Ç.Ü Fen ve Mühendislik Bilimleri Dergisi Yıl 2020 Cilt: 39-10

EFFECT OF DIFFERENT IRRIGATION LEVELS ON YIELD AND QUALITY OF BLACK CUMIN (*Nigella sativa* L.) [1]

Çörek Otu'nun (*Nigella Sativa* L.) Verimi ve Kalitesi Üzerine Farkli Sulama Seviyelerinin Etkisi

Laura María Vanessa GUTIÉRREZ PRIETO
Field Crops Department

Prof.Dr. Saliha KIRICI
Field Crops Department

ABSTRACT

Nigella sativa, also known as black cumin, is one of those medicinal plants, its seeds show a wide therapeutic potential, and they are used as spice in different kind of foods. The present work had the objective of evaluating the effect of different irrigation levels on yield and quality of black cumin seeds. The experiment was carried out in the experimental field of the Field Crops Department of Çukurova University. The trial was arranged based on a Randomized Complete Block design, with five treatments (0%, 10%, 50%, 70% and 100% of the crop´s water requirements) and four replications.

Concerning the irrigation levels, the highest seed yield belonged to the 50% IR treatment (1199 kg/ha). The 0% IR- treatment produced the highest essential oil yield (0.69%). The major compounds of the essential oil varied from treatment to treatment, the compound farnesol was found in concentrations never before seen in amounts ranging from 3.04% to 20.79%. The highest fixed oil content belonged to the 50% IR-treatment with 36.33%. The major fatty acids composing black cumin seeds were linoleic acid and oleic acid, the average values being 60.08% and 20.52% respectively. It can be concluded that deficit irrigation is a valuable strategy to manage the water resource in *Nigella sativa* crop.
Key words: *Nigella sativa* L., medicinal plant, irrigation, evaporation

ÖZET

Nigella sativa L., aynı zamanda çörek otu olarak bilinen, bu şifalı bitkilerden biridir. Tohumları geniş bir terapötik potansiyele sahiptir ve farklı gıdalarda baharat olarak kullanılırlar. Bu bitkinin muazzam potansiyeline rağmen yetiştirme ve üretim bilgisi sınırlıdır. Şu anki iklim koşullarında su yönetimi özellikle önem kazanmakta, su tüketiminin azaltılması ve daha verimli kullanılması gerekmektedir. Mevcut çalışmanın iki amacı vardı: öncelikle farklı sulama miktarının çörek otu tohumlarının verimi ve kalitesi üzerindeki etkisini değerlendirmek ve ikincisi bitkinin fenolojisini karakterize etmektir. Araştırma, Çukurova Üniversitesi Ziraat Fakültesi,Tarla Bitkileri Bölümü araştırma alanında tesadüf blokları deneme deseninde dört tekrarlamalı olarak yürütülmüştür. Sulama seviyeleri; buharlaşma temelinde belirlenen su ihtiyacının % 0, %10, %50, %70 ve %100'ünün alınması şeklinde beş uygulama olacak şekilde *Tohum Olgunlaşma* aşamasında uygulanmıştır.

[1] Aynı başlıklı Yüksek Lisans tezinden üretilmiştir.

Sulama miktarıyla ilgili olarak, en yüksek tohum verimi (1199 kg/ha), %50 IR uygulamasından alınmıştır. % 0 IR uygulamasında en yüksek uçucu yağ oranı (0.69%) elde edilmiştir. Uçucu yağın başlıca bileşikleri, uygulamalara göre değişmiştir. Uçucu yağ bileşenlerinden farnesol %3.04 ile %20.79 arasında değişen oranlarda bulunmuştur. En yüksek sabit yağ %36.33 ile 50% IR-uygulamasından elde edilmiştir. Çörekotu tohumlarında esas yağ asitleri linoleik ve oleik asit olup, ortalama değerleri sırasıyla %60.08 ve % 20.52 olmuştur. Sonuçlara dayanarak, kısıtlı sulamanın *Nigella sativa* bitkisinde su kaynağını yönetmek için faydalı bir strateji olduğu sonucuna varılabilir.
Anahtar kelimeler: *Nigella sativa* L., tıbbi bitkiler, sulama, buharlaşma

