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Effect of Biochar and Vermicompost on Growth Parameters and Physiological Characteristics of Feverfew (*Tanacetum parthenium* L.) Under Drought Stress

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Abstract

Drought stress is one of the most prevalent problems that limit the growth and lifespan of plants. Knowing the specifics of plant response to drought stress can be useful in the management and development of plant cultivation. The feverfew plant (*Tanacetum parthenium* L.) is an ornamental and medicinal plant native to Iran and its cultivation in the landscape seems valuable as a wildflower due to its beauty. The factorial experiment was conducted to investigate the effect of biochar and vermicompost on feverfew (*Tanacetum parthenium* L.) in loamy soils under drought stress conditions based on a completely randomized design (CRD) in three replicates. The results showed that drought stress caused a decrease in shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, and leaf relative water content (RWC), compared to the control treatment. On the other hand, there was an increase in catalase enzyme because of the drought stress. By improving the soil condition, vermicompost and biochar caused an increase in fresh and dry weight of shoots and roots, chlorophyll content, and leaf RWC. However, it decreased the activity of catalase and superoxide dismutase enzymes. In general, the combination of vermicompost and biochar was the best treatment for enhancing the soil condition and increasing the growth characteristics of feverfew plants under drought stress.

Keywords: Antioxidant enzymes, Feverfew, Organic fertilizers, Osmotic stress, Water deficiency.

INTRODUCTION

The feverfew plant (*Tanacetum parthenium* L.) is a medicinal and ornamental plant native to Iran. It is widely distributed in most parts of the country and the Middle-Eastern region. This plant has valuable medicinal effects that are anti-inflammatory, anti-migraine, and anti-bloating, while its inherent compounds are capable of strengthening vascular smooth muscles, inhibiting histamine release, and counteracting cancer (Pareek *et al*., 2011; Alenzi *et al*., 2021). In terms of appearance, this perennial plant is short, bushy and aromatic that grows 0.3 to 1 m in height (Pareek *et al*., 2011). Its almost hairless, pinnate-bipinnate, and fewer than 8 cm long yellow-green leaves have chrysanthemum-like characteristics. About 2 cm is the diameter of its blossoms. They contain a single layer of white outer-ray florets and resemble those of chamomile (*Matricaria chamomilla*), with which they are occasionally mistaken. This aromatic plant has a powerful bitter odor and composite white flowers with yellow centers. Its downward-curving, alternate, yellow-green leaves have small hairs and grow at alternating levels on both sides of the stem (Pareek *et al*., 2011). Recently, the cultivation of this plant has been developed in different regions with the aim of increasing the beauty of green spaces and taking advantage of its medicinal benefits.

Drought is one of the most prevalent environmental factors that usually has adverse effects on the growth and development of plants. In most cases, stress is measured in relation to growth (biomass accumulation) or primary assimilation processes (absorption of CO_2 and minerals) (Silva *et al*., 2020). Usually, drought cannot affect plants immediately, because plants use protective mechanisms that delay or stop the chemical and thermodynamic disturbances caused by drought on cellular activity (Silva *et al*., 2020). Drought affects plants at different levels, morphologically and physiologically (Zahedyan *et al*., 2020; Es-sbihi *et al*., 2021; Ezzati Lotfabadi *et al*., 2022). One of the physiological changes that may occur during drought stress is the change in osmotic pressure. Any increase in the osmotic pressure of the cell can help maintain turgor pressure against drought stress, and, in fact, small changes in the turgor pressure mean that the stress has exerted its effects on the metabolism of the plant so that necessary actions must be taken (Yu *et al*., 2020). Under stressful conditions, plants attempt to adjust the right amount of water and carbon dioxide exchange by changing the size and density of the stomata. In plants, the stomatal response to stress and fertilizers can be variable. Under the influence of osmotic stress, changes may occur in the size and density of the pores and secretory glands that produce essential oils (Es- sbihi *et al*., 2021). In recent years, using organic products in plant nutrition has served as a fundamental asset in the development of integrated plant nutrition management systems. The common aim is to increase the quantity and quality of food per unit area through the integration of mineral-based nutrients and plant organic matter (Bakhtiari *et al*., 2020). In sustainable agricultural systems, it is essential to use renewable resources that have maximum ecological benefits and minimum environmental side-effects (Bakhtiari *et al*., 2020).

