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Evaluation of vermicompost application and stress of dehydration on mullein medicinal plants

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Summary: The use of organic fertilizers is one of the suitable solutions in the organic production of medicinal plants due to its good effect in improving soil properties, reducing environmental effects, and better plant growth. To investigate the effect of vermicompost organic fertilizer application and water stress on some morphological and physiological traits of the Mullein medicinal plant, research was conducted at Isfahan Azad University in the form of split plots in the form of a randomized complete block design with 4 replications. The test factors included the application of vermicompost organic fertilizer at three levels of 0, 4, and 8 kg per square meter of soil and water stress at two levels of normal irrigation and irrigation at the time of 50% of the soil's agricultural capacity as the main treatment in research farm conditions. The results of the experiment showed that the application of vermicompost organic fertilizer and water stress improved the morphological and physiological characteristics of the Mullein medicinal plant compared to the control, i.e. no application of organic fertilizers. The results showed that the highest number of secondary branches, number of flowers of the secondary stem, diameter of flowering stem, the diameter of flower, and fresh weight of shoot in the Mullein medicinal plant were obtained by applying vermicompost organic fertilizer at the rate of 4 and 8 kg of soil. The application of vermicompost organic fertilizer at the rate of 8 kg in the soil increased flavonoids compared to the non-use of vermicompost treatment. However, to improve the vegetative growth and increase the reproductive efficiency of the Mullein plant and reduce production costs, the use of vermicompost organic fertilizer is recommended at the rate of 4 and 8 kg of soil, respectively.

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Key words: medicinal plant, vermicompost, dryness, photosynthesis

Introduction

Today, dehydration is one of the most important limiting factors for crop growth in arid and semi-arid regions, and growth reduction due to drought stress is much higher than other environmental stresses. Water shortage and salinity stress have a key effect on the survival of crops and sustainable food production (Azizi et al., 2016). Drought stress, which occurs due to the reduction of water in the root growth environment, leads to the closing of stomatal cells and the limitation of carbon dioxide gas. Losing a large amount of water causes the breakdown of metabolism and cell structure and leads to the cessation of the catalytic effects of enzymes. Severe water stress may prevent photosynthesis, disrupt metabolism and eventually lead to plant death (Bartles & Sunkar, 2005). Drought stress causes a decrease in plant growth through changes in the biochemical and physiological processes of the plant, including changes in enzyme activity, cell membrane permeability, leaf water status, and plant photosynthetic rate (Narkhede et al., 2001).

Plant leaves are more sensitive to drought stress than other plant organs. Reduction of leaf growth or aging of leaves under drought stress conditions is one of the adaptation mechanisms of plants in response to drought stress and reduced transpiration. Leaf growth is reduced due to the unavailability of the required water and reduced food absorption (Azizi et al., 2016). Today, the unconventional use of chemical inputs in agricultural production and social concerns about environmental pollution, and the extinction of biological species have led to the use of more natural inputs, including biofertilizers. Biofertilizers refer to fertilizing materials that contain a sufficient number of one or more species of beneficial microorganisms or the products of these organisms, which are offered on suitable preservatives (Nirmala et al., 2009). Among these fertilizers, we can mention vermicompost, one of the most important biological fertilizers, which plays an important role in increasing the quantity and quality of the product (Chamani et al., 2008).

The characteristics that make vermicompost an excellent biofertilizer include: the presence of enzymes such as protease, lipase, amylase, and cellulase (which decomposes agricultural residues in the soil and makes the attack of other microbes faster), being rich in vitamins, antibiotics, and growth hormones, free from pathogenic factors, increasing the stability of soil structure and maintaining soil moisture (Mortezae Nejad, 2013). It has good drainage and a high capacity for ventilation and high water storage. It also contains humates, which have a similar effect to plant growth regulators. Vermicompost, having a wide and active microbial biodiversity compared to the composts produced in the thermal process, is used as an important soil purifier and modifier (Aremu et al., 2014). In a research conducted on the medicinal plant Chamomile, it was observed that with the use of vermicompost, the height of the plant and the performance of this plant increased significantly (Bharti et al., 2016). It was also observed that the use of vermicompost increased plant height, biological yield and seed yield of fennel plant. Laden Moghadam et al. (2012) in investigating the effect of different levels of vermicompost on the evergreen plant showed that the 40% treatment has a favorable effect on the plant performance. Investigating the effect of vermicompost on the morphological and physiological characteristics of the summer savory plant showed a significant increase in all vegetative parameters except the dry weight ratio of the branch to the root (Sharif et al., 2016).

