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ORIGINAL ARTICLE

The Effect of Nitrogen Chemical Fertilizer and Zinc Sulfate Application on Yield and its Components of *Nigella sativa* L. under different Humidity Conditions

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ABSRACT

Nigella sativa L. is one of the important medicinal plants from Ranunculaceae family that grows at different parts of Iran. Drought Stress is the important limiting factor in the world, result in reduction of plant production. To exposing grain yield and yield components of Nigella sativa under nitrogen chemical fertilizer and zinc sulfate application under different humidity conditions, an field experiment was carried out in Factorial arrangement using randomized complete block design with four replications at Agriculture and Natural Research Resource Center, Ilam, Iran, during 2011-2012 growing season. Treatments included of four levels of nitrogen fertilizer (0, 33, 66 and 100 kg.ha^{-1}) and foliar application of zinc sulfate (application and non-application). Results showed that nitrogen had no significant effect on all studied traits, except the number of follicles per plant. The Using of 66 kg.ha^{-1} nitrogen had the highest yield with mean of 395.1g.m^{-2}. Stress conditions had a significant effect on all traits, except harvest index, so that grain yield with mean of 416.5g.m^{-2} was obtained from irrigated treatment. The application of Zinc sulfate had a significant effect on all traits, except the number of follicles.plant^{-1} and harvest index. Grain yield was obtained from using of zinc sulfate with mean of obtain 392.2 g.m^{-2}. Interaction effect of nitrogen chemical fertilizer and zinc sulfate was significant on grain yield and biological yield. Interaction effects of stress condition and nitrogen chemical fertilizer was significant on the number of branches.plant^{-1}. Twofold Interaction effect of stress condition and zinc sulfate was significant on the number of branches.plant^{-1}and the number of follicles.plant^{-1}.

***Keywords**: Nigella sativa, Drought stress, Zinc sulfate, Gran yield, Nitrogen chemical fertilizer*

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INTRODUCTION

Scientific name of Nigella is *Nigella sativa* L. it is dicotyledonous, herbaceous and perennial belonging to the family Ranunculaceae [1], which grows in West Asia and the Mediterranean regions. Seeds of this plant contain 20-27% protein, 7.3-4.9 % ash, 4.33% carbohydrate and 34.5-38.7% extracted fat [2]. It is more than two thousand years that *Nigella* has been used as a medicinal plant [3]. Drought stress is one of the most important stresses in many parts of the world, and especially in dry climates that limited the crop yield [4]. Water stress is the most common type of stress on the plant and often is associated with long-term shortage of moisture or temporary drought on hot days with high radiation or both [5]. Many reports has been stated that show lack of water from some turn to intensive stress about disturbance of plants physiological processes change in carbohydrates and nitrogen metabolism and change in proteins construction and enzymes' activity [6-7]. Reduction of moisture cause to reactions, such as protein degradation and accumulation of free amino acids in the cell result in osmotic pressure [8]. Faker Baher et al., [9] study effects of water stress on plant height and number branches and showed the highest levels

of water stress branch of plant height and number of shoots significantly reduced. Because of low yield of many of cultivation and medicinal plants in rainfed condition, irrigated condition of these plants, with removal of respective preventive by easy achieving to water sources can be increased its yield. The application of different fertilizer sources of nitrogen fertilizer (manure and chemical) and the spray can be a way to increase production in the medical plants. Nitrogen fertilizers are important Fertilizers in plant nutrition. Availability of nitrogen for crops is one of the main limiting factors for agricultural production. The importance of adequate nitrogen nutrition and low available soil nitrogen reserves of nutrients because of other than nitrogen the risk of loss and recovery rates of less than half the applied (of thirty-three percent), agriculture application of nitrogenous fertilizers raises [10]. Micronutrient deficiency in most plants it is expanding globally. Continuous cultivation, calcareous soils and lack of fertilizers containing needed nutrients, are including causes of zinc deficiency in most soils of Iran. Zinc sulfate is one of the essential elements and low use for plants that absorbed in from of $Zn+^{2}$, which contributes to the formation of indole acetic acid and regulates plant growth [11]. One way to meet the requirements zinc sulfate of the plant is sprayed zinc. Because the plant is not able to be re-sprayed zinc so it is more suitable [11]. In a research, nitrogen increases the number of flowering branches, biological yield and grain yield *Nigella Sativa* [12]. In a separate experiment, the effect of different amounts of nitrogen and phosphorus on yield and yield components of Nigella Sativa were studied, The results indicated that the nitrogen on stem diameter, number of flowers and seed capsules per plant and the number of positive the capsule and seed weight per capsule was significantly negatively affected, but the application of 30 kg nitrogen per hectare and higher levels of nitrogen (60 and 90 $kg.ha^{-1}$), the difference was not significant. However, the nitrogen on grain yield, biological yield, days to 50 % flowering, plant height, flower capsules and weight ratio was not significantly affected. Maximum yield with a 5.8 % increase was obtained compared to the non-application of nitrogen (control), the highest level of nitrogen (90 $kg.ha^{-1}$), respectively [13]. *Nigella sativa* is one of the important medicinal plants in producing countries to date few studies have been done in the field. In Iran, too, little research has been done on these plants and the traditional methods of cultivation. Therefore, because of its important role in the treatment of plant diseases and crop food research in the field is essential, the current present study aimed to investigate the effect of different levels of nitrogen chemical fertilizer and zinc sulfate under irrigated and rainfed condition on grain yield and its components in *Nigella sativa*.

