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Effects of Municipal Compost on Yield and Some Quantitative and Qualitative Characteristics of Nigella Sativa under Drought Stress

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Abstract- In order to analyze the effects of drought stress and compost on quantitative and qualitative characteristics of the medicinal plant *Nigella sativa,* this research was performed on split plots in a completely randomized block design with three replications in the research farm of the Agricultural Department (Sistan Dam) of Zabol University, 2012. Irrigation, as the most factor of this treatment, included three levels: (1) control (no stress) with the irrigation cycle of 6 days, (2) moderate drought stress with the irrigation cycle of 10 days, and (3) severe drought stress with the irrigation cycle of 14 days. Its supplementary factor, Municipal Compost, contained lack of compost application (control), and applying 10, 20, and 30 tons/ ha compost, respectively. The results showed that dry tension had a significant effect on biologic yield, HI, 1000-seed weight, and seed yield of *Nigella sativa,* so that any increase in stress led to reduction of the biologic yield, 1000-seed weight, and seed yield. Moreover, if the compost level increases, it can increase traits such as plant height, number of capsules per plant, number of leaves per plant, number of seeds per plant, biological yield, 1000- seed weight, grain yield, extract percentage, and extract yield. Based on the results, it seems that using 30 tons/ ha urban compost and lack of draught stress is quite normal in Zabol climate since it can produce more extract and higher yield production.

Keywords*- herbal plant, irrigation cycle, organic fertilizers*

I. INTRODUCTION

Nigella is the oldest medicinal plants with the scientific name of Nigella sativa L. In their growth environment, plants continually face multiple tensions, which limit their growth and survival chances. Drought stress is one of the most important factors that will reduce crop production at the global level. Iran has an arid and semi-arid climate and its average rainfall is about one-third of the global average precipitation. Therefore, frequent drought and famine are inevitable.

Globally, drought is one of the major inhibitors in plant production in many arid and semiarid regions (Reddy et al, 2004). Although secondary metabolite biosyntheses are controlled due to their genetic problems, the environmental conditions have greater impact on their productions. It has been observed that under different circumstances, there appeared some changes and variations in concentration and amount of these substances, including volatile oils (extracts). These environmental conditions of the area affect the growth of in three dimensions: (a) impact on total amount of active ingredient, (b) impact on the constituent elements of active ingredients, and (c) impact on the production and weight of dry matter. (C) is by itself the most essential factor in production of active ingredients in medicinal plants and shows presence of the environmental stresses, especially drought stress (Najafi, 2011).

The effects of deficit irrigation on vegetative and reproductive stages and grain yield and quality of psyllium (Plantago psyllium) and Nigella sativa were studied. The results showed that deficit irrigation reduces the psyllium yield, whereas Nigella showed a better tolerance towards water cut, except in the aggregation stage. In addition, water cut treatments did not significantly decrease oil concentration of Nigella and mucilage percentage of psyllium (Bannayan et.al, 2008).

One of the major negative impacts of drought is reduced availability and uptake of nutrients for plant. This non-availability may cause nutrients shortage in plants. This factor may lead to physiological activity disturbances such as heavier photosynthesis, respiration, and synthesis of organic compounds, irregularities in enzyme production and activity and generally disrupts the biochemical and physiological activities. As a result, some qualitative and quantitative changes will occur in active ingredients (Misra and Srivastava, 2000; Pirzad et.al, 2006). Therefore, plant nutrition management in stress conditions is one of the main problems in crops production (Mohammadkhani and Heidari, 2007).

Due to the constructive effects on the physical, chemical, and biological traits and soil fertility, organic matters have been recognized as one of the pillars of soil fertility. Soils without organic matter or low organic matters cannot be fertilizing, so they do not have good yield (Akbarnejad et.al, 2001). Generally, compost is used in soil to maintain and increase grain soil persistence and stability, soil fertility and fecundity of crops, so it has been of particular importance in the past decades (Lanlande et.al, 2000). Studies conducted in this area have referred to some positive effects of organic matter quality on growth and development of plants (Razavi Tousi et.al, 2003). This study was designed to investigate the effects of water stress and the application of different amount of compost on yield and some other quantitative and qualitative characteristics of Nigella sativa in the area.

II. MATERIALS AND METHODS

This experiment was performed in 2012-13 at the Agricultural Research Station in Zabol University, near Sistan dam at 15 km west of Zabol. Zabol is located in the geographical position of 61° 29' east longitude and 30° 13' north latitude and altitude of 498.2 m above the sea level.

