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Productivity and Quality of *Nigella sativa* L. Plant Influenced by Moringa Extract application under Different drip irrigation Levels

Dina M.G. Hendi[1], F.E.M Saleh[1] and M. Hefzy[2]

[1]Medicinal and Aromatic Plants Research Department, Horticulture Research Institute, Agricultural Research Center (ARC), Giza, Egypt

[2]Water requirements and field irrigation Department, Soil water and Environment Research Institute, Agricultural Research Center (ARC), (Affiliation ID: 60019332), 9 Gamaa Street, 12619 Giza, Egypt

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ABSTRACT

Irrigation water use management is one of the most important factors of agricultural sustainability. Therefore, an experiment was conducted at the Experimental Farm of Arab El- Awammer Research, Station, Assiut, Egypt. during the two successive growing seasons of 2017/2018 and 2018/2019, to study the foliar application with different concentrations of Moringa leaves extract (control (zero), 2 and 4%) under different levels of deficit irrigation (60, 80% and 100% ETc). The results showed that, all evaluated parameters of black cumin plant (height, number branch, number of capsules /plant, weight of seeds (gm)/ plant and weight of seeds (kg)/fed.) significantly decreased with increasing water stress, inversely water stress increased significantly unsaturated fatty acids percentage (linoleic, oleic acids, Eicosadienoic acid). Economic productivity of irrigation water and IWUE, were significantly increased at 60% ETc compared to 80 and 100% ETc. The mean values of all studied characters were significantly increased as the moringa extract concentration increased in both seasons. While the highest mean values of fixed oil, total protein and total carbohydrate were obtained with100% and 80% water interacted with the highest moringa extract applied level (4%). The combination of full irrigation and 4% MLE gave the highest values of most previous parameters; additionally insignificant differences were noticed between full irrigation and moderate stress treatments with the same concentration. Therefore, it could be recommended by foliar application of 4% MLE with 80% Etc irrigation water for obtaining higher yield and quality of black cumin.

Keywords:*Nigella sativa,* drought stress, moringa, fatty acid, chemical composition

INTRODUCTION

Nigella sativa Family Ranunculaceae is a widely used medicinal plant throughout the world, Due to its miraculous power of healing, (Ahmad, *et al.,* 2013). Black cumin (*Nigella sativa* L.) is an annual aromatic plant native to Southwest Asia and the Mediterranean region. Presently, it is cultivated in various parts of the world. Seed of black cumin contain about 21% protein, 35% carbohydrates and 35-38%plant fats and oils (Ahmad and Ghafoor 2007). As fatty components, linolic acid (50-60%), oleic acid (20%), dihomolinoleic acid (10%) and eicodadienoic acid (3%) are the main unsaturated fatty acids and the palmitic acid and stearic acid belong to saturated fatty acids in *N. sativa* (Karna, 2013). One third of the world lands are classified to arid and semi-arid region and the remains are faced with water seasonal fluctuations (Beweley and Krochko, 1982). Management of water is a great challenge for the coming decades. The inadequate irrigation capacity and the cost of irrigation pumping as well as limited water sources are among the reasons that force many farmers to reduce their irrigation applications. In the case of medicinal plants, water deficit may cause changes in the yield and composition of their oil content. Effect of water stress on morphological characteristic, yield, oil content and secondary metabolites of different medicinal and aromatic plants has been reported in several studies; Tucker and Maciarello (1994) found that water stress has negative effect on biomass and essential oil content in oregano (*Origanum vulgare* L.). Also, Hassani (2006) reported that the plant height, number of shoots, fresh and dry herb yield of *Dracocephalum moldavica* was declined with decreasing soil water content. *Nigella sativa* plant originally grown in arid and semi-arid regions (Antuono *et al.,* 2002). Some studies reported that, the black cumin is able to tolerate moderate levels of water stress and others have focused on response of black cumin to different irrigation intervals and irrigation scheduling based on developmental stage (Bannayan, *et al.,* 2008, Mozzafari, *et al.,* 2000 and Babai, 1995). Moreover, deficit irrigation is one way of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied where crop is exposed to a certain level of water stress either during a particular period or throughout the entire growing season (English and Raja, 1996). Modern irrigation system is a must to increase water use efficiency. The drip irrigation method decreases the use of water and has more efficiency rather than surface irrigation and even sprinkler methods (Abd El-Hady and Ebtisam, 2016). Nowadays, there is a lot of awareness has been offered in order to reduce pollution in sustainable agricultural practices. One of the ways to decrease soil pollution is the use of organic compounds or Bio-stimulants compounds. Amongst naturally occurring plant growth stimulants; moringa (*Moringa olifera* L.) belongs to Moringaceae family has being rich in cytokinin, antioxidants and macro–micro nutrients in its leaves. It is one of such alternatives, being investigated to ascertain its effect on growth and yield of crops and thus can be promoted among farmers as a substitute to inorganic fertilizers (Phiri, 2010). Moringa leaf extract is a rich source of amino acids, vitamin E, ascorbates, potassium, calcium, iron, phenolic compounds and growth regulating hormones like zeatin (Makkar and Becker, 1996 and Nagar *et al.,* 2006). The active growth enhancing substances in Moringa leaf extract are reported to be isopentyladenine, zeatin and dihydrozeatin which are natural endogenous cytokinins (Price, 2007). Zeatin is the most naturally occurring cytokinin that not only promotes the growth of plants by facilitating cell division and cell elongation as well as its anti-aging potential and protective effects in plants (Shehata,2018). Cytokinins delay the processes of senescence and aging in many plant tissues, promote nutrient uptake and alternate apical dominance in plants (Taiz and Zeiger, 2006). Moringa leaf extract has been reported to increase the yield of many crops; cereals as reported by Phiri (2010) and Abbas *et al.,* (2013), tomato (Culver *et al.,* 2012), and Roselle (Hassan and Abd El-Samee, 2015). Considering the above facts, the experiment was conducted to evaluate the effect of Moringa leaf extract and determine the optimum level of irrigation for obtaining better yield and high quality.