The high amount of nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium compared to other organic fertilizers, as well as microelements such as iron, zinc, copper, and manganese in a form that is easily absorbable and available for the plant, is one of the advantages of vermicompost. Studies have shown that vermicompost improves photosynthetic pigments, water relations, and ionic absorption of plants in stress-free and salinity conditions. As an example, vermicompost has increased the chlorophyll index and the rate of photosynthesis of the lemon medicinal plant (Ashraf & Foolad, 2007). These researchers stated that the use of vermicompost increases the amount of nitrogen in the plant and increases the number of chlorophylls and carotenoids. It is also reported that under salinity stress conditions, vermicompost has increased the concentration of nitrogen, phosphorus, iron, and magnesium in the aerial parts of spinach (Tajzadeh & Morteza Nejad, 2016).

On the other hand, the need to expand the sustainable green space to increase the health of the soul and body of humans is a necessary and inevitable thing (Bradley et al., 2010). The latter case can be met by using medicinal-ornamental plants due to the low level of expectation of these plants concerning water and tolerance to stresses (Moghadam et al., 2012). Among the plants that have this feature, we can mention the plant (*Verbascum thapsus*). This plant belongs to the genus Mullein, in which more than 360 species have been identified so far, which are widely distributed in the temperate regions of Asia, Africa, and Europe (Edwards et al., 2010). This plant genus has been less studied, and with more studies, more species of this plant genus are being reported regularly (Khorram Del et al., 2016). Mullein plant is one of the popular medicinal plants and its flowers are used as an antitussive and expectorant medicine and also for lung ailments (Rashmi et al., 2008). For the design of urban green spaces and considering the recent droughts, the use of medicinal-ornamental plants such as Mullein plant, which tolerate environmental stresses such as drought, have priority(Moghadam et al., 2012). Although this plant is tolerant to water stress, if the minimum water requirement of the plant is not met, water stress can cause severe damage to the plant in the sensitive stages of its growth. According to the mentioned materials, this study aimed to investigate the effect of vermicompost fertilizer on reducing the effects of drought stress on the Mullein plant.

Materials and methods

This experiment was conducted at Isfahan Azad University in the form of chopped plots in the form of a randomized complete block design with 4 replications. The experimental treatments included two levels of stress (normal irrigation and irrigation at the time of 50% of the agricultural capacity of the field) which were in the main plots and three levels of vermicompost fertilizer (0, 4, and 8 kg/m^2) which were placed in the secondary plots. The results of soil vermicompost analysis are presented in ***Tables 1-2***.

Table 1. Results of vermicompost analysis used.

Potassium (%)	Phosphorus (mg/kg)	Total nitrogen (%)	Organic carbon (%)	pH	EC (dS/m)
0.31	1.418	1.75	18.1	7.09	2.74

Table 2. Soil analysis results.

EC (dS/m)	pH	Organic matter (%)	Lime	P mg/kg)	K (mg/kg)	Soil texture
4.48	7.32	1.06	38	39.7	210.08	loamy - sandy

The seeds were disinfected with 5% commercial sodium hypochlorite for 5-7 minutes and washed several times with distilled water. The seeds used were obtained from the Seed Research Center, Azad University of Isfahan, and we planted them in the research greenhouse of the university with a density of 20 seeds in pots with an opening diameter of 16 cm and a height of 24 cm at a depth of 2-3 cm. Soil with silty-loam texture and leaf fertilizer was poured into all the pots in a ratio of 2:1. Water with an electrical conductivity of 0.49 decisions/meter was used to irrigate the pots. The conditions of the greenhouse were set as 15 hours of light and a temperature of 29 °C during the day and 22 °C at night, as well as 74% humidity. In the middle of March, to strengthen the plants, the pots were moved out of the greenhouse for a week, and then they were cultivated at the five-leaf stage in the experimental field of Azad University. Until the time of greening, all the pots were watered daily and after the establishment of the plant, water stress treatment was applied. The mentioned seedlings were planted in 1x2 meter plots and 8 seedlings were planted in each plot. The plant water requirement for the control treatment was estimated using the long-term average of the daily data of meteorological parameters recorded in Isfahan Meteorological Station and the relationship ($ETc = ET0 \times Kc$). ETc: water requirement of Verbascom plant (mm per day), ETo: plant transpiration evaporation (mm per day) and Kc is Mullein plant coefficient. It is necessary to explain that ETo values were estimated based on the standard FAO-Penman-Manith method. After calculating the ETc values, the net requirement and irrigation water values of Mullein plants were estimated based on the cultivation intervals, the type of irrigation system, and the irrigation cycle, and then irrigation was given to the plant at each turn. To calculate the water requirement of each plant, the total amount of water given to each plant during the growth period was calculated, in which case the water requirement of each plant was estimated for the control treatment. The water requirement of other treatments (deficiency stress treatments) was estimated and distributed based on the water requirement of the control treatment and the percentage of water stress (50%). At the end of the experiment, to measure the traits, samples were randomly selected from each experimental unit, and then after 24 hours, sampling was done from the depth of root development (0 to 30 cm) (Tatari et al., 2013).