TABLE I. PHYSICAL AND CHEMICAL PROPERTIES OF SOIL BEFORE THE EXPERIMENT

Electrical conduction	pH	Nitrogen	phosphorus	potassium	zinc	organic carbon	organic matte	silt	clay	Sand	Soil texture
				ppm					Percentage		
1.48	8	6.3	9.2	125	2.8	0.47	0.81	20.4	32.6	45	clay loam

TABLE II. SOME DETAILS ABOUT USING COMPOST (SOURCE CATALOG: MASHHAD MUNICIPALITY)

organic matter	Nitrogen (percentage)	Phosphorus (percentage)	Potassium (percentage)	pH	EC (Ds/m)	Moisture (percentage)
22.7	1.3	0.50	1.42	7.3	7.2	30

A split plot experiment was conducted in a completely randomized block design with three replications. As a major factor, draught stress was considered in three levels: 1 - control (no stress) with irrigation cycle of 6 days, 2 - mild drought stress with irrigation cycle of 9 days and 3 - severe drought stress with irrigation cycle of 12 days. The secondary factor, levels of municipal compost, included 1 - Lack of compost application (control), 2 – 10 tons/ ha compost, 3 – 20 tons/ ha compost, and 4 – 30 tons/ ha compost. Each plot contained five rows in 3 m length.

The distance between the rows was 30 cm, the distance of two plants in each row was 8.3 cm, the distance between the main plots and blocks was 1.5m, and the distance between subplots was 0.5 m. In late August, the land was plowed in the cattle condition. The plots were prepared and separated. Within the plots, compost fertilizer was applied in a specified amount in terms of the planting plan and then it was mixed with soil. On December 1, planting seeds were planted per row and irrigation was applied immediately. Post-planting cares, including thinning, weeding, watering, and regular crusting were conducted.

Five plants were randomly selected for sampling and their regarded features including plant height, number of branches, number of seeds per plant, number of seeds per capsule, and number of leaves per plant were measured. In order to prevent from losing the seeds, harvest was done when the plants went yellow and at least 80% capsules were grown. Different layers of stress treatment, A3 (severe stress), A2 (mild stress) and A1 (control) were made on May 14, 23 and 30, respectively. For this reason, three middle rows within each plot were chosen and with respect to 30 cm from the edge of both sides as border, the plants were cut using clipper and then were weighed after drying to determine their biomass.

Capsules were also isolated. Grains were winnowed and segregated by a thresher machine, and then, they were weighed. Seed oil extracting was conducted with Clevenger set, distillation method, and steam for 3 hours. The statistical analysis and diagram drawings were done using EXCEL and MSTATC software. Mean comparisons was performed using the least significant difference (LSD).

III. RESULTS AND DISCUSSION

A. *Plant height*

The analytical results of data variance showed that the only effect of compost treatment on this trait was significant at the 5% level (Table 3). It was found that with increasing compost application led to an increased plant height, although this increase was not significant and a significant difference was observed only between the control and compost levels. The maximum plant height with a mean of 18.60 cm was from compost treatment (30 tons/ ha), and the lowest height (16.69 cm) was the result of the control treatment (without compost) (Figure 2). It was due to the availability of suitable nutritional components along with probable moisture. So using organic fertilizers (especially at high levels of stress) can partially reduce incidence of adverse effects of drought stress over plant height. Among other impacts of compost on dry height and weight can be its positive effect on soil physical properties used in this material, which improves soil structure, and increases soil porosity and aeration. On the other hand, this substance itself contains nutrients such as nitrogen and its effect on soil's ability to absorb certain nutrients by plants will increase.

Meanwhile, it is also easier for the plant to obtain nutrients. On the other hand, instead of increasing the root, the height of its aerial organs will extend (Beffa et.al, 1995). With application of different amounts of compost and fertilizer in olives, it can be concluded that in the treatments with compost, organic carbon of soil and its sodium elements, copper, zinc, manganese, iron and phosphorus available in soil increased (Soumare et.al, 2003).

B. Number of sub-branches in the plant

There was no significant effect of experimental treatments on this trait (Table 3). It seems that in Nigella, greater number of branches was mostly affected by the plant's genetics. In addition, the density for *Nigella sativa* was the same and this plant has a low volume. Its huge branching, which is the result of drought stress, is considered an undesirable trait because it leads to unnecessary consumption of soil moisture (Ogbonnaya et.al, 1998).