One of the ways to increase plant tolerance to stress is to use vermicompost and, recently, the use of biochar has been recommended. Vermicompost is made by earthworms through the processing of organic waste such as animal manure and plant residues, and it has received a lot of attention due to its significant potential for soil improvement. Vermicompost increases the water-holding capacity in the soil, increases ventilation, and improves the physical and chemical properties of the soil (Feizabadi *et al*., 2021). Biochar is a carbon-based material obtained by heating plant residues and waste in an environment containing limited or no oxygen

(Ali *et al*., 2017). It has a high level of stability and is produced to manage waste, reduce climate change, create energy, and improve soil properties. The unique features of biochar have made it a suitable option for use in the soil. Biochar affects various physical properties of the soil (e.g. soil structure, specific gravity, hydraulic conductivity), and chemical attributes (e.g. acidity, cation exchange capacity, and organic matter). It also benefits the biological aspects of the soil (i.e. microbial activity, microbial diversity, enzyme activity, and microbial population). More importantly, biochar has reportedly improved soil fertility (Ali *et al*., 2017). By providing part of the elements needed by the plant, biochar increases the performance of plants. In most cases, the use of biochar improves soil fertility (Mansoor *et al*., 2021) and increases the main and secondary plant products. Biochar fertilizers play an important role in increasing soil fertility and tree growth (Herrmann *et al*., 2019).

Considering the continuous threat of drought in arid regions and developments in the approach to ornamental plants, organic solutions are aimed at empowering plants with stress tolerance. Thus, the use of stress-mitigating agents seems necessary. Therefore, these soil amendments could be evaluated in reducing the effects of drought stress on the feverfew plant. This research examined the effects of biochar and vermicompost application on the growth parameters of feverfew plants under drought stress, as well as their physiological and phytochemical characteristics.

MATERIALS AND METHODS

This research aimed to evaluate the effects of biochar (Fifth Season company, Shiraz, Iran) and vermicompost (Turanbiotech Company, Shahrud, Iran) on feverfew plants the effect of biochar and vermicompost on feverfew (*Tanacetum parthenium* L.) in loamy soils under drought stress in a factorial layout based on a completely randomized design (2021-2022). The experiment was located in the greenhouse (Karaj, Iran) with a photoperiod of 16 hours of light and 8 hours of darkness. The relative humidity ranged from 65 to 80%, while maximum and minimum temperatures were 29 °C and 15 °C, respectively. In early February, feverfew seeds were sown in culture trays containing perlite, and healthy seedlings were transferred to pots at the four-leaf stage.

The treatments included two factors of drought stress at four levels (100, 75, 50, and 25% of field capacity) and soil amendment at four levels; vermicompost 20% w/v, biochar 5% w/v, vermicompost 10% w/v + biochar 2.5% w/v and the control. The experiment was conducted in 16 treatment groups, three replications, and two observations. Feverfew seeds were purchased from Poponik Company, were disinfected, and planted in plastic culture trays containing perlite. Then, the seedlings were transferred to 3-liter pots containing a specific composition of soil (Table 1). Vermicompost and biochar were mixed with farm soil. The characteristics of vermicompost and biochar are shown in table 2.

Table 1. Physical and chemical characteristics of the loamy soil.

Sand (%)	Silt (%)	Clay (%)	pH	EC (mS/cm)	Organic carbon (%)	Total nitrogen (%)	Available phosphorous (mg/kg)	Absorbable potassium (mg/kg)
26	47	27	6.8	1.2	0.67	0.11	15.3	225

Table 2. Compositions of biochar and vermicompost.

Variable	Unit	Biochar	Vermicompost
Organic matter	%	91.6	72.7
Organic carbon	%	75.8	35
Nitrogen	%	0.45	2.90
Nitrate	mg/kg	64	3100
Sulfur	mg/kg	940	520
Sodium	%	0.520	0.30
Potassium	%	20	0.54
Phosphorous	%	0.370	0.436
Electrical conductivity	mS/cm	37.5	175
pH	-	9.5	6.5
Total ash	%	8.4	27.3
Apparent density	g/cm^3	0.207	0.131

Drought stress was applied based on the field capacity of the soil at the 6-leaf stage. The weight of soil moisture was determined at 100, 75, 50, and 25% of field capacity. At first, the dry soil weight and field moisture percentage were measured, and the appropriate weight of each pot was monitored per drought treatment (Benami and Ofen, 1984).

Equation 1: $Vn= (FC-PWp) \times Vp \times F$

Where Vn is the amount of water provided for each pot (in cubic meters) in each irrigation cycle. FC is the soil moisture at field capacity, PWP is the permanent wilting point (%), Vp is the volume of the pot, and F is the irrigation management coefficient, which is 0.5 in the case of optimal irrigation. Forty days after transferring the seedlings to the pots, the drought stress treatment commenced. The duration of the treatment period was 50 days. One week after the end of the stress period, the plants were harvested and the traits were measured. At the end of the vegetative period, the morphological, physiological, and biochemical traits were measured.

Fresh and dry weights of the shoots and roots

The fresh weight of shoots and roots after harvesting was weighed with a digital scale (0.01 g accuracy). After drying the shoots and roots of the plant in an oven at 72 °C for 24 hours, their dry weight was determined with the digital scale (Inbar *et al*., 1994).