Introduction

The use of medicinal plants has been recorded particularly in Egyptian, Chinese, Indian and Islamic civilizations (Elsafi, 2003). *Nigella sativa*, otherwise known as black cumin, is one of the medicinal plants that have been used for the treatment of a wide range of illnesses. The genus Nigella, belonging to Ranunculaceae family contains about 20 species (Telci *et al*. 2014). *Nigella sativa* is an annual herb native to Mediterranean and western Asia regions (D'Antuono *et al*. 2002). The dried seeds of *N. sativa* are the commercial product. Pharmaceutical studies carried out on *N. sativa* have shown the large therapeutic potential of this species, including antibacterial, antifungal, antioxidant, antidiabetic, anticancer, anti-inflamatory, cardiovascular, gastro-protective, hepatic-protective, nephroprotective, pulmonary-protective, testicular-protective, neuro-pharmacological, hypoglycemic, smooth muscles relaxant and immunostimulant effects (Nickavar *et al.* 2003; Ahmad *et al.* 2013).

Currently, *Nigella sativa* seed-producing countries are: India, Pakistan, Sri Lanka, Bangladesh, Nepal, Egypt, Syria, Saudi Arabia, Turkey, Iran, and Iraq (Malhotra & Vashishtha, 2008; Haq *et al.* 2015). The sown area as well as the production had been increasing in the last years, going from a sown area of 2299 decares and a production of 161 tons in 2012, to a planted area of 23.160 decares and a production of 2527 tons (Anomymous, 2016). Despite the enormous potential of *Nigella sativa* as medicinal plant, and its increasing demand in the pharmaceutical and perfume industry, limited information about its cultivation and production practices is available (Talafih *et al.* 2007; Shah, 2008). The need to find new cultivation strategies for stressful weather conditions to reduce the water consumption and make a more efficient use of the available resources, focused on maximizing water savings and improving its final productivity is evident.

Considering the aforementioned, and given the fact that Turkey as a subtropical country might have a bigger possibility of suffering water scarcity in the next decades, the present study aims to evaluate the effect of different irrigation levels on yield and quality characteristics of *Nigella sativa* L.

Materials and Methodology

Experiment Site: *Nigella sativa* seeds belonging to Çameli variety, were brought from the Institute of Agricultural Research of Eskişehir (Eskişehir-Turkey) and used as vegetal material. The experiment was carried out in the experimental field of the Field Crops Department of Çukurova University, Adana (37° 2´ 2.23" N and 35° 20´ 52.12" E).

Soil Features: Soil analysis was performed one month before establish the experiment, that is to say on October 2016. It is a Clay-Loam soil, with a pH close to neutrality and, low content of organic matter (Table 2). Based on the soil analysis and the available recommendations so far for black cumin crop, nitrogen and phosphorus applications in granulated form was done at the same time as the sowing, in amounts of 15 kg/da and 1 kg/da respectively. Foliar nitrogen application at a rate of 1.5 mL per liter of water was done in April 20th, 2017.

Climate Features: the experiment was carried out in Adana city, on the Mediterranean Sea (23 meters above mean sea level), consequently the climate is Mediterranean, characterized by mild wet winters and hot dry summers. In Table 3 the main climate features during the crop season as well as the historical weather data are shown. During the crop season June was the hottest month, with a maximum temperature of 32.15°C; the coldest month was January and the wettest month was December with an average of 131 mm of rain.

Experiment Design and Statistical Analysis: The experimental design was Randomized Complete Blocks with four replications. The treatments consisted in the application of different amounts of water, said amounts corresponding to different percentages of the irrigation requirements (IR), which was determined based on evaporation, thus, the treatments were: 10% IR, 50% IR, 70% IR, and 100% IR of the crop water requirements, furthermore, a Control treatment consisting in no-irrigation (0% IR) was settled on; the treatments were applied during the Seed Maturation stage. Each treatment had four replications. The data were analyzed using InfoStat software, analysis of variance (ANOVA) was made with a variance level of 0.05%.

Agronomic Management: The study was initiated on November 8th, 2016. Before sowing a chisel plow pass as well as a land leveller pass were done. In the time first instance, while taking into account that the percentage of germination is rarely near to 100% (El-Ghamery et al. 2003; Jamian et al. 2014), one gram of seed was sown to 0.5 cm of depth of 0.5 cm along each 3-metre-long row.