MATERIALS AND METHODS

Site and experimental description

Two field experiments were conducted under drip irrigation system in sandy calcareous soil at the Experimental Farm of Arab El-Awammer Research Station, Agric. Res. Center (A.R.C.), Assiut Governorate, Egypt (which, lies between latitude 27°, 11′ N, longitude 31°, 06′ E and 71 m above sea level) during two growing winter seasons of 2017/2018 and 2018/2019 at the period from 25th October (sowing date) to 5th April (harvesting date) for the two seasons, to detect the growth and quality of *Nigella sativa* as influenced by irrigation levels(60%, 80% and 100% of crop evapotranspiration, ETc), which assigned in main plot, and foliar application with three concentrations of Moringa Leaf Extract (MLE); control “tap water” (M1), 2% moringa extract (M2) and 4% moringa extract (M3) as sub plot and their interaction. Climatic data for experimental sites during the two growing seasons are shown in Table (1) while the important physical and chemical characteristics of representative soil samples from the surface layer (0-25 cm) of the field experimental site are shown in Table (2).

Experimental Design and Field Conditions

The plots with dimensions of 1.5× 2 m were prepared and the spacing of 40 cm between the rows. There was a space of one meter between the plots and 2 meters between replications. Seeds of black cumin were sown on pipe lines from plastic material of 16 mm diameter. The spaces between mentioned them were 70 cm and the distance between hills was 40cm as well as thinning to one plant /hill was made 20-days sowing.

Preparation of moringa extracts

Drain the plant material in an electric oven at a temperature of 70º C for 48 hr. and then grind in a grindery and passed through a 40mesh screen. To prepare the extracts, 50 g of each ground plant material were macerated in 500 ml distilled water. Solutions were placed in orbital shaker at room temperature for 24 hr. The extracts were filtered using Whatman filter paper No.1 (Dayanada *et al.,* 2010). The obtained extracts were diluted order to achieve the concentrations. Drought treatment was imposed after the thinning. Each aqueous extract was applied three times after one month from planting and after each two weeks later. All necessary cultural practices for all the plots were done during the entire period of experimentation.

Collection of data

At the end of the growth stage, data were collected from the inner rows of each plot to avoid the border effect. Ten randomly selected plants from each plot were used for morphologic characteristics and yield (root length, plant height, number branch, number of capsules /plant, weight of seeds(gm) /plant and weight of seeds(kg)/fed. fixed oil content, total protein and total carbohydrate).

Determination of total carbohydrates content was according to Herbert, *et al.,* (1971).
Fixed oil content: The air-dried seeds balanced (50 g) were powdered mechanically and extracted with light petroleum ether (60 – 80 °C) for 4h in a Soxhlet apparatus. Removal of the solvent was done under reduced pressure gave the fixed oils (Horwitz *et al.,* 1970).
Lipids obtained after extraction of seed oil were converted to corresponding FAMEs by trans-esterification with potassium hydroxide (ISO 5509, 2000). The mixture was shaken for 2 minutes in a closed 20-ml vial. After settling, the supernatant was injected.

Gas chromatographic (GC) analysis of the oil

Gas chromatographic (GC) analysis of the oil samples were carried out by using Ds Chrom 6200 Gas chromatograph apparatus, fitted with a capillary columnBPX-5 phenyl (equiv.) polysillphenylene-siloxane 30×0.25mmIDμ film, with a flame ionization detector (FID) and a split/splitless injection port (used in the split mode, with a split vent flow of 40 ml/min), was used for analysis of the oil. The inlet liner was a deactivated 4 mm ID split sleeve. The injector and detector ports were set at 225° C and 230° C, respectively. The oven temperature program was initially set at 165° C for the first 15 minutes, and then increased at a rate of 2°C/min to 220° C, where it remained for the last 5 minutes. The carrier gas was helium and the linear velocity of 40 cm/sec. was measured at the initial temperature

Irrigation-water measurements and crop-water relations

Crop evapotranspiration (ETc)

CROPWAT model was used to calculate reference evapotranspiration according to Penman Monteith.