Relative water content (RWC)

The youngest developed leaves of each plant were separated and immediately weighed using a scale (LiBROR AEL model 40SM, SHIMADZU Co., Kyoto, Japan) with an accuracy of 0.0001 g, and then the leaf RWC was calculated according to the following equation by Ritchie *et al*. (1990).

$$\text{Equation 2: } RWC=\frac{FW-DW}{TW-DW}\times 100$$

Plant pigments

The chlorophyll content was determined by a common method (Arnon, 1949). First, 0.1 g of plant leaf sample was completely ground in a Chinese mortar with 3 ml of 80% acetone and the final volume of the extract reached 15 ml. Then, the extract was clarified using a centrifuge for 10 minutes at a speed of 5000 × g. A spectrophotometer (Shimadzu UV-160) was used for measuring the absorbance of each sample. First, the device was brought to a default condition with 80% acetone, and then the absorbance of each extract was read at 645 nm and 663 nm wavelengths. The calculation of values was made by the following equations for chlorophyll a (equation 3), chlorophyll b (equation 4) and total chlorophyll (equation 5). In the following, A is the amount of absorption in the given wavelength, V is the final volume of 80% acetone in ml, and W is the size of the fresh leaf in grams.

Equation 3: $[(12.7\times A663) - (2.69\times A645)] \times V / 1000\times W = mg\ g^{-1}$ of chlorophyll a of leaf
Equation 4: $[(22.9\times A645) - (4.69\times A663)] \times V / 1000\times W = mg\ g^{-1}$ of chlorophyll b of leaf
Equation 5: $[(20.2\times A645) + (8.02\times A663)] \times V / 1000\times W = mg\ g^{-1}$ of total chlorophyll of leaf

Antioxidant enzymes

The extraction of antioxidant enzymes and their measurement was done according to a relevant method by Vanacker *et al*. (1998) with minor modifications. Superoxide dismutase (SOD) enzyme activity was measured with reference to Giannopolitis and Ries (1977). The activity of SOD was determined by its ability to inhibit the photochemical reduction of nitro blue tetrazolium (NBT). Catalase enzyme activity was measured according to a method by Macadam *et al*., (1992), ultimately using a spectrophotometer to measure the absorbance at 240 nm for 30 seconds.

Data analysis

The data analysis of variables in this research was done by Microsoft Excel and then analyzed by SAS statistical software version 9.3. The comparison of mean values entered the LSD test at 1 and 5% levels of significance.

RESULT AND DISCUSSION

Shoot fresh weight

The simple effect of drought stress and soil amendments was significant on the measured parameters ($P<0.01$). The interaction effect of the treatments on the root fresh weight was also significant ($P<0.05$) (Table 3).

Table 3. Analysis of variance on the effect of drought stress and soil amendments on fresh and dry weights of feverfew (*Tanacetum parthenium* L.).

S.o.V	df	MS				
		SFW	SDW	RFW	RDW	RWC
Drought	3	82.41**	6.60**	40.52**	3.94**	1135.13**
Soil amendment (SA)	3	22.32**	1.89**	13.43**	1.2**	103.41**
Drought × SA	9	1.05*	0.083^{ns}	0.494*	0.064*	5.33^{ns}
Error	30	0.62	0.06	0.25	0.026	5.54
CV (%)	-	5.94	6.59	7.03	7.05	2.88

*, ** and ns: Significant at $P < 0.05$, $P < 0.01$ and insignificant based on the LSD test, respectively. SFW: Shoot fresh weight, SDW: Shoot dry weight, RFW: Root fresh weight, RDW: Root Root dry weight, RWC: Relative water content.

The comparison of mean values showed that drought stress decreased the shoot weight, whereas vermicompost and biochar improved soil conditions and water retention, compared to the control. The shoot fresh weight was enhanced in the treatment group of drought stress + vermicompost, and also in the combination of biochar and vermicompost treatments, compared to the drought stress treatment (25% FC) without vermicompost and biochar which led to the lowest shoot fresh weight (17.23 g) (Table 4).

Table 4. Comparison of mean values and the interaction effect of drought stress and soil amendments on plant features of feverfew (*Tanacetum parthenium* L.).