Water Management and Water Requirements Calculation: In relation to water management, it was performed as follows: sprinkler-irrigation was done three times, including the irrigation applied at sowing. When the crop reached the Seed Maturation stage; drip irrigation (Table 1) was applied to provide the exact amount of water required by the plant, so as mentioned above, each treatment corresponded to a certain percentage of IR. Irrigation requirements were calculated by using the formula IR (Liters) = CPE (mm) * K_p * K_c * W_p (%) * S (m^2). Where IR is the volume of water to apply [liters/plant]; CPE being the cumulative pan evaporation during the days between two consecutive irrigation events [mm], for the case 7 days; K_p is the pan coefficient, which depends on the relative humidity, wind speed and the distance between the crop and the pan (Allen *et al.* 2006); K_c is the crop coefficient, its value depends on the type of crop, the growth stage of the plant, and the weather, it was taken from a study carried out by Ghamarnia *et al.* (2014), W_p is the percentage of crop area wetted by the drip irrigation system (0.8 %); and, S is the crop density [m^2], which was 0.15 m*0.25 m. (Sampathkumar et al. 2013); besides a Class-A pan was used to obtain the evaporation datum.

Table 1. Days of Drip Irrigation

Irrigation Days
May 15^{th}, 2017
May 22th, 2017
May 29^{th}, 2017
June 5^{th}, 2017

Measured Parameters and Sampling: *Yield* and *quality* features of black cumin seeds, yield measurements were taken at harvest time. To do these measurements forty (40) plants were randomly selected as sample from each treatment. All the measures taken are shown below:

Number of Capsules per Plant: amount of capsules produced by a single plant.

Number of Seeds per Capsule: amount of seeds contained in a capsule

Capsule Diameter (cm): length of the section through the center and touching two points on the edge of the top of the capsule.

Capsule Length (cm): distance between the uppermost point and the bottom of the capsule.

Plant Weight (g): weight of the plant after harvesting.

Weight per 1000 seeds (g): weight corresponding to 1000 seeds.

Harvest Index (%): weight of the harvest product as a percentage of the total plant weight of the crop that is, the ratio between the weight of the produced seeds and plant weight, multiplied by 100.

Seed Yield (kg/ha): total amount of the seeds produced.

Essential Oil Content (%): proportion of essential oil produced by a 50-gram seed sample. The essential oil was extracted by hydrodistillation for 3 hours using a Clevenger apparatus.

Essential Oil Composition: analysis of the oils was carried out on a 7000 Series Triple Quad GC/MS apparatus [Agilent], equipped with split-splitless injector and automatic liquid sampler, attached to HP-5MS capillary column (30 m x 0.25 mm x 0.25 µm film thickness, %5 phenyl methyl poly siloxane). The carrier gas flow rate (He) was 1 ml/min, split ratio 1:30, oven temperature program was started at50°C (held for 3 min.) while column temperature was linearly programmed from 50-240°C (at rate of 3°/min). For this measurement only three of the four replications were sampled.

Fixed Oil: In order to determine the yield of fixed oil in black cumin seeds, three grams of powder seeds were extracted with hexane as the extraction solvent using a Soxhlet apparatus for 3 hours (Ghourchian et al. 2016).

Fatty acid content: The fatty acid content of fixed oil was deteminated by GC analysis of their methyl esters. Fatty acids were analyzed using a Clarus 500 gas chromatograph with an autosampler (PerkinElmer, Shelton, CT, USA) equipped with a flame ionization detector and a fused-silica capillary SGE column (30 m × 0.32 mm, ID 0.25 μm, BP20 0.25 UM; PerkinElmer, Austin, TX, USA). The oven min^{-1} and to 220 °C at a rate of 1°C min^{-1}, while the injector and the detector temperatures were set at 220 and 280°C, respectively. The sample volume was 1 temperature was held at 140°C for 5 min and then raised to 200°C at a rate of 4°C μL, and the carrier gas was controlled at 16 PSI. The split ratio was 1:100. Fatty acids were detected by comparing the retention indices of the FAMEs with a standard 37-component FAME mixture (Supelco, Bellefonte, PA, USA). Triplicate GC analyses were performed and the results were expressed as a mean GC area (%).