The samples were weighed immediately and then transferred to the oven and dried for 48 hours at 70 degrees Celsius finally the dried samples were weighed again. Flower lifespan was determined based on appearance characteristics, i.e. the state of the petals where the first signs of turgescence reduction and wilting appeared, and the moisture percentage was calculated. After applying the treatments, traits such as the number of secondary branches, the number of flowers on the secondary stem, the diameter of the flowering stem, the diameter of the flower, the fresh weight of aerial parts and carotenoids were measured using the method (Bates et al., 1973), chlorophyll A and B using the method (Kumar et al., 2016) and flavonoids.

The number of sub-branches was counted from the soil surface to the end of the stem. After that, the diameter of the flowering stem was measured from the part where the first flower appeared to the end point. Also, the number of opened secondary stem flowers was counted. To determine the content of leaf pigments according to Arnon's method (Arzamjo et al., 2007), 0.5 g of leaf tissue was weighed and mixed with 20 ml of 80% acetone on ice and with a cold porcelain mortar, and the extract obtained was centrifuged for 10 minutes at 3000 RPM. And then the amount of chlorophyll and zinc in the third young leaf before harvesting and its absorption was measured by a spectrophotometer (model AA-6500 Shimadzu, Shimadzu company, Japan) at wavelengths of 645, 470, and 663 nm. The collected data were analyzed using SAS 9 statistical software and the comparison of means was done by Duncan's multi-range test at the probability level of 0.05.

Results and discussion

The results of the analysis of variance showed that the effect of vermicompost fertilizer on the characteristics of secondary branches, the number of secondary stem flowers, the diameter of the flowering stem, the diameter of the flower, and the wet weight of the aerial parts measured was significant (***Table 3***).

The comparison of average traits showed (***Tables 4-5***) that the application of vermicompost organic fertilizer has increased the growth of aerial parts of the Mullein plant, which can be caused by the increase in the absorption capacity of nutrients and more access to these minerals in the soil, which results in the improvement of physical, chemical and biological properties Soil is provided (Sangwan et al., 2010).

The results of comparing the averages of the interaction effect of stress treatment and Vermicompost on the Mullein plant showed that the highest number of sub-branches 15.75 was obtained in the irrigation treatment at the time of 50% of the field's agricultural capacity and the application of 4 kg of vermicompost. While the lowest amount in the normal stress factor was observed without applying vermicompost with the rate of 1.75 flowers (***Figure 1***).

The highest number of secondary stem flowers in the irrigation treatment at the time of 50% of the field's crop capacity and applying 8 kg of vermicompost with the rate of (50/53) numbers were obtained. While the lowest rate was observed in the non-use of vermicompost factor and without stress treatment flowers (Sheikhi & Raunghi, 2012; Moghadam et al., 2012) (***Figure 2***).

According to the results of comparing the averages, the maximum diameter of the flowering stem was obtained in the factor of applying stress once for 10 days and using 8 kg of vermicompost to the extent of (11.75 cm). The lowest amount was observed in the factor without applying the vermicompost factor and not using stress (6.25 cm) (***Figure 3***).

So, the largest diameter of the flower was observed in the treatment of 4 kg of vermicompost and the application of stress treatment with the amount of (3.80 cm) and the lowest amount without the use of stress treatment and without the use of vermicompost treatment with the amount of (3.10 cm) (***Figure 4***).

It was consistent with the results obtained from the experiment of Alidost et al. (2012). Moghadam et al. (2012) also reported that the application of vermicompost with hybridized Asiatic concentration caused an increase in volume in hybridized Asian Lilium, causing an increase in the flowering stem, leaf wet weight, stem height and diameter, and the number and length of roots as a result of improving the absorption of A. In both tissues (Fe and Zn) and low consumption (K and Ca), it has been used in roots and stems. The highest wet weight of the shoot was observed without stress treatment and with 4 kg vermicompost treatment with 200.75 grams. While the lowest amount was obtained without using stress treatment and without using vermicompost treatment with the amount of 125 grams (***Figure 5***).

It seems that the application of biological fertilizers, in addition to improving the physical characteristics of the soil, including increasing the soil moisture retention factor, is effective in the coloring and appearance of flowers and ornamental plants (Bates et al., 1973). Moghadam et al. (2012) reported that the improvement of flowering capacity and the appearance of flowers in ornamental plants is a result of the use of biofertilizers due to the availability of nutrients such as nitrogen, phosphorus, and potassium and low consumption elements. Also, according to the report of Edward et al. (2010) and Ghahremaninejad et al. (2015), vermicompost increased the fresh weight and yield of bean plants and caused more germination in comparison with the control treatment.