Crop evapotranspiration (ETc) was calculated according to (Allen *et al.,* 1998)

$$ETc = ET_0 \times Kc$$

Where: -

ETc = Crop ~~evapotr~~anspiration., ET_0 = Reference evapotranspiration, and Kc = Crop coefficient (from FAO paper 56).

Table (1): Average monthly meteorological data of Assiut weather station during the two growth seasons of 2017/2018 and 2018/2019.

Parameter Month	Temperature (C°) Max	Temperature (C°) Min	Relative Humidity %	Wind Speed km/h	Sun-shine hours	ET_o mm/day
2017/2018						
October	30.3	16.5	47	17.2	10.0	6.94
November	25.1	10.9	54.6	15.2	9.4	4.75
December	23.2	9	58.8	14.6	9.0	3.98
January	19.9	6.5	57.4	15.3	8.9	3.77
February	26.1	11.2	44.3	14.4	9.7	5.63
March	30.5	14.2	36.2	16.9	9.9	7.90
April	32.4	16.6	36.2	18.4	10.3	10.93
2018/2019						
October	32.6	18.9	46.5	18.1	10.0	7.58
November	26.5	13.1	53.8	14.7	9.4	4.93
December	20.8	8	62.8	16.3	9.0	3.62
January	19.3	5.8	52.8	13.9	8.9	3.70
February	21.8	7.6	51.4	17.3	9.7	4.93
March	24.7	9.9	42.9	19.8	9.9	6.64
April	29.6	14	36.5	21.3	10.3	8.93

Table (2): Physical and chemical properties of representative soil samples from the field experimental site of the surface layer (0-25 cm).

Physical properties									
Particle size distribution				Moisture content % (w/w)			Organic Matter %	Total $CaCO_3$ %	Bulk Density
Sand %	Silt %	Clay %	Texture Grade	S.P.	F.C.	W.P.			
90.91	5.90	3.19	Sandy	23.70	10.97	4.45	0.22	33.4	1.63

Chemical properties									
pH (1:1)	EC (1:1) Ca^{++}	Soluble Cations (meq / L)				Soluble Anions (meq / L)		Total N (%)	Available P (mg/kg)
		Mg^{++}	Na^+	K^+	CO_3^-+HCO_3^-	Cl^-			
8.73	0.97	4.79	2.77	1.55	0.47	4.71	3.71	0.009	7.63

Irrigation applied water

The amounts of actual irrigation applied water under each irrigation treatment were determined using the following equation: James (1988).

$$I.Ra = \frac{(ETc+Lf)}{Er}$$

Where:

I.Ra = total actual irrigation applied water mm/ interval. ETc = Crop evapotranspiration, Lf = leaching factor 10 %, and Er = irrigation system efficiency.

Irrigation water use efficiency (IWUE): -

The irrigation water use efficiency (IWUE) values were calculated as follows:

$$IWUE = \frac{Total\ yield\ (Kg\ /\ fed.)}{Irrigation\ water\ Applied\ (m^3\ /\ fed.)}$$

Economic productivity of irrigation water

Irrigation productivity of irrigation water can be expressed as economical productivity (EPIW) according to Molden (1997). It was calculated as follows:

$$EPIW = \frac{Gross\ value\ of\ product\ (L.E.\ fed.^{-1})}{Total\ amount\ of\ irrigation\ applied\ water\ (m^3\ fed.^{-1})}$$

Statistical analysis

Data were statically processed by analysis of variance using Statistix 8.1 software and data showing significant difference at $P \leq 0.05$ was put to comparison of treatments means by the Tukey's comparison test.

RESULTS AND DISCUSSION

Vegetative growth and yield characters

Table 3: Effect of three irrigation levels and moringa extract on the Root length, plant height and number of branches/ plants, of *Nigella sativa* L. through two seasons (2017/2018 and 2018/2019).