Table 2. Soil Analysis

Depth (cm)	**Texture**				**pH**	**Salt**	**Organic matter**	**Lime**	**P_2O_5**	**K_2O**	**Fe**	**Zn**	**Mn**	**Cu**
	Sand (%)	**Silt (%)**	**Clay (%)**		**(1:2,5)**	**(mmho s/cm)**	**%**		**kg/da**		**mg/kg**			
0-30	22.9	42.4	34.7	CL	7.8	0.2	1.1	15.2	10.8	65.9	3.7	0.3	8.9	1.2
30-60	21.2	46.3	32.5	CL	7.7	0.2	0.9	15.0	6.3	54.5	3.5	0.3	8.1	1.0

Table 3. Weather Data during the Growing Cycle and Long Years Data (1950-2015).

Parameter	**Nov 2016**	**Dec 2016**	**Jan 2017**	**Feb 2017**	**March 2017**	**April 2017**	**May 2017**	**June 2017**
Maximum Temperature (C°)	23.2	17.1	13.9	17.6	21.1	24.7	27.4	32.1
Minimum Temperature (C°)	11.4	7.2	5.08	5.59	10.3	13.0	17.0	21.3
Precipitation (mm)	58.4	131.0	51.8	0.80	65.4	65.9	45.9	17.3

Relative Humidity (%)	61.3	66.8	62.1	50.7	62.8	60.7	68.8	69.1

Parameter	**Nov**	**Dec**	**Jan**	**Feb**	**March**	**April**	**May**	**June**
Long Years Data								
Average Temperature (C°)	15.5	11.0	9.4	10.4	13.3	17.3	21.6	25.5
Maximum Temperature (C°)	22.6	16.7	14.8	16.0	19.4	23.6	28.2	31.7
Minimum Temperature (C°)	10.6	6.8	5.1	5.9	8.2	11.8	15.7	19.7
Daylight Hours	6.6	4.4	4.4	5.2	6.0	7.1	9.1	10.4
Rainy Days	6.7	10.1	10.3	10.1	9.5	8.5	6.1	2.9
Precipitation (mm)	71.1	120.1	108.2	91.0	65.4	51.2	47.3	20.5

Source: Turkish state meteorological service

Results and Discussion

According to the analysis of variance for seed yield of black cumin, the different treatments affected the seed yield (Table 4). The highest yield belonged to the50% IR-treatment, followed by the 10% IR- treatment, the 100% IR-treatment, the 70% IR-treatment and finally the 0% IR- treatment. In regard to the irrigation effect on the seed yield, the results of the present study do not agree with studies previously performed. Research carried out by Ghamarnia *et al.* (2010) (827 - 1056 kg/ha), Safaei *et al.* (2014) (484 - 621 kg/ha), Al-Kayssi *et al.* (2011) (347– 1736 kg/ha), and Arslan, (2015) (720 - 1880 kg/ha), concluded that higher amounts of water applied produced higher seed yields. The present study, on the other hand, showed that shortages of 90% and 50% in the water supply (10% IR and 50% IR treatment respectively) did not affect negatively the seed yield, on the contrary, said deficits produced the highest yields.

Table 4. Morphological and Yield Parameters of *Nigella sativa* L.

Treatment	Plant Height (cm)	Capsule per Plant	Seeds per Capsule	Capsule Diameter	Capsule Length	Plant Weight
0% IR	69.40	20.21	85.80	1.017	1.501	11.98
10% IR	76.05	35.60	83.85	0.973	1.485	20.88
50% IR	73.60	29.70	94.73	1.010	1.428	18.33
70% IR	68.80	35.33	81.40	0.997	1.500	19.43
100% IR	68.83	28.23	92.20	1.031	1.436	15.10
Tukey (5%)	ns	ns	ns	ns	ns	8.41

Treatment	1000-seed Weight	Harvest Index (%)	Seed Yield (kg/ha)	Essential Oil Content (%)	Fixed Oil Content (%)
0% IR	2.25	34.96	218.13	0.69	35.25
10% IR	2.24	35.04	1068.3	0.01	35.12
50% IR	3.00	47.42	1199.0	0.04	36.33
70% IR	2.50	36.64	741.88	0.36	32.38
100% IR	2.41	39.68	742.93	0.43	32.01
Tukey (5%)	ns	ns	337.91	0.23	2.33