Singh et al. (2008) believe that the increase in leaf area and leaf dry weight in strawberries cultivated in vermicompost is due to the presence of high humic acids in vermicompost. In pepper plants, the application of vermicompost in concentrations of 15 and 20% caused an increase in plant growth parameters in comparison with the application of chemical fertilizer and also the control without vermicompost in pots and ground. The use of higher concentrations of compost in this experiment is not absorbed by the products and remains in the soil (Arnon, 1967). The positive effect of vermicompost on the growth of plant species can be attributed to the improvement of its physical and chemical properties, as well as the increase in plant access to mineral nutrients (Arancon et al., 2004). In a research it showed that the increase in nitrogen level as a result of the application of vermicompost led to an increase in plant growth and chlorine content. The positive effect of vermicompost treatment on the leaf chlorophyll content in marigold plants with a 2-fold increase in 27 days after germination has also been reported (Andreev et al., 2016). The results of the analysis of variance showed that the effect of vermicompost fertilizer on measured carotenoid, chlorophyll A, chlorophyll B, flavonoid 270, flavonoid 300, and flavonoid 330 traits is significant (***Table 6***).

Considering the significant effect of vermicompost treatment and stress and the mutual effect of these two treatments on the number of tested factors of the Mullein plant (***Tables 7-8***).

Table 3. The results of analysis of the variance of the effect of stress and vermicompost by Duncan's multi-range test method.

Sources of changes	Degrees of freedom	Average of squares				
		Number of secondary stems	The number of flowers on the secondary stem	Flowering stem diameter	Flower diameter (cm)	Wet weight (g)
Error	3	7.38	11.61*	4.61*	0.08	32.15
Stress	1	20.17	42.67**	77.4**	0.05	5.92
Error × stress	3	5.71	0.56	0.22	0.02	108.7
vermicompost	2	228.1**	59.38*	13.63**	0.51*	10123.6**
Vermicompost × Stress	2	23.29*	15.29	5.04	0.17	795.5*
Error	12	3.92	10.67	1.67	0.10	155.0
CV (%)		24.74	6.38	14.97	8.93	7.29

*,**: Significant at 5 and 1%, Respectively

Table 4. Comparison of the average traits of the simple effect of stress by Duncan's multi-range test method.

Factor stress	Average of squares				
	Number of secondary stems	The number of flowers on the secondary stem	Flowering stem diameter	Flower diameter (cm)	Wet weight (g)
Normal	[b] 7.08	[a] 46.42	[b] 6.83	[a] 3.46	[a] 170.17
Stress	[a] 8.92	[a] 49.08	[a] 10.42	[a] 3.55	[a] 171.16

In each column, means with different letters are significantly different at the 5% level of Duncan's test.

Table 5. Comparison of simple averages on traits by multi-domain test of Duncan vermicompost.

Vermicompost	Average of squares			
	Number of secondary stems	The number of flowers on the secondary stem	Flowering stem diameter	Flower diameter (cm)
Check	[c] 2.38	[b] 46.50	[b] 7.13	[b] 3.30
4 kg	[a] 13.00	[b] 45.88	[a] 9.25	[a] 3.79
8 kg	[b] 8.63	[a] 50.88	[a] 9.50	[b] 3.43

In each column, means with different letters are significantly different at the 5% level of Duncan's test.

Table 6. ANOVA Results of the effects of stress and vermicompost on some physiological traits of *Verbascum thapsus.*

Sources of changes	Df	Mean of square					
		Carotenoid mg/g	Chlorophyll a mg/g	Chlorophyll b mg/g	Flavonoid 270 mg/g	Flavonoid 300 mg/g	Flavonoid 330 mg/g
Repetition	2	0.00002**	0.0008	0.00005	0.00002**	0.00005	0.00009**
Stress	1	0.004**	0.0022	0.0024*	4.00**	1.99**	0.97**
Error1	2	0.0000009	0.0006	0.00005	0.00	0.000006	0.000
Vermicompost	2	0.021**	0.30**	0.042**	3.87**	1.90**	0.92**
Vermicompost × Stress	2	0.001**	0.012**	0.0036**	1.19**	0.59**	0.29**
Error2	8	0.000003	0.0005	0.00002	0.00001	0.00003	0.00004
Coefficient of variation (%)		0.60	0.63	1.19	0.16	0.36	0.66

ns, * and ** indicate no significant difference and significant difference at 5% and 1% levels, respectively.

Table 7. Comparison of the average effects of simple stress factor on some physiological traits of the plant *Verbascum thapsus.*

Stress factor	Mean of square					
	Carotenoid mg/g	Chlorophyll a mg/g	Chlorophyll b mg/g	Flavonoid 270 mg/g	Flavonoid 300 mg/g	Flavonoid 330 mg/g
Normal	[a]0.28	[a]1.08	[a]0.35	[a]2.54	[a]1.78	[a]1.25
Stress	[b]0.27	[b]1.06	[b]0.33	[b]1.60	[b]1.12	[b]0.79

In each column, means with different letters are significantly different at the 5% level of Duncan's test.

