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Original Article

ASSESSMENT THE YIELD AND QUALITY OF *NIGELLA SATIVA* UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

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ABSTRACT

Objective: Nowadays, one of the growing industries is the herbal drug-based medicaments. This study sought to assess the quality and yield characterizes of black cumin under different locations through Egypt to introduce final analysis information for producers and exporters in Egypt.

Methods: This experiment was carried out in seven sites in different locations through Egypt to assess the growth, yield and essential oil content of black cumin plants as following; four sites in El-Minya Governorate, two sites in Bahariya Oasis, and one site in Aswan Governorate.

Results: Cultivation locations significantly affected on quality and growth characteristics. The highest seed and fixed oil yields (830 kilogram seeds and 206 kilogram fixed oil) were observed under clay loam soil (Old Land farm), while the lowest yields (500 kilogram seeds and 105 kilogram fixed oil) were observed under sandy soil (El-Nanaaih farm) at El-Menya. The highest content of active substance (Fixed oil %) was observed in clay loam sandy soil of Sekem farm and the lowest in Lena farm with sandy soil at Bahariya Oasis. Neither seed yield nor fixed oil content showed significant correlation with Na^+, Cl^-, and $HCO_3^{--}$of irrigation water. Although plants cultivated in Wadi El-Nokra at Aswan produced low fixed oil content (18.3%), main components, Linoleic and Oleic acid, were relatively high.

Conclusion: The assessment of *Nigella sativa* under different locations gave evidence of the interactions between weather and soil properties and their impact on the quality and yield of oil of *Nigella sativa* plants.

Keywords: *Nigella sativa*, Fixed oil, Linoleic acid, Oleic acid

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INTRODUCTION

The medical and curative properties of medicinal plant are returned to the active substances in its tissues. Aromatic and medicinal plants are considered an important source from agriculture components in several countries [1]. They are a major source of ingredients for the known drugs. Nowadays, production of herbal-based medicaments is one of the industrial growths in Egypt. In addition, particular extracts and herbal drug components production in some pharmaceutical companies are known as modern medicine [2].

Egypt is characterized by a great diversity of environmental conditions, including the climatic aspects and soil types, which lead to spread different plant species containing around 2000 wild species in addition to introduced species [3]. Due to the high productivity of medicinal plants in Egypt and the international raising demand, medicinal plants became an important sector to elevate the Egyptian exports volume. In spite of the growing global exchange of medicinal plants, there are many factors restrict their entry into the global market and put them in an extremely unsuitable position [4]. Researchers should pay attention to discover the biologically active substances of these plants to determine its therapeutic properties.

Black cumin, (*Nigella sativa* L.), is classified to Ranunculaceae family and it is one of the most nutrient-rich herbs throughout history around the world [5]. Black cumin has a high nutritional value and because it contains a high percentage of minerals, protein, vitamins and fiber. Moreover, black cumin seeds contain elements with high levels, including folic acid, copper, calcium, phosphorus, thiamin, zinc, iron, pyridoxine as well as niacin [5]. Furthermore, the Black cumin plant contains several important components as sterols, saponins, essential oils and alkaloids. Many of these components is not biologically tested and is not chemically characterized. The Black cumin seeds contain 26-34% fixed oil. The main fatty acids are palmitic acid and linoleic. The seed oil is consisting of 0.4%–2.5% essential oil [6]. From those components, thymoquinone which shows wide therapeutic properties found as an important component in the essential oil and it is the most biologically active compound [7]. Nigella sativa showed many medicinal properties that contribute to treating some diseases [8].

Mineral nutrients and water are principal resources that can restrict plant growth and survival which are mainly determined by some factors such as local climate, regional and soil. The requirements of soil and nutritive vary extremely among plant species. Previous studies revealed the effects of light intensity, water availability, mineral nutrients and altitude on plants growth and quality [9, 10]. The aim of the present research is to assess the growth, yield and quality of black cumin (*Nigella sativa*) plant under varied regions in Egypt to provide final analysis information for producers and exporters in Egypt.

MATERIALS AND METHODS

Black cumin, *Nigella sativa*, annual plant of the ranunculus family (Ranunculaceae), has been collected from strains grown in the studied areas. Seven sites in different locations through Egypt were chosen to assess the growth, yield and essential oil content of Egyptian black cumin plants as following; four sites in El-Minya Governorate (El-Nanaaih Farm, Moftah Farm, Biosystem Farm, Sekem Farm), two sites in Bahariya Oasis (Lena Farm, Sekem Farm), and one site in Aswan Governorate (Wadi El-Nokra).