In regard to the content of essential oil content, the results (Table 5) showed that the amount of water applied to black cumin did have effect significantly (1%). The highest value of essential oil was obtained from the 0% IR-treatment, which had a content of 0.69% essential oil of seed, followed by treatments of 100% IR (0.43%), 70% IR (0.36%), 50% IR (0.04%), and 10% IR (0.01%). According to the results, the higher the amount of applied water, the higher the essential oil content, except for the 0% IR- treatment, which despite the fact of not being watered, showed the highest essentiel oil content. The results of the present study suggest that the water stress applied to *Nigella sativa* plants should be either quite severe or very slight in order to obtain high yields. Althought the 0% IR and 10% IR treatments are pretty close to one another in terms of the amount of water applied to the plants, the yields obtained from said treatments are very contrasting; which might suggest that there is a critical and very narrow thereshold at which the water stress turns from having a positive effect on the production of secondary metabolites, such as essential oils, to having a detrimental effect. Nevertheless, broadly speaking, the present findings somehow agree with the results of the increasing research carried out in recent years on secondary metabolism, and particularly with studies about the effect of water stress on the production of essential oil production of aromatic and medicinal plants (Khalid, 2006; Maatallaha *et al.* 2016; Chrysargyris *et al.* 2016; Mandoulakani *et al.* 2017), which have demonstrated that water stress induces an increase in the production of secondary metabolites like essential oils, which are constituted mainly of monoterpenes and sesquiterpenes, compounds that provide to the plants the characteristic aroma and biological properties (Morshedloo *et al.* 2017).

Concerning the essential oil composition (Table 4), the results evidence that it differed from treatment to treatment.

Table 5. Composition of the Essential Oil of *Nigella sativa* L.

Compound	**RT**	**0%**	**10%**	**50%**	**70%**	**100%**
4-methyl-2-pentanone	3.413	0.55	-	-	4.42	-
Octane	3.617	9.01	12.24	10.42	18.29	17.04
Alpha-phellandrene	7.065	1.67	-	-	-	0.65
n-valeraldehyde	8.236	1.14	0.34	0.33	0.36	-
Alpha-terpinene	10.531	1.04	-	-	-	-
p-cymene	10.857	**10.45**	4.58	1.74	2.63	**6.78**
Gamma-Terpinene	12.364	**42.03**	**7.81**	1.91	2.76	5.43
Lycopen-16-ol	25.120	0.55	-	-	-	-
Beta-caryophyllene	27.369	**9.10**	4.01	3.61	1.23	**7.46**
Pentadecane	31.279	0.55	0.56	0.75	0.54	0.40
2-undecanone	31.291	-	0.56	0.58	-	0.59
Citronellal	34.369	1.80	1.15	2.53	1.27	1.82
Nerolidol	38.191	-	2.24	**7.13**	-	0.41
Unkwon	48.022	-	-	2.57	-	0.57
Hexenal	48.766	-	0.55	0.76	-	0.61
Lauryl alcohol	53.314	0.76	1.56	2.12	1.50	1.34
Tetracosane	53.403	7.41	27.17	20.63	30.14	13.53
Farnesol	53.829	3.52	**14.58**	**20.79**	3.04	**20.05**

Eicosane	57.560	1.53	2.52	-	-	-
Unkwon	57.558	-	6.29	-	4.83	1.93
TOTAL		**91.08**	**86.14**	**75.85**	**70.99**	**78.58**