Table 8. Comparison of the average effects of simple vermicompost factor on some physiological traits of the plant *Verbascum thapsus*.

Vermicompost	Mean of square					
	Carotenoid mg/g	**Chlorophyll a mg/g**	**Chlorophyll b mg/g**	**Flavonoid 270 mg/g**	**Flavonoid 300 mg/g**	**Flavonoid 330 mg/g**
Check	^{c}0.21	^{c}0.81	^{c}0.25	^{c}1.29	^{c}0.90	^{c}0.63
4 kg	^{b}0.30	^{b}1.17	^{b}0.36	^{a}2.90	^{a}2.03	^{a}1.42
8 kg	^{a}0.32	^{a}1.22	^{a}0.41	^{b}2.03	^{b}1.43	^{b}1.00

In each column, meanings with different letters were significantly different at the 5% level of Duncan's test.

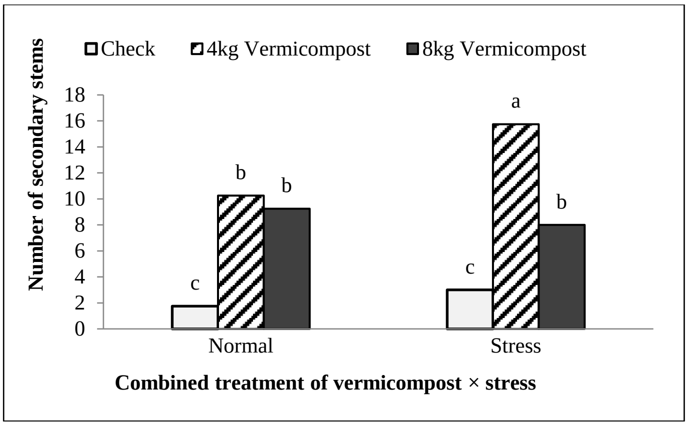

Figure 1. The mutual effect of vermicompost and stress on the number of secondary stems of Verbascum plant. Averages with the same letters are not significantly different at the 5% level of Duncan's test.

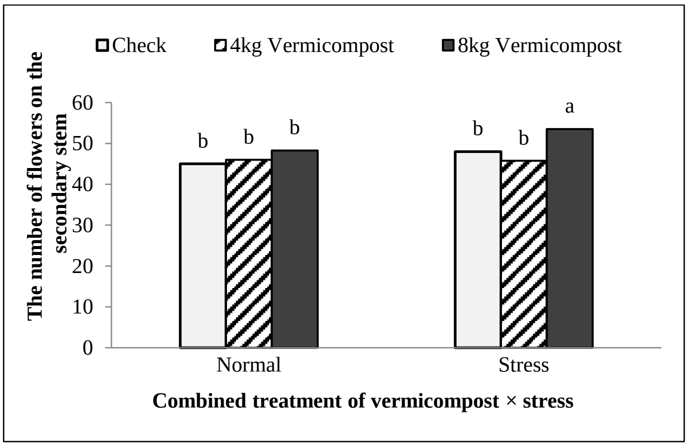

Figure 2. The mutual effect of vermicompost and stress on the number of flowers on the secondary stem of Verbascum plant. Averages with the same letters are not significantly different at the 5% level of Duncan's test.

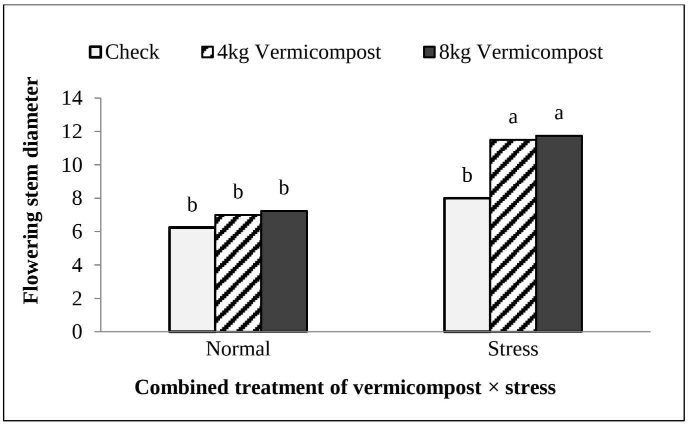

Figure 3. The mutual effect of Vermicompost and stress on the diameter of the flowering stem of Verbascum plant. Averages with the same letters are not significantly different at the 5% level of Duncan's test.