MATERIAL AND METHOD

In order to study the effect of nitrogen fertilizer application and zinc sulfate use on yield and yield components of *Nigella sativa* under drought stress conditions, an experiment was carried out in Factorial arrangement using randomized complete block design with four replications under irrigated and rainfed condition at Agriculture and Natural Research Resource Center, Ilam, Iran during 2011-2012 growing season. Treatments included of four levels of nitrogen chemical fertilizer (0, 33, 66 and 100 $kg.ha^{-1}$) and foliar application of zinc sulfate (consumption and non-consumption). The average annual rainfall was 550 mm, and the average maximum temperature, minimum temperature of 42 degrees Celsius and average -7°C, respectively. Each replication consisted of 9 treatments. Each plot had an area of 10 square meters (2×5 mm) and 8 row spacing. Plots within each replicate, 1meter line spacing of 25 cm, and the distance between replications each other were 1.5 meter. Density in the surveys conducted in recent years in the area of intended for 250 $seed.m^{-2}$ for irrigated and 150 seeds m^{-2} for rainfed planting. Sampling was carried out from two central rows and from each line harvested one plant. In this experiment, plant height (using a ruler), number of $branches.plant^{-1}$, number of grain. $Follicle^{-1}$, number of $follicles.m^{-2}$ (product of density and the number of follicles per plant), grain weight (using scales precision 0.001), grain yield ($g.m^{-2}$), biological yield ($g.m^{-2}$) and HI (harvest index) was calculated divided by grain yield on biological yield. Statically analysis was conducted using SAS software. Mean comparison was also conducted with Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Plant Height

Results showed that the effect of stress condition (SC) (rainfed and irrigated conditions), nitrogen chemical fertilizer and zinc sulfate were significant on plant height in probable level of 1%, but other treatments of experiment had not significant effect on this trait (Table 1). Results showed that using of 100 $kg.ha^{-1}$ N, plant height, with mean of 11.36 cm had 15% increasing in comparison to control treatment. Among nitrogen levels, there was not significant effect on this trait (Table 3). Also, by using zinc sulfate, plant height, obtained 37.03 cm, which showed an increase of 16% compared to witness treatment (Table 3). The results showed that Stress condition, the amount of height 0f plant obtained from irrigated treatment wit mean of 41.71 cm, which compare to the rainfed (drought) increased by

68% (Table 3). Razmjoo et al., [14] stated that irrigation increased from 2 days to 10 days, chamomile reduces the height of chamomile plant from 43.08 cm to 32.33 cm was. Plant height reduction due to drought stress is one of the most obvious symptoms. It is known that stress, by reducing the growth rate, plant height is reduced. Since the stress is closer to the end of the growing season, there is less effect on plant height [15].

Rahmani [16] stated that nitrogen had a significant effect on marigold plant height. Maximum height of plant obtained with 90 kg.ha^{-1} nitrogen, the amount of 31.8 cm. Also, it was stated that nitrogen increases the growth. Kherandish [17] reported that foliar application of zinc on soybean plant was increased plant height. Razmjoo et al., [14] stated that irrigation increased from 2 days to 10 days, cause to reduction of the height of chamomile the 43.08 cm to 32.33 cm.