C. Number of leaves per plant

Due to drought stress (Table 3), it seems that the effects of this experimental treatment on this trait were not significant; so that the number of leaves was thus more influenced by plant genetics. Using compost fertilizer on the number of leaves showed that the greatest number of leaves per plant (5/1) was obtained from the application of 30 t/ha compost and its lowest rate (3/8) was related to the non-application of fertilizer (control) (Figure 2). One reason for this increase in the number of leaves in this experiment was the provision of foodstuff by the compost (Bhattacharyya et.al, 2005).

In fact, compost increases uptake of high consumption nutrients in soil. Increased nutrients such as nitrogen, phosphorus, and potassium in the soil were due to presence of large amounts of these elements in the compost. It is often increases nitrogen, phosphorus, potassium, and organic carbon in the rhizosphere. Having plenty of organic matters, compost is a suitable place for growth of microorganisms in soil and it plays a main role in improving structure and adjusting soil texture. Mixed with soil, compost reduces its apparently specific weight and in return, its increases available water. It may also reduce evaporation and increase water storage (Opera et.al, 1987). The interaction of stress factors and different levels of compost on the number of leaves per plant was non-significant (Table 3).

D. Number of capsules per plant

Experimental results showed that the number of capsules per plant was not affected by drought stress (Table 3). Compost treatment effect on the number of capsules per plant was significant at 5% level (Table 3) and the number of capsules in the plant increased insignificantly with further application of compost. In fact, there was only a significant difference between the control (without compost) and the third (20 tons/ ha) and fourth levels (30 tons/ ha). So maximum number of capsules per plant (5/4 pcs) were obtained from application of 30 tons/ ha compost and the lowest (4/0 pcs) corresponded with non-application of fertilizer (control) (Figure 2), and because of the increased nutrients by composting, the number of reproductive organs increased. Interaction of treatments on the number of capsules per plant was not significant (Table 3).

E. Number of seeds per capsule

Experimental treatments and their interaction on this trait were not significant (Table 3), because this trait was mainly influenced by the genetic control of the plant and less affected by environmental factors.

F. Number of seeds in the plant

Under drought stress, number of seeds per plant was non-significant (Table 3). In this experiment, a significant difference was observed due to using four levels of compost on the number of seeds in the producing herb (Table 3). This significant difference was at the probability level of 1% and a significant difference was observed between control level (without compost) and the third (20 tons per ha) and the fourth level (30 tons/ha) of compost. The highest number of seeds per plant (297.7 pcs) was related to compost application (30 tons/ ha), and the minimum number of seeds per plant (181.9 pcs) was the result of control treatment (without compost) (Figure 2). The interaction of stress and compost factors on the number of seeds in the herb was non-significant (Table 3).

G. Biological yield

For this trait, the effect of drought stress at the probability level of 1% was significant (Table 4). According to the data mean comparison test, a significant difference was observed between control level (without tension) and the second and third levels of stress. In addition, the biomass decreased with increasing drought, where the highest biological yield (1498/65 kg/ha) was related to control treatment (no stress) and the lowest biological yield (1100/12 kg per ha) resulted from the stress treatment which was severe (Figure 1). Here, the yield at the level of severe stress reduced as much as 36.23% more than the control treatment (without tension).

Water stress can enlarge and elongate cells (growth) and decrease photosynthetic materials made in plant, and reduce biomass production in plants (Koochaki et.al, 1993). Compost effect on biological yield was significant at the 1% level of probability (Table 1). Applying more compost increased Biomass in which the highest biological yield (1427.14 kg per ha) was related compost application (30 tons/ ha) and the lowest biological yield (1050.6 kg per ha) was related to the control treatment (without compost application) (Figure 2). In fact, biological yield increased 35.84% more than the control and it was due to increased nutrients needed in plants, which was provided by the compost. Studies showed that organic fertilizers used in cultivation of medicinal plants can increase biomass production and their extracted compositions (Scheffer and Koehler.1993). Interaction of drought stress and composting levels on biological yield was not significant (Table 4).

H. Seed yield

Analysis of variance (Table 4) showed that the effects of drought stress and composting of Nigella sativa seed yield was significant at the level of probability of 1%. According to data mean comparisons, the highest seed yield (523.49 kg/ha) was obtained from stress- free treatment (every 6 days) and the lowest (412.59 kg/ha) was related to severe stress treatment (every 12 days) (Figure 1), which due to stress, seed yield reduced by 26.88%. a significant difference was observed between the levels of non-stress level(mild stress) and the third level (high stress).