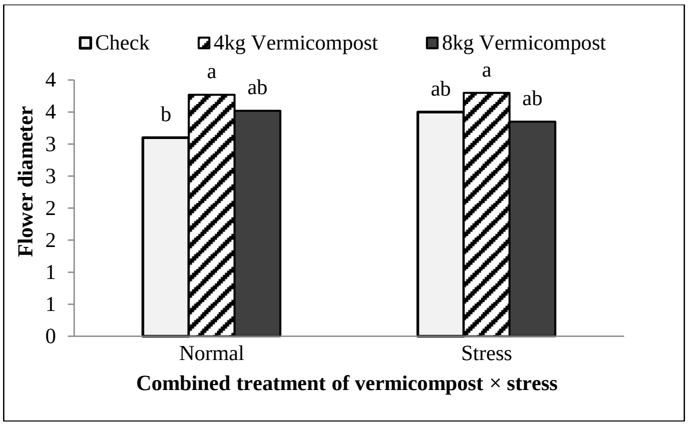

Figure 4. interaction effect of vermicompost and stress on flower diameter of Verbascum plant. Averages with the same letters are not significantly different at the 5% level of Duncan's test.

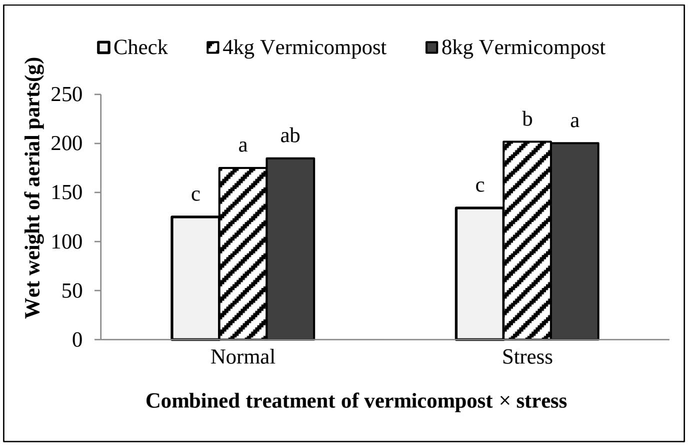

Figure 5. interaction effect of vermicompost and stress on wet weight of Verbascum plant. Averages with the same letters are not significantly different at the 5% level of Duncan's test.

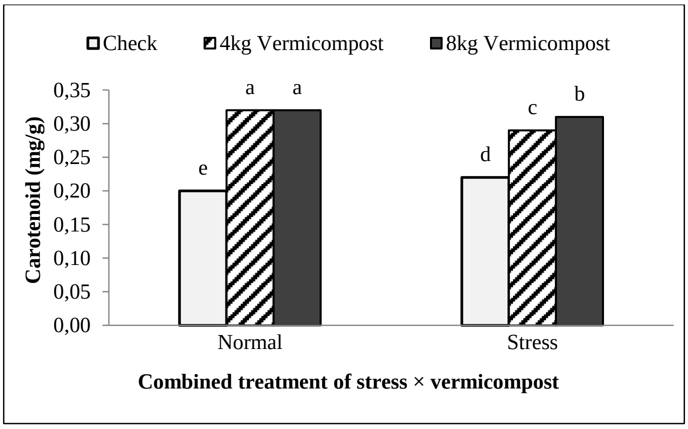

Figure 6. Interaction effect of vermicompost and stress on carotenoids of Verbascum plant. Averages with the same letters are not significantly different at the 5% level of Duncan's test.

The highest amount of carotenoids was observed in the treatment of 8 kg of vermicompost without stress treatment at the rate of (0.32 mg/g), while the lowest amount was observed without the use of stress treatment and without the use of vermicompost treatment at the rate of (0.20 mg/g) was observed (***Figure 6***).

The highest amount of chlorophyll a was observed in the treatment of 8 kg of vermicompost without the use of water stress treatment (1.26 mg/g). While the lowest amount was observed without using stress treatment and without using vermicompost treatment (0.77 mg/g) (***Figure 7***).

The highest amount of chlorophyll b was observed using the treatment of 8 kg of vermicompost using the stress treatment (0.42 mg/g). While the lowest amount was observed without using stress treatment and without using vermicompost treatment (0.24 mg/g) (***Figure 8***).