Number of branches.plant^{-1}

Results showed that this traits was affected by the effect of stress condition (SC) (rainfed and irrigated conditions), nitrogen chemical fertilizer and zinc sulfate (Table 1), Also, interaction effect of EC and nitrogen chemical fertilizer and SC and zinc sulfate were significant on Number of branches per plant (Table 1). Results showed that consumption of 100 kg.ha^{-1} N had the highest the number of branches per plant with mean of 6.78 branches so that 17 % increased in compared to witness treatment (Table 3).

Also, by using Zinc sulfate, number of branches per plant was obtained with mean of 7.04 branches that increased by 21% when compared to control treatment (Table 3). The results showed under EC, number of branches per plant, obtain 6.46 branches compare to rainfed conditions (drought) increased by 19% (Table 3). About interaction effect of nitrogen and EC, Maximum number of branches per plant, in the treatment of use obtain between irrigated condition and 66 kg.ha^{-1} N with mean of 7.22 branches so that in compared to non usage of nitrogen chemical fertilizer and rainfed condition 30 % increased (Table 7). Interaction effect between SC and zinc sulfate showed that the maximum number of branches per plant was obtained from irrigated condition and usage of zinc sulfate with mean of 41.7 branches, which was took place in the treatment of dry, 45 % increase (Table 9). The reduction in shoot production in drought stress is stated so that-indole acetic acid oxidase activity of the enzyme (IAAO), the fast-growing plant tissues are very low, but the activity of this enzyme increase in drought conditions and cause to analysis of the plant hormone auxin [18]. Razmjoo et al., [14] stated that irrigation increased from 2 days to 10 days, caused a significant reduction in the number of branches of chamomile. Letchamo [19] , was studied the effect of ammonium nitrate fertilizer at four levels of 0, 0.4, 0.8 and 1.2 grams per pot containing four plants diploid and tetraploid genotypes on the performance of the assay German chamomile. In this study, the results of the use of nitrogen chemical fertilizer, plant height and number of branches to be significantly increased. Singh and Jet [20] obtain similar results with P application and coriander that consistent on the results of this study. Zinc is one of the elements that can be absorbed in the plant through the branches and leaves of the plant, so that foliar Zn can be absorbed by the branches, thereby increasing the yield.

Table 1: Analysis of variance (Mean Square) for studied traits in *Nigella sativa*

S.O.V	df	Plant height	Number of branches .plant^{-1}	Number of follicles.m^{-2}	Number of follicles .plant^{-1}
Condition	1	3359.8 **	3.0501 **	14262236 **	43.93*
Block	6	38.96 **	0.7670 **	550653**	4.65*
Nitrogen	3	72.462 **	3.2766 **	150367ns	6.29 ns
Zinc Sulfate	1	419.84 **	24.2759 **	360185ns	6.59 ns
Nitrogen* Zinc Sulfate	3	13.921ns	0.1899 ns	4859125**	4.42 ns
Nitrogen* Conditions	3	6.023 ns	3.3129 **	1044850*	11.67 ns
Conditions * Zinc Sulfate	1	9.115 ns	1.4959 *	15191 ns	0.83ns
Nitrogen* Zinc Sulfate* conditions	3	8.927 ns	0.2974 ns	428795 ns	6.77 ns
Error	42	10.124	0.23107	234928	4.11
CV (%)	-	9.23	7.48	18.02	11.60

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

Table 2: Analysis of variance (Mean Square) for studied traits in *Nigella sativ*a

S.O.V	df	1000-grain weight	Biologic yield	Gran yield	Harvest index
Condition	1	2.2313 **	1613252**	130711**	0.029 ns
Block	6	0.0303 ns	15412*	1622**	0.430 ns
Nitrogen	3	0.0984 *	177628**	13711**	6.717**
Zinc Sulfate	1	1.1157 **	404456**	30547**	0.274ns
Nitrogen* Zinc Sulfate	3	0.0373 ns	35539**	2678**	0.110ns
Nitrogen* Conditions	3	0.0152 ns	6625 ns	537ns	0.086ns
Place* Zinc Sulfate	1	0.0019 ns	7984ns	927ns	0.103ns
Nitrogen* Zinc Sulfate* conditions	3	0.0517 ns	11541ns	983ns	0.012ns
Error	45	0.0249	5721.9	475.3	0.190
CV (%)	-	8.97	5.79	5.87	1.53