One reason for this reduced yield during an increase of drought stress could be related to an increased allocation of photosynthetic matters to the root rather than the aerial organs of the plant (Sreevalli et al, 2001). The first sign of water shortage is reduced torquescence that leads to reduction in growth and development of the host cells, especially in stem and leaves. This reduced growth of cells limits the size of organs, so the first noticeable effect of dehydration on the plants can be detected in smaller leaves or shorter plant height (Hsiao, 1973). In addition to the low water conditions, nutrient absorption also reduces and the growth of leaves is limited (Mandal, 1986). Subsequently, reduction of leaf area reduces light absorption and photosynthetic capacity of the plant (Hsiao, 1973).

Comparing effect of compost on 1000- seed yield showed a meaningful difference between application levels, in which its maximum amount (553.61 kg/ ha) was due to compost treatment as a rate as 30 tons per ha and the minimum seed yield (345.20 kg/ ha) was because of control treatment (without compost) (Figure 2). Here, due to compost application (30 tons/ ha), seed yield increased 33.3% more than no compost application. In the experiment using compost and stress levels, the increase of drying yield of the municipal solid waste compost on Peppermint at high levels of drought stress was allocated to the effect of urban waste compost in increasing the nutritional elements of soil as well as the availability of their absorption capability by the plant.

In addition, municipal solid waste compost increased nitrogen balance and efficiency of phosphorus absorption. It was effective in improving soil porosity and increasing plant tolerance to heavy metals (Brussard and Ferrera-Cenato, 1977). Furthermore, citing the findings of Iqbal et al (2004), 1-2 year use of compost could significantly increase corn yield. The significant difference of yield using compost for two consecutive years and the use of these fertilizers for a year can represent an increase of organic compost over time to improve the physical condition of the soil and also provide greater chemical nutrients for the plants (Marjavi and Jahadakbar, 2002).

I. Harvest Index (HI)

The analytical results of data variance showed that the harvest index was affected by draught stress (Table 4) so that the treatment without stress had less HI than other treatments with stress level. Based on comparing data means, it was found that there was a significant difference between without- stress level and other levels (mild and severe stresses). So that the maximum harvest index (0.47) was the result of the severe stress treatment and its minimum (0.42) was because of control treatment (without tension) (Figure 1). Values of Harvest Index at the 70% conditions of available water plant in comparison with 50% and 30% levels were 29.4%, 64.9% and 20.21%, respectively. The maximum Harvest Index was reported in control conditions (field capacity) at a rate of 31.5% and the highest harvest index was reported in control condition (field capacity) at a rate of 31.5% (Shekari, 2001).

J. 1000-Seed Weight

The analytical results of data variance showed that the effects of drought stress on 1000- seed weight was significant at the probability level of 1% (Table 4). Based on the data mean comparison test, the1000- seed weight was reduced by increasing drought stress, but this decrease was not significant. the only significant difference was observed between the levels without stress and other stress levels in which the highest 1000-seed weight (2.66 g) was the result of the control treatment (without stress) and its minimum amount (2.53 g) was of the severe stress treatment (Figure 1).

Stress at the growth level, at the start of the pod to the grain full size, affects by reducing the transporting supplies to the seed that is because of water limitations. On the other hand, it reduces current photosynthesis of leaves or has negative effects on 1000- seed weight (Chaves et al., 2002). In their researches on maize and sunflower, Sajedi et al, 2009) and Nazem et.al, 2008, respectively, reported reduced 1000- seed weight which was the result of water shortage.

Effects of compost on 1000- seed weight was significant at the 5% level (Table 4) in which the highest 1000- seed weight (2.66 g) was obtained with use of compost (30 tons/ ha) and the minimum amount (2.59 g) was the result of the control treatment (without compost) (Figure 2). In another experiment, the use of biological fertilizers significantly increased 1000-seed weight in wheat. (Kundu and Gaur, 1980).