Similarly, Kumar and colleagues (Lotfi et al., 2013) reported that the chlorophyll content in leaves increased with the application of 20% vermicompost. Mani et al. (2016) showed that the level of nitrogen in the application of vermicompost led to an increase in plant growth and chlorophyll content. The positive effect of vermicompost treatment on the content of leaf chlorophyll in the crown plant with an increase in 27 days after germination has also been reported (Mozafarian, 2012). The application of vermicompost with different concentrations on mung bean and Centella Asiatica plants increased the growth, biomass, and chlorophyll content of these plants. On the other hand, the maximum response of the plant was obtained in the 20% concentration of vermicompost in the soil, and its higher concentration had no effect (Peters et al., 2009).The increase of chlorophyll activity under water stress in plants has been reported in different ways. The present experiment is consistent with the results of Rahmani et al.'s experiment (Razavizadeh et al., 2013) on the wild mustard plant. In this study, enzyme activity increased with increasing dehydration stress. In explaining this issue, it should be said that the increase in tension causes the increase of oxygen radicals. As a result of the increase of these metalloenzymes, it collects toxic radicals that are constantly formed as aerobic products. This enzyme can be used to determine drought-resistant species (Razavizadeh et al., 2013). The highest amount of flavonoid 270 was observed using the treatment of 4 kg of vermicompost without the use of stress treatment (3.78 mg/g). While the lowest amount was observed without the use of stress treatment and without the use of vermicompost treatment (1.29 mg/g) (***Figure 9***).

Flavonoid is an enzyme found in plant cells and plays a role as one of the most important pigments and plays an important role in removing oxygen produced by processes such as beta-oxidation of fatty acids, oxidation during photorespiration and It plays the role of electron transfer in the respiratory chain of mitochondria (Asghari et al., 2015). The results obtained from the present study are equal to the results obtained from the experiment of Rahmani et al. (Razavizadeh et al., 2013) on the mustard plant. In this study, the activity of the flavonoid enzyme increased with the increase of dehydration stress. Based on the result, it can be concluded that increasing the activity of flavonoids in stress conditions is vital because these enzymes are necessary for cell survival and for organs to continue (Khorram Del et al., 2016). The highest amount of flavonoid 300 was observed using the treatment of 4 kg of vermicompost without using stress with the amount of 2.65 mg/g. While the lowest amount was observed without the use of vermicompost treatment and with the use of stress treatment at the rate of 0.8 mg/g ***(Figure 10)*** (Shirvani et al., 2014).

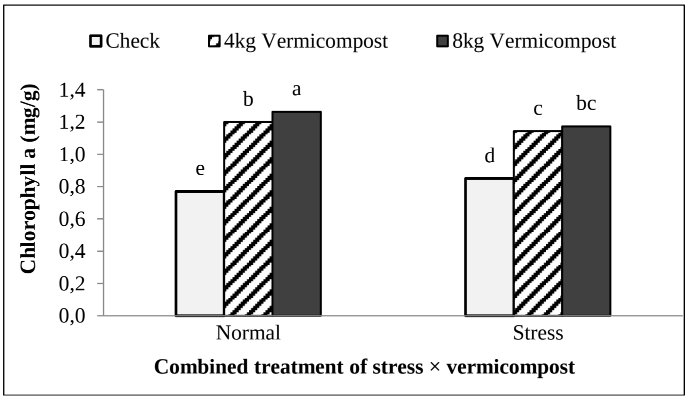

Figure 7. Interaction effect of vermicompost and stress on chlorophyll a of Verbascum plant. Averages with the same letters are not significantly different at the 5% level of Duncan's test.

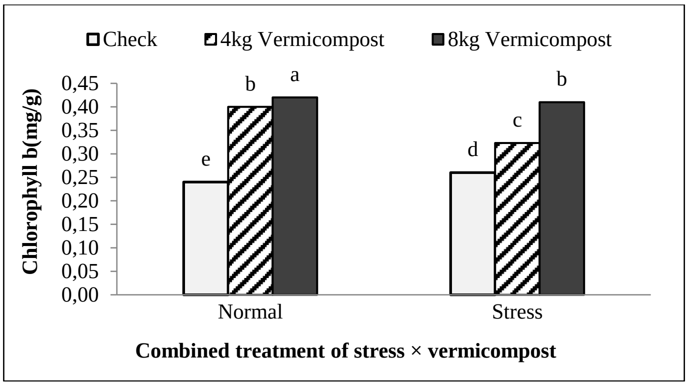

Figure 8. Interaction effect of vermicompost and stress on chlorophyll b of Verbascum plant. Averages with the same letters are not significantly different at the 5% level of Duncan's test.

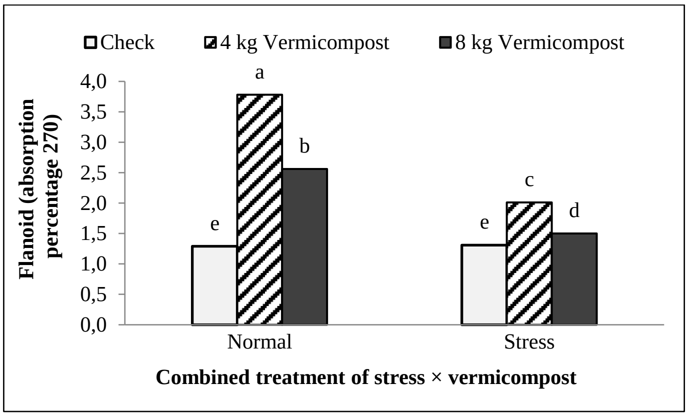

Figure 9. Interaction effect of vermicompost and stress on flavonoid 270 of Verbascum plant. Averages with the same letters are not significantly different at the 5% level of Duncan's test.