Table (1 and 2) showed texture properties and chemical properties of for different locations and table (3) showed the chemical analysis of irrigation water. The physical and chemical features of both soils and irrigation water were determined based on Klute [11].

This study was conducted out during two successive seasons (2016/2017 and 2017/2018). The black cumin seeds were directly sown in the open field on the beginning of November in each year. The experimental plot was 30 m^2 (4×7.5 m) comprised of 15 rows;

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the distance between hills was 0.25 m and 0.5 m apart. At 21 d, plants were thinning out for two plants per hill. During April in each year, the plants were harvested and the vegetative parameters were recorded; Plant height, capsules number, and seed yield.

Table 1: Texture properties of studied soils in different sites of Egypt

Locations	Course sand %	Soft sand %	Silt %	Clay %	Texture
A) El-Menya Governorate					
1-El-Nanaaih Farm	38.3	34.2	18.5	9.0	Sandy
2-Old Land Farm	8.9	19.2	36.3	35.0	Clay Loam
3-Biosystem Farm	33.40	60.26	3.97	2.37	Sandy
4-Sekem Farm	37.4	38.2	17.9	6.5	Sandy Loam
B) Bahariya Oasis					
5-Lena Farm	40.3	46.5	10.7	2.5	Sandy
6-Sekem Farm	30.0	39.3	10.2	22.1	Clay Loamy Sand
C) Aswan Governorate					
7-Wadi El-Nokra	34.0	38.4	19.0	8.6	Sandy Loam

Table 2: Chemical properties of studied soils in different sites

Locations	EC 1:5 dSm^{-1}	pH (2.5:1)	Soluble Cations (meq/l)				Soluble Anions (meq/l)			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
A) El-Menya Governorate										
1-El-Nanaaih Farm	7.96	0.71	2.10	0.80	3.8	0.60	-	2.20	3.50	1.60
2-Old Land Farm	5.83	0.76	1.00	0.40	1.9	0.60	-	1.33	1.50	1.00
3-Biosystem Farm	8.27	2.82	5.00	2.90	18.7	1.50	-	1.90	11.00	15.20
4-Sekem Farm	7.69	1.14	3.40	2.40	5.1	0.80	-	1.40	7.50	2.80
B) Bahariya Oasis										
5-Lena Farm	8.11	0.70	2.30	1.50	2.6	0.60	-	2.10	2.50	2.40
6-Sekem Farm	7.78	0.43	0.70	0.30	2.6	0.50	-	1.10	2.00	1.00
C) Aswan Governorate										
7-Wadi El-Nokra	8.00	0.56	1.00	0.50	3.6	0.90	-	1.90	3.50	0.60

EC (dSm^{-1}), electrolytic conductivity (deci siemens per meter); meq/l, milligram per litter; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; CO_3, carbonate; HCO_3, bicarbonate; Cl, chloride; SO_4, sulphate.

Table 3: Chemical properties of irrigation water for studied locations

Locations	EC 1:5 dSm^{-1}	pH (2.5:1)	Soluble Cations (meq/l)				Soluble Anions (meq/l)			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
A) El-Menya Governorate										
1-El-Nanaaih Farm	1.39	7.94	1.90	0.7	10.7	0.90	-	1.90	9.0	3.30
2-Old Land Farm	0.37	7.38	1.30	0.5	1.6	0.32	-	1.10	2.30	0.32
3-Biosystem Farm	0.42	8.96	1.10	0.4	2.3	0.32	-	1.0	2.50	0.62
4-Sekem Farm	0.96	7.82	4.0	1.2	3.6	0.87	-	0.9	2.80	5.97
B) Bahariya Oasis										
5-Lena Farm	0.45	7.16	1.20	1.0	1.7	0.20	-	1.3	2.3	0.5
6-Sekem Farm	0.38	7.14	1.10	0.5	1.8	0.50	-	1.3	2.3	0.5
C) Aswan Governorate										
7-Wadi El-Nokra	0.69	8.08	2.1	0.80	3.8	0.30	-	1.50	5.0	0.5

EC (dSm^{-1}), electrolytic conductivity (deci siemens per meter); meq/l, milligram per litter; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; CO_3, carbonate; HCO_3, bicarbonate; Cl, chloride; SO_4, sulphate.