Soil amendment	Treatments	Traits					
	Drought stress (% FC)	SFW (g)	SDW (g)	RFW (g)	RDW (g)	CAT (unit/ mg protein)	SOD (unit/ mg protein)
Control	100	13.63fde	3.93cde	6.70g	2.17e	0.34e	3.57f
	75	13.50ab	3.83e	7.00g	2.30ed	0.37e	4.33e
	50	11.63cde	3.23fg	5.27h	1.67f	0.56b	6.60c
	25	7.07a	2.03i	4.17i	1.40f	0.67a	8.97a
Vermicompost	100	16.20fde	4.67ab	8.77cde	2.80cb	0.34e	3.40f
	75	15.17cb	4.30bc	9.07cb	2.93ab	0.35e	3.70f
	50	13.07cd	3.73e	7.30fg	2.40ed	0.45d	5.53d
	25	9.97ab	2.87gh	4.77hi	1.57f	0.54bc	7.37b
Biochar	100	14.40g	4.03cde	8.00def	2.50d	0.35e	3.43f
	75	14.67f	4.20cd	8.80cd	2.80cb	0.35e	3.50f
	50	13.30fe	3.77g	6.53g	2.13e	0.44d	5.30d
	25	9.97fde	2.80h	4.40i	1.47f	0.54bc	6.83bc
Vermicompost biochar	100	17.23i	4.80a	9.80ab	3.13a	0.35e	3.47f
	75	16.47h	4.77a	10.10a	3.17a	0.36e	3.37f
	50	13.77h	3.97cde	7.93ef	2.53cd	0.44d	5.57d
	25	11.50g	3.30f	5.40h	1.67f	0.53c	6.93bc

*In each column, means with similar letter(s) are not significantly different ($P < 0.05$) using the LSD test. SFW: Shoot fresh weight, SDW: Shoot dry weight, RFW: Root fresh weight, RDW: Root dry weight, CAT: Catalase, SOD: Superoxide dismutase.

Shoot dry weight

Soil amendments and drought stress had significant effects on the shoot dry weight ($P<0.01$) (Table 3). The comparison of mean values showed that biochar and vermicompost increased the shoot dry weight, compared to the control treatment. The highest amount of shoot dry weight (4.20 g) was observed in the combined treatment of vermicompost and biochar, whereas the lowest amount of shoot dry weight (3.25 g) was observed in the control treatment (25% FC) (Table 4).

Root fresh weight

Drought stress and soil amendments significantly affected the measured parameters ($P<0.01$). The interaction effect of the treatments on the root fresh weight was also significant ($P<0.05$) (Table 3). The comparison of mean values showed that vermicompost and biochar increased the root fresh weight through enhanced water retention under drought stress when soil amendments were used. The highest root fresh weight was observed in the treatment group of drought stress + the combination of vermicompost and biochar (75% FC). In the severe drought stress treatment (25% FC), the combination of vermicompost and biochar increased the root fresh weight by 29.59%, compared to the control treatment (Table 4).

Root dry weight

Drought stress and soil amendments had significant effects on the measured parameters

($P<0.01$). Also, the interaction effect of the treatments was significant on the root dry weight ($P<0.05$) (Table 3). The comparison of mean values showed that in the drought stress treatment, vermicompost and biochar enhanced the root dry weight, compared to the control treatment without soil amendments. The highest root dry weight occurred in response to the vermicompost and biochar combination at 75% FC (Table 4).

Mira *et al*. (2018) stated that one of the most important reasons for the decrease in plant weight during stress is the adverse effects of stress on plant growth and physiology, including vegetative growth, photosynthetic performance, nutrient absorption, and nitrogen metabolism. In stress conditions, the reduction of dry matter can occur due to the loss of turgor pressure in cells, followed by a reduction of plant height and leaf surface (Luvaha *et al*., 2010). Drought usually leads to oxidative stress, because the imbalance between reactive oxygen species (ROS) production and their elimination causes damage to macromolecules and cell membranes, followed by reduced plant growth (Ennajeh *et al*., 2009). As the level of drought stress intensifies, and leaf photosynthesis decreases, the demand for sugar increases to maintain osmotic regulation in the plant, and, thus, root growth may inevitably cease (Yazdanpanah *et al*., 2011). The increase in plant leaf area, leaf count, root length, as well as root and shoot biomass have reportedly occurred due to the combined application of vermicompost and biochar (Nazarideljou and Heidari, 2014; Álvarez *et al*., 2017; Kalhor Monfared *et al*., 2023). The use of biochar increases soil fertility, plant growth, and establishment in dry soils (Durukan *et al*., 2020; Zhang *et al*., 2020). Previous research indicated significant improvements in plant photosynthetic rate, xylem water potential, chlorophyll content, plant hormone production, biomass, and overall growth when biochar was used (Ali *et al*., 2017; Semida *et al*., 2019). The application of biochar on *Phragmites karka* under drought stress significantly increased fresh and dry weights, root and stem lengths, chlorophyll content, net photosynthesis rate, and the water-holding capacity of soils (Abideen *et al*., 2020). Vermicompost increased the availability of nutrients in the soil and increased the fresh weight of plants (Singh *et al*., 2011). Vermicompost facilitated root growth and expansion due to the availability of more nutrients and a higher ability to retain water (Dobbss *et al*., 2010).