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

Number of follicles.m^{-2}

Present results showed that the effect stress condition (SC) (rainfed and irrigated conditions), nitrogen chemical fertilizer and zinc sulfate were significant effect on number of follicles.m^{-2}, but other treatments were not significant effect on this trait (Table 1). By using zinc sulfate, follicle number.m^{-2} as compared to the non-using with mean of 2924.7 follicles was increased to 23% (Table 3). The results showed that in the stress condition (SC), the Number of follicles.m-2 was 2177.1 follicles that compared to rainfed conditions decreased by 31% (Table 3). Rahmani [16] reported reducing the number of reproductive organs Potmarigold herb with reduces stress intensity. Naghdiabadi et al., [21], in an experiment reactions of Potmarigold to different types of nitrogen fertilizer, stated that in general, nitrogen cause to improve flowering aspect in this plant, compared to control. Bagheri Kholenjany [11] showed that zinc fertilizer had no significant effect on the number of capitol in safflower.

Table 3: Mean Comparison of main effects of stress conditions, nitrogen chemical fertilizer and zinc sulfate on studied traits in Nigella *sativa*

		Plant height (cm)	Number of branches plant^{-1}	Number of follicles.m^{-2}	Number of follicles.plant^{-1}
Nitrogen (kg.ha^{-1})	0	31.36b	5.79c	2520.7	17.8ns
	33	34.02a	6.4b	2334.3	17.6ns
	66	36.1a	6.71ab	2942.1	17.9ns
	100	36.11a	6.78a	2638.2	17.8ns
Zinc Sulfate	Non-application	31.9b	5.81b	2373.6b	16.8ns
	Application	37.03a	7.04a	2924.7a	17.7ns
Stress conditions	Irrigated	41.71a	6.64a	3121.2a	18.3a
	Rainfed	24.77b	5.55b	2177.1b	16.6b

Means, in each column, fallowed by similar letter(s) are not significantly different at the %5 probability level- using Duncan's Multiple Range Test.

Table 4: Mean Comparison of main effects of stress conditions, nitrogen chemical fertilizer and zinc sulfate on studied traits in *Nigella sativa*

		1000-grain weight (g)	Biologic yield (g.m^{-2})	grain yield (g.m^{-2})	Harvest index (%)
Nitrogen (kg.ha^{-1})	0	1.78ab	1149.8c	328.5c	28.54ab
	33	1.85a	1339.1bc	382.6ab	28.58ab
	66	1.76b	1362.6ab	395.1a	29.01a
	100	1.66c	1373.9a	378.0bc	27.49b
Zinc Sulfate	Non-application	1.63b	1226.8b	349.2b	28.48
	Application	1.89a	1385.8a	392.9a	28.35
Stress conditions	Irrigated	1.95a	1465.1a	416.3a	28.43
	Rainfed	1.59b	991.8b	325.9b	28.52

Means, in each column, fallowed by similar letter(s) are not significantly different at the %5 probability level- using Duncan's Multiple Range Test.

Number of follicle.plant $^{-1}$

This trait was significantly affected by stress condition (SC) (rainfed and irrigated conditions) and interaction effect between SC and zinc sulfate but other treatments had no significant effect on this trait (Table 1). The results showed that irrigated conditions, the number of follicle.plant $^{-1}$ obtained 18.3 follicles that in compare to rainfed condition (drought) increased by 10% (Table 3). Generally, the use of zinc sulfate in rainfed conditions, were improved reproductive characteristics. Rahmani [16] reported increased the number of reproductive organs marigold herb reduces stress intensity. Reduce water cause to reduction of plant consolidation and will loss follicles.

1000-grain weight

This trait was significantly affected by stress condition (SC) (rainfed and irrigated conditions), nitrogen chemical fertilizer and zinc sulfate but other treatments had no significant effect on this trait (Table 2). Results showed that consumption of 33 kg.ha^{-1} N, the highest 1000-grain weight was obtained with mean of 85.1g. On the other hand, the lowest 1000-grain weight was obtained from the consumption of 100 kg.ha^{-1} N with mean of 1.66 g (Table 4). Also, by use of Zn, 1000-grain weight, obtain number 89.1g that was increased by 15% when compared to control treatment (Table 4).