Fixed oil extraction

The extraction protocol of fixed oil has been done according to A. O. A. C. [12] from the seeds of black cumin plants. The dried seeds have been weight and were used for oil extraction using n. hexane solution. The total extract has been subjected to anhydrous sodium sulphate for drying, and then solvent extraction has been distilled under reduced pressure. The crude lipids of fixed oil were weighed and calculated at the basis of a dry weight basis.

Gas-liquid chromatographic analysis of fatty acids

Samples of the 2nd season were used. The lipids of selected samples were saponified with 20% w/v potassium hydroxide solution. Heating treatment has been applied on the mixture for 30 min on a water-bath at 100 °C and kept overnight at room temperature. The unsaponified matter was extracted with diethyl ether three times. Acidification process of the fatty acids potassium salt has been done using Hydrochloride acid (6 N) and the extraction of liberated fatty acids has been done using HCl diethyl ether for three times. Washing process for the total ether extract has been done many times, dried overusing anhydrous sodium sulphate, and then filtered. Fatty acids were turned to methyl esters according to Vogel [13] using a diazomethane ethereal solution. A 99% pure of standard fatty acids were purchased from Nu-Chek-Prep and checked by Gas-Liquid Chromatography.

RESULTS AND DISCUSSION

Crop production is determined by environmental conditions, which are the main determinant factor of crop success in specific area. The agro-climatic zone and selection of suitable locations could be important strategies for optimizing the yield and quality of medicinal plants [14, 15]. On the other hand, irrigation water and mineral nutrition are key resources that can determine plant growth and survival which are affected by various factors, including climate and soil properties [16, 17]. Soil type also had a pronounced impact on growth parameters and essential oil and its constitutions [18, 19]. In this study, black cumin was evaluated through Egypt under different locations within different climatic-zones in addition to great differences of soil and irrigation water properties in these locations, even within the same governorate. ANOVA Analysis indicated that location had a greatly significant impact on yield and

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growth characters as well as fixed oil content in black cumin plants (table 4). The tallest and shortest plants were shown at El-Menya governorate in both seasons. The tallest plants were recorded in Old land with clay loam soil texture, while the shortest plants were observed in Sekem farm (sandy loam) and El-Nanaaih farm (sandy) in the first and second season, respectively (fig. 1). In the same line, the capsules number per plant reached to their maximum under Lena Farm at Baharia Oasis and old land at El-Menya in the 1st and 2nd season, respectively. In contrast, the capsules number reached to their minimum under El-Nanaaih farm at El-Menya in both seasons.

Table 4: Summary of analysis of variances for morphological and yield traits and fixed Oil of *Nigella Sativa* plant as affected by different locations

Sources	df	Plant height	Capsules number	Seed yield		Fixed oil	
				g/plant	Kg/Fed.	Oil %	ml/plant
(1st Season)							
Rep.	2	5.375	1.125	2.636	3.125	2.161	0.022
Locations	7	1581.56***	795.07***	376.4***	2223699***	267.6***	27.11***
Error	14	0.232	0.554	0.338	0.554	0.561	0.071
(2nd Season)							
Rep.	2	0.143	1	1.286	75.571	0.0128	1.462
Locations	6	613.93***	66.8***	34.739***	20005.4***	2.608*	2.546***
Error	12	1.476	0.277	0.952	21.571	0.670	0.263

df, degree of freedom; g/plant, gram per plant; Kg/Fed., kilogram per feddan (4200 m^2); ml/plant, milliliter per plant