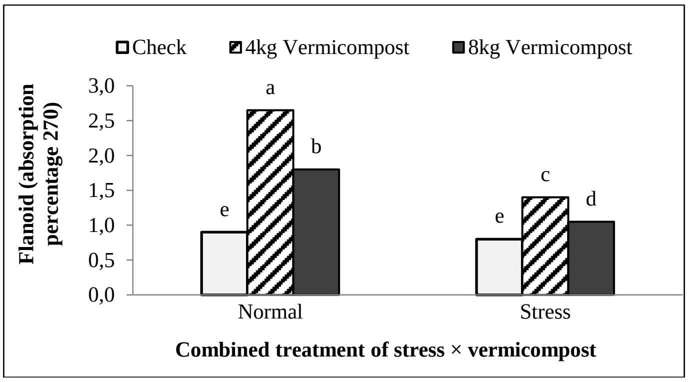

Figure 10. Interaction effect of vermicompost and stress on flavonoid 300 of Verbascum plant. Averages with the same letters are not significantly different at the 5% level of Duncan's test.

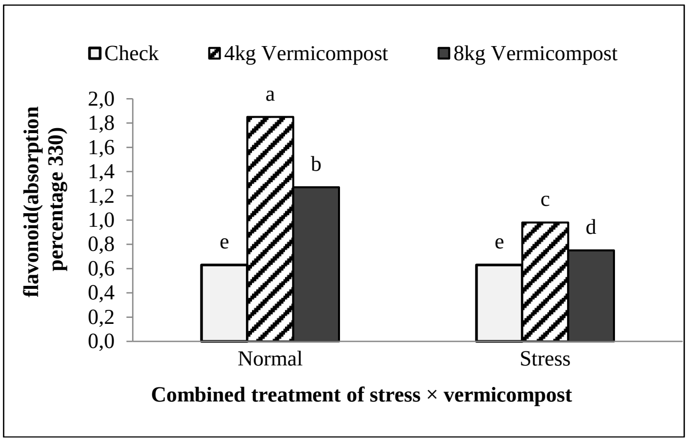

Figure 11. Interaction effect of vermicompost and stress on flavonoid 330 of Verbascum plant. Averages with the same letters are not significantly different at the 5% level of Duncan's test.

The highest amount of flavonoid 330 was observed using 4 kg of vermicompost treatment without stress treatment with a rate of 1.85 mg/g. While the lowest amount was observed without the use of vermicompost treatment and without the use of stress treatment at the rate of 0.63 mg/g (***Figure 11***).

The accumulation of osmolytes is one of the most well-known mechanisms of increasing stress tolerance in plants. It has also been suggested that the accumulation is suitable for selecting species tolerant to stressful conditions. Concerning the amount of flavonoid production, it has been reported that a plant with proper access to sufficient water produces a lot of free flavonoids, for this reason, the flavonoid is produced more in plants that are under severe stress (Rehana et al., 2003), which is in line with The results of the study are leading. Several studies have introduced flavonoid as an enzyme, flavonoid increases stress tolerance and develops stress tolerance in plants (Noorzad et al., 2014).

Conclusions

The results of this research showed that the use of vermicompost fertilizer and water stress improved the morphological and physiological characteristics of the Mullein medicinal plant compared to no treatment. Vermicompost fertilizer is a suitable fertilizer, therefore, it is recommended to use this fertilizer in drought stress conditions to overcome the destructive effects of stress. Vermicompost had a positive effect on the amount of photosynthesis and improved plant height through high water absorption power and optimal supply of high and low-consumption nutrients. The highest number of secondary stem flowers, diameter of flowering stem, number of secondary branches, and reproductive efficiency were obtained in Mullein medicinal plant with the use of vermicompost fertilizer and water stress of 4 and 8 kg per square meter of soil. The content of chlorophyll pigments increased with the application of vermicompost fertilizer by 8 kg/m^2 of soil compared to the absence of vermicompost factor. In general, due to the importance of using less chemical inputs, including nitrogenous chemical fertilizers, and improving the chemical and biological characteristics of the soil environment as a result of the use of organic fertilizers due to the increase in the content of organic matter, easier access to food elements, especially low consumption elements, and increasing storage capacity. water in the soil, it can be concluded that the application of organic fertilizer and water stress at the rate of 4 and 8 kg per square meter of soil and water stress is recommended to improve vegetative growth and increase reproductive efficiency of Mullein plant and reduce production costs.

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