Relative water content

Drought stress and soil amendments significantly affected the leaf RWC ($P<0.01$) (Table 3). According to the comparison of mean values, vermicompost and biochar increased the leaf RWC. The highest RWC occurred in response to the combination of biochar and vermicompost, which caused an increase of 8.6%, compared to the control (Table 6). A decrease in RWC is usually an initial impact of drought stress on plants. The plant growth analysis indicated that activated biochar regulated wheat plant water relations under reduced irrigation, as can be seen by 2.3-fold improved relative growth rate, 2.2-fold higher leaf area ratio, 24-fold higher net assimilation rate, and 4-fold higher apparent water productivity in 5% activated biochar amendment soil (Jahan *et al*., 2023). Ahmad *et al*. (2018) showed that the decrease in RWC occurs mainly due to drought stress, which leads to the closure of stomata, and, thus, weakens stomatal conductivity. Ali and Hassan (2017) reported that under drought stress, a decrease was observed in growth parameters (i.e. plant height, number of branches, plant dry weight, and leaf area), plant yield, and RWC. Saud *et al*. (2014) showed that drought stress reduced photosynthesis, transpiration rate, stomatal conductance, RWC, relative growth rate, and water use efficiency. Zeighami Nejad *et al*. (2020) indicated that drought stress significantly reduced leaf and root dry weights of orange fruits (*Citrus aurantifolia* cv. 'Mexican Lime'). However, treating the plants with vermicompost caused an increase in leaf and root fresh weights, leaf chlorophyll content, and RWC, compared to the control.

Photosynthetic pigments

Chlorophyll a

The effects of drought stress and soil amendments were significant on chlorophyll a content (P<0.01) (Table 5).

Table 5. The analysis of variance showing the effects of drought stress and soil amendments on the biochemical compounds of feverfew (*Tanacetum parthenium* L.).

S.o.V	df	MS				
		Chl. a	**Chl. b**	**Total Chl.**	**CAT**	**SOD**
Drought		0.357**	0.056**	0.673**	0.132**	43.44**
SA	3	0.045**	0.014**	0.105**	0.0117**	3.11**
Drought × SA	3	0.0013^{ns}	0.00048^{ns}	0.0019^{ns}	0.0037**	0.462**
Error	9	0.0011	0.0004	0.0012	0.00027	0.121
CV (%)	30	3.39	4.83	2.21	3.82	6.81

** and ^{ns}: Significant at P < 0.01 and insignificant based on the LSD test, respectively. SA: Soil amendment, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Total Chl: Total Chlorophyll, CAT: Catalase, SOD: Superoxide dismutase.

The highest amount of chlorophyll a content (1.07 mg/g) was observed in the combination of vermicompost and biochar treatment, whereas the lowest amount (0.922 mg/g) was observed in the control treatment (Table 6).

Table 6. Comparison of mean values and the effects of soil amendments on feverfew (*Tanacetum parthenium* L.).

Treatment	RWC (%)	Chl. a (mg/g F.W.)	Chl. b (mg/g F.W.)	Total Chl. (mg/g FW)
Control	77.42 c	0.92 d	0.37 c	1.47 c
Vermicompost	82.08 b	1.01 b	0.42 b	1.61 b
Biochar	83.00 ab	0.98 c	0.43 b	1.58 b
Vermicompost+biochar	84.08 a	1.07 a	0.45 a	1.69 a

*In each column, means with similar letter(s) are not significantly different (P < 0.05) using the LSD test. RWC: Relative water content, Chl. a: Chlorophyll a, Chl. b: Chlorophyll b, Total Chl: Total Chlorophyll.

Chlorophyll b

Drought stress and soil amendments significantly affected chlorophyll b content (P<0.01) (Table 5). The highest amount of chlorophyll b (0.452 mg/g) was observed in response to the vermicompost and biochar combination, whereas the lowest amount (0.37 mg/g) was observed in the control treatment. The combination of vermicompost and biochar increased the amount of chlorophyll b by 22.29%, compared to the control treatment (Table 6).

Total chlorophyll

Drought stress and soil amendments had significant effects on total chlorophyll content (P<0.01) (Table 5). The highest and lowest amounts of total chlorophyll content (1.69 and 1.46 mg/g) were observed in the combination of vermicompost-biochar treatment and the control treatment, respectively. The combination of vermicompost and biochar caused a moderate increase (15.51%) in total chlorophyll content, compared to the control treatment (Table 6).