Season	2017/2018				2018/2019			
Treatments	60%ETc	80%ETc	100%ETc	Mean	60%ETc	80%ETc	100%ETc	Mean
	Root length(cm)							
M1	13.2^{BC}±0.66	12.2^{BC}±0.24	11.0^{C}± 0.82	12.13^{B}	14.7^{A}±0.44	12.4^{BC}±0.14	11.9^{C}±0.67	13.00^{B}
M2	13.6^{A}±0.85	13.2^{BC}±0.24	12.7^{BC}±0.94	13.16^{B}	12.6^{BC}±0.46	12.85^{B}±0.68	12.3^{BC}±0.66	12.58^{B}
M3	15.8^{A}±0.62	14.0^{AB}±0.82	14.67^{AB}±0.47	14.82^{A}	15.3^{A}±0.70	14.03^{AB}±0.39	14.78^{A}± 0.33	14.70^{A}
Mean	14.20^{A}	13.13^{B}	12.79^{B}		14.19^{A}	13.09^{A}	12.99^{A}	
Plant height(cm)								
M1	61.2^{E} ±0.98	71.3^{C}±0.62	70.9^{CD}±0.29	67.80 ^{C}	60.9^{E} ±0.65	67.0^{CD} ±0.82	68.4^{BD} ±0.26	65.43^{C}
M2	68.4^{D} ±1.02	72.9^{BC} ±0.98	75.3^{AB}±0.47	72.21^{B}	65.5^{D} ±1.78	68.33^{BD}±1.25	71.4^{B} ±0.90	68.41^{B}
M3	74.5^{AB}±1.76	76.9^{A}±0.82	77.7^{A} ±0.47	76.35^{A}	69.8^{BC}±0.62	71.3^{BC} ±0.47	75.2^{A}±0.24	72.10^{A}
Mean	68.00^{C}	73.70^{B}	74.63^{A}		65.4^{C}	68.9^{B}	71.66^{A}	
No. of branches/ plant								
M1	± 0.29 12.3^{G}	±0.71 15.2^{EF}	17.0^{CD} ±0.51	14.83^{C}	12.93^{F}±0.52	15.3^{E}±0.39	17.2^{D} ± 0.43	15.14^{C}
M2	13.8^{F}±0.26	16.3^{D}±0.08	18.6^{B}± 0.31	16.26^{B}	16.2^{DE}±0.76	17.7^{CD}±0.17	17.6^{CD}±0.34	17.16^{B}
M3	± 0.43 18.2^{B}	19.4^{AB}±0.21	20.7^{A}±0.50	19.45^{A}	19.7^{B} ±0.46	20.5^{AB} ±0.50	21.8^{A} ±0.41	20.66^{A}
Mean	14.76^{C}	16.96^{B}	18.77^{A}		16.26^{C}	17.83^{B}	18.86^{A}	

Table 4: Effect of three irrigation levels and moringa extract on the number of capsules /plant, weight of seeds(gm)/plant and weight of seeds(kg)/fed., of *Nigella sativa* L. through two seasons (2017/2018 and 2018/2019).

Season	2017/2018				2018/2019			
Treat-ments	60%ETc	80%ETc	100%ETc	Mean	60%ETc	80%ETc	100%ETc	Mean
	number of capsules /plants							
M1	33.67^{E}± 0.68	37.00^{D}±0.86	43.63^{C}±0.61	38.10^{C}	35.20^{G}±1.14	38.83^{FG}±0.54	44.33^{DE}±1.3	39.46^{C}
M2	39.33^{D}± 0.84	42.73^{C}±0.56	48.74^{B}±0.63	43.60^{B}	39.7^{EFG}±1.0	43.0^{DEF}±1.56	47.20^{CD} ±1.21	43.30^{B}
M3	47.60^{B}± 0.86	49.30^{B} ±0.80	54.70^{A} ±0.29	50.53^{A}	50.97^{BC}±0.95	52.80^{AB}±2.7	57.77^{A}± 1.31	53.84^{A}
Mean	40.20^{C}	43.01^{B}	49.03^{A}		41.96^{C}	44.88^{B}	49.77^{A}	
weight of seeds(gm)/plant								
M1	13.99^{D}±0.61	±0.23 18.22^{C}	21.03^{BC}±1.4	17.74^{C}	±0.15 15.16^{F}	20.03^{E}±0.36	23.23^{D}±0.35	19.47^{C}
M2	18.78^{C}±0.63	20.02^{BC}±0.66	22.61^{AB}±0.4	20.47^{B}	20.03^{E}±0.18	22.40^{D} ±0.51	25.00^{BC} ±0.29	22.48^{B}
M3	±1.04 22.83^{A}	24.00^{A}±0.36	24.67^{A}±0.91	23.83^{A}	24.51^{C} ±0.42	25.89^{B} ±0.23	27.76^{A} ±0.39	26.05^{A}
Mean	18.54^{C}	20.75^{B}	22.77^{A}		19.89^{C}	22.78 ^{B}	25.33^{A}	
weight of seeds(kg)/fed.								
M1	274.20^{G}±2.8	±4.70347.97^{F}	±5.4 412.12^{C}	344.76^{C}	297.66^{F} ±3.7	392.59^{E} ±7.1	455.24^{D} ±6.9	381.83^{C}
M2	368.15^{E}±2.0	392.39^{D}±5.43	±3.8 443.00^{B}	401.18^{B}	±3.5 392.52^{E}	439.11^{D}±10.0	±5.6 490.07^{BC}	440.57^{B}
M3	447.53^{B}±6.2	392.39^{D}±2.11	483.47^{A}±4.7	468.22^{A}	480.33^{C} ±8.3	507.58^{B} ±4.4	544.10^{A}±7.7	510.67^{A}
Mean	363.30^{C}	404.67^{B}	446.20^{A}		390.17^{C}	446.42^{B}	496.47^{A}	