The results showed that SC had the maximum 1000-grain weight with mean of 1.9g that increased by 22% in comparison to rainfed conditions (Table 4). Rahmani [16], reported decrease of Potmarigold herb seed weight severe levels of drought stress. It seems that the water deficit in the aggregation stage cause to abortion in some capsules, that in resulting cause to loss of them and seed reduced weight. Das et al., [22] studied the effect of nitrogen fertilizer coriander and concluded that the seed weight increase by use of, 40 kg.ha^{-1} N. Rastegar and Shamsi-Mahmoudabadi [23] stated that zinc treatment has a significant effect on cumin grain weight.

Table 5: Interaction effect of nitrogen chemical fertilizer and zinc sulfate on studied traits in *Nigella sativa*

Zinc Sulfate	Nitrogen ($kg.ha^{-1}$)	Plant height (cm)	Number of branches per plant	Number of follicles $.m^{-2}$	Number of follicles $.plant^{-1}$
Non-application	0	38.49	5.26d	2255.1ns	17.3ns
	33	41.05	5.68cd	2334.3ns	17.7ns
	66	43.03	6.02bc	2453.1ns	17.6ns
	100	44.27	6.27bc	2452.0ns	16.2ns
Application	0	24.77	6.32b	2786.2ns	18.4ns
	33	27.00	7.13a	2942.1ns	18ns
	66	29.16	7.41a	3045.4ns	17.7ns
	100	27.95	7.3a	2925.1ns	16.8ns

Means, in each column, fallowed by similar letter(s) are not significantly different at the %5 probability level- using Duncan's Multiple Range Test.

Table 6: Effect of nitrogen chemical fertilizer and zinc sulfate on studied traits in *Nigella sativa*

Zinc Sulfate	Nitrogen ($kg.ha^{-1}$)	1000-grain weight (g)	Biologic yield ($g.m^{-2}$)	Grain yield ($g.m^{-2}$)	Harvest index (%)
Non-application	0	1.96	1077.1d	307.6d	28.53
	33	1.99	1209.9c	347.0c	28.68
	66	1.96	1264.4c	368.9bc	29.19
	100	1.88	1356.0b	373.3b	27.50
Application	0	1.59	1222.5b	349.5c	28.55
	33	1.71	1468.3a	418.2a	28.50
	66	1.56	1460.7a	421.2a	28.85
	100	1.44	1391.7ab	382.7b	27.49

Means, in each column, fallowed by similar letter(s) are not significantly different at the %5 probability level- using Duncan's Multiple Range Test.

Biological yield

This trait was significantly affected by stress condition (SC) (rainfed and irrigated conditions), nitrogen chemical fertilizer and zinc sulfate but other treatments had no significant effect on this trait (Table 2). This trait was significantly affected by stress condition (SC) (rainfed and irrigated conditions), nitrogen chemical fertilizer and zinc sulfate and interaction effect between zinc sulfate and nitrogen chemical fertilizer, but other treatments had no significant effect on this trait (Table 2).

Results showed that by usage of 100 $kg.ha^{-1}$ N had the highest biological yield with mean of 1373.9 $g.m^{-2}$ that increased by 19% in compared to control treatment (Table 4). Also, by using zinc sulfate, the biological yield obtained with mean of 1358.8 $g.m^{-2}$, which was increased by 10% un compared to witness treatment (Table 4). The maximum and minimum biological yield was obtained from in irrigated and rainfed conditions, respectively (Table 4). Interaction effect between nitrogen chemical fertilizer and zinc sulfate showed that the maximum biological yield belonged to 33 $kg.ha^{-1}$ N and application of zinc sulfate with mean of 1468.3g that in compared to no consumption treatment obtained by taking each 36 % increase (Table 6).

Mirza et al., [24] stated that *satureja hortensis* flowering, the specimens under drought stress occurs sooner than the others and tension, reduce fresh and dry weight of shoots and roots in stressed samples.

Rahmani et al., [16] stated that by the use of nitrogen in 6 pure levels respectively of zero, 20, 40, 60, 80 and 100 kg ha found that the highest yield for Potmarigold was obtained from the application of 80 $kg.ha^{-1}$ N. Singh and Jet [20], by phosphorus and zinc application on coriander find similar results, which are consistent with the results of this research. It can be because of increased auxin biosynthesis in the presence of zinc.