For the 0% IR- treatment the major compounds were: γ- Terpinene (42.03%), p-Cymene (10.45%) and β-Caryophyllene (9.09%). The components α-terpinene and Lycopen-16-ol were found to be exclusively in this treatment in amounts of 1.035% and 0.545% respectively. In the treatment 10% IR, the compounds found in higher quantities were: Farnesol (14.58%), γ- Terpinene (7.81%), and p-cymene (4.58%). Concerning the 50% IR- treatment, Farnesol (20.79%), β-Caryophyllene (3.61%), and Citronellal (2.53%) were the major compounds. In the treatment 70% IR, Farnesol, γ- Terpinene, and p-Cymene were the major components with amounts of 3.04%, 2.76%, and 2.63% respectively. In regard to the 100% IR-treatment, Farnesol (20.05%), β-Caryophyllene (7.46%), and p-cymene (6.78%) were found in higher concentrations. The compound Farnesol was found in never before seen amounts in black cumin essential oil. Although Kokoska *et al.* (2008), Benkaci-Ali *et al.* (2011), and Harzallah *et al.* (2011) did find farnesol to be present in the essential oil of *Nigella sativa* seeds, the reported concentrations were very low, ranging from less than0.05% to as much as 0.9%. The concentration of Farnesol does not seem to have relationship with the amount of water applied. Harzallah *et al.* (2011) did find farnesol to be present in the essential oil of *Nigella sativa* seeds, the reported concentrations were very low, ranging from less than0.05% to as much as 0.9%.

Fixed Oil Content: According to the results, the treatments applied affected black cumin fixed oil content (Table 5). The highest yield belonged to the 50% IR-treatment with 36.33% fixed oil; there was no significant difference between the treatments 50% IR, 10% IR, and 0% IR. The fixed oil content obtained in the present research are higher than those reported by Elsafi, 2003 (29.2%), El-Mekawy, 2012 (25.7% - 33.6%), Bannayan *et al.* 2008 (25.9% - 32.3%), Ghamarnia *et al.* 2010 (29.10% - 30.40%), Hamrouni-Sellami *et al.* 2007 (31.7%), and Piras *et al.* 2013 (21% - 26%). Apart from that, the results obtained here are in agreement with Elsafi (2003), who also found that the fixed oil yield increased as a consequence of lessening the amount of water applied. On the other hand the study performed by Ghamarnia *et al.* (2010) showed that the higher the amount of water applied, the higher the fixed oil yield. Having into account the fact that thymoquinone is contained not only in the essential oil, but also in the fixed oil (Houghton *et al.* 1995), and that the fixed oil is also used extensively in traditional medicine (Zaoui *et al.* 2002), the results found in the present study come to be noteworthy inasmuch as high yields can be obtained at the same time that amounts of water as high as the equivalent to 50% of the water requirements of the crop can be saved.

Fixed Oil Composition: As shown in Table 6, the major fatty acids composing black cumin seeds were linoleic, oleic, and palmitic acids, the average values being 60.08%, 20.52% and 12.89% respectively.

Conclusions

- The amount of water applied during the *Seed Maturation* stage differentially affected the seed yield, the essential oil content as well as the fixed oil content of *Nigella sativa*. On the one hand, plants receiving lower amounts of water were more efficient at seed production, except the treatment consisting in no-irrigation, which exhibited the lowest seed yield. On the other hand, the treatment consisting of no-irrigation showed the highest essential oil content. Concerning the yield of the fixed oil, the highest yields were obtained when water quantities equal to fifty percent or less of the irrigation requirements were applied. Ultimately the results show that applying higher amounts of water does not necessarily result in better seed, essential oil and/or fixed oil yields; certain degrees of water stress stimulates responses at the physiological level that at last produce increases of essential oil and fixed oil yields as well as seed yield.

Table 7. Compositions of the Fixed Oil of *Nigella sativa* L.

Fatty Acid	0% IR	10% IR	50% IR	70% IR	100% IR	Average
Linoleic acid	59.86	59.52	58.46	61.17	**61.41**	60.08
Oleic acid	19.36	**21.39**	21.22	20.58	20.06	20.52
Palmitic acid	**13.37**	12.88	13.17	12.39	12.66	12.89
Stearic acid	2.39	2.30	**2.68**	2.39	2.33	2.42
Margaric acid	**2.54**	1.66	1.44	1.12	1.09	1.57
Myristic acid	0.68	0.37	**0.97**	0.36	0.45	0.57
Palmitoleic acid	**0.42**	0.32	0.41	0.33	0.32	0.36
Linolenic acid	0.36	0.29	**0.37**	0.34	0.52	0.38
Ecosenoicacid	-	0.28	0.29	**0.32**	0.16	0.26
Total	99	99	99	99	99	99