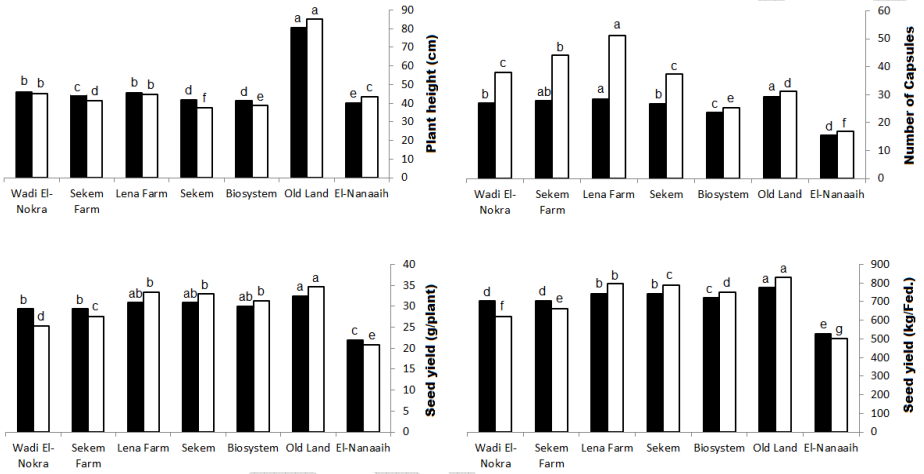

Fig. 1: The Plant height, number of capsules, seed yield (g/plant, gram per plant), and seed yield (kg/Fed., kilogram per feddan "4200 m^2") of black cumin, *Nigella sativa*, under different location in El-Minya Governorate (El-Nanaaih, Old Land, Biossytem, Sekem), Bahariya Oasis (Lena farm, Sekem farm), and Aswan (Wadi El-Nokra)

The highest and lowest yield of seeds and fixed oil were shown at El-Menya in both seasons. The plants cultivated in clay loam soil at Old land recorded the highest yield; meanwhile, in sandy soil at El-Nanaaih produced the lowest yields. On the other hand, the highest fixed oil content in seed was observed in Bahariya Oasis and El-Menya. The highest values (31.25% and 23.95%) were observed in plants cultivated in Sekem farm (Clay Loamy Sand) and under Old Land at El-Menya in the 1st and 2nd season, respectively. The minimum mean value of oil percentage was extracted from plants cultivated under El-Nokra at Aswan in both seasons (fig. 2). The main components of fixed oil were Linoleic and Oleic acid. Linoleic acid is characterized as polyunsaturated and omega-6 acid. It is essential fatty acids for humans [20]. On the other hand, oleic acid is characterized as a monounsaturated omega-9 acid that naturally occurs in animal and vegetable sources [21]. The quality of fixed oil determined by Linoleic and Oleic acid contents. The best-fixed oil quality was observed in under Old Land farm at El-Menya and the poorest quality was observed in El-Nanaaih farm at El-Menya (table 5). Regarding soil characters, plant height negatively correlated with soil Ec (r=-0.95** and-0.96** in the 1st and 2nd season, respectively). Meanwhile, seed and fixed oil yield negatively correlated with water properties such as Na^+, $Cl^-$and HCO_3^-contents (fig. 3). These results is consistent with previous finding [15], suggested the important role of soil and irrigation water properties as limiting factors of medicinal plant yield and quality.

Table 5: Fatty acid composition of black cumin, *Nigella sativa*, plants under different locations (2nd Season)

Locations	Myristic (14:0)	Palmitic (16:0)	Palmiteleic (16:1)	Stearic (18:0)	Oleic (18:1)	Linoleic (18:2)	Linolenic (18:3)	Arachidic (20:0)	Eicosenoic (20:1)	Eicosadienoic (20:2)
A) El-Minya Governorate										
1-El-Nanaaih	0.160	12.35	0.163	3.313	18.53	40.30	0.44	0.160	0.326	2.435
2-Old Land	0.213	14.07	0.175	3.541	25.21	50.34	0.580	0.176	0.413	3.67
3-Biosystem	0.168	12.56	0.167	3.493	21.91	45.34	0.514	0.171	0.321	2.780
4-Sekem	0.178	12.78	0.169	3.671	20.35	43.21	0.520	0.167	0.331	2.651
B) Bahariya Oasis										
5-Lena Farm	0.177	12.87	0.165	3.501	19.99	41.45	0.489	0.165	0.367	2.543
6-Sekem Farm	0.176	12. 86	0.164	3.218	19.30	43.24	0.476	0.169	0.364	2.555
C) Aswan Governorate										
7-Wadi El-Nokra	0.201	12.99	0.169	3.210	23.23	47.32	0.534	0.172	0.367	2.875