Interaction of treatments on 1000- seed weight of Nigella sativa was significant at the 1% level (Table 4). It can be seen that the effect of different levels of drought stress on 1000-seed weight is based on stress level. In fact, any increase of stress levels can reduce 1000- seed weight (Figure 3). In other words, this increased stress in all levels decreased 1000- seed mean weight. In different fertilization levels, increased tension is the result of fertilizer increase in the mean of 1000- seed weight. Typically, increasing the amount of compost resulted in more 1000- seed weight mean. Regarding the effect of stress on reduction of 1000- seed weight, it is believed that in stress levels, reduction of water and nutrition uptake leads to slower growth of the leaf because of the direct effect of the biochemical and biophysical effects of water on leaf area; hence, less photosynthesis occurs. Likewise, other physiological responses such as ABA hormone formation and pore blockage leave adverse effect on the rate of photosynthetic assimilates and less photo-assimilate will be transmitted to the seeds (Taiz and Zaiger, 1991).

In a research on chickpea cultivars plants, due to presence of enough moisture and nutritional conditions, the growth and maturity of pods occurred in a longer period of time and pea plants had more opportunity for conducting the growing substances and seed filling. Therefore, under the experimental treatments, 1000- seed weight of chickpea cultivars increased significantly (Patel, 2005, Pacucci et al., 2006).

K. Seed essential oil percentage

The results of the experiments indicated that the effect of drought on seed oil percentage was insignificant (Table 4). Compost effect on this trait was significant at the probability level of 5% (Table 4). Data mean comparison showed that no significant difference was observed among the treatments. However, there was a significant difference between the second (10 tons per ha) and third levels (20 tons per ha), in which the maximum essential oil amount (2.08) was the result of compost application (30 tons per ha) and the minimum essential oil percentage (1.48) was due to control treatment (without compost) (Figure 2) . Here, the essential oil percentage was increased by 40.5% after using compost. In addition, a significant difference was observed among application levels of compost. It has been reported that the use of organic fertilizers increases the essential oil content in herbs (Atiyeh2000). In another study, it was found that using compost instead of chemical fertilizers can be more effective on increasing essential oil level of funnel plant ,i.e., the essential oil percentage increased by increasing the applied compost (Mona et al ., 2008). The interaction between stress and composting level treatments on seed essential oil percentage was not significant (Table 4).

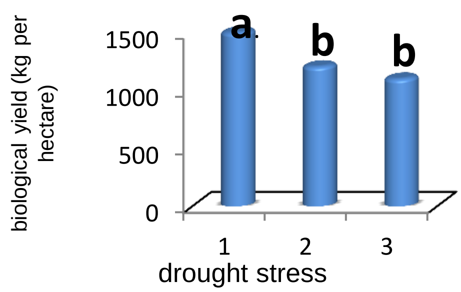
L. Essential oil yield

Based on the analytical results of the data variance, the effect of drought stress on essential oil yield was significant at the probability level of 5% (Table 4). The data comparison test showed that there was a significant difference between mild stress and levels of severe stress and no stress, in which the minimum rate (10.43 kg/ ha) and the maximum essential oil yield (15.39 kg per ha) were the results of extreme stress treatment and control treatment (no stress), respectively (Figure 1). The test results indicated that the effect of compost treatment on this trait was significant at 1% level (Table 4). The essential oil yield multiplied by increasing the compost level, so that a significant difference was observed between control treatment and the second (10 tons per ha) and the fourth (30 tons per ha) levels. The maximum essential oil yield (14.62 kg per ha) was the result of using compost (30 tons per ha) and the minimum essential oil yield (9.91 kg per ha) was related to control treatment (without compost) (Figure 2). After applying compost, the essential oil yield of the seed increased by 47.5% and a significant difference was observed between the compost levels. Organic fertilizers increased the yield of fennel essential oil (Mona et.al, 2008). The highest percentage and performance of Deracocephalum moldavica L. were obtained at moisture conditions of 70% and 100% of the farm capacity (Hassani, 2006).

In the greenhouse test, the effects of three levels of soil ((50%, 70%, and 90% of field capacity) were investigated on Thymus vulgaris. The result showed that the highest rate of dry matter accumulation was at 90% farm capacity of and the maximum percentage of essential oil was obtained at farm moisture of 70% (Letchamo et.al, 1994). The interaction of stress and compost levels treatments on essential oil yield was non-significant (Table 4).

IV. Conclusion

Based on the results of this study, it can be said that using compost can have positive effects on yield and essential oil of *Nigella sativa*. In addition, because of compost effects on soil characteristics, under water deficit conditions, using compost can lead to stress reduction. Totally, in Zabol weather, applying 30 tons/ ha compost and 6- day irrigation cycles for production of *Nigella sativa* seems suitable.