Drought stress usually affects the metabolism of cells in the mesophyll region, and, thus, reduces the photosynthetic capacity by disrupting the synthesis of the ribulose-bisphosphate enzyme and the activity of the Rubisco enzyme. In effect, drought stress decelerates plant growth by closing the stomata as an initial response. During the early stages of drought, stomatal closure becomes a major limiting factor of photosynthesis (Amiripour *et al*., 2021). The application of organic soil amendment increased the amounts of chlorophyll contents, primarily because they improved the absorption of essential macronutrients for chlorophyll biosynthesis (Ghanbari Jahromi and Aboutalebi, 2009). In previous research, using a combination of biochar and vermicompost reportedly increased chlorophyll content, photosynthesis, and biomass production (Wang *et al*., 2017).

Catalase

The effects of drought stress, soil amendments, and their interaction were significant on the amount of catalase enzyme ($P<0.01$) (Table 5). The comparison of mean values showed that the highest amount of catalase enzyme (0.666 enzyme units) was observed in the severe drought stress treatment (25% FC) without the application of any soil amendment. At the same level of drought, however, the combined application of vermicompost and biochar decreased the amount of catalase enzyme by 20.99%, compared to the control treatment (Table 4).

Superoxide dismutase

Drought stress, soil amendments, and their interaction effects were significant on the amount of superoxide dismutase ($P<0.01$) (Table 5). The comparison of mean values showed that the highest amount of superoxide dismutase enzyme (8.96 enzyme units) was observed in the severe drought stress treatment (25% FC) in the absence of soil amendments (Table 4).

Antioxidant enzymes are the front line of plant protection against ROS in both biotic and abiotic stress conditions. Stressful conditions often lead to excessive accumulation of ROS, which causes oxidative stress. Eliminating ROS is directly related to the activity of antioxidant enzymes such as superoxide dismutase and catalase. The activity of these enzymes generally increases parallel to an increase in stress intensity (Scherer *et al*., 2013). In harsh conditions of environmental stress, such as severe drought, growth promoter systems become elicited by genes that respond to drought stress and the damages caused by adverse conditions (Nasirzadeh *et al*., 2021). Vermicompost can increase the tolerance and growth of plants in these conditions by strengthening plant defense, boosting photosynthesis, and influencing plant growth in these conditions (Feizabadi *et al*., 2021). Also, by improving soil conditions, biochar increases plant tolerance to drought stress (Mansoor *et al*., 2021).

CONCLUSION

This research showed that drought stress caused a decrease in fresh and dry weights of shoots and roots, leaf RWC and chlorophyll content. However, vermicompost and biochar mitigated the effects of drought stress on fresh and dry weights, photosynthetic pigments, and leaf RWC. When used in combination, vermicompost, and biochar optimally improved the soil condition and increased the growth characteristics of feverfew under drought stress. The results of this research can benefit green space management, medicinal plant research, as well as vegetable and fruit production. Also, in order to give farmers cost-effective and more practical suggestions, it is also necessary to evaluate the impact of using lower levels of soil amendment in the next studies.

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Literature Cited

Abideen, Z., Koyro, H. W., Huchzermeyer, B., Ansari, R., Zulfiqar, F. and Gul, B. J. P. B. 2020. Ameliorating effects of biochar on photosynthetic efficiency and antioxidant defence of *Phragmites karka* under drought stress. Plant Biology, 22 (2): 259-266.

Ahmad, Z., Waraich, E. A., Akhtar, S., Anjum, S., Ahmad, T., Mahboob, W. and Rizwan, M. 2018. Physiological responses of wheat to drought stress and its mitigation approaches. Acta Physiologiae Plantarum, 40 (4): 1-13.

Alenzi, K.A., Alharbi, F.H., Tawhari, F.M. and Fradees, G.S. 2021. Alteration of coagulation test results and vaginal bleeding associated with the use of feverfew (*Tanacetum parthenium*). Journal of Medical Cases, 12(1): 9-12.

Ali, E. F. and Hassan, F. A. S. 2017. Water stress alleviation of roselle plant by silicon treatment through some physiological and biochemical responses. Annual Research & Review in Biology, 21 (3): 1-17.

Ali, S., Rizwan, M., Qayyum, M. F., Ok, Y. S., Ibrahim, M., Riaz, M. and Shahzad, A. N. 2017. Biochar soil amendment on alleviation of drought and salt stress in plants: A critical review. Environmental Science and Pollution Research, 24 (14): 12700-12712.

Álvarez, J. M., Pasian, C., Lal, R., López Núñez, R. and Fernández Martínez, M. 2017. Vermicompost and biochar as substitutes of growing media in ornamental-plant production. Journal of Applied Horticulture, 19(3): 205-214.

Amiripour, A., Jahromi, M. G., Soori, M. K. and Mohammadi Torkashvand, A. 2021. Changes in essential oil composition and fatty acid profile of coriander (*Coriandrum sativum* L.) leaves under salinity and foliar-applied silicon. Industrial Crops and Products, 168: 113599.

Arnon, D. I. 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. Plant Physiology, 24 (1): 1-15.