Table 7: interaction effect of stress condition and nitrogen on studied traits in Nigella sativa

Stress condition	Nitrogen ($kg.ha^{-1}$)	Height (cm)	Number of $branches.plant^{-1}$	Number of follicles $.m^{-2}$	Number of follicles $plant^{-1}$
Irrigated	0	38.49b	6.03cd	3214.6ns	16.1ns
	33	41.05ab	6.97ab	3047.7ns	16.9ns
	66	43.03a	7.22a	3112.3ns	17.1ns
	100	44.27a	6.35bc	3110.4ns	16.3ns
Rainfed	0	24.77c	5.55d	1826.8ns	19.6ns
	33	27 c	5.84cd	2228.7ns	18.6ns
	66	29.16c	6.21c	2386.2ns	18.1ns
	100	27.95c	7.21a	2266.7ns	16.8ns

Means, in each column, fallowed by similar letter(s) are not significantly different at the %5 probability level- using Duncan's Multiple Range Test.

Table 8: interaction effect of stress condition and nitrogen on studied traits in Nigella sativa

Stress condition	Nitrogen ($kg.ha^{-1}$)	1000-grain weight (g)	Biologic yield ($g.m^{-2}$)	seed yield ($g.m^{-2}$)	Harvest index (%)
Irrigated	0	1.96	1307.8	373.6	28.57
	33	1.99	1480.0	422.3	28.55
	66	1.96	1511.3	437.9	29.00
	100	1.88	1561.3	431.2	27.62
Rainfed	0	1.59	991.8	283.4	28.52
	33	1.71	1198.2	343.0	28.63
	66	1.56	1213.9	352.3	29.04
	100	1.44	1186.4	324.8	27.37

Means, in each column, fallowed by similar letter(s) are not significantly different at the %5 probability level- using Duncan's Multiple Range Test.

Table 9: Interaction effect of stress condition and zinc sulfate on studied traits in Nigella sativa

Zinc sulfate	Stress condition	Plant height (cm)	Number of branches .$plant^{-1}$	Number of follicles.m^{-2}	Number of follicles $plant^{-1}$
Non-application	Irrigated	39.53	5.87bc	2761.b	16.8ns
	Rainfed	21.53	5.10c	2681bc	18.7ns
Application	Irrigated	43.89	7.41a	2899a	16.5ns
	Rainfed	28.01	6.01b	2648bc	20.4ns

Means, in each column, fallowed by similar letter(s) are not significantly different at the %5 probability level- using Duncan's Multiple Range Test.

Grain yield

This trait was affected by stress condition (SC) (rainfed and irrigated conditions), nitrogen chemical fertilizer and zinc sulfate, also interaction effect between nitrogen chemical fertilizer and zinc sulfate was significant, but other treatments had no significant effect on this trait (Table 2). Results showed that consumption of 66 $kg.ha^{-1}$ N had the highest grain yield, with mean of 395.1 $g.m^{-2}$ so that in compared to non-consumption, increased by 20% (Table 4). The maximum grain yield with mean of 392.2$g.m^{-2}$ observed by application of zinc sulfate (Table4). Irrigated condition had the maximum grain yield (416.5$g.m^{-2}$) so that in comparison to rainfed conditions, increased by 28% (Table 4). In the experiments of Naseri et al., [25] and Soleymanifard et al., [26] on *Nigella sativa* indicated that drought stress result in decreasing in grain yield and its components. The maximum grain yield with mean of 241 $g.m^{-2}$ by interaction effect between nitrogen chemical fertilizer and zinc sulfate (Table 6). The first apparent effect of low water on plant leaves or plant height is smaller in size and fewer in number, which is due to reduced cell expansion. All of these factors ultimately result in a lower yield [27]. Najafpournouraei [28] reported that in the plant *Atropea belladana* increased to 60 $kg.ha^{-1}$, cause to higher yield. The researchers stated that application of 40 kg N ha had no significant effect on seed yield models. Increased use of fertilizer, resulting in increased vegetative growth and flowering period will result in delays. This process reduces the flowering period and yield may be reduced [29].