- The amount of water to apply should be selected depending on the purpose of the producer; if the interest of the producer were the essential oil production, 70% of the plant's water requirements should be applied during the *Seed Maturation stage*. Even though the essential oil content of said treatment was not the highest, this treatment did have a significantly higher seed yield in comparison with the 0% IR-treatment, thus, the lower content of essential oil would be compensated by a higher quantity of seeds from which the essential oil is extracted. If instead, the purpose of the producer were to maximize seed production, the recommendation would be to apply 10% of the water requirements throughout the S*eed Maturation* stage, the benefit would be to both increase the seed yield and to save water. Finally, in order to obtain high fixed oil yields and to save water it is recommended to apply amounts of water ranging from 0% to 50% of the crop's evapotranspiration.

References

Ahmad, A., A. Husain, Mujeeb, M., S.A. Khan, Najmi, A.K., N.A. Siddique, Damanhouri, Z.A., F. Anwar. 2013. A review on therapeutic potential of *Nigella sativa*: A miracle herb. *Asian Pacific Journal of Tropical Biomedicine*. 3(5): 337-352.

Al-Kayssi, A.W., R.M., Shihab, Mustafa, S.H. 2011. Impact of soil water stress on Nigellone oil content of black cumin seeds grown in calcareous- gypsifereous soils. *Agricultural WaterManagement*. 100: 46-57.

Allen, R.G., L.S. Pereira, Raes, D., M. Smith. 2006. Crop evapotranspiration: guidelines for computing crop water requirements. FAO Irrigation and drainage paper No. 56.

Anonymous. 2016. Turkish Statistical Institute. Condimentary plants (1988-2016). Available in: http://www.tuik.gov.tr/PreIstatistikTablo.do?istab_id=72.

Benkaci-Ali, F., A. Baaliouamer, Wathelet, J.P., M. Marlier. 2011. Chemical Composition of Volatile Oils from Algerian *Nigella sativa* L. seeds. *Journal of Essential Oil Research*.22: 318-322

Chrysargyris, A., S. Laoutari, Litskas, V.D., M. C. Stavrinides, Tzortzakis, N. 2016. Effects of Water Stress on Lavender and Sage Biomass Production, Essential Oil Composition and Biocidal Properties Against *Tetranychus urticae* (Koch). *Scientia Horticulturae*. 213: 96-103.

D'Antuono, L.F., A. Moretti, Lovato, A.F.S. 2002. Seed Yield, Yield Components, Oil Content and Essential Oil Content and Composition of *Nigella sativa* L. and *Nigella damascena* L. *Industrial Crops and Products*. 15: 59-69

El-Ghamery, A.A., M. El-Kholy, El-Yosser, M.A.Abou. 2003. Evaluation of cytological effects of Zn^{2+} in relation to germination and root growth of *Nigella sativa* L. and *Triticum aestivum* L. *Genetic toxicology and environmental mutagenesis*. 537: 29-41.

Elsafi, H.H. 2003. Effect of water quantity and irrigation intervals on vegetative growth and yield of black cumin (*Nigella sativa* L.). (Master thesis). Sudan University of Science and Technology. Sudan.

Gali-Muhtasib, H., N. El-Najjar, Schneider-Stock, R. 2006. The Medicinal Potential of Black Seed (*Nigella sativa*) and its Components. *Lead Molecules for Natural Products*.133-153.

Ghamarnia, H., H. Khosravy, Sepehri, S. 2010. Yield and water use efficiency of *Nigella sativa* L. under different irrigation treatments in a semi.arid region in the west of Iran. *Journal of Medicinal Plants Research*. 4(16): 1612-1616.

Ghamarnia, H. & Jalili, Z. 2013. Water stress effects on different black cumin (*Nigella sativa* L.) components in a semi-arid region. *International Journal of Agronomy and Plant Production*. 4(4): 753-762.

Ghamarnia, H., E. Miri, Ghobadei, M. 2014. Determination of water requirement, single and dual crop coefficient of black cumin (*Nigella sativa* L.) in a semi-arid climate. *Irrigation Sci.*. 32: 67-76.

Harzallah, J., B. Kouidhi, Flamini, G., A. Bakhrouf, Mahjoub. T. 2011. Chemical Composition, Antimicrobial Potential Against Cariogenic Bacteria and Cytotoxic Activity of Tunisian *Nigella sativa* essential oil and thymoquinone. *Food Chemistry*. 129: 1469-1474.