Bakhtiari, M., Mozafari, H., Asl, K. K., Sani, B. and Mirza, M. 2020. Bio-organic and inorganic fertilizers modify leaf nutrients, essential oil properties, and antioxidant capacity in medic savory (*Satureja macrantha* L.). Journal of Biological Research, 93(1):1-9. doi:10.4081/jbr.2020.8477

Benami, A. and Often, A. 1984. Irrigation engineering sprinkler, trickle, surface irrigation: Principles, design and agricultural practices. Irrigation Engineering Scientific Publisher, pp. 257.

Dobbss, L. B., Pasqualoto Canellas, L., Lopes Olivares, F., Oliveira Aguiar, N., Peres, L. E. P., Azevedo, M. and Façanha, A. R. 2010. Bioactivity of chemically transformed humic matter from vermicompost on plant root growth. Journal of Agricultural and Food Chemistry, 58 (6): 3681-3688.

Durukan, H., Demirbas, A. and Turkekul, I. 2020. Effects of biochar rates on yield and nutrient uptake of sugar beet plants grown under drought stress. Communications in Soil Science and Plant Analysis, 51 (21): 2735-2745.

Ennajeh, M., Vadel, A. M. and Khemira, H. 2009. Osmoregulation and osmoprotection in the leaf cells of two olive cultivars subjected to severe water deficit. Acta Physiologiae Plantarum, 31 (4): 711-721.

Es-sbihi, F. Z., Hazzoumi, Z., Aasfar, A. and Amrani Joutei, K. 2021. Improving salinity tolerance in *Salvia officinalis* L. by foliar application of salicylic acid. Chemical and Biological Technologies in Agriculture, 8: 1-12.

Ezzati Lotfabadi, Z., Weisany, W., Abdul-razzak Tahir, N. and Mohammadi Torkashvand, A.

2022. Arbuscular mycorrhizal fungi species improve the fatty acids profile and nutrients status of soybean cultivars grown under drought stress. Journal of Applied Microbiology, 132 (3): 2177-2188. https://doi.org/10.1111/jam.15326

Feizabadi, A., Noormohammadi, G. and Fatehi, F. 2021. Changes in growth, physiology, and fatty acid profile of rapeseed cultivars treated with vermicompost under drought stress. Journal of Soil Science and Plant Nutrition, 21 (1): 200-208.

Ghanbari Jahromi, M. and Aboutalebi, A. 2009. Garden compost as a substrate for vegetable transplant production. *In*: V International Symposium on Seed, Transplant and Stand Establishment of Horticultural Crops, 898: 165-170.

Giannopolitis, C. N. and Ries, S. K. 1977. Superoxide dismutases: II. Purification and quantitative relationship with water-soluble protein in seedlings. Plant Physiology, 59 (2): 315-318.

Herrmann, L., Lesueur, D., Robin, A., Robain, H., Wiriyakitnateekul, W. and Bräu, L. 2019. Impact of biochar application dose on soil microbial communities associated with rubber trees in North East Thailand. Science of the Total Environment, 689: 970-979.

Inbar, J., Abramsky, M., Cohen, D. and Chet, I. 1994. Plant growth enhancement and disease control by *Trichoderma harzianum* in vegetable seedlings grown under commercial conditions. European Journal of Plant Pathology, 100 (5): 337-346.

Jahan, S., Ahmad, F., Rasul, F., Amir, R. and Shahzad, S. 2023. Physicochemical analysis of vermicompost-perlite based activated biochar and its influence on wheat (*Triticum aestivum* L.) growth under water stress. Journal of Soil Science and Plant Nutrition, 23: 1-17. https://doi.org/10.1007/s42729-023-01258-8

Kalhor Monfared, R., Ardakani, M. R., Paknejad, F., Sarajuqi, M. and Naghdi Badi, H. A. 2023. Effects of intercropping forage turnip (*Brassica rapa* L.) and basil (*Ocimum basilicum* L.) and applying vermicompost and biochar as soil amendments on quality and quantity of the forage turnip crop. Biological Agriculture and Horticulture, 39 (2): 129-147. https://doi.org/10.1080/01448765.2023.2172691

Luvaha, E., Netondo, G. W. and Ouma, G. 2010. Effect of water deficit on the physiological and morphological characteristics of mango (*Mangifera indica*) rootstock seedlings. American Journal of Plant Physiology, 5 (1): 7-21.

MacAdam J.W., Nelson C.J. and Sharp R.E. 1992. Peroxidase activity in the leaf elongation zone of tall fescue. Plant Physiol. 99: 872–878.