Table 10: Interaction effect of e stress condition and zinc sulfate on studied traits in *Nigella sativa*

Zinc sulfate	Stress condition	1000-grain weight (g)	Biologic yield ($g.m^{-2}$)	Grain yield ($g.m^{-2}$)	Harvest index (%)
Non-application	Irrigated	1.82	1396.8	398.2	28.54
	Rainfed	1.40	946.5	270.1	28.50
Application	Irrigated	2.08	1533.4	434.3	28.33
	Rainfed	1.78	1037.1	296.7	28.54

Means, in each column, fallowed by similar letter(s) are not significantly different at the %5 probability level- using Duncan's Multiple Range Test.

Harvest index (HI)

This trait was affect by nitrogen chemical fertilizer and other treatments had no significant effect on this trait (Table 2). Results showed that with consumption of 66 $kg.ha^{-1}$ N had the highest HI observed with mean of 29.01% (Table 4), between consumption of 66 and 33 $kg.ha^{-1}$ there was not significant effect.

Alizadeh-Sahzabi et al., [30], in their research on the herb *satureja hortensis* stated that nitrogen has a significant effect on HI. The lowest HI was obtained from the application of 100 kg. ha^{-1}N and excessive nitrogen reduced HI.

Table 11: Interaction effects of stress condition, Zinc sulfate and nitrogen chemical fertilizer on studied traits in *Nigella sativa*

Stress condition	Zinc sulfate	Nitrogen (kg.ha^{-1})	Plant height (cm)	Number of branches .plnt^{-1}	Number of follicles.m^{-2}	Number of follicles .plant^{-1}
Irrigated	Non-application	0	35.42	5.43	2773.2	18.7
		33	36.99	5.93	3656	18.7
		66	42.01	6.31	3214.6	17.7
		100	43.69	5.82	2792.9	15.1
	Application	0	41.57	6.63	3656	20.4
		33	45.12	8.01	3214.6	18.5
		66	44.04	8.13	2792.9	18.6
		100	44.85	6.88	3302.5	18.4
Rainfed	Non-application	0	21.53	5.10	1737.1	15.9
		33	24.02	5.43	1916.5	16.5
		66	26.14	5.73	1826.8	17.5
		100	25.44	6.71	1875.7	17.2
	Application	0	28.01	6.01	1916.5	16.4
		33	29.98	6.26	1826.8	17.3
		66	32.19	6.69	1875.7	16.8
		100	30.46	7.72	2581.8	15.3

Means, in each column, fallowed by similar letter(s) are not significantly different at the %5 probability level- using Duncan's Multiple Range Test.

Table 12: Interaction effects of stress condition, Zinc sulfate and nitrogen chemical fertilizer on studied traits in *Nigella sativa*

Stress condition	Zinc sulfate	Nitrogen (kg.ha)	1000-grain weight (g)	Biologic yield (g.m^{-2})	Grain yield (g.m^{-2})	Harvest index (%)
Irrigated	Non-application	0	1.88	1207.6	345.0	28.57
		33	1.79	1372.3	393.5	28.68
		66	1.88	1429.3	417.8	29.24
		100	1.75	1577.9	436.6	27.67
	Application	0	2.05	1407.9	402.3	28.57
		33	2.20	1587.8	451.0	28.42
		66	2.05	1593.3	458.0	28.75
		100	2.00	1544.7	425.9	27.57
Rainfed	Non-application	0	1.40	946.5	270.1	28.50
		33	1.55	1047.5	300.6	28.69
		66	1.36	1099.5	320.1	29.14
		100	1.44	1134.1	310.1	27.34
	Application	0	1.78	1037.1	296.7	28.54
		33	1.86	1348.9	385.4	28.57
		66	1.76	1328.2	384.5	28.95
		100	1.45	1238.8	339.6	27.40

Means, in each column, fallowed by similar letter(s) are not significantly different at the %5 probability level- using Duncan's Multiple Range Test.

CONCLUSION

In general, results showed that *Nigella sativa* is susceptible to drought stress, as result showed grain yield and its components decreased because of water deficiency, and irrigated condition had the maximum grain yield. Application of nitrogen chemical fertilizer had positive effect on traits but excessive use of nitrogen chemical fertilizer was not increased in grain yield and associated traits. Application of zinc sulfate in comparison to control treatment (non application) had the positive effect on studied traits.

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