M1= without moringa extract M2 = 2% moringa extract M3 = 4% moringa extract

The results in Tables 3 and 4 showed that the increasing of irrigation water deficit led to significant decrease of vegetative growth and yield character (height (cm), branch number per plant, number of fruits per plant, seed yield (g)/plant and seed yield (kg)/fed.) of black cumin except in case of root length was increased with increasing water deficit in two cultivated seasons. The minimum and maximum values of seed were 363.3, 446.2Kg / fed. and 390.2, 496.52Kg/fed. for irrigation levels 60% and100% ETc, respectively during the two successive seasons. The plants received higher number of irrigation produced maximum number branches, number of capsule per plant , number of seed per capsule and seed yield per hectare (Karim, *et al.,*2017). Furthermore, the effect of reduced irrigation on growth of plant may be due to the lower availability of sufficient moisture in rhizosphere and the lower absorption of nutrients (Singh *et al.,* 1997).our results showed that vegetative growth and yield characters significantly and successively increased as the moringa extract concentrations increased. The highest mean values were obtained from the highest concentration of moringa extract (40 g/l (M3) as optimal treatment for the production of high yield and good quality. During both seasons, the interaction between irrigation water levels and foliar application with MLE showed that the combination of moderate irrigation level (80% ETc) and 4% MLE gave high values of most effective previous parameters exceeded by full irrigation with the same concentration of MLE while the values recorded at 60%Etcwere generally constituted the lowest values. As the same results, all investigated vegetative growth characters, significantly, decreased with reducing of moringa extract, Zeatin is the most naturally occurring cytokinin that not only promotes the growth of plants by facilitating cell division and cell elongation as well as its anti-aging potential and protective effects in plants (Shehata, 2018),Spraying the leaves of plants with the MLE prepared in produced some notable effects such as increase in yield of between 20-35 % (Mall and Tripathi, 2017).

Figure (1): Effect of three irrigation levels (L1=60, L2 = 80 and L3= 100%ETc) and moringa extract (M1=0, M2=2 and M3=4%) on the fixed oil %, protein% , total carbohydrate (%) of *Nigella sativa* L

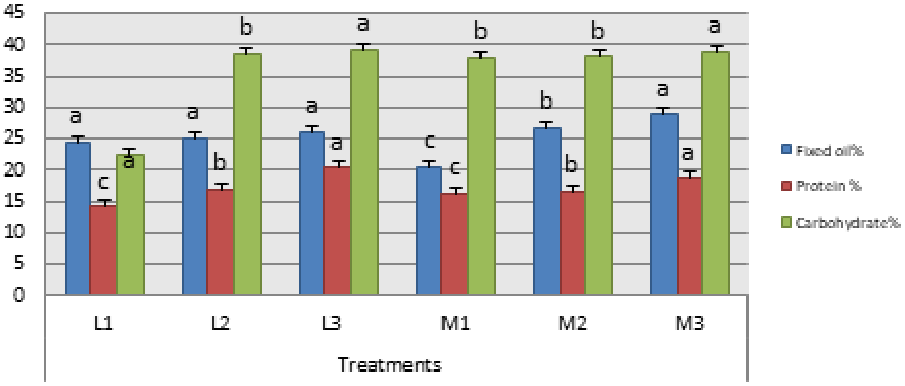
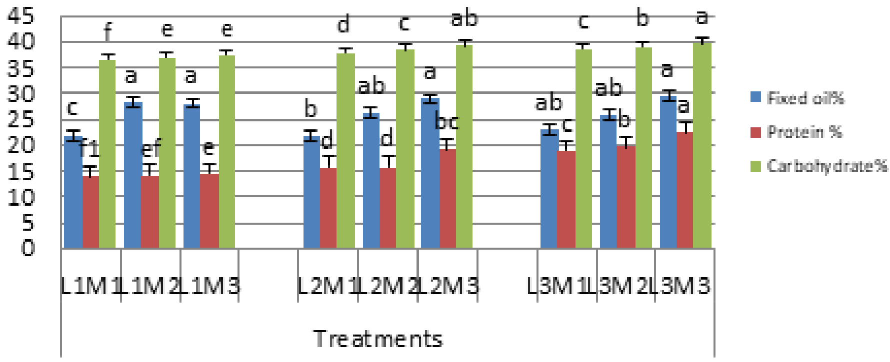


Figure (2): Effect of the interaction between three irrigation levels (L1=60, L2 = 80 and L3= 100%ETc) and moringa extract (M1=0, M2=2 and M3=4% concentration on the fixed oil %, Protein%, Total carbohydrate (%), of *Nigella*