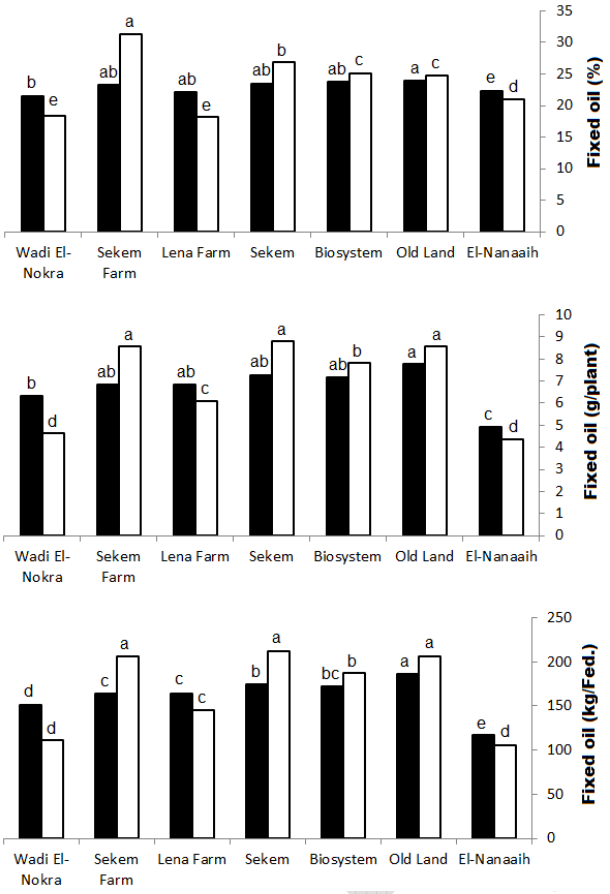

Fig. 2: Fixed oil content of black cumin, *Nigella sativa*, under different location in El-Minya Governorate (El-Nanaaih, Old Land, Biossytem, Sekem), Bahariya Oasis (Lena farm, Sekem farm), and Aswan (Wadi El-Nokra). Fed= 4200m²

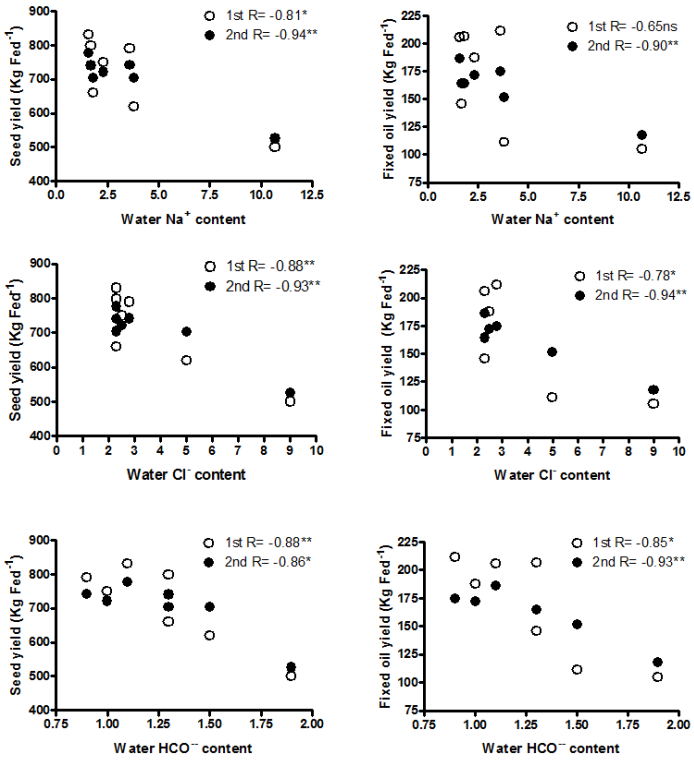

Fig. 3: The correlation coefficients of water properties (Na^+, Cl^-, and HCO^{--}) with seed and fixed oil yields in the 1st and 2nd season of cultivation. Na, sodium; Cl, chloride; HCO_3, bicarbonate; Fed= 4200m²

Aswan governorate characterized the warmest and driest climate according to the weather data, while El-Menya had the coldest and wettest climate. The soil texture was sandy loam in Wadi El-Nokra at Aswan. Although soil texture was similar in Wadi El-Nokra and Sekem farm at El-Menya, plants cultivated in Seken farm at El-Menya revealed higher yield of both seeds and oil compared to those in Wadi El-Nokra. In contrast, the plans cultivated in Wadi El-Nokra revealed taller plant with higher Linoleic and Oleic acid contents.

CONCLUSION

The assessment of black cumin under different locations concluded the significant effects of locations on quality and yield characterizes of black cumin. The highest yield of both seed and fixed oil were observed in plants grown under clay loam soil. From the results of this study, a guide for producers and exporters is concluded on the importance of selecting the right location to cultivate *Nigella sativa* in terms of soil type and climatic conditions.

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AUTHORS CONTRIBUTIONS

All listed authors have contributed equally in all steps of the research, including conceiving the presented idea, designing and performing of the research to the analyzing of the data. All authors discussed the results and contributed to the final manuscript.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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