Haq, M.Z., M.M. Hossain, Haque, M.M., M.R. Das, Huda, M.S. 2015. Blossoming Characteristics in Black Cumin Genotypes in Relation Seed Yield Influenced by Sowing Time. *American Journal of Plant Sciences*. 6: 1167-1183.

Houghton, P.J., R. Zaraka, Delas Heras, B., J.R Hoult. 1995. Fixed Oil of *Nigella sativa* and derived thymoquinone inhibit eicosanoid generation in leucocytes and lipid peroxidation. *Planta Med*. 47: 119-126.Jamian, S.S., K.S. Asilan, Mehrani, S., A.T. Tabrizi, Goharian, A. 2014. Effects of elevated temperatures on sedd germination and seedling growth in three medicinal plants. *International Journal of Agriculture and Crop Sciences*. 7(4): 173-177.

Kokoska, L., J. Havlik, Valterova, I., H. Sovova, Sajfrtova, M., I. Jankovska. 2008. Comparison of Chemical Composition and Antibacterial Activity of *Nigella sativa* Seed Essential Oils Obtained by Different Extraction Methods. *Journal of Food Protection*. 71(12): 2475-2480.

Maatallaha, S., N. Nasri, Hajlaoui, H., A. Albouchi, Elaissi, A. 2016. Evaluation Changing of Essential Oil of Laurel (*Laurus nobilis* L.) Under Water Deficit Stress Conditions. *Industrial Crops and Products*. 91: 170-178.

Malhotra, S.K. and Vashishtha, B.B. 2008. Response of nigella (*Nigella sativa* L.) variety NRCSS AN-1 to different agro-techniques. *Journal of Spices and Aromatic Crops*, 17 (2): 190-193.

Mandoulakani B.A., E. Eyvazpour, Ghadimzadeh, M. 2017. The Effect of Drought Stress on the Expression of Key Genes Involved in the Biosynthesis of Phenylpropanoids and Essential Oil Components in Basil (*Ocimum basilicum* L.). *Phytochemistry*. 139: 1-7.

Morshedloo, M.R. L. E. Craker, Salami, A., V. Nazeri, Sang, H. F. Maggi. 2017. Effect of Prolonged Water Stress on Essential Oil Content, Compositions and Gene Expression Patterns of Mono- and Sesquiterpene Synthesis in Two Oregano (*Origanum vulgare* L.) Subspecies. *Plant Physiology and Biochemistry*. 111: 119-128.

Nickavar, B., F. Mojab, Javidnia, K., M.A. Roodgar Amoli. 2003. Chemical composition of the fixed and volatile oils of *Nigella sativa* L. from Iran. S. Beheshti Univ. of Medical Sciences. 620-631.

Sampathkumar, T., B.J. Pandian, Rangaswamyc, M.V., P. Manickasundaram, P. Jeyakumar. 2013. Influence of deficit irrigation on growth, yield and yield parameters of cotton–maize cropping sequence. *Agricultural Water Management*. 130: 90-102.

Shah, S.H. 2008. Effects of nitrogen fertilization on nitrate reductase activity, protein and oil yields of *Nigella sativa* L. as affected by foliar GA_3 application. *Turk Journal of Botany*. 32: 165-170.

Talafih, K.A., N.I., Haddad, Hattar, B.I., K. Kharallah. 2007. Effect of some agricultural practices on the productivity of black cumin (*Nigella sativa* L.) grown under rainfed semi-arid conditions. *Jordan Journal of Agricultural Science.* 3(4): 385-396.

Telci, I., A. Sahih-Yağlioğlu, Eser, F., H. Aksit, Dermitaş, I., S. Tekin. 2014. Comparison of seed oil composition of *Nigella sativa* L. and *N. damascena* L. during seed maturation stages. *Journal of the American Oil Chemists Society*. 91: 1723-1729.

Zaouil, A., Y. Cherrah, Mahassini, N., K. Alaoui, Amarouch, H., M. Hassar. 2002. Acute and chronic toxicity of Nigella sativa fixed oil. *Phytomedicine*. 9: 69-74.