Fixed oil, protein and carbohydrate

The highest and lowest fixed oil percentages were achieved in 100% and 60% Etc respectively as shown in Figure 1. Significant differences were observed between water levels and chemical composition such as enhancing the rates of physiological processes and increasing the total protein and carbohydrate with decreasing water stress. While, no significant differences in fixed oil (%) were observed between different irrigation levels. Inagreement with our results. The maximum values of fixed oil were obtained by irrigation every 2 days, whereas the minimum values were obtained when plants irrigated 6 days intervals before or after flowering (El-Mekawy, 2012). Ghamarnia, *et al.,* (2010) detected that no significant differences in oil (%) were observed for different drip irrigation treatments, and Bannayan *et al.,* (2008) reported that no reductions in oil concentration of black cumin were observed because of deficit different irrigation treatments. As for the impact of foliar application of moringa, results exhibited that, the previous parameters were increased compared to the control (without moringa) indicated that the effect of moringa extract had pronounced effect on black cumin fixed oil percentage, total protein and carbohydrate. Furthermore, spraying 4% (MLE) with 100% and80% Etc recorded the maximum fixed oil, whereas MLE increased the production of secondary metabolites by compensate the drought stress and gradually release the necessary plant elements. From the results obtained, it can be said that the Interaction of treatments had a considerable effect on alleviation water stress. Yasmeen *et al.,* (2013) reported that moringa leaf extract when it applied for drought or salt stressed plants modified plant phenotypic response to positively affect growth and productivity with alteration in metabolic processes.

Table 5: Chemical composition of *Nigella sativa* fixed oil as influenced by irrigation water levels, different concentrations of moringa extract and their interactions

Treatments	60%ETc	80%ETc	100%ETc	Mean	60%ETc	80%ETc	100%ETc	Mean
	Linoleic acid				Oleic acid			
M1	42.26^{G}±0.08	43.27^{F}±0.04	39.53^{I}± 0.06	42.36^{C}	15.61^{G}±0.07	16.40^{E}±0.04	12.17^{I}±0.05	15.05^{C}±0.06
M2	45.82^{C}±0.04	44.61^{E}±0.09	41.41^{H}± 0.10	43.50^{B}	15.90^{F}±0.06	16.70^{D}±0.06	13.14^{H}±0.06	16.13^{B}±0.06
M3	46.15^{B}±0.01	45.29^{D}±0.04	48.75^{A}±0.04	46.65^{A}	19.25^{A}±0.05	16.97^{C}±0.03	17.69^{B}±0.06	16.76^{A}±0.05
Mean	44.89^{A}	44.39^{B}	43.230^{C}		16.98^{A}	16.69^{B}	14.33^{C}	
Palmitic acid					Eicosadienoic			
M1	8.20^{H}± 0.05	9.25^{F}± 0.03	8.20^{H}±0.07	8.55^{C}	9.97^{A}± 0.02	4.26^{H}± 0.06	7.32^{C}± 0.08	7.18^{A}± 0.05
M2	9.89^{D}± 0.04	8.54^{G}± 0.08	11.26^{B}±0.05	9.90^{B}	6.54^{F}± 0.08	5.29^{G}± 0.07	6.97^{E}± 0.02	6.26^{B}± 0.04
M3	9.54^{E}± 0.02	10.58^{C}±0.06	11.69^{A}±0.06	10.61^{A}	7.20^{D}± 0.03	2.31^{I}± 0.12	8.11^{B}± 0.07	5.88^{C}± 0.05
Mean	9.21^{C}	9.46^{B}	10.39^{A}		7.90^{A}	3.95^{C}	7.47^{B}	
Linolenic acid					Arachidic acid			
M1	3.34^{B}± 0.04	2.39^{C}± 0.02	1.89^{DE}± 0.05	2.54^{B}	3.51^{A}± 0.05	3.45^{A}± 0.12	2.80^{D}± 0.04	3.25^{A}±0.06
M2	1.79^{F}± 0.08	1.57^{G}± 0.08	1.96^{D}± 0.02	1.77^{C}	2.36^{F}± 0.06	2.22^{G}± 0.08	2.56^{E}± 0.06	2.38^{C}±0.05
M3	4.29^{A}± 0.03	1.85^{EF}± 0.04	2.35^{C}± 0.04	2.83^{A}	2.93^{C}± 0.04	2.32^{F}± 0.05	3.15^{B}± 0.10	2.80^{B}±0.01
Mean	3.14^{A}	1.94^{C}	2.06^{B}		2.80^{B}	2.67^{C}	2.83^{B}	

M1= without moringa extract, M2= 2% moringa extract and M3= 4% moringa extract

Figure (3): Gas chromatographic (GC) analysis of *Nigella sativa* fixed oil under water stress