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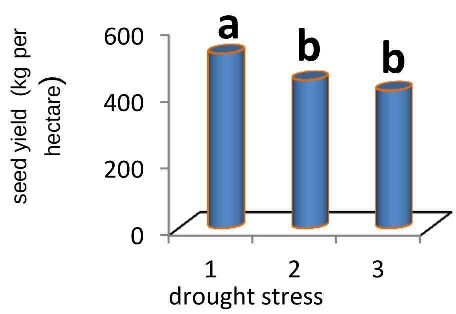

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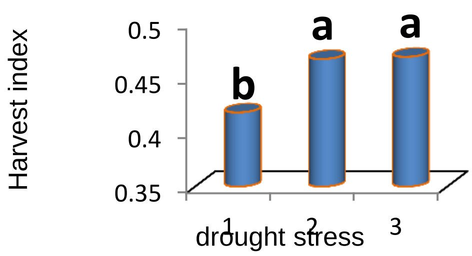

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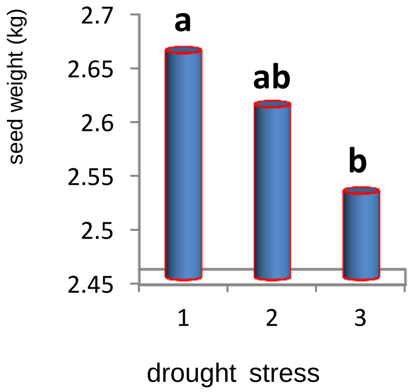

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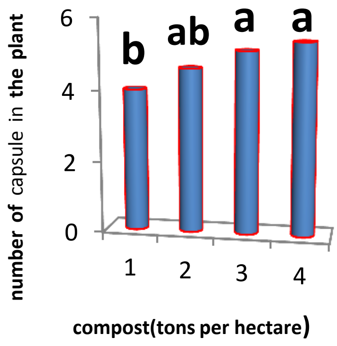

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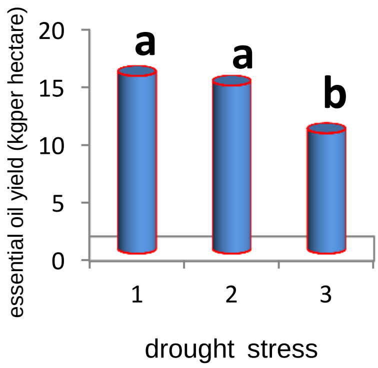

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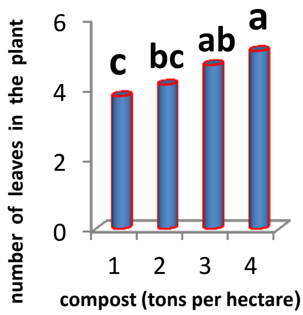
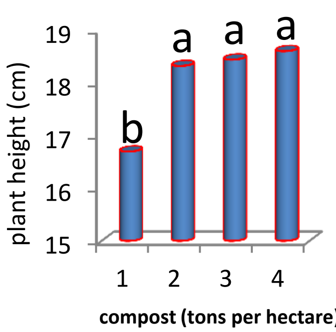


(c)

Figure 1. Effect of drought stress on biological Yield of (a) seed yield (b), Harvest index (c), Seed weight (d) and Essential oil yield (e).



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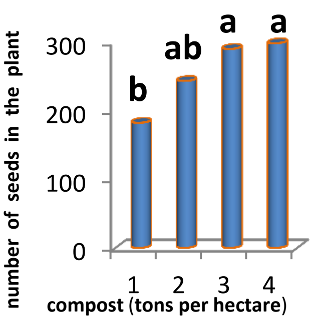

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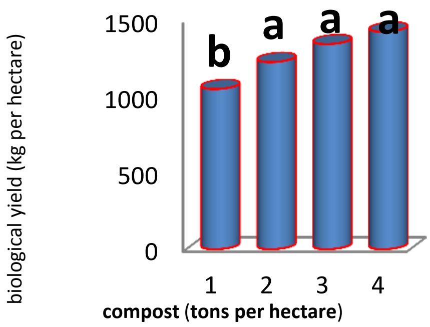

