers availability, cost and marketing needs.

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