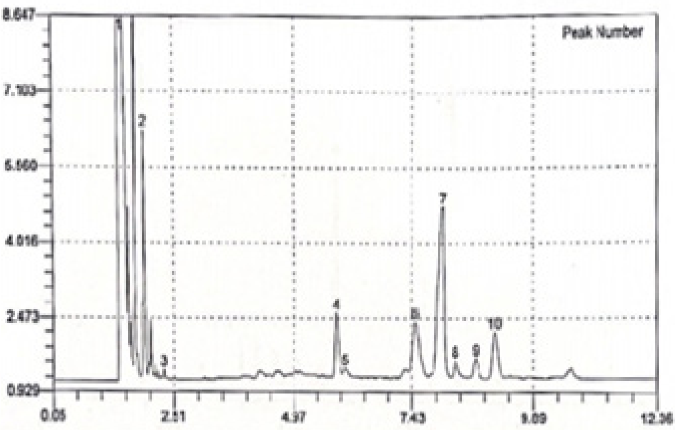
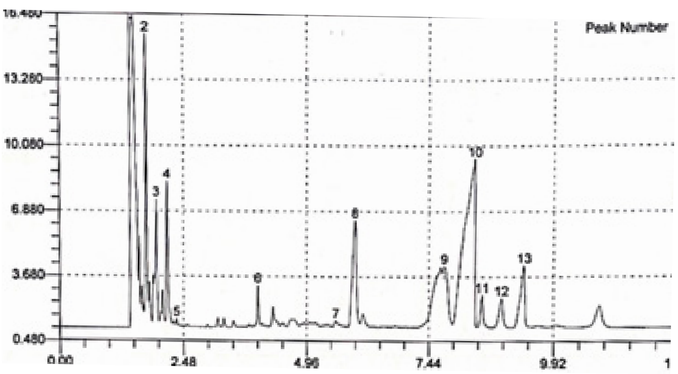


Figure (4): Gas chromatographic (GC) analysis of *Nigella sativa* fixed oil under water stress (60%Etc) and treated with 4% moringa leaf extract



The interaction between irrigation water levels and foliar application with moringa extract (figure 2) showed significant results, as well as 4% MLE interacted with100% followed 80% Etc were recorded the highest values of the mentioned parameters but insignificant differences were noticed between full irrigation and moderate stress treatments with MLE. Abou-Sreea and Matter (2016) on fennel found that using 10% of moringa leaf extract plus 50 ppm of GA3 recorded the highest fruit yield/plant, fruit yield/feddan and oil yield/ plant

Identification of fatty acids

The identification of the individual fatty acids of *Nigella sativa* seed oil was carried out by gas chromatography. Six fatty acids represented about 82% of oil contents have been identified as the major fatty acids in all treatments (Table 5 and figer 3). The results revealed that the major components of fatty acids are linoleic, oleic acids, Eicosadienoic acid, as unsaturated fatty acids. The oil also contains larger amounts (8.20% to 11.69%) of saturated normal chain fatty acid (palmitic acid). Furthermore, linoleic, oleic and linolenic acids were increased with increasing water deficit, Similarly, Experimental results were showed that drought stress reduced the components of black cumin yield but improved qualitative factors such as fatty acids percentage in addition linolenic content increased during drought stress condition (Alaghemand *et al.,*2019). While using moringa extract, the promotion effect was observed in both seasons. On the other hand, significant correlations between foliar application of moringa extract and irrigation levels were observed. The greatest unsaturated fatty acids were recorded by 4%extract with60%Etc in both seasons. Furthermore, the main unsaturated fatty acids were gradually increased by increasing moringa

Figure (5): Irrigation water applied (m3/fed.) at different growth stages of *Nigella sativa* grown under different irrigation regimes during the seasons of 2017/ 2018(a) and 2018/2019 (b).

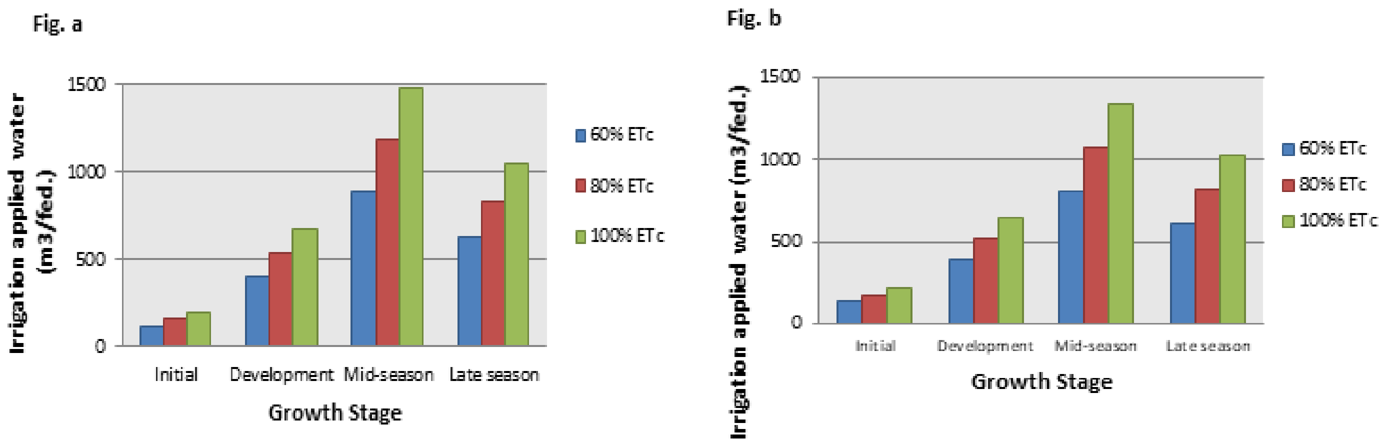


Table (6): Nigella sativa Irrigation water used efficiency (kg/m3) and Economic productivity of irrigation water of *Nigella sativa* as influenced by irrigation regime and moringa extract during 2017/2018 and 2018/2019 seasons.