Mansoor, S., Kour, N., Manhas, S., Zahid, S., Wani, O. A., Sharma, V. and Ahmad, P. 2021. Biochar as a tool for effective management of drought and heavy metal toxicity. Chemosphere, 271: 129458. https://doi.org/10.1016/j.chemosphere.2020.129458

Mira, S., Veiga-Barbosa, L., González-Benito, M. E. and Pérez-García, F. 2018. Inter-population variation in germination characteristics of *Plantago lanceolata* seeds: Effects of temperature, osmotic stress and salinity. Mediterranean Botany, 39 (2): 89-96.

Nasirzadeh, L., Sorkhilaleloo, B., Majidi Hervan, E. and Fatehi, F. 2021. Changes in antioxidant enzyme activities and gene expression profiles under drought stress in tolerant, intermediate, and susceptible wheat genotypes. Cereal Research Communications, 49 (1): 83-89.

Nazarideljou, M. J. and Heidari, Z. 2014. Effects of vermicompost on growth parameters, water use efficiency and quality of zinnia bedding plants (*Zinnia elegance* 'Dreamland Red') under different irrigation regimes. International Journal of Horticultural Science and Technology, 1 (2): 141-150.

Pareek, A., Suthar, M., Rathore, G.S. and Bansal, V. 2011. Feverfew (*Tanacetum parthenium* L.): A systematic review. Pharmacognosy reviews, 5(9): 103.

Ritchie, S.W., Nguyen, H.T. and Holaday, A.S. 1990. Leaf water content and gas-exchange parameters of two wheat genotypes differing in drought resistance. Crop science, 30(1):105-111.

Saud, S., Li, X., Chen, Y., Zhang, L., Fahad, S., Hussain, S. and Chen, Y. 2014. Silicon application increases drought tolerance of Kentucky bluegrass by improving plant water relations and morphophysiological functions. Scientific World Journal, 2014: 368694. doi: 10.1155/2014/368694

Scherer, R., Lemos, M. F., Lemos, M. F., Martinelli, G. C., Martins, J. D. L. and da Silva, A. G. 2013. Antioxidant and antibacterial activities and composition of Brazilian spearmint (*Mentha spicata* L.). Industrial Crops and Products, 50: 408-413.

Semida, W. M., Beheiry, H. R., Sétamou, M., Simpson, C. R., Abd El-Mageed, T. A., Rady, M. M. and Nelson, S. D. 2019. Biochar implications for sustainable agriculture and environment: A review. South African Journal of Botany, 127: 333-347.

Silva, O. L. L., Veríssimo, S. M. M., da Rosa, A. M. B. P., Iguchi, Y. B., de Lima, E. D. S. C., de Moraes, C. M. and da Rocha, R. M. 2020. Effect of environmental factors on microbiological quality of oyster farming in Amazon estuaries. Aquaculture Reports, 18: 100437.

Singh, B. K., Pathak, K. A., Verma, A. K., Verma, V. K. and Deka, B. C. 2011. Effects of vermicompost, fertilizer and mulch on plant growth, nodulation and pod yield of French bean (*Phaseolus vulgaris* L.). Vegetable Crops Research Bulletin, 74 (1): 153-165.

Vanacker, H., Carver, T. L. and Foyer, C. H. 1998. Pathogen-induced changes in the antioxidant status of the apoplast in barley leaves. Plant Physiology, 117 (3): 1103-1114.

Wang, X. X., Zhao, F., Zhang, G., Zhang, Y. and Yang, L. 2017. Vermicompost improves tomato yield and quality and the biochemical properties of soils with different tomato planting history in a greenhouse study. Frontiers in Plant Science, 8:1978. doi: 10.3389/fpls.2017.01978

Yazdanpanah, S., Baghizadeh, A. and Abbassi, F. 2011. The interaction between drought stress and salicylic and ascorbic acids on some biochemical characteristics of *Satureja hortensis*. African Journal of Agricultural Research, 6 (4): 798-807.

Yu, Z., Duan, X., Luo, L., Dai, S., Ding, Z. and Xia, G. 2020. How plant hormones mediate salt stress responses. Trends in plant science, 25(11):1117-1130.

Zahedyan, A., Aboutalebi Jahromi, A., Zakerin, A., Abdossi, V. and Mohammadi Torkashvand, A. 2020. Effects of fertilizer types on the quantitative and qualitative attributes of muskmelon (*Cucumis Melo* L. cv. Ahlam) under different levels of drought stress. Plant Archives, 20 (2): 3669-3677.

Zeighami Nejad, K., Ghasemi, M., Shamili, M. and Damizadeh, G. R. 2020. Effect of mycorrhiza and vermicompost on drought tolerance of lime seedlings (*Citrus aurantifolia* cv. Mexican Lime). International Journal of Fruit Science, 20 (3): 646-657.

Zhang, Y., Ding, J., Wang, H., Su, L. and Zhao, C. 2020. Biochar addition alleviate the negative effects of drought and salinity stress on soybean productivity and water use efficiency. BMC Plant Biology, 20 (1): 1-11.

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