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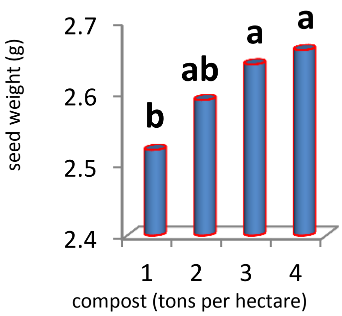

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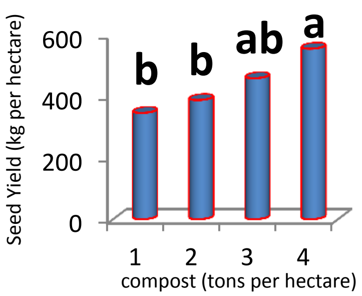

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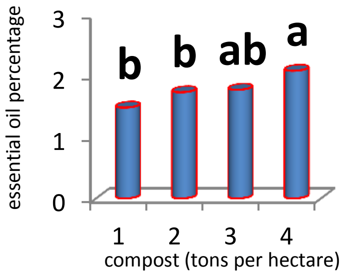

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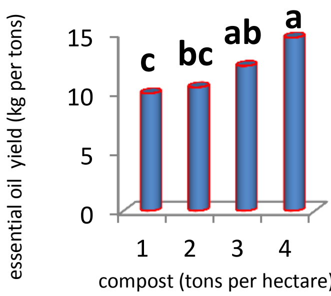

(l)

Figure 2. Effects of compost on plant height (a), number of capsules per plant (b) number of leaves per plant (c), number of seeds per plant (d), biological yield (e), seed weight (f), grain yield (g), essential oil percentage (h) and Essential oil yield (l)

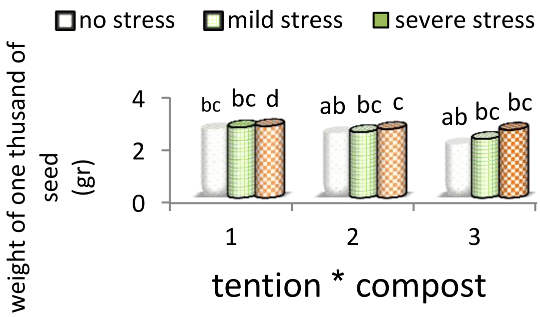

Figure 3. The interaction of tension and compost treatments on the mean weight of seeds of Nigella sativa

TABLE III. ANALYSIS OF VARIANCE OF QUANTITATIVE AND QUALITATIVE CHARACTERISTICS OF NIGELLA SATIVA AFFECTED BY DROUGHT AND COMPOST

Change source	Mean Squares						
	Freedom degree	Plant height	Number branch	Number leaf	Number capsule	Number seed per capsule	Number seed per plant
repetition	2	12.82 ns	0.418 ns	1.93 ns	2.092 ns	121.904 ns	36144.1 ns
Drought stress (A)	2	4.46 ns	0.003 ns	2.146 ns	2.507 ns	2.318 ns	13412.63 ns
Main error	4	3.94	0.412	1.477	1.065	124.145	7441.121
Compost (B)	3	7.025*	0.429 ns	2.955*	3.266*	111.227 ns	25434.85**
A*B	6	2.32 ns	0.193 ns	0.714 ns	1.510	43.620 ns	5512.179 ns
Sub-errors	18	1.72 ns	0.180 ns	0.686 ns	0.687 ns	67.849 ns	4154.979 ns
CV(%)		7.82	16.71	18.80	17.37	15.87	25.47

TABLE IV. ANALYSIS OF VARIANCE OF QUANTITATIVE PROPERTIES OF NIGELLA SATIVA AFFECTED BY DROUGHT AND COMPOST

Change source	Mean squares						
	Freedom degree	Seed yield	Biological yield	Harvest index	Seed weight	Essential oil percentage	Essential oil yield
repetition	2	25.331 ns	2889.921**	0.031**	0.095**	0.039 ns	1406.255 ns
Drought stress (A)	2	694.76**	7139.191**	0.010*	0.048*	0.112 ns	6151.57*
Main error	4	21.321	29.129	0.001	0.005	0.190	612.43
Compost (B)	3	199.87**	1163.131**	0.002 ns	0.036*	0.543*	7120.60**
A*B	6	14.898 ns	147.994 ns	0.001 ns	0.044**	0.029 ns	379.540 ns
Sub-errors	18	11.627	127.420	0.003	0.008	0.128	1264.133
CV(%)		6.90	10.16	11.20	3.45	12..94	25.46

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