Seasons	2017/2018				2018/2019			
Treatments	60%ETc	80%ETc	100%ETc	mean	60%ETc	80%ETc	100%ETc	Mean
	IWUE (kg/m3)							
M1	0.133^{EF}	0.130^{F}	0.120^{G}	0.128^{C}	0.153^{D}	0.150^{D}	0.14^{0E}	0.148^{C}
M2	0.180^{B}	0.147^{D}	0.130^{F}	0.152^{B}	0.200^{B}	0.17^{0C}	0.150^{D}	0.173^{B}
M3	0.220^{A}	0.170^{C}	0.140^{DE}	0.177^{A}	0.246^{A}	0.197^{B}	0.170^{C}	0.204^{A}
Mean	0.178^{A}	0.149^{B}	0.130^{C}		0.200^{A}	0.172^{B}	0.153^{C}	
EPIW (L.E./m3)								
M1	6.49^{E}	6.15^{F}	5.83^{G}	6.154^{C}	7.38^{D}	7.30^{D}	6.77^{E}	7.152^{C}
M2	8.68^{B}	6.93^{D}	6.26^{EF}	7.291^{B}	9.73^{B}	8.17^{C}	7.29^{D}	8.397^{B}
M3	10.54^{A}	8.37^{C}	6.83^{D}	8.583^{A}	11.91^{A}	9.44^{B}	8.09^{C}	9.817^{A}
Mean	8.569^{A}	7.152^{B}	6.308^{C}		9.676^{A}	8.303^{B}	7.387^{C}	

M1= without moringa extract, M2 = 2% moringa extract M3 = 4% moringa extract

concentrations (figure 4).

Irrigation applied water

The data in figure 5a and b indicate that the irrigation water applied vary from growth stage to another through the two growth seasons. The seasonal irrigation water applied was mostly influenced by irrigation levels. The increase in irrigation water applied under 100% ETc may be attributed to the increase in direct evaporation. Therefore, the seasonal irrigation water applied is higher under 100% ETc followed by 80% ETc for *Nigella sativa* during the two growth seasons. The results also, indicated that the total irrigation applied water values in the first season were higher than the values of the second season. This difference may be due to the increasing reference evapotranspiration in the first season compared to the second season. These results are in the same line with those reported by Zahran *et al.,* 2020, Mansour *et al.,* 2020, Refai, *et al.,* 2019 and Ghamarnia, *et al.,* (2010) found that, the total applied irrigation water for *Nigella sativa*, varies between 413.59 to 827.18 mm according to the different irrigation treatment under surface drip irrigation system.

Irrigation water use efficiency (IWUE)

The results were illustrated in Table 6 showed that the IWUE rates varied between 0.121 and 0.141 kg/m^3 at control under irrigation with 100% ETc, while the highest (0.220 and 0.248 kg/m^3) values were obtained at M3 extract under irrigation with 60 % ETc, in the first and second seasons, respectively. Application M3 extract increased irrigation water used efficiency at different levels of irrigation water. The resulted are agreement with those obtained by Ghamarnia *et al.,* 2010 and 2013, Senyigit and Arslan 2018; Refai *et al.,* 2019; Zahran *et al.,* 2020 and Mansour *et al.,* 2020.

Economic productivity of irrigation water

Economic productivity of irrigation water in agricultural production system is focused on gross value of product, L E m^{-3}. EPIW shows in Table 6 take the same liner of IWUE, it was significantly increased when *Nigella* *sativa* was irrigated with 60% ETc compared to 80 and 100% ETc. The highest EPIW, 10.54 and 11.91 LE m^{-3} in the first and second seasons respectively were produced by 4% MLE under irrigated with 60% ETc. Similar results were reported by Zahran *et al.,* 2020 and Mansour *et al.,* 2020.

CONCLUSION

According to the results obtained, it can be concluded that growth and yield parameters of *Nigella sativa* were adversely affected with water stress. However, the percentage of major fatty acid compositions was significantly increased with the limited water supply. Irrigation water amount should be applied to meet full evapotranspiration requirement under conditions where the water is sufficient, Foliar application of4% moringa leaf extract increased irrigation water used efficiency and Economic productivity of irrigation water of *Nigella sativa* at all levels of irrigation water. Under drip irrigation system and calcareous sandy soil, 80% ETc with Bio-stimulants (4% moringa leaf extract) can increase and improve yield and quality of *Nigella sativa* and saving irrigation water.

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